S. HRG. 111–681

NATIONAL ASSESSMENT OF ENERGY POLICIES—SIGNIFICANT ACHIEVEMENTS SINCE THE 1970S AND AN EXAMINATION OF U.S. ENERGY POLICIES AND GOALS IN THE COMING DECADES

HEARING

BEFORE A

SUBCOMMITTEE OF THE

COMMITTEE ON APPROPRIATIONS
UNITED STATES SENATE

ONE HUNDRED ELEVENTH CONGRESS

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NATIONAL ASSESSMENT OF ENERGY POLICIES—SIGNIFICANT ACHIEVEMENTS SINCE THE 1970S AND AN EXAMINATION OF U.S. ENERGY POLICIES AND GOALS IN THE COMING DECADES

WEDNESDAY, APRIL 28, 2010

U.S. SENATE,
SUBCOMMITTEE ON ENERGY AND WATER DEVELOPMENT,
COMMITTEE ON APPROPRIATIONS,
Washington, DC.

The subcommittee met at 10:02 a.m., in room SD–124, Dirksen Senate Office Building, Hon. Byron L. Dorgan (chairman) presiding.

Present: Senators Dorgan, Feinstein, Landrieu, Cochran, Alexander, and Voinovich.

OPENING STATEMENT OF SENATOR BYRON L. DORGAN

Senator DORGAN. We are going to begin the hearing today. We have chosen a room in order to demonstrate that America has an energy problem. It is a room without adequate heat and without adequate lights. I am told that those who know about heat and lights are working on the problem, but I think we do need to begin on time.

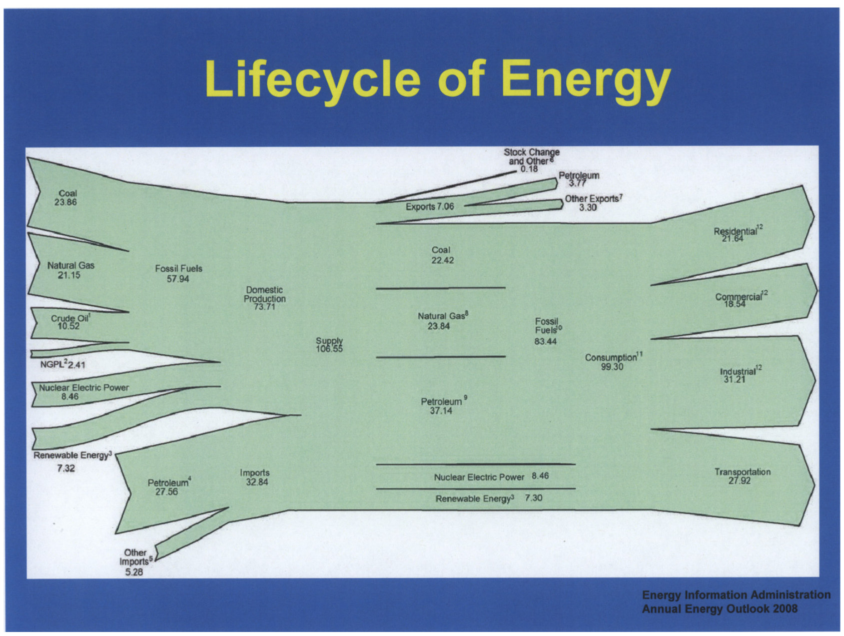
Mr. Secretary, thank you very much for being here. We appreciate your willingness to testify.

This hearing is a bit of a different hearing than the normal hearings we have held, and it is to take a broader look, a bigger-picture look at our energy future and talk about where we have been and where we are heading. We are doing that because we are so engaged in the incrementalism on a lot of public policy, including energy.

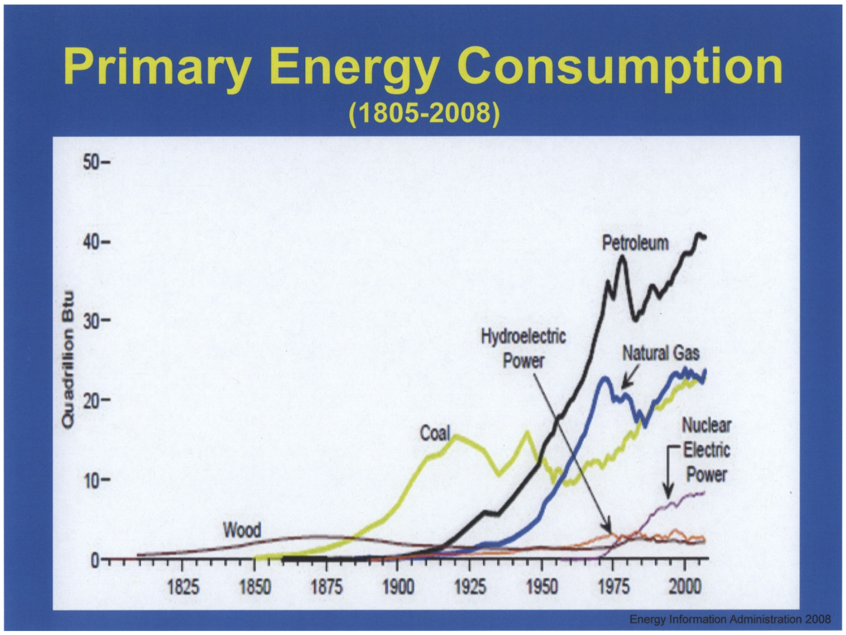
I believe Mr. Fri in his testimony has a chart, or at least a piece in his testimony that reminds me of the urgency for us to do this as we now look forward to an energy future that we want to try to create. His chart says Stops and Starts in Energy Technology Policy, and he will describe it in more detail. But he goes back to 1970, the Nixon policy of a virtually pollution-free car; reinventing the car under Carter; the partnership for a new generation of vehicles under Clinton; the freedom car under Bush. That is just in vehicles. In coal, the Synthetic Fuels Corporation in 1979; clean coal technology in 1987; the clean coal power initiative, 2001; nuclear technology, Clinch River breeder reactor, 1970 to 1983; liquid metal reactor, 1989–1994. And the list goes on.

When you look at these issues, you see that we have different administrations coming in and then we go one way for a while in a very significant effort. Then we go another for a while, and we kind of zigzag, always moving forward a bit, but never in a very consistent direction that has put America on a path to be where it wants to be with respect to a destination.

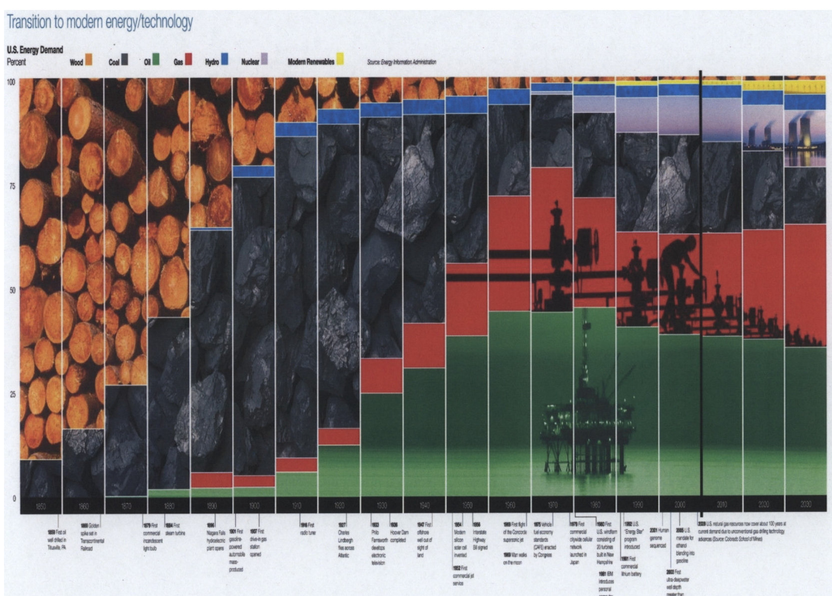
I wanted to show just several charts that you probably cannot see very well. And this chart you certainly cannot read, and it is not intended for you to read. But it is a chart that shows where the energy comes from, the source of energy, and on the left-hand side, it talks about coal, natural gas, crude oil, nuclear electric power, renewable energy, petroleum and then on the right-hand side, its use, residential, commercial, industrial, transportation. And that gives us a sense as of 2008 at least of where their energy is coming from, that is, the source, and how it is being used or who needs it.



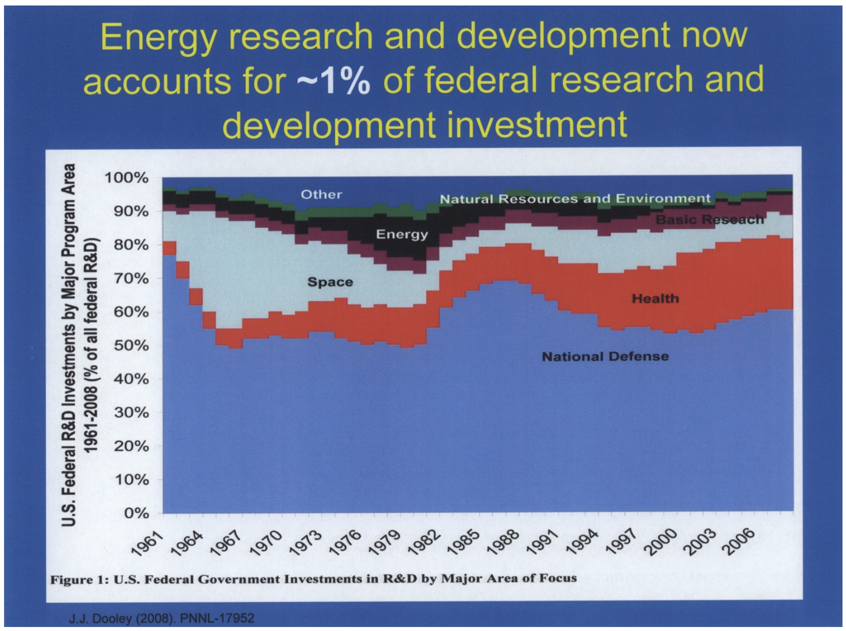
The second chart is an interesting chart that goes all the way back to the 1850s and describes our energy use. As you can see, going all the way back on the left-hand side in the middle of the 1800s, we basically just burned wood for energy and then began using coal, which is the second tranche, and coal became a dominant source of energy, and then began natural gas and oil and some renewable up on the top. But it is interesting to see how we have changed our energy use in a very significant way in about 150 years.



The next chart shows this same phenomenon in graphic form, the sources of energy and the growth or the increase in those sources of energy. The top line, by the way, is petroleum. The second line is natural gas. The green line is coal.



The next chart shows research and development by the Federal Government, and it shows that energy research and development accounts for about 1 percent of Federal research and development investment. You will see the bottom tranche is national defense. That is a very large portion. Then it is health, then space, and so on.



Energy, while in the late 1970s had somewhat of a resurgence in the amount of money spent in research and development, is now somewhere around 1 percent, probably just slightly more now as a result of what was done in the Economic Recovery Act.

But here is the reason I wanted to have a bigger-picture hearing. The world's population is growing. We in this country have a prodigious appetite for energy. We use almost a quarter of the world's oil every single day. But we also know that with a growing population in the world, there are going to be hundreds of millions of people in China and India that want to find a gas station probably once a week or once every couple weeks in the future. So we are going to have substantially increased demand for energy, and the question is where it is going to come from.

There are many aspects to the energy policy issues that confront us: supply and distribution and the effects of it on our national security and that relates to one piece of this, which is excessive dependence on foreign supplies of oil; and the cost of energy and the effects of energy costs on the economy; and then the environmental impacts of energy production, climate change, water scarcity, pollution, and so on.

So all of these play a role in both the development of policies and where we get our energy and how we use our energy and what kind of destination we would like for energy policy well out into the future.

I had asked some years ago of the Energy Department what are you driving us toward in terms of a set of goals and policies well out into the future. In other words, where would you want America to be in the year 2050 with respect to the use of energy, supply of energy, source, and so on? And the answer was, well, you know what? We are just struggling to get along in the next 5 years let alone the next 40 or 50 years.

I understand that answer, but I do not think, given where we are these days and the challenges we face, it is an acceptable answer. Nor do I think it is acceptable to revert back to what Mr. Fri is describing in his testimony, you know, 6, 8, or 10 or 15 or 20 different iterations of energy technology policy—let us go this way for a while with this emphasis, and then let us turn go this way for a while. I know that time and circumstances change, but it seems to me not so much as we have seen the different initiatives by different administrations.

What I am hoping that our country will do and I hope that the policy choices and discussions about policies will lead us to is some better understanding of what is our destination out there. What are we really striving to achieve and what will be the mix of policy choices that will allow us to get there. That is the purpose of this hearing. I hope I have described it as best I can in a way that you might understand it.

We asked the Secretary to be here as the first witness, I think very appropriately. He is a scientist. He runs the Energy Department, has massive amounts of money given the Economic Recovery Act and the $36 billion or $37 billion, which someone described as the largest energy venture fund on the planet. He has a permanent grin as a result of having all that money to invest, and I think the actions of this Energy Department and this administration will take in many ways will set us on a course that is very important.

So let me call on my colleagues, if they have any comments at the front end. Senator Voinovich?

STATEMENT OF SENATOR GEORGE V. VOINOVICH

Senator VOINOVICH. Thank you, Mr. Chairman.

First, I want to welcome our witnesses today, Dr. Chu and the other witnesses.

I like the fact that this is an assessment of national energy policies, what we have achieved over the last decades and what our goals are for the coming decades. The hearing is timely and relevant. One of the most important lessons we have learned about national energy policies is that their key to success is ensuring that they are comprised of comprehensive solutions, solutions for strengthening both our national and economic security.

I certainly believe we were thinking comprehensively, Mr. Chairman, when we introduced our National Energy Security Act which was intended to increase and diversify the supply of domestic energy resources, promote electric and alternative fuel transportation and strengthen our energy infrastructure. And I was pleased that many of the provisions of our bill were included in the Bingaman-Murkowski bill that was passed out of the Energy Committee last year. As you know, we started in 2003 to start doing something about this and finally got a bill in 2005, 2007, now in 2009.

And I would really hope that in spite of the fact that people are conscientiously working on some kind of a climate bill that serious consideration be given to the energy bill, which is something on a bipartisan basis that I really think we could actually get done in this session of the Congress.

For the last 10 years, I have spent a lot of time as ranking member and chairman of the Environment and Public Works Committee on Nuclear Safety. The goal was to try and create an environment where we could take advantage of nuclear power. I refer to nuclear power as a "three-for." First of all, it is a way of reducing our carbon emissions. Without it, we are not going to be able to provide the baseload energy that our country demands, and without it, I think we are missing an amazing opportunity to strengthen our U.S. manufacturing base and create good-paying jobs. It is a part—not the total solution, but it is part of it.

Although we have seen some gains, a number of formidable challenges to realizing a renaissance remain particularly in the areas of regulatory uncertainty, financing, availability of human capital, expansion of the domestic supply chain infrastructure, and used nuclear fuel management. I believe that solving the challenges are paramount to the safe and secure growth of the U.S. energy sector as a whole because utilizing nuclear energy is absolutely essential if we are going to harmonize the country's needs for energy security, economic competitiveness, and a healthy environment.

So in closing, I must say that time is of the essence. You are right. The Department has some money through the—what do we call that?

Senator DORGAN. The economic recovery bill.

Senator VOINOVICH. Yes. And Dr. Chu and his colleagues have a wonderful opportunity to send us in a new direction, and I am really anxious to hear what your thoughts are about where we ought to be going.

Senator DORGAN. Senator Voinovich, thank you very much.

Senator Feinstein?

STATEMENT OF SENATOR DIANNE FEINSTEIN

Senator FEINSTEIN. Well, Mr. Chairman, I am the unhappy Senator from California. And I have written a multitude of letters on this subject and the answers have been nonresponsive and unacceptable. So I am going to say a few things.

Many California companies have applied for DOE loan guarantees under title VII of Energy Policy Act of 2005, which was expanded in the American Recovery and Reinvestment Act. The Department of Energy simply has not fixed the problems that I believe a commitment was made to fix, and I would like to give a few examples.

Multiple applicants tell me that DOE does not stick to its own schedules. Although I wrote to Secretary Chu on October 30 and April 6 to raise concerns in this area, there is no evidence of improvement. I am told by my staff that DOE cannot at this time identify how many application reviews are behind schedule.

Point two. Applicants trying to develop solar projects on disturbed private lands, like Abengoa Solar, tell me they are in permitting no man's land because DOE refuses to initiate a NEPA process while the California Energy Commission is aggressively permitting. My April 6 letter addressed this.

Point three. Firms proposing to develop multiple sites on disturbed land, instead of one large plot of public land, inform me their applications are being turned down. I wrote to you, Secretary Chu, on February 23 to ask that this matter be addressed, but it has not.

Point four. Governor Schwarzenegger's team reports that DOE encouraged Next Light Energy to withdraw its application to build a project on disturbed private land in California and focus on its project on public land in Nevada. This is inexplicable. I wrote to you on November 17 to inform you that this project was one of the best in California.

Point five. Last week I learned that DOE turned down a loan guarantee application from Tessera Solar to build an 800-megawatt facility in Imperial County where unemployment is currently 27.2 percent. The project would have drastically lower environmental impacts than other projects, as I explained in my August 27 letter to you supporting the application. I understand DOE never asked the applicant a question—I have heard this from three sources—raised a concern or engaged in a dialogue regarding the application during 7½ months of review. The reasons given in their rejection letter, the applicant tells me, could have been quickly and easily resolved by a phone call, but none was made.

So I use this so that I can get the response from you during my question time. But let me say there are a number of very unhappy people trying to do positive things in my State.

Thank you.

Senator DORGAN. Senator Feinstein, thank you very much.

Senator Alexander, do you wish to make an opening comment?

STATEMENT OF SENATOR LAMAR ALEXANDER

Senator ALEXANDER. Well, thank you, Mr. Chairman. Excuse me for being late.

Dr. Chu, it is good to see you. I admire your service and the quality of talent that you have attracted to your Department and your independence. I agree with much of what you do.

The observation that I wanted to make—and then I will save my other remarks for questions, Mr. Chairman—is that it seems to me that there is an increasing amount of consensus about clean energy between the President and the Senate anyway and in a bipartisan way. We notice that Senator Dorgan and Senator Merkley and others and I have been working together, for example, on electric vehicles. The administration has taken a number of very important steps to encourage electric vehicles. Senator Merkley and I were this morning seeing a new FedEx truck that is 100 percent electric. FedEx has 40,000 trucks. They just have four of these, but if they were to have 40,000, that could make a real dent. I believe that the greatest untapped resource in our country probably is the amount of electricity we already have at night that is unused. So we have bipartisan support on the idea of moving ahead to encourage electric cars and trucks.

Because of your leadership, Secretary Chu, we have begun to make a shift from what I have called a national windmill policy toward a real national energy policy that also includes an emphasis on nuclear power, and I look forward to talking with you more about that during the questions and answers. So there is more of a bipartisan consensus on that.

The same is true on energy research and development. I think all of us on both sides of the aisle see the need for the 500-mile electric battery or the photovoltaic cell that is much more efficient. So there is agreement on that.

There is agreement on some offshore drilling.

And there is agreement on reducing air pollution because the environment goes right along with energy production. And while we still do not have agreement on how to deal with carbon, we do have agreement; it seems to me, on what to do about mercury, sulfur, and nitrous oxide. And a bipartisan group of about 15 of us now support a strong clean air bill.

So my hope would be that we take advantage of this broad consensus on nuclear power, electric cars, offshore drilling, and energy research and development, as well as clean air, and move ahead with it this year in every way that we can. We still can argue and work on the difficult questions about how to deal with carbon, but there is no need to stop our efforts to clean up the air and move ahead with clean energy until we have a consensus on carbon. It took us several years to get it on clean air. It took us several years to get it on clean energy. I think it may take us a while longer to do it on carbon, even though I think a majority of us recognize that there is a real problem there.

So I welcome you and I welcome your leadership. I look forward to talking with you specifically about a new generation of nuclear reactors and small modular reactors when my turn comes back around.

Thank you, Mr. Chairman, for your courtesy.

Senator DORGAN. Senator Alexander, thank you very much.

I wanted to mention that Senator Bennett is not able to be with us today, but he had an opportunity to look at the testimony.

Senator Cochran, do you have a comment?

STATEMENT OF SENATOR THAD COCHRAN

Senator COCHRAN. Mr. Chairman, I simply want to bring to the attention of the subcommittee a question that relates to environmental impact statements and record of decision progress in connection with the Strategic Petroleum Reserve. We have provided funds and we have Federal policies on the books now relating to the Strategic Petroleum Reserve as a matter of national security and economic security for our country in case something happens to energy supplies.

One of the areas being looked at was in the State of Mississippi, the Richton salt dome, and there had been funding made available to study that and to make a report on the suitability of that area and what the intentions of the Department of Energy would be with respect to construction. And on your Web site, Mr. Secretary, there is a provision explaining that a new site in Richton, Mississippi would be constructed. Existing sites would be expanded as well. And we have provided some funds and asked for a report on what the intentions were. When would this happen?

And the fact is apparently nothing has happened. So we are curious to know what the Department of Energy is going to do. Are you going to keep the money? What are you going to do? Are you going to give it back? Are you going to say that you found things that the previous administration overlooked? I am just curious to know what is happening.

Senator DORGAN. Senator Cochran, thank you very much.

There is an old saying that if you do not care where you are going, you will never be lost. And so the question is, where are we going? Where are we headed with respect to energy policy? What is our destination?

Mr. Secretary, we are very pleased that you are here to share your thoughts with us about that subject, and you may proceed. Your entire statement will be made a part of the permanent record.

STATEMENT OF HON. STEVEN CHU, SECRETARY, DEPARTMENT OF ENERGY

Secretary CHU. Thank you, Chairman Dorgan and members of the subcommittee.

My written statement cannot be read. It is too long. I have some brief oral statements that are taken from that, and I want to rush through them so we can get to the questions as quickly as possible.

Senator DORGAN. Mr. Secretary, in addition to not having heat or adequate lighting in this room, we apparently have inadequate microphones. Maybe if you will just move it away from you that would be helpful.

Secretary CHU. America is highly dependent on oil and our climate is changing as a result of our carbon emissions. In order to mitigate the considerable risks to climate change, the world has to transition to a sustainable energy future. And America's future jobs and prosperity may well depend on whether we lead or follow in this transformation.

As an example, leaders in China now recognize if the world continues on its current path, climate change will be devastating to China and the rest of the world. They also see the economic opportunity that clean energy represents. One company in China, State Grid, is investing $88 billion by 2020 in ultra-high voltage transmission lines. These lines will allow China to transmit power from the huge wind and solar farms far from the cities. China is also building—now under construction—20 nuclear power plants, and it is playing to win in this clean energy race.

For the sake of our economy, our security and our environment, America must develop decisive policies that will allow us not only to compete in the clean energy race, but to become a leader in providing clean energy technology to the world. And what will be required is nonpartisan leadership and collaboration between Congress and the administration.

Several studies have concluded that aggressive deployment and evolutionary advances in technology will help us achieve our energy climate goals at an affordable cost. With a robust R&D effort and the right policy signals, I believe we can achieve our goals even more economically.

As we have seen many times in history, for example, with catalytic converters, the acid rain program, the phase-out of fluorocarbons, and appliance efficiencies, once a problem is taken away from lobbyists and given to scientists and engineers and American businesses, it can be solved much more quickly and cheaply than anticipated.

We need a policy framework that emphasizes two parties, policies that will accelerate innovation and policies that will drive the private sector investment in clean energy. As stated in a comprehensive report, America's Energy Future, issued by the National Academies recently—and I quote—"Actions taken between now and 2020 to develop and demonstrate the viability of several key technologies will, to a large extent, determine our Nation's energy options for many decades to come."

So here are a few steps that we need to take.

First, we need to accelerate efforts in energy efficiency, our cleanest and cheapest energy resource, to save money and create jobs. The National Academies' report states that we could save about 30 percent of the energy used annually in buildings, transportation, and industry sectors. This estimate only included those investments which could provide a minimum of a 10 percent return on your investment based on net present value.

Strong efficiency standards and the enforcement of those standards will be of the highest importance.

And we need new models to overcome barriers, barriers such as lack of information and lack of financing, so that you can achieve widespread adoption of cost effective home energy efficiency technologies. The administration is working with Congress to establish the HOMESTAR program, designed to jump-start our economic recovery by boosting demand for energy efficiency products and installation services.

Second, we have to develop and deploy cleaner energy technologies for electricity generation. We need to provide market draw for renewable energy sources. In a preliminary 2010 report, EIA projects that non-hydro renewables will account for more than 10 percent of electricity sales in 2020 without any additional Federal or State policies. And I note that RES proposals often exempt smaller generating sources such as a cogeneration plant at a university. It would be not wise to demand that they have a renewable portfolio standard, but with those exemptions, that could reduce the effective target by several percentage points below the nominal target.

We need to invigorate America's nuclear power industry. Earlier this year, DOE made a conditional commitment to finance the construction of what will be the first nuclear reactor to break ground in decades. In fiscal year 2011, the Department is requesting an additional $36 billion in loan guarantee authority for nuclear power, and with this additional authority, DOE estimates we could support six to nine reactors in the next few years.

The barriers to CCS deployment must be addressed. As America's Energy Future report says, through a combination of retrofits and new plant construction, quote, "the entire existing coal powered fleet could be replaced by CCS coal power by 2035."

To help realize the potential of CCS technologies, President Obama has established an interagency task force to look at overcoming barriers to the widespread, cost effective deployment of CCS within 10 years, with a goal of bringing 5 to 10 commercial demonstration projects online by 2016.

In addition, the Department of Energy is completing an R&D road map to further reduce the cost of CCS.

Third, we need to modernize our electric grid. Smart metering technologies can save money for consumers and reduce the need to build new power plants to meet peak load requirements.

Fourth, we need transportation policies and technologies that can cut emissions and reduce our dependence on oil. The best near-term option for reducing dependence on imported petroleum is through greater vehicle efficiency. We also need to develop better batteries and address the other barriers to electrification of vehicles. Biofuels, particularly advanced biofuels that can be generated from agricultural residues can play a significant addition to our transportation fuel supply. The National Academies' study pointed out that there are a number of potentially viable technologies which can add to our energy security that have negative CO_2 equivalent emissions, such as growing plants that grab carbon dioxide out of the air. When you make biofuels, you sequester the excess carbon dioxide. You burn that fuel. The net life cycle cost is you have taken net CO_2 out of the atmosphere.

Fifth, we need a sustained commitment to research and development. Only research and development can yield game-changing technologies to lower costs, accelerate innovation, and drive new American industries. It is imperative that the Government support R&D investment, especially at the front end. Through a continued commitment in efforts like the DOE's Energy Innovation Hubs and ARPA–E, we can marshal the Nation's brightest minds to accelerate the development of new technologies.

All these efforts will be vital to our energy future, but even these steps will not be enough in the end. To truly drive changes, we need a policy that will guide investments over a generation. We need to put a long-term cap on carbon that ratchets down over time. Only a cap on carbon will give industry the direction and certainty it needs.

For example, suppose you operate a utility company and have a coal plant that is near the end of its life. A new coal plant will cost billions of dollars. If you knew there would be a cost to emitting carbon, you would have to think hard about whether the next plant should run on coal that captures carbon emissions or gas or nuclear power or wind or solar. Eventually there will be a cost, and because you do not know when, you limp along with the old plant until you know what the costs would be and how they would be structured.

Industry is asking for certainty.

PREPARED STATEMENT

Thank you again for the opportunity to testify, for holding this hearing. America still has the opportunity to lead the world in a new industrial revolution that we need, but only if we make wise choices today. Thank you.

[The statement follows:]

PREPARED STATEMENT OF HON. STEVEN CHU

Chairman Dorgan, Ranking Member Bennett, and members of the subcommittee, thank you for the opportunity to appear before you to discuss our Nation's energy policy.

We are driven to change our energy habits by several serious challenges. America is highly dependent on oil. Our climate is changing as a result of our carbon emissions. In order to mitigate the considerable risks of climate change, the world must transition to a sustainable energy future, which will require nothing short of a new industrial revolution. America's future jobs and prosperity may well depend on whether we lead or follow in this transformation.

The leaders in China now recognize that if the world continues on its current path, climate change will be devastating to China and to the rest of the world. They acknowledge that China's growth in carbon emissions is environmentally unsustainable and are working hard to lessen their emissions growth. They also see the economic opportunity that clean energy represents. China is investing $44 billion by 2012 and $88 billion by 2020 in Ultra High Voltage transmission lines. These lines will allow China to transmit power from huge wind and solar farms far from its cities. While every country's transmission needs are different, this is a clear sign of China's commitment to developing renewable energy. They also currently have 20 nuclear power plants under construction and more construction starts are expected soon. China largely missed out on the IT revolution, but it is playing to win in the clean energy race. For the sake of our economy, our security, and our environment, America must develop decisive policies that will allow us not only to compete in this clean energy race, but to become the leader in providing clean energy technology to the world.

The American Recovery and Reinvestment Act made a down payment on our clean energy future, while creating jobs and putting Americans back to work. For example, we are on track to double our renewable energy generation capacity by 2012.

But for the longer term, we will need a comprehensive energy and climate policy. Before becoming Energy Secretary, I was a member, along with three Assistant Secretaries now serving in the Department of Energy, of the National Academies committee that issued a comprehensive and authoritative report, *America's Energy Future*. That report stated: "The United States has never implemented a truly comprehensive set of national policies for obtaining and using energy to meet national goals for sustainability, economic prosperity, security, and environmental quality." [1]

America's competitiveness is inseparable from our energy policy. With the right policies and a sustained national commitment, we can mobilize America to lead the world in the transition to a sustainable energy future and guarantee prosperity for ourselves, our children and our grandchildren. What will be required is non-partisan leadership and collaboration between Congress and the administration.

In addition to the *America's Energy Future* report, several studies have examined the feasibility of achieving President Obama's 2020 and 2050 greenhouse gas reduction targets, including analyses by the Environmental Protection Agency (EPA) and the Energy Information Administration (EIA) of comprehensive energy and climate legislation. These studies concluded that aggressive deployment and evolutionary advances in technology will help us achieve our goals at an affordable cost. With a robust R&D effort and the right policy signals, I believe we will be able to achieve our goals even more economically.

As we have seen many times in history—for example with catalytic converters, the Acid Rain Program, the phase-out of chlorofluorocarbons, and appliance efficiencies—once a problem is taken away from the lobbyists and given to the scientists, engineers, and American businesses it can often be solved much more quickly and cheaply than anticipated. For example, while compliance costs for EPA's acid rain program were originally estimated in 1990 to be $750 per ton of sulfur emitted, by 1996 the cost was $70 per ton of sulfur.

Let me be clear, however, that our success is not inevitable. We need a policy framework that emphasizes two priorities: policies that will accelerate innovation and policies that will drive private sector investment in clean energy. We must harness America's entrepreneurial spirit and leverage private sector imagination and

[1] *America's Energy Future*, Summary Edition, 2009, page 26.

ingenuity to transform the way we produce and use energy. Part of those policies must promote the research and development of key technologies needed in the coming decades without crowding out private investment. As stated in America's Energy Future: "Actions taken between now and 2020 to develop and demonstrate the viability of several key technologies will, to a large extent, determine the Nation's energy options for many decades to come."

Here are a few of the steps we need to take:

—*We Need to Accelerate Efforts in Energy Efficiency—Our Cleanest, Cheapest Energy Resource—to Save Money and Create Jobs*.—Energy efficiency and conservation will remain the lowest hanging fruit for reducing carbon emissions for the next few decades. The National Academies report states that "Technology exists today, or is expected to be developed over the normal course of business between now and 2030 that could save about 30 percent of the energy used annually in the buildings, transportation and industrial sectors. These savings could easily repay, with substantial dividends, the investments involved."[2] This estimate was based on only those investments that could provide a minimum 10 percent rate-of-return on investments based on net present value.

—*Strong Efficiency Standards and the Enforcement of Those Standards Will Be of the Highest Importance*.—For example, the improvement in the efficiency of refrigerators alone since the 1970s is responsible for energy savings today greater than all non-hydro renewable power generation. During that time, the inflation adjusted cost of refrigerators dropped by about one-half while energy consumption was simultaneously reduced by more than 75 percent. There are many opportunities to make our buildings, vehicles, and appliances more efficient and save money. Appliance standards issued in the last 16 months alone will save American consumers more than $250 billion over the next 20 years.

—*We Need New Models to Overcome Information, Financing and Other Barriers to Rapid, Widespread Adoption of Cost-Effective Home Energy Efficiency Technologies*.—The administration is working with Congress to establish the HOMESTAR program, which has the potential to jumpstart our economic recovery by boosting demand for energy efficiency products and installation services. For middle-class families, this program will help them save hundreds of dollars a year in energy costs while improving the comfort and value of their most important investment—their homes. In addition, the program would help reduce our economy's dependence on oil and support the development of an energy efficiency services sector in our economy. In addition, DOE is also trying new approaches to promoting energy efficiency through our Retrofit Ramp-Up initiative. Communities, governments, private sector companies and non-profit organizations will work together on innovative programs to enable retrofits of entire neighborhoods and towns. These programs are expected to save households and businesses about $100 million annually in utility bills, while leveraging private sector resources to create an estimated 30,000 jobs during the next 3 years.

We Need to Develop and Deploy Cleaner Technologies for Electricity Generation

We Need to Provide a "Market Draw" for Renewable Energy Sources.—In April of 2009, EIA updated its "reference case" to account for the anticipated impacts of the Recovery Act. One the most striking changes is a significant increase in renewable electricity generation. In the preliminary 2010 report, EIA projects that non-hydro renewables will account for more than 10 percent of electricity sales in 2020 without any additional Federal or State policies. Implementing new market-based policies, such as pricing carbon and a strong national renewable electricity standard can create new demand for renewable energy and its upstream manufacturing activity. I note that RES proposals often exempt some smaller generating sources, such as a cogeneration plant at a university, which reduces the effective target several percentage points below the nominal target. For example, last April, EIA found that a nominal share of 25 percent results in only about 13 percent of electricity coming from non-hydroelectric renewable sources in 2025. This 12 point gap is due to exemptions for small retailers, exemptions for hydroelectric facilities, and energy efficiency credits.

We Need to Reinvigorate America's Nuclear Power Industry.—Earlier this year, DOE made a conditional commitment to finance construction of what will be the first nuclear reactor to break ground in the United States in decades. In fiscal year 2011, the Department is requesting an additional $36 billion in loan guarantee authority for nuclear power. With this authority and the $18.5 billion in existing authority, DOE estimates we could support 6 to 9 new reactors in the next few years.

[2] *America's Energy Future*, Summary Edition, 2009, page 82.

We're also pursuing new technologies, such as Small Modular Reactors, which could serve as drop-in replacements at utility sites too small to accommodate the large present-day nuclear reactors. We see the possibility of significant new American export opportunities.

Barriers to CCS Deployment Must Be Addressed.—While CCS technology available today is costly, the technical potential for CCS is considerable. As America's Energy Future states: "Coal-fired plants with carbon capture (CCS) could provide as much as 1200 TWh of electricity per year by 2035 through repowering and retrofits of existing plants and as much as 1800 TWh per year by 2035 through new plant construction. In combination, the entire existing coal power fleet could be replaced by CCS coal power by 2035."[3] To help realize the potential of CCS technologies, President Obama has established an Interagency Task Force on Carbon Capture and Storage, co-chaired by the Department of Energy and the Environmental Protection Agency. The task force is looking at overcoming barriers to the widespread, cost-effective deployment of CCS within 10 years, with a goal of bringing 5 to 10 commercial demonstration projects online by 2016. The plan should address any financial, economic, technological, legal, institutional, social, or other barriers to deployment. In addition, the Department of Energy is completing an R&D roadmap beyond 2016 to further reduce the costs of carbon capture and sequestration in both coal and gas plants.

We Need to Modernize Our Electric Grid

Smart Metering Technologies Can Save Money for Consumers and Reduce the Need to Build New Power Plants to Meet Peak Load Requirements.—An analysis by the Electric Power Research Institute estimates that implementation of smart grid technologies could reduce electricity use by more than 4 percent per year by 2030. That would mean annual savings in 2030 of more than $20 billion for businesses and consumers around the country.

A Smarter Grid Can Facilitate a More Efficient and Effective Use of Intermittent Energy From Renewable Sources Like Solar and Wind Power as Well as Enable Plug-in Vehicles to Buy and Sell Power to the Grid at Optimal Times.—We also need better batteries to provide grid-scale storage. Modernizing our transmission and energy storage systems is largely still an unsolved problem and an opportunity for America's international leadership in a key technology area.

We Need Transportation Policies and Technologies That Cut Emissions and Reduce Our Dependence on Oil.—Transforming the transportation sector is one of our most difficult tasks. Oil has a very high energy density that makes it a particularly good transportation fuel. In order to decrease our dependency on government-controlled oil supplies from the most politically fragile parts of the world, we should embark on a three part strategy:

—*Fuel Efficiency is Critical*.—The best near-term option for reducing dependence on imported petroleum is through greater vehicle efficiency. The administration recently announced vehicle standards that will ultimately require an average fuel economy standard of 35.5 mpg in 2016, but we can do even better in subsequent years. The first improvements could come from improved internal combustion engines and from lighter weighting of cars.

—*We Also Need to Develop Better Batteries and Address Other Barriers to Electrification of Vehicles*.—A battery that can last for 5,000 deep discharges and has 4–5 times higher storage capacity and lower cost will lead to large scale penetration of hybrid electric and all-electric vehicles.

—*Biofuels, Particularly Advanced Biofuels That Can Be Generated From Agricultural Residues, Can Be a Significant Addition to Our Transportation Fuel Supply*.—The Renewable Fuels Standard recently put into place requires that 36 billion gallons of renewable fuel be blended into gasoline by 2022. Of this requirement, 58 percent is to be met by advanced biofuels that achieve at least a 50 percent reduction in greenhouse gas emissions over conventional petroleum-based fuel. The National Academies study also pointed out that there are a number of potentially viable technologies which can add to our energy security and have negative CO_2 equivalent emissions. That is to say, the production and use of these fuels will not add to CO_2 pollution, but rather have the potential to provide a net *removal* of CO_2 from the atmosphere. All of these technologies require the capture and sequestration of carbon in the fuel making process. Plants capture CO_2 from the atmosphere, and enough carbon can be sequestered to more than compensate for the carbon released when the fuel is used.[4]

[3] *America's Energy Future*, Summary Edition, 2009, page 51.
[4] *America's Energy Future*, Summary Edition, 2009, page 71–73 and Figure 2.16.

We Need a Sustained Commitment to Research and Development.—Only R&D can yield game-changing technologies to lower costs, accelerate innovation, and drive new American industries and jobs.

—*It is Imperative That Government Support R&D Investment*.—Especially at the front end when private investments would not recoup the full value of the shared social good or when a new technology would displace an embedded way of doing business. As the National Economic Council recently stated: "Certain fundamental investments and regulations are necessary to promote the social good. This is particularly true in the case of investments for research and development, where knowledge spillovers and other externalities ensure that the private sector will under-invest—especially in the most basic of research." Through a continued commitment to efforts like DOE's Energy Innovation Hubs and ARPA–E, we can marshal the Nation's brightest minds to accelerate the development of new technologies.

All of these efforts will be vital to our energy future, but even these steps will not be enough in the end. To truly drive the changes we need—and create the jobs of the future—we need a policy that matches the scale of this problem and that will guide investments over a generation: we need to put a long-term cap on carbon that ratchets down over time. Only a cap on carbon will give industry the direction and certainty it needs.

For example, suppose you operate a utility company and have an old coal plant that is near the end of its life. A new coal plant will cost billions of dollars. If you knew there would be a cost to emitting carbon, you would have to think hard about whether the next plant should run on coal that captures the carbon emissions, or gas, or nuclear power or wind or solar energy. Eventually, there will be a cost, but if you didn't know when, you would try to limp along with the old coal plant until you knew what the costs would be and how they would be structured.

Providing certainty will drive investment and job creation today as well as the changes we need in our energy mix over the long term.

Finally, I want to mention that, as we continue our examination of energy and climate policy options, independent and impartial data and analysis, particularly from the Energy Information Administration, will become increasingly important. EIA provides vital information about where we are and where we are going, and, if we are to make sound, data-driven decisions, we must make sure EIA has the tools it needs to do this work.

Thank you again for the opportunity to testify and for holding this hearing. America still has the opportunity to lead the world in the new industrial revolution that we need but only if we make wise choices today.

Senator DORGAN. Mr. Secretary, thank you very much for that analysis.

Since the oil embargo of 1973–1974, the U.S. Government has spent billions on energy research, although as I indicated, it is nonetheless a small part of the amount that we spend on research in the Federal Government. But we have spent a substantial amount to create new energy technologies and reduce vulnerability to foreign imports, and yet all these years later, 40 years later, we are more dependent on foreign oil for our energy, especially in transportation, than we were 40 years ago.

So what do you anticipate will be our energy supply mix 40 years from now, for example, and do you have some optimism that we will have a different mix and be less vulnerable and less dependent? I guess, what is the outlook for the mixture of fuels for the United States in the next 10, 20, 30 years?

Secretary CHU. Well, I do have some optimism. I think what happened in the past, particularly in the late 1970s/early 1980s in the first of these oil shocks and the long gasoline lines, was that there was great energy and enthusiasm to do something about it, but when the price of oil went down to $20–$30 a barrel and stayed there for a number of years, I think that enthusiasm was depleted.

There are new factors now, the rise of developing economies, things like that. It is a safe bet to say—although one cannot predict the price of oil in the next year or two—over the long term, it is a safe bet to say it will be as high or higher than it is today, according to the Energy Information Administration and other private financial predictors. That is one thing.

The other thing is the growing concern about carbon emissions.

So to answer your question, what is the mix that I anticipate 40 or 50 years from today, well, in electricity generation, we are now 20 percent nuclear, I hope that will, as a minimum, be maintained and perhaps be increased to 30 percent or perhaps even higher.

We will be increasing renewables, but that will take time because we have to concurrently build up the electricity distribution and transmission system to handle these variable sources, and again, this is going to take decades.

In terms of transportation fuel, I outlined a three-point strategy that does make sense that will get us to, hopefully, greatly decreasing our oil imports.

The first is efficiency. We have accelerated the energy efficiency of cars now to 35 miles a gallon for cars and light trucks. I think this is a start. We should continue to accelerate that.

Regarding biofuels and advanced biofuels in particular, great progress in the labs is being made today. So I am very optimistic. This will also create great wealth in rural America because in rural America, you now have the opportunity not only to raise food crops, but you can use your agricultural residues to create value.

The electrification of vehicles is another one that I think you and Senator Alexander and others have mentioned. There has been great progress in the last 5 years on batteries. When you start with plug-in hybrids and go to electric vehicles that can greatly offload the transportation needs for local city and suburban driving. So I think with those things, I believe in the next 50 years, we can greatly reduce the transportation need for external oil.

Senator DORGAN. Mr. Secretary, I showed a chart a while ago that shows back to 1850 or so, and if we had had an Energy Secretary back then and you had been the Energy Secretary and someone had asked you at this table, what will our energy mix be in 150 years, of course, you probably would have said, well, we are going to probably use a little less wood and a little more coal, based on what you see and know then. But obviously energy uses have changed, as we have discovered oil and natural gas and used renewables.

I would like you, as a scientist, to think out about 40–50 years. I think you and all of us on the subcommittee are thinking in terms of that right side of the chart because that is what we know. Yet at Sandia National Laboratory there are some folks working on the proposition of getting fuel from thin air, maybe, maybe not, I do not know, when somebody says we can create fuel out of thin air, I say, well, that is something that I cannot contemplate, but maybe scientists do.

As you think as a scientist out 40 or 50 years beyond just the traditional things that we understand and know and think about, what do you see?

Secretary CHU. Well, the fuel out of thin air, thin air plus sunlight, is one of the energy hubs we are proposing, to actually use the sunlight energy and directly make transportation fuel. We think that has sufficient promise that we had proposed this so-called energy hub to do that. So we are exploring radical departures which we think have a shot.

Actually I love that graph because it actually shows you what the challenge is. If you look at the time it takes to transition from wood to coal, coal to oil and gas, it is typically a half a century. We do not have that time to transition to a lower-carbon economy. So one of the things that in the Department of Energy we are thinking very hard about is how do you make that transition in a way that can be faster and that speed will also be very helpful in our economic prosperity because if we lead in that transition and develop those technologies, this is great for American competitiveness.

Senator DORGAN. But in many ways, the question is transition to what, and we are in a frantic search for what.

Secretary CHU. So I commend this report, America's Energy Future, and it calls for—and I agree with this—a diversified supply of energy. It does not sound like the right answer is to pick only one thing that will solve our problem, because if you look at what we have in the United States, we have still abundant sources of natural gas, we have oil. We are the third or fourth largest producer of oil in the world. We have great agricultural resources that can be used, in part, again including the agricultural residues, to make energy as well as food.

So what I believe has to be done is to create diversity of supply, because of what we have been blessed with. But we have some, as I mentioned, nuclear technology. We anticipate a renaissance in nuclear technology. We anticipate that solar will get better and better, but it is still more expensive, to be quite frank, than fossil fuel generation. But it has gone down considerably.

I still believe it needs about a factor of 4 decrease before people put it on their rooftops and in fields without subsidy. And factor 2 is in the cards. We see that very clearly. But the other factor of 2 I think needs more R&D and radical R&D that could be game-changing. And it is the whole cost. It is not just the solar modules.

So it is not satisfying, but I think bits and pieces are the way to go. I go back to energy efficiency, huge, huge gains in energy efficiency. The average cost of decreasing our energy consumption and our dependency and the carbon emissions is something like a few cents a kilowatt-hour. And in many instances, as I pointed out in my testimony, it is actually a money-maker. If an industry says I can invest a hunk of change—let us say $1 million—and I get a 10 percent return on my capital to save energy, now sadly that may not be enough for industry because industry might be expecting a 20 percent return on their investment of capital. But if you want to save energy, if you want to decrease our carbon emissions, if you want to decrease our dependence on importing foreign sources of energy, we should think hard about what it will take to get industry to make those investments.

Senator DORGAN. Mr. Secretary, thank you. I have exceeded my time.

I will call on Senators in order of appearance, Senator Voinovich.

Senator VOINOVICH. Thank you, Mr. Chairman.

First of all, I want to congratulate you on the people that you have got working in the nuclear area and also in the area of fossil fuels. One of the things that puzzle me is what are we doing to coordinate the effort to get to clean coal technology more rapidly than it appears that we are doing. You are talking about building some CCS plants in the next several years. We have China building them every day or a couple a week. And it seems that the money for the technology is spread all over.

For example, I have introduced the Asian-Pacific Partnership bill in the Foreign Relations Committee. It is ready to come out. It creates a separate committee in the Asian-Pacific Partnership that deals with clean coal technology and puts in, I think, $200 million a year from the United States to match the other countries that participate. Senator Rockefeller and I are working on a bill to deal with this, and that provides about $20 billion over 10 years.

You have got money that you are working on.

And it seems to me that one of the best things that we could possibly do for the United States or internationally would be to come up with some concept of where we could create some kind of an international DARPA that would move this clean coal technology forward rather than the 10 years that MIT says is going to be required. We know darned well that even though The Sierra Club and others are shutting down new coal-fired IGCC plants in this country, China is building them. India is building them. In fact, India said they are going to build the biggest coal-fired plant ever in the history of the world.

And I am just wondering from our point of view and internationally, what thought is being given to China to coordinate all of this effort? So we are doing our thing. You talked to the Canadians. They are doing their thing. The Brits will tell you we are doing our thing. You know, everybody is doing their own thing, and what is being done to try to coordinate this? Because I think if we do not do it, in terms of greenhouse gas emissions, you can shut everything down here in the United States and we are still not doing anything about that. And we know we should be building coal because of our supply. We know the Chinese are buying up coal mines all over. So what are we doing to coordinate that effort?

Secretary CHU. There are a number of coordinations. The Australians have set up a worldwide initiative that we are members of. Specifically with China, the President announced—I think it was about 6 months ago—a research cooperative where it is $150 million in three areas: energy efficient buildings, vehicle electrification, and clean coal technologies. So China and the United States are putting $25 million apiece into co-developing some clean coal technology we can both use.

I agree with you absolutely that China and India are not going to turn their back on coal, and so we have to develop the technologies that can use coal. And the United States, quite frankly, I do not believe will turn its back on coal as well. So we do need to develop these clean coal technologies.

Jim Markowsky, who I believe you know, an old friend of mine, is a very, very capable person. He and his team put together a road map of three or four technologies we think are promising, and we are working hard. How do you push these? One way is the retrofitting of existing coal plants. New existing coal plants, the highly efficient coal plants will not be shut down. These are multi-billion investments, so one has to develop the technologies to retrofit those. In addition, the other plants you mentioned, the gasification plants, are another technology. And finally, there is something where you separate out the oxygen from the nitrogen and you burn coal in an oxygen plus CO_2 atmosphere. It creates a pure stream of carbon dioxide that you can then sequester. So these are three primary approaches. We need to look at all three of them because of the existing fleet and what might come before.

Now, Jim Markowsky believes that the IGCCNN will probably be less expensive, but we are pushing very hard. The cost is still too high, and so although we are piloting things for 2016, there will be very valuable lessons learned. We are more ambitious and we still want to drive the cost down. So there is coordination.

I have already talked to my counterparts in Europe. And my counterparts are the energy ministers, but in addition, the scientists there. We are beginning to think of how we are going to trade notes, not only trade notes, but actually co-invest in pilot projects. These pilot projects are not inexpensive. They are pretty expensive. So we actually say, okay, we are going to be testing this technology, that technology, this technology. And my proposal, which has always been met favorably, is to say by co-investing, you do not mean necessarily money the way, let us say, we are doing with China, but at the very minimum, we actually put engineers, when these pilot projects are being done, on the site. So the lessons learned are immediately seen and felt by people in other countries. So these are some of the things we are trying to do to coordinate this and again to accelerate this transition.

Senator VOINOVICH. Thank you.

Senator DORGAN. Senator Voinovich, thank you very much.

Senator Feinstein.

Senator FEINSTEIN. Thank you very much, Mr. Chairman.

Mr. Secretary, I gave you my litany of complaints. Let me try to ask a couple of generic questions about it.

What is the Department's policy with respect to building solar and wind on disturbed private lands?

Secretary CHU. Well, in terms of the loan guarantees, what we try to do is evaluate the loan guarantee on several major criteria. One of them is the——

Senator FEINSTEIN. Is it permitted?

Secretary CHU. On disturbed private land?

Senator FEINSTEIN. That is correct.

Secretary CHU. I believe that should be fine.

Senator FEINSTEIN. So there is no disincentive in the permitting process——

Secretary CHU. As far as I know, that is correct.

Senator FEINSTEIN. Well, I am not sure that is correct. So if it is correct, I think that is fine, and I am going to hold you to your word.

Secretary CHU. Yes. I mean, I think it would be more appropriate in terms of the specifics of your things——

Senator FEINSTEIN. Okay, let me give you a specific. Small proposals, close to cities, maybe 30–50 megawatts and multiple sites from one person that wants to, let us say, build three sites where they have got transmission, where it is easy to do on disturbed private land.

Secretary CHU. Okay, sorry.

I would have to look at the specifics of that particular loan because sometimes loans are turned down not for those reasons, but they may be turned down for reasons of the financial viability of the company, the backing of the company. So it would have to be looking at—you know there is no policy that says you cannot do that on disturbed private land, absolutely not. But I think in some of the instances, I believe—this hearing is not the appropriate time to look at specific companies.

Senator FEINSTEIN. Right. Well, I am going to do——

Secretary CHU. Right. But I would love to talk to you in private——

Senator FEINSTEIN. I agree with that, but I want to get your attention.

Secretary CHU [continuing]. On the specifics of specific loans regarding the financial issues.

Senator FEINSTEIN. All right.

Now, I am going to talk about one company and that is Tessera that wanted to build a large facility, 800 megawatts, in Imperial County. The technology they are going to use was produced by Sandia. Sandia just won an award on that technology. Their application was summarily turned down. Nobody talked to them for 7½ months. Should that be?

Secretary CHU. Actually, no, but again, no in the sense that if there were clarifications and issues of that nature, they should be talking with the applicants, clarifications of the application.

If there were other issues, again if there were sort of balance sheet issues, things of that nature, that were giving the loan guarantee program pause, I am not sure whether it is necessary to have a discussion with that because that is all black and white. That is on paper. But again, I would have to look at the specifics of that particular loan.

Senator FEINSTEIN. Well, the point that I am trying to make with you is there is a problem with California projects. I do not know whether there is a bias. I do not know whether there is a problem in the projects. I have written to you. I do not get adequate responses. I would like an opportunity to be able to express this to you in another forum if that would be agreeable.

Secretary CHU. I would love to talk to you about those loans.

Senator FEINSTEIN. Okay.

Secretary CHU. We believe we have no bias against California. I can say that as a Californian. No bias for or against.

Senator FEINSTEIN. Okay.

I was going to ask you a quick question on the NIF, the National Ignition Facility. Many believe it might be a prototype for a fusion nuclear powerplant some day, and I gather that the National Academies and the Academy of Engineering are now conducting a study on inertial fusion energy to explore the viability of that vision.

Do you agree that the results of that study could be enhanced if the NIF is able to provide the Academies with analysis and testing?

Secretary CHU. Yes.

Senator FEINSTEIN. So——

Secretary CHU. We have great hopes for NIF. So far as they have turned on, that facility has worked very well. We anticipate, although it cannot be predicted with certainty that you could get an ignition in a year or two. The technical milestones, as they begin to put it through its paces, have been met, and in the last communication I had, they are ahead of schedule. So there is an opportunity, and both the Department of Energy and the National Academies are looking at now saying, okay, it looks like if you do get ignition, let us develop a scientific program that can actually explore those areas where it might be possible to develop commercial inertial fusion.

Senator FEINSTEIN. So, in other words, they can participate together with the Academies.

Secretary CHU. Yes. I think we in the Department of Energy applaud what the Academy is doing because now is the time to start thinking about what experiments to do to test the commercial feasibility.

There are two issues. The major issue is the lasers. Right now NIF on a good day can have a couple of shots. Let us say one or two shots. In a commercial reactor, you will need 20 a second and not have down time. So there is a huge difference. So there are numbers of very capable people also looking at whether it is possible to make cost effective lasers that have that degree of reliability. But in the meantime, there are still some fundamental issues on how you can make this efficiently.

And finally, the lessons learned from laser fusion can be also used to explore inertial fusion using ions as well.

So it is a technology I do not anticipate in the next couple of decades will go commercial, but it is like magnetic fusion. It is something that you want to look at because if you do get fusion, it is cleaner source of energy, much, much less reactivity issues.

Senator FEINSTEIN. It is very exciting. I have been to the facility, and it is an amazing place.

Thank you.

Secretary CHU. Thank you.

Senator FEINSTEIN. We agree on one thing. Thank you.

Secretary CHU. I think we agree on more.

Senator FEINSTEIN. Well, I hope so.

Senator DORGAN. Senator Alexander.

Senator ALEXANDER. Thank you, Mr. Chairman.

The chairman has constructed this hearing around the future of energy. Let us talk about the Department of Energy's future. You have a goal to reduce your greenhouse gas emissions from the Department of Energy by 28 percent by 2020 I believe.

Secretary CHU. Right.

Senator ALEXANDER. In one of your recent articles in the Wall Street Journal on nuclear power, you commented on the interest in smaller modular reactors——

Secretary CHU. Correct.

Senator ALEXANDER [continuing]. If I am correct.

I am told that a single 125-megawatt reactor would help the Department of Energy meet one-half of its greenhouse gas goals by 2020. Does that sound about right?

Secretary CHU. That sounds about right.

Senator ALEXANDER. A 125-megawatt reactor would also be about the amount of electricity that the entire Oak Ridge National Laboratory and the computers would use.

What I am leading to is—well, let me ask this. The Navy has small reactors, right? I mean, the United States Navy.

Secretary CHU. Right.

Senator ALEXANDER. And the United States Navy approves its own reactors, right? It does not go through the Nuclear Regulatory Commission.

Secretary CHU. Correct.

Senator ALEXANDER. And do you know if there has ever been an accident on a Navy sub or a Navy ship in the 60 years?

Secretary CHU. Well, there have been accidents, but I do not believe there——

Senator ALEXANDER. That has harmed someone?

Secretary CHU. There certainly have been unfortunate accidents on nuclear submarines, but I believe——

Senator ALEXANDER. Yes, not the result of the reactor.

Secretary CHU. Not the result of a nuclear malfunction.

Senator ALEXANDER. The Navy's safety record on small nuclear reactors is pretty good——

Secretary CHU. Correct.

Senator ALEXANDER [continuing]. Over that period of time.

I am wondering if your own departmental goals for greenhouse gases and the interest in small modular reactors might offer a way to accelerate pilot programs to see how they work. I know that in Alaska, for example, Senator Murkowski has said that for the last 10 years a remote community in Alaska has considered the idea of a small modular reactor because it has no better way to get electricity. I was thinking of the Oak Ridge example. It might even be a reactor operated by the Department of Energy. I was thinking there might be a naval base in Hawaii or some other place where the Department of the Navy might have a small reactor.

I am sure that the first three, four, five small reactors would have an additional cost to them, a risk cost that is always associated with a startup, but if it were part of a Navy installation or part of a Department of Energy greenhouse gas goal or part of some other relevant goal—you have got the Tennessee Valley Authority who is interested in this, and they are a Federal utility who are supposed to do things for the Nation rather than just for private investors.

So I am running it through my mind whether, given your interest and that of so many people in smaller, cheaper modular reactors, if maybe a Navy reactor, a Department of Energy reactor, as well as a Nuclear Regulatory Commission reactor over the next 5 or 10 years might not be a wise approach.

Secretary CHU. Well, Senator, as you know, I am a big fan of small modular reactors. I think the economy of scale you get from making these very big 1/1.5-gigawatt reactors you can perhaps recover by mass producing the smaller ones.

When I first became Secretary, I asked Admiral Donnelly whether we can modify a nuclear submarine reactor for this. He smiled at me. He laughed and said you cannot afford our nuclear reactors.

They are very high-performance, very robust reactors. And they also work on highly enriched uranium which is something we prefer not to do.

But let me just say that we are very keen on it. We put it in our budget to help build and license two to try to accelerate the development of those reactors. We think it is useful for a wide variety of purposes. The Oak Ridge example—you are absolutely right about that. In fact, there is a site near Oak Ridge that was designed for a reactor that is waiting and ready to be used. If you build, let us say, 100 megawatts or something like that, you can size the number of modules to fit the site, to fit the electrical distribution system of that site. Many sites cannot accommodate a large 1.5-gigawatt reactor, both for the cooling and for the electricity transmission distribution.

You also can size it to the finances of the company because if you have a $7 billion or $8 billion thing and your total capitalization of the company is on the order of $10 billion or $20 billion, you are essentially betting your company on a single reactor, whereas if you go to one-third, one-quarter, it satisfies a lot of needs.

And finally, it is an area where we think the United States can be a technological leader. We lost the lead in the large ones over the years, especially after we were sending signals that we were going to run out the current fleet of nuclear reactors, close them down, and that would be it. Now because of the carbon dioxide issues, there are a number of people, including many environmentalists, who say now we should bring this back.

So as we bring this back, small modular reactors are one area where we think we can take a technological lead, and it would be great for export as well. So there are many, many reasons why we want to do this.

Senator ALEXANDER. Thank you, Mr. Chairman.

Senator DORGAN. Thank you very much.

Senator Landrieu.

Senator LANDRIEU. Thank you, Mr. Chairman, for calling this really important, very important hearing.

And Mr. Secretary, thank you for your leadership.

I want to follow up, staying on the nuclear theme for just a minute. One of the unfortunate changes in U.S. policy over the last 30 years has been the almost complete abandonment of our nuclear program. And I for one and many of my constituents are very pleased that it is coming back with your leadership and your determination with President Obama. We hope to reinvigorate the U.S. nuclear power since it is a plentiful source of emission-free and carbon-free electricity that this country is going to need.

So Senator Voinovich has been a tremendous leader in this area. The former chair of the Energy Committee, Pete Domenici, helped to lead this effort.

I wanted to ask just a question, though, about something that may be a small blockage in our move forward. The President's budget this year requested an additional $36 billion for nuclear loan guarantees, as you are aware. It is my understanding, however, that there are two nuclear projects that are ready to go kind of neck in neck. Both show a lot of promise, but unfortunately, the budget may be insufficient.

Is that your understanding that the budget is currently insufficient to support both, and if so, what is your recommendation?

Secretary CHU. That is my understanding. $8.3 billion was used at the Vogel site for two reactors. We have roughly $12.3 billion and some change left. There are two. There is possibly even a third application not immediately ready to go, but it could be done before the 2011 budget. We feel that if you allow that both of them have the opportunity to build, we would need, in addition to the $12.3 billion—$12.5 billion—I forget the exact number—an additional $4 billion. There is a third reactor that we are looking at. If you want to capture all three, that would be an additional $9 billion.

Senator LANDRIEU. So basically for almost $50 billion—$50 million—is it billion?

Secretary CHU. Well, okay, so here——

Senator LANDRIEU. Well, I know it is billion, but it is only 1 percent that it would score. So actually for a $50 million appropriation, we could potentially leverage those three projects. Am I doing that correctly?

Secretary CHU. I think it is $9 billion in authority. So $90 million would get the three projects, so we would have a total of five.

Senator LANDRIEU. So it would be $90 million. I said $50 million. It would be $90 million. Okay.

You know, Mr. Chairman and Senator Voinovich, I really think that this is something specific that we should look at. I mean, for a relatively small additional investment, we could really leverage the culmination of many years of work to actually get these projects built and underway. I just wanted to mention it because I think it is very significant. And as a member of the Appropriations Committee, I will be working closely with you to see what we can do.

Second, let me ask this. We have spent a lot of time both in this subcommittee and others focused on also increasing demand for new kinds of vehicles, which is very important as we try to put a climate bill together, as you know. And we want vehicles that can run on reduced carbon emissions, both kind of new engines, electric engines, et cetera and hybrid.

But in the meantime, as we are building the technology to do that, we also have some innovative projects. DOE has been looking at some of them. One of them happens to be in Louisiana, but we are not the only one. It is a car that runs a much more highly efficient conventional internal combustion engine that will get more than double the current capacity.

Could you comment on just the general kind of conventional but highly efficient vehicles? Do you think that there is a place for them as a bridge vehicle so we can move our country to actually carbon-free emission vehicles?

Secretary CHU. Yes. In fact, I briefly mentioned in my testimony today that the immediate way we reduce our dependency on foreign oil is to drive toward efficiency, and it is efficiency in commercial internal combustion engines. There is now being developed a clean generation of diesel, small diesels, that can even satisfy California pollution air standards, a lighter weighting, better rolling resistance on the tires. Even though it is not dramatic—it is not going to a plug-in hybrid, all-electric vehicle—the market penetration could be must faster because until we get batteries that can last 15 years of deep dischargers that are reduced in present cost, the forecasters are not saying that this is going to be truly significant.

Now, I applaud what companies like GM and their Chevy Volt are doing. I think those are great things. The Nissan Leaf, all these things are wonderful. But the low-brow internal combustion engine—if you make it 10 percent more efficient, it affects all of them. If you get better tires, it affects everything immediately. If you get better, you know, lighter weighing materials, those things go immediately into the entire fleet.

Senator LANDRIEU. Well, that is very good to know—my time is up—because we have a project that will meet those guidelines, as you know, and we are excited about the possibility.

Thank you so much, Mr. Chairman.

Senator DORGAN. Senator Landrieu, thank you very much.

Mr. Secretary, thank you very much for appearing here today. I hope you will be available if we wish to submit some written questions to be able to respond to them. But we appreciate your leadership and the work. As several of my colleagues have indicated, I think you have put together a very strong team at the Department of Energy, and we appreciate the work of all of them.

Secretary CHU. And could I make one last——

Senator DORGAN. Yes, of course.

Secretary CHU. In response to the intent of this hearing, we are developing a road map master plan. It will be heavily influenced by this very authoritative report, America's Energy Future. This plan is not just a laundry list but timelines of what we think can happen in the years and folding in the economics.

So we are busily working with the team that we now have in the Department of Energy—it is an extraordinary bunch of individuals. Just as an example, there are five members now in our team that are either members of the National Academy of Engineering or National Academy of Science, which is unusual. One of them, a member of the National Academy of Engineering, also has 25 years of industrial experience. He worked in a power company. He built coal plants. So in addition to being—so they are not all academic scholars—this is Jim Markowsky—and people who have founded many companies. So we have a team we think that can perhaps start to lay a rational road map that, as you say, does not lunge here and there, but perhaps can give us ideas on formulating a comprehensive energy policy.

Senator DORGAN. Well, I have a copy of the summary edition of America's Energy Future here. It is a great menu of all of the things that have been discussed here and much, much more. So I am encouraged by your report.

Secretary CHU. Thank you.

Senator DORGAN. Thank you very much, Mr. Secretary. We appreciate your being here.

Next we will call on the second panel: the Honorable Phil Sharp, President of the Resources for the Future in Washington, DC; Mr. Robert Fri, who is the Past President and Visiting Scholar, Resources for the Future, Washington, DC; and Dr. Eric Loewen, who is the Chief Consulting Engineer, Advanced Plants Technology, at the GE Hitachi Nuclear Energy facility, Canonsburg, Pennsylvania.

Mr. Sharp, I have had the pleasure of serving with you a long, long time ago in the U.S. House of Representatives and have long, long admired your work both there and since you have left the U.S. House. But welcome to you and to Mr. Fri and Mr. Loewen.

We will begin, Mr. Sharp, with you. As I indicated, all of the testimony will be part of the permanent record in its entirety, and we will ask the witnesses to summarize. Thank you.

STATEMENT OF HON. PHILIP R. SHARP, PRESIDENT, RESOURCES FOR THE FUTURE

Mr. SHARP. Well, Mr. Chairman, thank you very much for inviting me. It is an honor to be here. You folks have played an incredible role for years. You personally have and are going to be gone, unfortunately, from this chamber—and dealing with energy questions. So I am not sure how much of what I have to say will be new to you, but I think some of the things it is important for us to look back and remember as we try to figure out where to go in the future.

First, let me just quickly say I must say these are strictly my own views, not those of the scholars at Resources for the Future. I deserve any blame or credit and do not hold it against our hard-nosed scholars who are quite independent.

I was asked to give something of an historical perspective since now I am part of history, and basically let me suggest a couple things.

We are at a time of incredible change in our energy markets and, indeed, in our energy policy as well. And I think it is important to recognize this, and it is something that you and others are focused on. This is not a pattern of usual work if you are trying to make investments, if you are trying to figure out where the future is.

Our markets have gone through, in several years, a radical change in prices, obviously in oil, but also even in natural gas, beginning earlier in the decade. And those price shifts, as they did in past history, have had profound impacts on how investors behave, on how consumers behave, and on how Government operates in terms of policy. Indeed, if there is anything that is clear from the experience of the operations of Congress in 2005, 2007, and in the stimulus package is that we have significantly expanded the Government's role and its intervention in our energy markets. By the way, this is happening around the world. And that is a radical change that is, frankly, akin to what many of us went through in the 1970s.

Compared to the 1970s—and I do not want to stay focused on them and live in them too much, but it is important to recognize that today we have incredible technological and even fuel options that were not readily available or on the horizon. They were a glint in somebody's eyes. This subcommittee and others made major investments over those years, as did the private sector, that in fact have put before us these options that several of you folks have mentioned this morning.

But the question becomes why they did not get into the marketplace. And of course, Secretary Chu in two sentences answered the question essentially, and that is, once oil prices dropped in 1986, simply the investments fell flat. Many people lost money in the market, and indeed, what policies had been adopted in terms of investments from the Federal Government certainly did not look wise and many of them, obviously, were repealed or failed.

Let me just mention a couple of the assumptions that were very broadly held in industry, Government, and academia when we were engaged in a lot of policymaking in the 1970s because I think one of the hardest things we struggle with, as you think about a 50-year period, is we frankly have great difficulty getting it right and knowing where the world is going to be, which I think suggests to you having a robust set of policies and a robust marketplace are the only approach to hedging against this intellectual as well as economic and political uncertainty.

But let me quickly mention them. They are outlined here and you will not be surprised.

But it was widely believed that we would see major disruptions and we were at risk for disruption in the oil supply since we had been disrupted in 1973. We drove to try to cut imports through additional production, through CAFE standards. We drove to prepare for emergencies with the Strategic Petroleum Reserve and even the crazy thought that we might be able to ration gasoline again in this country. But our experience since then, frankly, has been that this global oil market has been quite robust and resilient. And while we have had disturbances we do not like, the fact is it has delivered the oil even with military action in the Middle East, even with political turmoil in Venezuela and Nigeria and other places that at times in the past we would have thought would have been devastating to us.

That does not mean because we have had this good experience, we are not still at risk, however. And as we know today, there are possibilities for major military or terrorist activities that could significantly disrupt and probably create lengthy disruptions in oil supplies which would have a major impact on the world economy and probably would lead to significant political and social instability in any number of governments.

The second assumption was that whether it got disrupted or not, we would see oil prices continue to rise. The real argument was how fast and how far they would go. Widely accepted, so major private investments were made. Major public investments were made in technologies, in efficiencies and alternative fuels that we thought would quickly come into being cost effective in the marketplace. But of course, that 1986 drop and persistent drop in prices just totally undermined that.

I only want to say in pricing one of the biggest mistakes made in the 1970s that is now, I think, deep in people's knowledge was when we had price controls on the oil system—by the way, on the gas system too. That was a profound mistake that even when we had these radical price increases in 2006 and 2007, we did not see anyone on Capitol Hill advocating price controls. And so I think we probably learned our lesson from that.

But my point here is the obvious one that everybody knows. Major shifts in the price of oil still can have major impacts to either enhance the policy you are trying to get across or to undercut it. And that is something we, frankly, do not have an effective tool in my view to deal with unless you are willing to tax oil in a persistent manner to keep it at a certain price level.

The third assumption that was often involved was the domestic gas supply was in decline naturally in the United States. Of course, we find getting rid of the oil price controls, opening to Canada, we had plenty of gas. Then we thought we were in shortage again, and you folks in 2005 and 2007—the prevailing assumption was we needed to have LNG because now we see we have more supply, although there is a great deal of uncertainty of how much, what its impact is on transportation, like will it undermine the electric car, will it not, what it will do in the electric power field. The point is that is another of the uncertainties we face, although that is a positive uncertainty in the sense that we have that.

Let me just say, to wrap up on the carbon challenge, which is the longer-term, most profound complication that we face. Even though much is happening, as we know, you folks are engaged in a discussion of what should be the architecture or the framework of policy going forward to constrain emissions. And we have two broad strategies before us: try to set up a pricing on carbon either through cap and trade or tax or a combination; or we have under the Clean Air Act somebody may be able to figure out another strategy, but at the moment those are the two broad strategies.

Nearly every analyst and economist believes that, depending on the details, the much smarter strategy from a cost effective way for this country is to go with some kind of pricing of carbon because in the end I think there are three things that we want to keep just in front of us as we go ahead with some kind of profound move to change the system for carbon or for oil security.

And that is, one, what the Secretary said, what is the central point of the American energy future that you just held up is you must go for a portfolio. We do not know for sure which things will really work out to what extent. So have a portfolio of fuels, a portfolio of energy efficiency technologies.

Two, have serious independent review periodically, perhaps every 4 or 5 years, of whether these policies are really paying off. Are they cost effective? Is the problem still what we thought it was?

PREPARED STATEMENT

And three and finally, which is I think a prevailing view today, is wherever possible capitalize on the competitive marketplace to help drive the policy we need. The Government will have to do things, and it is doing things. But it must, every time it can, leave the possibility for the innovation, the drive, the incentive, and I think we are most likely to have a better energy future in that way.

Thank you very much, Mr. Chairman.

[The statement follows:]

PREPARED STATEMENT OF HON. PHILIP R. SHARP

Chairman Dorgan, thank you for the opportunity to be here today. For the record, I am president of Resources for the Future (RFF), a 58-year-old research institution based in Washington, DC that focuses on energy, environmental, and natural resource issues. RFF neither lobbies nor takes institutional positions on specific legislative or regulatory proposals.

I emphasize that my views today are my own, and not those of Resources for the Future. I have included in an appendix, however, some related key studies and forthcoming research from RFF.

In the last few years, U.S. energy markets and energy policies have undergone incredible change. Ahead, we face more significant developments and uncertainties.

Markets have seen radical price swings. World oil prices began rising above $40 per barrel in 2004, reached an extreme peak of $137 in July 2008, and fell back to a low of $34.00 in January 2009. Today, prices hover above $80. Natural gas prices in this decade made similarly radical shifts.

Rising prices energized both markets and politics. Investors, consumers, and Government policy changed in significant ways. New attention has been given to efficiency and to alternatives to oil and natural gas—much as we witnessed in the 1970s.

Government efforts to influence energy markets dramatically increased with the landmark energy legislation of 2005 and 2007 and the stimulus package of 2009.

A host of mandates, regulations, and subsidies have been adopted to influence investor and consumer behavior. A variety of goals is cited for various interventions: oil security, protection of the economy, and environmental urgency, especially with regard to climate change. Congress, of course, is currently grappling with major initiatives embodied in the House-passed Waxman-Markey bill and the proposals under construction in the Senate.

These policy actions represent a level of market intervention not seen since the 1970s.

From the mid-1980s to early in this decade, market liberalization was the prevailing view. The most significant policy initiatives were the efforts in the 1990s to restructure the electric industry to bring competition into those markets, often misnamed "deregulation." There were only a few significant Federal market interventions such as adoption of the production tax credit for renewables and the advancement of appliance efficiency standards. The Clean Air Act amendments of 1990, of course, imposed significant requirements on energy industries entailing major investments, but generally the changes were achieved at less cost than previously advertised. This was especially the case with the Acid Rain Program, which imposed a cap-and-trade system on electric utilities.

Compared to the 1970s, we now have available many technologies and techniques that are already changing our energy systems or have the potential to do so. This is in no small part due to past private and public investment in technology development, heavily pushed in the 1970s by the allure of rising energy prices and Government policies—technologies that did not make it into our markets after world oil prices dropped in 1986 and Government incentives were either repealed or became irrelevant.

During that time the Nation also was embarking on serious environmental regulation that had major effects on industry and consumer behavior. Today we are focusing on greenhouse gas (GHG) emissions, which will have a profound effect, over time, on the production, distribution, and use of energy.

ASSUMPTIONS UNDERLYING POLICY IN THE 1970S

Oil crises in 1973 and 1979 generated intense public focus on energy markets and policy. During that decade a number of widely held assumptions about our energy future influenced much of the policy that was adopted; indeed there was also much private investment driven by the same assumptions. Some have relevance for today.

1970s Assumption—Oil Supply Disruptions Likely.—It was widely expected that oil supplies from the Middle East were vulnerable to periodic disruption, creating major costs for our modern economies and potential security issues for the West, especially vis á vis the Soviet Union.

Presidents of both parties made it a high priority to achieve "oil independence." A host of policies were adopted that presumably would cut oil imports. Most knowledgeable people understood such a goal to be very challenging, requiring a transformation of energy markets that would be costly at least in the near term, though public rhetoric often made the path sound cheap and easy.

Major public investments were made in research, development, and even deployment of technology to push the use of domestic coal, gas, oil, and nuclear power and also advance solar, wind, geothermal, ethanol, and other longer-term possibilities.

Fuel economy standards (CAFE) were adopted in 1975 as the primary measure to cut gasoline consumption. Though strongly advocated by policy wonks and by President Carter, a major gasoline tax increase was not imposed.

Emergency preparedness also became a major policy focus. The Strategic Petroleum Reserve was created but took years to fill with crude oil. This program has been sustained for decades but we still have not achieved a clear consensus on when we should use the reserve.

Among other emergency measures was a plan for rationing gasoline. Billions of coupons were printed but later torched in the 1980s. At the time, many of us doubted we could successfully manage such a system, the likes of which had last been tried during World War II in a far smaller market.

The "oil crises" generated widespread public outrage and intensely volatile politics in Washington. In 1979, the shortage of gasoline and the long lines at filling stations ignited public fury, sparking a few instances of serious social disorder. In areas facing shortage, States adopted restrictions, allowing cars to be filled only every other day depending on the odd or even last number on license plates.

It is critical to note that Federal policy at the time—price and allocation controls—almost certainly contributed to the regional gasoline shortages.

Our experience since the 1970s with respect to disruptions has been far more sanguine that expected. The global oil market has been far more resilient than predicted in the face of military actions in the Middle East and political and social turmoil that limited production from other key suppliers such as Nigeria and Venezuela.

Oil dependency remains a serious security issue for the United States. Ahead, of course, the possibility remains that a terrorist or military attack on critical oil facilities in the Middle East and elsewhere could create major and lengthy disruptions with great economic cost and potentially significant consequences for political and social stability in many countries.

1970's Assumption—Oil Prices Would Rise.—It was widely believed that world oil prices would continue to rise in the years ahead. Disruptions in oil supply immediately translate into price spikes, but even in the absence of disruptions, oil prices were expected to rise, though there were major differences of opinion about how far and how fast. Some believed OPEC could and would push them higher; others believed global production would "peak" in the foreseeable future.

Such an assumption about the future meant there were big opportunities for private investment in alternatives to conventional oil and provided justification for many of the Government's investments in the commercialization of unconventional fuels, which became the focus of the Government's $88 billion Synthetic Fuels Corporation.

The radical drop in oil prices in 1986 shattered this assumption, killing all kinds of private investments, and pulling the rug out from under claims about the cost-effectiveness of various Government policies, many of which were repealed or went dormant. Today, the Great Plains coal gasification project is one of the few survivors from that era.

Many observers have long cited the Synthetic Fuels Corporation and other such policies as major failures. Clearly they did not produce the intended results, though a few defenders argue the Government failed to stick it out. Given the major role oil prices play, it seems highly unlikely the goals could have been met without dramatically increasing oil costs either through taxation or regulation.

But, we should also recognize that some of the technology choices on the horizon today were advanced through past Government investment. Public research and investment have contributed to today's new shale gas supplies; to the variety of transportation fuel and technology options, such as plug-in hybrids and fuel cells; to breakthroughs in lighting efficiency; to advanced designs in windmills and nuclear power plants; and to smart grid technologies and more.

It is important to say a word about Government efforts to directly control prices. Early in the 1970s price controls on domestic oil had been imposed as part of an economy wide anti-inflation program of wage and price controls; the controls were retained on the oil sector when the larger program lost credibility and was ended.

Such controls proved to be counterproductive to reducing oil imports. They deterred conservation and discouraged domestic production, and, further, they disrupted the internal shipment of fuels to consumers seen in the gasoline lines of 1979. We appear to have learned the lesson of such failure. During the recent run-up in oil prices, there were no political leaders calling for price controls.

So, Where Will World Oil Prices Head?—That is one of the most significant uncertainties that will shape our future energy markets. In general, many observers believe that as the world economy rebounds there will be upward pressures on price. Some analyst are even certain that we could face a major market upheaval; they expect us to reach "peak" production in the near future—a view that is not yet the conventional wisdom. And of course, there is the possibility that prices will fall back to lower levels. Only a couple of years ago, a major forecaster claimed that market fundamentals meant the markets would settle somewhere above $40 a barrel.

Despite major domestic and international efforts by industry, government, and academia to collect and analyze data, given the scale and nature of the global oil markets, we have difficulty answering with a high degree of certainty some of the most basic questions: How large are the reserves? What is the global level of production and consumption at any given moment? And, when are prices likely to radically shift?

1970s Assumption—Domestic Natural Gas Supply Would Decline.—For several decades prior to the 1970s, the Federal Government had been regulating well-head prices for gas sold into the interstate market. As a result, segregated markets had developed for "intrastate" gas in the producing States and adequacy of supply ultimately became a problem for much of the country beyond those States. Indeed, the big interstate pipelines were required to develop curtailment plans to establish which customers could be shut out during shortages.

In 1978, the National Gas Policy Act was adopted after ferocious political fighting. It was a complicated, but in the end effective, transition out of the bifurcated markets. Prices were deregulated for new supplies. (Old gas supplies were finally deregulated in 1989, without controversy.)

In 1978, the Fuel Use Act also was passed to block the burning of natural gas as a boiler fuel, especially when used in generating electricity, thus reserving it for preferred uses such as household heating, industrial processing, and chemical feedstock. When the supply assumption was shattered by a more favorable supply picture, the act was repealed.

At the same time, Canada was moving away from the "nationalistic" policies it had adopted during the 1970s energy crises and became a major supplier for the United States.

With gas deregulation and imports from Canada, supplies became readily available. Indeed, there was much talk about the "gas bubble" and argument over when it might break.

Over the last 40 years, we have witnessed several changes in the conventional wisdom about the availability of domestic natural gas.

In the 1990s, there was a major build-out of new gas-fired electric power plants. When gas prices unexpectedly rose significantly after the turn of the century, new concerns about supply availability arose.

Indeed, the prevailing assumption during consideration of the legislation in 2005 and 2007 was that we needed to accelerate the building of liquefied natural gas terminals to bring in foreign gas and resurrect plans for an expensive pipeline to bring natural gas from the Prudhoe Bay in Alaska down to the lower 48. (In the 1970s a major, but ultimately unsuccessful effort, was made to stimulate building of the line. Special regulatory incentives were adopted and a treaty was signed with Canada to facilitate construction.)

In only the last year or two, a whole new wisdom has emerged with the demonstration that we can economically extract gas from shale. We are only beginning to sort out just how large this supply may prove; how environmental regulation, especially with respect to water, may affect its availability; and what impact such supplies may have on fuel choices for electric generation and for transportation. Unless this new wisdom is short-lived, it will certainly reshape the thinking of energy investors and policymakers. Depending on policy choices, this new supply has the potential for making our path to decarbonization easier and cheaper over the next few decades.

1970s Assumption—Economic Growth is Dependent on Growth in Energy Supply.—This assumption was widely held, though vigorously contested at the time. There had been a pattern of one-to-one growth in the United States—meaning a 1 percent growth in GDP was accompanied by 1 percent growth in energy supply. For many that meant that expanding supply was the most important policy need. Others pointed to experience in Europe and Japan which suggested economic growth was not so rigidly connected to energy supply. There was almost a pitched battle between two camps: those believing we should conserve our way out of the crisis and those determined to produce our way out.

Our experience since that time demonstrates the fallacy of this assumption. The energy intensity of our economy has significantly declined because of major efficiency gains and because the character of the economy has been shifting away from industrial production toward services and the newer digital opportunities.

Among the efficiency initiatives of the 1970s, two in particular endured for several decades: CAFE in the auto sector and the Public Utility Regulatory Policies Act (PURPA) in the electric sector.

While there has long been argument over the cost-effectiveness of the fuel-economy standards compared to other policy choices, it is generally accepted that our oil use and therefore our oil imports would be higher today had we not had such a policy. Of course, now the standards are being redesigned and tightened.

PURPA, another part of the 1978 Carter Energy Act, required electric utilities, when adding generation, to buy power from cogeneration facilities and small renewable sources, when the cost estimates did not exceed new conventional generation, a determination made by each State. Today, we are still trying to encourage greater acceptance of combined heat and power systems for which Congress recently added incentives.

PURPA also sought to encourage States to reexamine how they regulated prices with a view toward achieving more efficient end use. In recent years, the Federal Energy Regulatory Commission and several States have tried a number of pricing formulations to encourage peak shaving and more persistent end-use conservation.

The fuller story of the 1970s includes a number of other efficiency policies such as tax credits for home insulation and weatherization for the poor.

Today there is far wider agreement that we still have considerable potential for efficiency gains that can reduce oil dependency, reduce carbon dioxide (CO_2) emissions, and contribute to a competitive 21st century economy.

Many studies have identified cost-effective possibilities throughout our economy, but we have learned over the years that there are many barriers to achieving such gains. Consequently, a number of policies have been put in place and are under consideration now in Congress: performance standards, tax incentives, Government purchase policies, public information systems, and so on. As we adopt regulation, however, we should not lose sight of the power of price to help drive innovation, speed the adoption of efficiency technologies, and change our habits.

Today, the digital revolution is empowering us to manage energy use in our homes, businesses, commercial buildings—in every aspect of our economy—with real-time knowledge about how much energy we are using, its changing costs, and how our usage compares to best practices. Much of this "management" can be automated to reduce the decisionmaking burden many consumers want to avoid. Several years ago, the Electric Power Research Institute tagged this possibility as "prices to devices." Digitalization is improving the efficiency of the energy industry itself. "Smart grid" is all about operating the electric grid more efficiently and reliably as well as empowering customers to more efficiently manage their needs.

Modernizing our technology not only should help us meet our energy needs and reduce our carbon emissions, it is likely to prove essential for a modern, competitive economy. But, with digitalization, of course, comes the new challenge of cyber security.

THE CARBON CHALLENGE

We are now grappling with how we should change and indeed, transform, our energy system to deal with global warming over decades ahead. Significantly cutting emissions of GHGs is a daunting challenge—global in scope, reaching deep into our economy, and requiring a long-term focus.

In the United States and elsewhere there are major public and private efforts underway to change the way we produce and use energy. Many incentives have been put in place to advance energy efficiency, renewables and lower-carbon fuels, and to develop potentially critical technologies such as carbon capture and storage and advanced nuclear reactors.

Currently under consideration are options for how to restrict GHG emissions, especially CO_2. A number of countries have adopted regulatory policies, as have several American States. The hard challenge is to design a policy framework or architecture which will hold up over many years and change our economy in the most cost-effective way.

At this time, we appear to have a choice between two broad strategies: (1) put a rising price on carbon, or (2) regulate emitters of carbon under the current provisions of the Clean Air Act. Pricing carbon, of course, can be accomplished either by adopting a tax that rises over time or adopting a cap on emissions with allowance trading—or some combination of the two. Either strategy—pricing carbon or regulating emitters—can put us on a path to cut emissions; both will spur some level of technological innovation.

Most economists and many policy analysts, however, believe the pricing option is superior in terms of finding the least-costly emissions reductions and providing incentives for continuous technological innovation.

Of course, in judging either strategy it is critical to know the details where the devil and angels reside. In pursuing such a long-term challenge requiring persistent policy, there are a few, perhaps obvious, lessons from our previous experience.

—We should pursue a portfolio of fuels and technologies—indeed, a portfolio of policies. This is a basic conclusion of multiple studies by multiple groups. Do not put all our eggs in a few baskets, as the saying goes.
—We should periodically conduct major assessments of the effectiveness of our policies—perhaps every 4 or 5 years. Such evaluation should not only be done inside the Government, but also independently of the Government. This subcommittee and other congressional committees, naturally, will need to continue their critical oversight role.
—And, whenever possible in policymaking, we should capitalize on the dynamism competitive markets can provide in meeting our policy goals.

APPENDIX: RELEVANT RESEARCH

Forthcoming Study—Toward a New National Energy Policy—Assessing the Options

Early this summer, Resources for the Future (RFF) will be presenting findings from its study entitled Toward a New National Energy Policy—Assessing the Options, funded by the George Kaiser Family Foundation. The main study report is designed to offer a thorough evaluation of the effectiveness and cost-effectiveness of a variety of energy policy alternatives, in order to provide decisionmakers with a clear basis on which to develop an overarching national energy policy that deals with the twin challenges of oil security and climate change.

In particular, the study uses the Department of Energy's National Energy Modeling System to examine and score on an "apples-to-apples" basis a variety of policies designed to spur reductions in oil consumption and greenhouse gas emissions in the United States. The report is being developed in collaboration with the National Energy Policy Institute (NEPI), and draws on several technical and background papers commissioned by RFF and NEPI.

Each technical paper focuses on a type of policy investigated in the study, including:

—Transportation policies such as fuel taxes, fuel economy standards, and feebates, as well as an emphasis on liquefied natural gas-fueled heavy trucks;
—Policies to promote deployment of hybrid, plug-in hybrid, and electric vehicles;
—Energy efficiency policies, such as building codes and subsidies versus financing of geothermal heat pumps;
—Carbon pricing policies (both cap-and-trade systems and carbon taxes);
—Policies such as clean energy portfolio standards that mandate electricity generation from renewables and other lower-carbon sources; and
—Policies (loan guarantees) to spur expansion of nuclear power generation.

(Some of the above policies are examined with and without newly expanded resources of natural gas.)

The report launch is currently scheduled for late June 2010, at which point a comprehensive Executive Summary will also be available.

Recent RFF Research on Energy and Climate

Recent RFF research addresses a number of questions central to the development of climate and energy policy. Topics include:

Options for Regulating Greenhouse Gases Through the Clean Air Act

Greenhouse Gas Regulation under the Clean Air Act: Structure, Effects, and Implications of a Knowable Pathway, Nathan Richardson, Arthur G. Fraas, Dallas Burtraw RFF Discussion Paper 10–23, April 2010

The Economic Impacts on U.S. Industries From Placing a Price on Carbon

Impact of Carbon Price Policies on U.S. Industry, Mun Ho, Richard D. Morgenstern, and Jhih-Shyang Shih RFF DP 08–37, December 2008

The Regional and Distributional Impacts of Different Allowance Allocation Approaches

The Incidence of U.S. Climate Policy: Alternative Uses of Revenues from a Cap-and-Trade Auction, Dallas Burtraw, Richard Sweeney, Margaret A. Walls RFF DP 09–17–REV, June 2009

The Relative Merits of a Carbon Tax Versus a Cap-and-Trade Approach

Should the Obama Administration Implement a CO_2 Tax? Ian W.H. Parry, RFF IB 09–09, April 2009

The Impact of a Price Collar on Greenhouse Gas Emissions and the Costs of Climate Policy

A Symmetric Safety Valve, Dallas Burtraw, Karen Palmer, and Danny Kahn RFF DP 09–06, February 2009

Alternative Approaches to Cost Containment in a Cap-and-Trade System Harrison Fell, Richard D. Morgenstern, RFF DP 09–14, April 2009

The Economic and Legal Implications of Different Approaches to Protecting Energy-intensive, Trade-sensitive U.S. Industries Under a U.S. Carbon Policy

Comparing Policies to Combat Emissions Leakage: Border Tax Adjustments versus Rebates, Carolyn Fischer and Alan Fox, RFF DP 09–02, February 2009

The Long-term Effect of Newly Increased U.S. Natural Gas Supplies on Carbon Emissions

Natural Gas: A Bridge to a Low-Carbon Future? Stephen P.A. Brown, Alan J. Krupnick, Margaret A. Walls RFF IB 09–11, December 2009

The Potential Role of Tropical Forests as a Source of Offsets

Forest Carbon Index: The Geography of Forests in Climate Solutions, Adrian Deveny, Janet Nackoney, Nigel Purvis, Mykola Gusti, Raymond J. Kopp, Erin Myers Madeira, Andrew R. Stevenson, Georg Kindermann, Molly K. Macauley, Michael Obersteiner, RFF Report, December 2009

The Effects of Cellulosic Fuel Mandates on U.S. Timber Markets

The Implications of Increased Use of Wood for Biofuel Production, Roger A. Sedjo, Brent L. Sohngen, RFF IB 09–04, June 2009

The Cost-Effectiveness of Energy Electricity Efficiency Programs

Cost-Effectiveness of Electricity Energy Efficiency Programs, Toshi Arimura, Richard G. Newell, Karen L. Palmer, RFF DP 09–48, November 2009

Other Relevant Studies

Published Studies:

Council on Foreign Relations. 2006. National Security Consequences of U.S. Oil Dependency. Washington, DC: Council on Foreign Relations. www.cfr.org/content/publications/attachments/EnergyTFR.pdf

Deutch, John and Ernest Moniz, co-chairs. 2003. The Future of Nuclear Power. Cambridge, MA: Massachusetts Institute of Technology. http://web.mit.edu/nuclearpower/pdf/nuclearpower-summary.pdf

Deutch, John and Ernest Moniz, co-chairs. 2007. The Future of Coal. Cambridge, MA: Massachusetts Institute of Technology. http://web.mit.edu/coal/The_Future_of_Coal.pdf

National Commission on Energy Policy. 2004. Ending the Energy Stalemate. Washington, DC: National Commission on Energy Policy. http://bipartisanpolicy.org/library/report/ending-energy-stalemate. NOTE.—A number of other topical studies are available on the NCEP Web site.

National Petroleum Council. 2007. Hard Truths: Facing the Hard Truths About Energy. Washington, DC: National Petroleum Council. http://www.npchardtruthsreport.org/

National Research Council. 2009. America's Energy Future: Technology and Transformation. Washington, DC: National Academies Press. http://sites.nationalacademies.org/Energy/index.htm

Revis James, Richard Richels, Geoff Blanford and Steve Gehl. 2007. The Power to Reduce CO_2 Emissions: The Full Portfolio. Palo Alto, CA: Electric Power Research Institute. MERGE/PRISM analysis available at http://mydocs.epri.com/docs/public/000000000001019563.pdf

Forthcoming Studies:

Deutch, John, Chair. The Future of Solar Energy. Cambridge, MA: Massachusetts Institute of Technology. http://web.mit.edu/mitei/news/spotlights/solar-future.html

Kazimi, Mujid and Ernest Moniz, co-chairs. The Future of the Nuclear Fuel Cycle. Cambridge, MA: Massachusetts Institute of Technology. http://web.mit.edu/canes/research/fuelcycle.html

The National Academies. America's Climate Choices. http://americasclimatechoices.org/

Senator DORGAN. Mr. Sharp, thank you very much.

Mr. Fri, you may proceed.

STATEMENT OF ROBERT W. FRI, PAST PRESIDENT AND VISITING SCHOLAR, RESOURCES FOR THE FUTURE

Mr. FRI. Thank you, Mr. Chairman. It is really a pleasure and an opportunity to appear before you today.

And what I would like to do is spend the next few minutes summarizing my full statement and focusing on the role of technology change in the energy policy portfolio. In doing so, I am going to draw extensively on a number of National Research Council studies in which I have participated happily, including America's Energy Future. But the views I express are, of course, my own.

We all know that from the time of the first OPEC oil embargo nearly 40 years ago, the United States has looked to technology for solutions to its energy problems. In fact, the first Government reports to recommend an energy research and development agenda appeared within a few weeks of that 1973 event.

But despite this evergreen promise of technology solutions, today's energy system is not very much different from the one that we had 40 years ago. It still relies on fossil energy, and the transportation sector is still dominated by the use of petroleum.

Now, the system has become considerably cleaner and more efficient over the past 40 years, and Federal energy R&D has made a positive, although modest, contribution to this evolutionary change in the system. But the record is uneven. A 2001 study by the National Research Council of DOE's applied research programs showed that a very few, inexpensive programs produced large economic benefits while some very expensive demonstration programs produced no benefit at all.

Well, although the record of the last 40 years, therefore, may leave something to be desired, I think it has taught us several valuable lessons about what the Government can do to accelerate technology change, and I would like to focus on how that might happen.

Now, perhaps the most important lesson is that unless the Nation responds affirmatively and aggressively to the challenges of energy security and climate change, the energy system of the future will look a lot like the energy system of today. It will be cleaner, again, probably more efficient, but fossil fuels, as Phil Sharp has just pointed out, will continue to be convenient and markets will work and will still rely pretty much on the same fuels we have today.

And, Mr. Chairman, if you look at that wonderful chart you had of the transitions from coal to oil and so forth and ask why those transitions took place, it was not because we preferred coal over wood or oil over coal. It is because we like cars better than horses. There was a societal reason driving change in the system. And that societal reason today that could drive fundamental change is going to look a lot like climate change and energy security.

But more of the same is not destiny because technology is capable of making this fundamental change, as the Secretary pointed out in referring to the America's Energy Future study. So the potential is there to make the change. The challenge of doing so is immense, and so the key question is, what can the Government do to accelerate technology change in the energy system? And building on the lessons of the past, four strategies seem to me to be particularly important.

First, as I have already said and others have said, align private incentives with public goals. Innovation, which is what we are talking about here, is a complex function of the private sector and, as such, innovation works best when it is economically rewarded in private markets. And experience strongly suggests that rewarding private sector activity that also produces a public good is the most powerful strategy for technology change, and I seriously doubt that an overhaul of the energy system will take place without such a reward.

Second, it is important to support purpose-driven, fundamental research. Virtually all authorities agree that funding fundamental research is an appropriate function of government, but beyond that, it is essential for driving technology change because it sets the table for innovation in the private sector in ways that we cannot really predict. But the research needs to be focused on basic problems which, if solved, would create fundamental change in the energy system. For example, the development of artificial photosynthesis would revolutionize the capture and storage of solar energy, and it seems to me that Secretary Chu's new ideas for organizing the research program at DOE are pointed very much in that direction.

Third, limit the applied research programs to overcoming well-defined market barriers. Unlike basic research, DOE's applied research program, that is, its fossil, efficiency, renewable, and nuclear programs, focuses on fairly well defined technologies. And experience suggests that in designing programs of applied research, the Government should observe two prerequisites. First, there must be a reasonable chance of adoption in the existing private market, and second, the Government intervention should focus tightly on removing well-defined barriers in the way of getting to that market. And that is evidence drawn from the National Research Council study where we looked back at 40 or so of these programs, and that is what characterized success.

Finally, invest with great care in technologies that do not yet have markets. In the past, Government energy research programs have invested pretty heavily in such technologies, the synthetic fuels program of the late 1970s, for example. Often the costs are high and the record of success is poor. Now, that is not to say the Government should avoid investing in insurance policies, only that it should do so with its eyes open. And Secretary Chu pointed out that the America's Energy Future study strongly recommends that moving ahead to demonstrate new nuclear technology and carbon capture and storage by 2020 is really important. We should do that. It is going to be expensive. It is possible that some of that money will not prove to be successful, but nevertheless important to do, and I fully support that recommendation.

PREPARED STATEMENT

Well, that is a very brief overview of a complex topic, Mr. Chairman, and I look forward to your questions. Thank you.

[The statement follows:]

PREPARED STATEMENT OF ROBERT W. FRI

REFLECTIONS ON 40 YEARS OF U.S. ENERGY POLICY

Mr. Chairman, thank you for the invitation to testify today about my reflections on the last 40 years of energy policy and my assessment of the implications of that history for future policy. It's a large question and I want to focus my comments on one important part of it—technological change.

From the time of the first OPEC oil embargo nearly 40 years ago, the United States has looked to technology for solutions to its energy problems. Indeed, the first Government reports to recommend an energy research and development agenda appeared within weeks of that 1973 event. In 1975, President Ford established the Energy Research and Development Administration, pulling together energy research programs scattered across the Federal landscape. In late 1977, ERDA became part of the new Department of Energy. And today, energy R&D remains a major element of DOE's mission, and of the administration's energy policy.

But despite the evergreen promise of technology solutions, the history of Federal energy R&D has been full of twists and turns in both program goals and management philosophy. President Nixon opted for energy independence. President Carter created the first National Energy Plan and with it, the Synthetic Fuels Corporation. Presidents Reagan and Bush preferred a more modest effort focused on precompetitive research and avoided large demonstration programs altogether. President Clinton favored efficiency and renewable energy programs, while reducing the nuclear budget at DOE to near zero. The second President Bush attempted to reverse some of the Clinton priorities, and laid management emphasis on achieving tangible results from Federal R&D. At the National Academies' Summit on America's Energy Future in 2008, Senator Jeff Bingaman summarized in the attached image these stops and starts of energy technology policy over this period.

Although this record leaves a lot be to desired, I believe it has taught us several valuable lessons. Today I'd like to focus on the lessons that seem to me to be most important, and then on what they can tell us about how the Federal Government might approach energy technology policy in the future. In doing so, I will rely on several National Research Council reports in which I've participated over the last dozen years. While these reports are exceedingly valuable sources, I should stress that the views I will express are my own.

LESSONS LEARNED

First, energy security and a clean environment are the overarching goals for energy policy, and hence for energy R&D. There are other desirable attributes of the energy system, such as reliability and affordability, but the private sector has substantial regulatory and economic incentives to provide them. But energy security and environmental goals dominate energy policy in two crucial ways. First, they are public goods, hard for the private sector to provide and so appropriate subjects for public policy. And second, unlike the more modest goals like affordability, meeting these overarching goals may well require a total overhaul of the energy system.

Energy security and a stable climate share another important characteristic. It's easy to see what needs to be done to meet them, but hard to decide how much to do. Thus, energy technology enhances energy security largely reducing the economy's dependence on oil the economy from all sources. Similarly, limiting future climate change requires greatly reducing the emission of carbon dioxide from the energy system. These strategies are clear and their costs are real. On the other hand, it's very hard to calculate the benefits of greater energy security or a more stable climate. As a result, policy makers face a difficult choice in balancing fairly certain costs against uncertain risks in deciding how to much oil or carbon dioxide to carve out of the system.

I dwell on this policy dilemma because it's easy to fall into the trap of doing nothing while waiting for science to provide some kind of optimal level of action. Waiting is not a strategy, and as I'll mention next, we've been doing a lot of waiting around when it comes to energy policy.

Second, today's energy system is cleaner and more efficient, but not fundamentally different, from the one we had 40 years ago. The Clean Air Act has driven a significant improvement in air quality associated with energy system emissions. For example, EPA reports[1] that between 1980 and 2008 national average atmospheric concentrations of sulfur dioxide has decreased by 71 percent, of nitrogen dioxide by 46 percent, and of ozone by 25 percent. Concentrations of particulate matter (PM10) declined 31 percent between 1990 and 2008, while concentrations of the smaller

[1] At http://www.epa.gov/airtrends/sulfur.html.

$PM_{2.5}$ particles dropped 19 percent between 2000 and 2008. These reductions were achieved despite an economy that more than doubled in size.[2]

The story on energy efficiency is similarly positive. EIA reports that the energy intensity of the U.S. economy[3] declined by 51 percent between 1973 and 2008, a substantial fraction of which can be attributed to improvements in energy efficiency (the balance is attributable to a structural economic shift from a manufacturing base of activities to a services base). The improvement was most dramatic in the consumption of petroleum and natural gas, where the intensity of these fuels dropped by 60 percent. Oil use alone fell by the same amount, arguably enhancing energy security by reducing national dependence on oil. The intensity of fuels connected with electricity use (coal, nuclear, renewables) fell less—by nearly 23 percent between 1973 and 2008, and by 31 percent from its peak in 1983.

But if the energy system has become cleaner and more efficient over the past 40 years, it is not much different. Importantly, the system still depends almost entirely on fossil fuels. In 1973, fossil fuels accounted for almost 93 percent of energy use in the United States.[4] By 2008, this fraction had dropped to 84 percent. However, the growth of nuclear power accounts for the entire decline. During this same period, the near monopoly of petroleum fuel in the transportation sector changed hardly at all, from 96 percent in 1973 to 94.5 percent in 2008.[5]

An important corollary to this continuing reliance on fossil fuels is that the basic technology of energy production and use has not changed much in 40 years. The internal combustion engine and the fossil fuel powerplant still dominate the system. That these technologies produce considerably fewer air pollutants is a tribute to increased efficiency and post-combustion clean-up devices, not to the deployment of a fundamentally cleaner way of making energy.

Third, Federal energy R&D has made a positive but modest contribution to changing the energy system. Since the consolidation of energy research into a single agency during the Ford administration DOE has been responsible for most of the Government energy R&D program. Between 1978 and 2009, DOE budgets added up to well over $100 billion on energy R&D (2000$). And since Government polices—from R&D cost-sharing to environmental regulation to tax incentives—strongly influence the allocation of private investment in energy R&D, the Federal Government has probably been the single largest force in U.S. energy R&D expenditures since 1978. This despite the fact that, adjusted for inflation, the total level of DOE-sponsored energy R&D sponsored in 2010 is one-half of what it was in 1980.

But what has this expenditure achieved? In 2001 the National Research Council published one of the few independent evaluations of the results produced by some of these R&D programs.[6] The review was limited to DOE's energy efficiency and fossil energy programs, and looked back at the benefits and costs of those programs over the first 25 years of DOE's existence. The net result of this evaluation indicated that DOE had made positive contributions to the changes in the energy system. In particular, the aggregate economic and environmental benefits attributable to these DOE programs exceeded the Government's total costs by a factor of more than two.

But this broad conclusion obscures a more complex dynamic. To paraphrase the study's conclusions:

—Almost all the benefits came from four programs—three that introduced new energy efficiency technology to large consumer markets (more efficient fluorescent light ballasts, more efficient windows, and more efficient refrigerators), and one that resulted in a major reduction in damages from NO_X emissions through the use of low NO_X burners and selective catalytic reduction. It is worth noting that the total Federal cost of the three efficiency programs was only $12 million, although they produced $30 billion in economic benefits.

—The large realized benefits accrued in areas where significant market barriers existed. For example, the building market is fragmented and not conducive to innovation in energy efficiency. And the NO_X reduction produces an environmental benefit that private markets cannot easily capture. Public funding would be expected to have considerable leverage in removing these barriers.

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[2] Despite this considerable progress, more remains to be done. A 2009 NRC report, The Hidden Costs of Energy, evaluates the damages from air pollution in the electric and transportation sectors caused by remaining pollution.

[3] Measured as quadrillion Btu of energy used per 2005 dollars of GDP; see http://www.eia.doe.gov/emeu/mer/pdf/pages/sec1__16.pdf.

[4] See http://www.eia.doe.gov/emeu/aer/pdf/pages/sec1__9.pdf.

[5] See http://www.eia.doe.gov/emeu/aer/pdf/pages/sec2__10.pdf.

[6] National Research Council, Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000, 2001. The summary benefit cost assessment on which this section is based is found at p. 6 of the report.

—Other programs produced important but smaller benefits. In all such cases, however, the report observed that DOE participation took advantage of private sector activity to realize an additional public benefit. In other words, getting the public benefit depended on the existence of a private market for the underlying technology. (In the case of NO_X controls, that market was established by the Clean Air Act and subsequent Federal requirements for NO_X controls on all new power plants.)

—In contrast, Government attempts to force introduction of new technologies for which there is no private market have rarely been successful. In this connection, the NRC study pointed especially to the large synthetic fuels demonstration programs that the Government undertook in the 1970s and early 1980s, but which produced no tangible benefit.

A number of technological advances in the energy system did in fact take place between 1978 and 2000, but the private sector was the principal source of technological innovation. The NRC study selected 23 of the most important innovations in fossil energy and energy efficiency during this period and determined the level of DOE contribution to their development. In only three cases was DOE research the dominant factor, while in 13 cases DOE's influence was absent or minimal. In the remaining 7 cases, DOE made an influential but not dominant contribution.

Finally, Innovation is More Than RDD&D.—From the beginning, it was understood that Government energy R&D had to develop products that would meet public policy goals by succeeding in the marketplace. This imperative thus raised the issue of how to design a Government program that would lead to private sector commercialization of new technology that had a public benefit. To resolve that issue, we needed a model of the commercialization process we wanted to influence.

At the outset, we picked the wrong model (I say "we" because I helped get it wrong). We borrowed from the Defense Department and NASA the standard model for Government product development—Research, Development, and Demonstration—and added a third "D"—Deployment. Unfortunately, the linear RDD&D model has had staying power, and indeed still sometimes appears in DOE's program designs. But it's not the right model.

A more useful model is the innovation process that routinely takes place in the private sector, because that is the process that DOE research needs to influence. Studies of this model[7] show that the innovation process is not neatly linear but messy; it is incremental, integrative, and cumulative. Innovators tend to take small, incremental steps to minimize the already considerable risk they are assuming in trying to develop a new product. They integrate ideas from a variety of sources, assembling them into an innovative product. And over time, these incremental steps cumulate into major—even disruptive—changes in technology. An excellent example of how this process has worked in the energy system is the introduction of the aeroderivative turbine for electricity generation. The basic technology was developed for defense programs to power aircraft, then borrowed from the aerospace industry, and ultimately adapted to electric generation applications to become a very energy efficient powerplant. The improved technology was so successful that for a time it dominated investments in new powerplants. And although this final result may have seemed like breakthrough technology, it was really a borrowed idea integrated into the energy system and improved incrementally over time.

It is also useful to see this innovation step as a part of a broader process of technological change. Rubin[8] describes the change process in four steps—invention, innovation, adoption, and diffusion. Invention involves the generation of the new scientific and technological ideas that set the table for innovation. The adoption step carries an innovative product into the marketplace. Diffusion happens as the product expands its markets, importantly due to learning than reduces costs and improves performance. Finally, it's important to note that both the innovation step and the whole change process are intensely recursive. Feedback loops and trial-and-error abound in this world until the innovator finally "gets it right" or loses his shirt.

LOOKING AHEAD

Against this background, what can we say about the future of the Federal energy R&D programs? Addressing this key issue posed by this subcommittee—requires answering four questions.

[7] For a summary of this research see, for example, Robert W. Fri, The Role of Knowledge: Technological Innovation in the Energy System, The Energy Journal, Vol.24:4.

[8] E.S. Rubin, "The Government Role in Technology Innovation: Lessons for the Climate Change Policy Agenda," Proceedings of the 10th Biennial Conference on Transportation Energy and Environmental Policy, Institute of Transportation Studies, University of California, Davis, Davis CA.

Should the Energy System Change in a Fundamental Way?—As noted earlier, the existing energy system is cleaner and more efficient, but not really different, from the one that existed in 1973. Looking forward, however, taking energy security and climate change seriously would mean decarbonizing the energy system and drastically cutting the Nation's dependence on oil. And that, of course, would require a wholesale change in the existing energy system.

As noted in the first lesson discussed above, the benefits of limiting climate impacts and enhancing energy security are real, but hard to pin down. The costs of a wholesale change in the energy system are real and potentially large. While economists have tried to quantify these values, unfortunately, science can't provide a clear balancing of the benefits and costs. Deciding how much climate change and how much oil use is acceptable are thus both crucial judgment calls.

My own view is that the benefits are real and potentially much larger than the costs of change. If I'm right, we should be planning for a major change in the energy system. If not, continuing the incremental improvements that have characterized the last 40 years is probably good enough and we will simply accept and adapt to whatever future climate change and oil price shocks may occur.

What Will the Future Energy System Look Like?—Unless the Nation responds aggressively to the challenges of energy security and climate change, the energy system of the future will look very much like the one of today. It will be cleaner as environmental regulations continue to tighten, and increasingly efficient as old capital stock turns over. But electricity will continue to be produced mostly by burning fossil fuels, and most light duty vehicles will continue to rely on gasoline. Renewable sources of electricity, alternative transportation fuels, and electric vehicles—pure or hybrid—will slowly gain market share. However, using fossil fuels will continue to be convenient and relatively cheap, so a fundamental change in the energy system is unlikely for a long time to come.

But more of the same is not destiny, for technology is capable of a fundamental change if we decide we want one. A recent NRC study, America's Energy Future (AEF), assessed the potential[9] of available (or nearly available) technology to change the energy system. Its key conclusions were:

—Efficiency measures can reduce energy consumption by 15 percent by 2020 and by another 15 percent by 2030. These reductions would more than offset the projected increase in energy consumption in the EIA 2007 reference case.

—Renewable energy sources, coal or natural gas-fired powerplants with carbon capture and storage, and new nuclear power could completely replace the existing electric power production system by 2035.

—Substantial opportunities to reduce fuel use in transportation exist, but liquid fuels made from biomass or coal have a limited potential to displace oil before 2035. Further reduction of oil use will require a new generation of vehicles, probably powered with electricity or hydrogen.

While this technical potential is impressive, optimism about actually realizing it should be guarded. A multitude of market imperfections, regulatory obstacles, and behavioral barriers stand in the way of reaching anything like the full potential. In addition, while AEF judged that carbon capture and storage and new nuclear technologies could be deployed in large quantity after 2020, it also noted that both technologies need first to be proved in the United States at commercial scale before attracting significant private investment—and we are only beginning to take the steps necessary for this purpose.

Finally, even if the technical potential reported in AEF were to be reached, the energy system would still depend largely on old technology, especially for electricity production. Moreover, AEF concludes that the cost of electricity would rise with any of the new production technologies. And new technology to reduce oil consumption in the transportation sector would be required, as noted earlier. For all these reasons, it seems likely that technologies that are yet to be invented must enter the energy system by 2035, and certainly beyond, if we are to have truly clean, efficient, and affordable energy system.

What can Government do to Accelerate Technological Change in the Energy System?—As discussed earlier, the experience of the last 40 years has provided a clearer picture of how Government policy can accelerate technological change in the private sector. Building on this experience, four strategies seem to me to be especially important in crafting this policy.

Align Private Incentives With Public Goals.—Innovation is a complex function of the private sector and as such innovation works best when it's economically re-

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[9] National Research Council, America's Energy Future: Technology and Transformation, 2009. In the AEF study, potential is defined as the maximum deployment of a technology with an aggressive (but not crash) program, and in the absence of any barriers to deployment.

warded in private markets. Indeed, experience strongly suggests that rewarding private sector activity that also produces a public good is the most powerful strategy for technological change. I seriously doubt that an overhaul of the energy system will take place without such a reward.

Both price signals and regulation can provide the necessary incentive. A price signal is usually more directly linked to the desired outcome (increasing the price of carbon directly affects CO_2 production, for example) and, if applied economy-wide, engages the maximum range of innovative activity. Regulation can also have a potent effect, as has been the case with refrigerator efficiency and light duty vehicles, but runs the danger of unintended side effects. Arguably, efficiency standards for light duty vehicles both substantially reduced fuel consumption for the target vehicles, but also helped to induce a vast market for unregulated trucks posing as sports utility vehicles.

Fund Purpose-driven Basic Research.—Virtually all authorities agree that funding basic research is an appropriate function of Government, and it is an essential one for changing the energy system for two reasons. As noted above, we need wholly new technologies create an energy system that is affordable and effective, particularly in reducing oil consumption. In addition, because innovation is an integrative process, it needs a robust menu of scientific and technological research on which to draw. Basic research thus sets the table for innovation in ways that cannot be predicted.

But this research needs to be plausibly connected to desired outcomes for the energy system. Broadly speaking, this connection can be made in two ways. One is to focus research on problems which, if solved, would create fundamental changes in our energy options. For example, artificial photosynthesis could revolutionize the capture and storage of solar energy. Similarly, basic advances in catalysis could greatly increase the attractiveness of carbon capture, especially if it promoted the retrofit of existing power plants. The second general approach is to encourage the application of diverse disciplines to energy problems. Both genomic engineering and nanotechnology could make important contributions to energy, although neither was developed with energy in mind.

Focus Applied Research to Overcoming Well-defined Market Barriers.—Unlike basic research, DOE's applied research (its fossil, efficiency, renewable, and nuclear programs) focuses on fairly well-defined technologies. In some cases, such technologies have a reasonable chance of market success if they meet attainable technical and commercial goals.

If a technology has a reasonable chance of market adoption, and if its adoption would also help achieve a public policy goal, then the Government has an interest in its success. Energy efficiency technologies often combine these attributes, for example. The NRC retrospective study noted earlier provides persuasive evidence that Government support of such technologies can be very effective if it is directed toward removing a well-defined barrier standing between the technology and the marketplace. The barrier may be a technical problem that an innovator is unable to solve, or it may be a problem of market structure. Many barriers to efficiency technologies are of the latter type.

In short, while designing programs of applied research is as much art as science, Government policy should observe two prerequisites. First, there must be a reasonable chance of adoption in an existing market. And second, the Government intervention should focus sharply on removing well-defined barriers in the way of getting to that market.

Invest With Great Care in Technologies That Do Not Yet Have Markets.—In the past, Government energy research programs have invested heavily in such technologies—the synthetic fuels program of the late 1970s, for example. The rationale for these investments is usually that, although not competitive now, the technology in question will be needed in the future to meet public policy goals. Unfortunately, such programs usually don't work out very well. The market turns out not to materialize, or if it does, it addresses the problem in ways that Government programs did not foresee. Thus, the crash of oil prices in the 1980s—and not the synthetic fuels program—solved the looming oil crisis of the late 1970s. Similarly, reductions in SO_X emissions required by the Clean Air Act amendments of 1990 were achieved initially by transporting low sulfur coal to eastern power plants, not by flue gas desulfurization technology that almost all policy analysts assumed.

This is not to say, of course, that Government should never invest in insurance policies, only that it should do so with its eyes open. In particular, the record of success is poor, and so the risk of loss is high. A current example will illustrate the nature of the risk. Both carbon capture and storage and evolutionary nuclear technology need demonstration at commercial scale before attracting significant private sector investment. But the market for both depends in a major way on Government policy that aggressively promotes decarbonization of electricity production. So the policy question is: in the absence of Government policy to control carbon, should Government invest in demonstrating CCS and evolutionary nuclear technology?

I advocate an aggressive Government demonstration program, fully understanding that the result may be money wasted. But because I think that the Nation is likely to have an aggressive carbon policy in the next few years, then CCS and nuclear could have a major market and play an important role in meeting climate objectives. However, both are large and expensive technologies at commercial scale, and their demonstration will take several years to produce the commercial experience that would give confidence to investors. As a result, waiting to conduct the demonstration until our climate policy is decided would only delay getting started on the challenge of reducing domestic carbon dioxide emissions. On balance, therefore, it seems prudent to me to move urgently to demonstrate these technologies in the hope that one or both proves to be a winner in a world of carbon dioxide control. That world may not happen, and commercial experience with one or both technologies may prove to be disappointing, but in this case the risk seems worth it.

What are the Main New Challenges for Research?—I'm confident that the scientists and technologists can craft a research agenda that expands basic research and that focuses applied research on specific market barriers. Indeed, Secretary Chu and his team have already introduced organizational innovations that seem to me to be very much in the right direction. So in concluding my testimony, I'd like to raise two issues from the social sciences that strike me as crucial to the success of technology change going forward.

First, we need to know more about household energy use and consumer behavior. Household decisions directly determine 40 percent of total energy use and another 30 percent indirectly. But household decisions are not always made on the sole basis of economic rationality. Energy efficiency programs famously fall short of the level of adoption that so-called rational behavior suggests should be the case. Therefore, it seems to me that behavioral science research may be as important as technology R&D in promoting the use of energy efficiency.

Second, it's clear that any program to change in a fundamental way the composition of the national energy system requires a sustained effort over a long period of time. The history of Government energy R&D, however, is one of twists and turns in goals and philosophy. Designing an energy R&D portfolio that maintains a reasonable degree of continuity over several decades is an extraordinary governance challenge, but one that needs to be addressed if the Nation is to see real results from its substantial investment.

Senator DORGAN. Mr. Fri, thank you very much.

Finally, we will hear from Dr. Eric Loewen, Dr. Loewen.

STATEMENT OF DR. ERIC P. LOEWEN, CHIEF CONSULTING ENGINEER, ADVANCED PLANTS TECHNOLOGY, GE HITACHI NUCLEAR ENERGY

Dr. LOEWEN. Mr. Chairman, Senator Alexander, my name is Eric Loewen, chief consulting engineer for advanced plants at GE Hitachi Nuclear Energy. Thank you for the opportunity to testify before you today to share with you a vision for a cleaner, more secure energy future for America.

Headquartered in Wilmington, North Carolina GE Hitachi Nuclear Energy is a world-class enterprise dedicated to serving the nuclear industry with over 100 years of combined experience, and our nuclear alliance with Hitachi is recognized as a world leader for boiling water reactors.

Today let us talk about American innovation for a solution to three challenges that face this country: used nuclear fuel; excess weapons material; and clean energy. U.S. innovation has always led this industry.

In 1954, Congress removed barriers to nuclear energy development, allowing for the commercialization of U.S. light water reactors which became the world standard. For the next 50 years, U.S.-developed technologies underpinned more than 300 plants in over 30 countries around the world.

The next great opportunity for the U.S.-developed technology is the GEN IV reactor. The GEN IV reactor that I am most familiar with is the PRISM, a sodium-cooled reactor under development since 1981. The PRISM is America's sodium-cooled reactor developed jointly by nine U.S. companies under the leadership of General Electric. PRISM is the only active small modular reactor design that has been reviewed by the Nuclear Regulatory Commission. The reactor can generate electricity. It can consume weapons-grade material and recycle used nuclear fuel.

Let me explain the vision for recycling under the context of the three R's: repository, reprocessing or recycling.

The repository, which many people think of as Yucca Mountain, was envisioned to store today's used nuclear fuel for 1 million years.

The reprocessing option is widely used today in the United Kingdom and in France and soon in Japan. It is a process that extracts plutonium from used nuclear fuel with an aqueous-acid system and organic solvents. The recovered plutonium is made into fuel for water-cooled reactors. The wastes, fission products, and transuranics are incorporated into a glass requiring safe storage for 10,000 years.

Finally, recycling simply put, turns waste into watts. This is an American technology we seek to commercialize from our Nation's national laboratories. The process recovers uranium and transuranics used in a molten salt bath, which become fuel in a sodium-cooled reactor. The wastes, just the fission products, are incorporated into a rock and a piece of metal requiring safe storage for 300 to 500 years. No pure plutonium is extracted. Therefore, proliferation risks are greatly reduced.

Earlier this year, President Obama directed Secretary Chu to establish a blue ribbon commission to make recommendations for used nuclear fuel. GE Hitachi has requested an opportunity to engage the commission to discuss the benefits of recycling, as we are doing today with the subcommittee. We believe that recycling is a credible alternative to Yucca Mountain that deserves serious consideration by Congress and the commission.

And some of the benefits of recycling are: first, it reduces the required storage time of wastes from greater than 1 million years to hundreds of years; second, the used nuclear fuel can generate the U.S. electricity needs for the next 100 years; and third, if you add in the U.S. inventory of depleted uranium, you can meet the electricity needs of the United States for close to 1,000 years.

While GEH believes that PRISM is an excellent technology, we acknowledge that it is not the only technology and we encourage Congress and the commission to embrace the concept of recycling rather than a particular technology. GEH supports establishing recycling projects in regions where the reactors stand and where consumers have paid into the Nuclear Waste Fund.

GEH believes that in order to sustain a long-term development of full recycling, the United States must learn from the United Kingdom, France, and Japan regarding best practices from reprocessing. But we must also stand on our own to develop full-recycling technology and the following will reduce the risks to get there.

First, we should competitively award industry-led licensing projects for the sodium-cooled reactors.

Second, reenergize the domestic manufacturing base by competitively awarding the manufacture and siting of two sodium recycling reactor vessels to support that licensing effort.

And third, allow for the use of sodium-cooled recycling reactors to use weapons-grade materials to generate electricity.

Our current challenges of finding a waste solution and disposing of weapons-grade materials calls for policymakers to take a fresh look at how to fast-track the building of a sodium-cooled recycling reactor to leap frog out allies leading to a transformational full recycling approach.

PREPARED STATEMENT

That is our vision for the future.

That concludes my remarks and I would be pleased to answer any questions, Mr. Chairman.

[The statement follows:]

PREPARED STATEMENT OF DR. ERIC P. LOEWEN

ADVANCING TECHNOLOGY FOR NUCLEAR ENERGY

Mr. Chairman, Senator Alexander, and members of the subcommittee, I am Eric Loewen, Chief Consulting Engineer of Advanced Plants at GE Hitachi Nuclear Energy. Thank you for the opportunity to testify before you today. As you look at energy policy over the past 40 years, I have been asked to help you look forward—to look at the next generation of nuclear technology—the technology that will help the United States achieve energy independence, create new jobs and move toward a low carbon future.

Headquartered in Wilmington, North Carolina, GE Hitachi Nuclear Energy (GEH) is a world-class enterprise with a highly skilled workforce and global infrastructure dedicated to serving the nuclear industry. We are proud of our record of accomplishments that spans more than five decades; our nuclear alliance is recognized as the world's foremost developer of boiling water reactors, robust fuel cycle products and highly valued nuclear plant services. Combining deep-rooted experience with fresh insight, we provide light water plant operators with responsive reactor services to support safe, efficient and reliable operation.

The Nation has already begun to witness the success of the recent Federal polices designed to bring about a renaissance of the nuclear industry in the United States. Today, with the incentives of the Energy Policy Act of 2005 in effect, the design and even some basic construction have begun on the next generation of light water reactors in the United States. Public support for clean, reliable nuclear energy is at record high levels. We have an opportunity to increase the percentage of electricity produced by nuclear plants above the current 20 percent.

My testimony today will give you an overview of how nuclear technology has developed over the past 40 years, the current state of technology in the United States and the rest of the world, and perspectives on where the technology might go in the 40 years to come.

OVERVIEW OF THE DEVELOPMENT OF NUCLEAR TECHNOLOGY

U.S. leadership in nuclear energy started in 1951 at the National Reactor Test Station near Arco, Idaho. This sodium-cooled reactor produced enough electricity to light four light bulbs. Interestingly, a study done for President Harry Truman in 1952 made a "relatively pessimistic" assessment of nuclear power and actually called for research instead in solar energy. President Eisenhower's call for "Atoms for Peace" 1 year later, however, led to the initial indication that the Federal Government would be a strong partner in the development of civilian nuclear energy. The Atomic Energy Act of 1954 removed barriers to nuclear energy development by the private sector. The stated purpose of the 1954 Act was to encourage widespread participation in the development and utilization of atomic energy for peaceful purposes, although nuclear materials remained under Government control. The new law for the first time permitted private industry to build and operate nuclear plants on their own initiative, and not just as Government contractors. GE, the first company to take advantage of this opportunity, built a reactor in Vallecitos, CA—the first commercially funded reactor in the United States. to provide power to the grid.

In 1955, an early concept of a boiling water reactor developed by Argonne National Laboratory powered a city—Arco, ID—the first such use of nuclear power in the world. This U.S. technical leadership lead to the first generation of commercial nuclear power plants (GEN I), some of which are still in operation. The world's first commercial nuclear power plant opened in England in 1956; the first plant in the United States came a year later in Pennsylvania. Availability of adequate funding to provide compensation in the very unlikely event of a nuclear or radiological incident was addressed through the passage of the Price-Anderson Act in 1957.

GE commercialized Argonne's concept of the boiling water reactor by first building a small commercial reactor at our GE facility in Vallecitos, CA, followed by the larger commercial boiling water reactors at the Dresden unit in Illinois, the KRB unit in Europe and the Tsuruga plant in Japan. GE management proceeded in the confident expectation that it could develop the Boiling Water Reactor (BWR) technology and have a commercially competitive product by the 1960s.

The construction of Generation II reactors followed in the early 1960s and represent the 104 nuclear power plants operating in the United States today. Of the GEN II reactors in the United States today, 34 percent are BWR designs and 66 percent are pressurized water reactors (PWR). The power output of U.S. GEN II reactors ranges from 482 to 1,300 MWe. In the early 1960s, these were built as "turnkey projects" to overcome the reluctance of utilities to assume the uncertain risk of building nuclear plants. By the mid 1960s, the industry had evolved to the point where architect engineers and constructors contracted directly with owners and turnkey plants were no longer offered.

During the 1960s, U.S. light water reactor (both BWR and PWR) technology also became established in the world nuclear market, with large orders in Western Europe and Japan. The light-water reactor became the world's technology standard, outstripping the British gas-cooled reactor and Canadian heavy-water reactor technologies by wide margins.

From the construction and operating experience of the GEN II reactors, design improvements were made by industry, and the U.S. Government improved the Nuclear Regulatory Commission's licensing processes. The Energy Policy Act of 1992 authorized the one step licensing process known better in the industry as "Part 52."

GE submitted its GEN III design, the Advanced Boiling Water Reactor (ABWR) to the NRC in 1987 and received design certification in 1997. To date, no certified GEN III reactor has yet been built in the United States. There are currently four

ABWRs operating in Japan and work will soon be complete on construction of two additional ABWRs in Japan and two in Taiwan.

The year 1992 was the high water mark for U.S. nuclear power plant installed capacity. The technical successes were enormous. We now have in operation nuclear power plants with a generating capacity greater than the total U.S. electrical capacity installed in 1940, and the plants have a superb safety record. The technical issues that the industry has been able to resolve are far greater than those that remain to be solved. Yet no new plants were started. Why? One significant reason is the substantial financial risks due to the large capital investment required and uncertainties about cost and schedule on new reactor designs.

The Energy Policy Act of 2005 responded to these financial risks by authorizing loan guarantees for carbon free technologies such as nuclear power plants, tax incentives for first movers, and risk insurance during the construction phase. This promise of these policies became reality when President Obama announced in February that the Department of Energy has offered conditional commitments for a total of $8.33 billion in loan guarantees for the construction and operation of two new nuclear reactors at a plant in Burke, Georgia. This project is expected to be the first new nuclear power plant to break ground in the United States in nearly three decades.

It is important to note that, despite the fact that the United States has not built any new plants in recent years, U.S.-developed light-water reactor technology has become the world standard. Japan, Germany, France, Italy, Spain, Sweden, and Switzerland have all adopted our light-water reactor design for their nuclear programs.

GEH submitted the next advancement in technology its GEN III+ design, the economic simplified boiling water reactor (ESBWR), to the NRC for design certification under part 52 in 2005, and is expecting final certification in September 2011. This effort was supported by the DOE Nuclear Energy Office through the Nuclear Power 2010 program.

Looking forward to the next generation of nuclear plant design, in 2000, the United States organized the world technical community to look at GEN IV reactors in order to improve safety, and address waste issues, and reduce cost and proliferation concerns. This international effort screened over 100 different reactor concepts to identify 6 plausible designs for continued study. Three of the six GEN IV reactor concepts could be used for nuclear fuel recycling.

RECYCLING—WHAT IS IT?

The next area for U.S. innovative leadership in nuclear energy is the commercialization of full-recycling technology.

There are three basic options for used fuel management: the 3 Rs—Repository, Reprocessing or Recycling. Let me provide an overview of each:

Repository.—Underground storage for used nuclear fuel from the GEN I and GEN II fleet, where it needs to be stored for at least 1,000,000 years.

Reprocessing.—Takes GEN I and GEN II used nuclear fuel for the separation of plutonium using an aqueous-acid system and organic solvents. The recovered plutonium is used in GEN II reactors. The wastes, fission products and high-heat-load transuranics (also known as actinides) are incorporated into glass requiring safe storage for at least 10,000 years. Reprocessing is done currently in the U.K. and France, and soon will be in Japan.

Recycling.—Takes GEN I–GEN III used nuclear fuel and separates the usable uranium and transuranics using a molten salt bath and electricity. The recovered uranium and transuranics are then used as fuel for GEN IV reactors, thereby generating electricity from nuclear waste. The remaining fission products wastes are placed into a rock (ceramic) and chunk of metal (a metallic alloy of Zr or Fe) requiring safe storage for just a few hundred years. Because no pure plutonium is extracted, the proliferation risks are eliminated. The United States uses a form of this approach currently in treating spent fuel at the Idaho National Laboratory. We call this process "full-recycling."

GE and now GEH have supported investigation of the full-recycling approach initially called the Integral Fast Reactor concept, which was funded under DOE's Advanced Liquid Metal Reactor program for 10 years and by the Global Nuclear Energy Partnership for the past 3 years. What does it take to recycle? A Generation IV reactor.

GENERATION IV REACTOR—WHAT IS IT?

Perhaps the greatest promise of the next generation reactor is the ability to recycle used fuel from today's light water reactors.

The GEN IV reactor that I am most familiar with is the PRISM, a Sodium Fast Reactor or "SFR" under development since 1981. The PRISM is America's sodium-cooled reactor, developed jointly by nine U.S. companies under the leadership of GE. The reactor recycles used nuclear fuel, generates electricity and incorporates the lessons learned from the development of earlier reactors.

Following is a brief overview of how the technology works. First, the recycled elements (uranium and transuranics) from today's light water reactors are fabricated into a metallic reactor fuel, which is submerged in liquid sodium. During operation the recycled material fissions (i.e. splits in half) releases energy, and is removed by the flow of sodium and ultimately turned into electricity. The unique element in this recycling reactor is the sodium coolant, which allows nuclear interactions at higher energies so that full-recycling can occur. This cannot occur in a water-cooled GEN II or GEN III reactor where nuclear reactions occur at lower energies.

The sodium-cooled GEN IV reactor is designed with passive safety features. These include passive reactor shutdown, passive shutdown heat removal (requires no human or automatic systems), and passive reactor cavity cooling (improves safety and reduces cost). The sodium-cooled GEN IV reactor supports a sustainable and flexible fuel cycle to consume transuranic elements within the fuel as it generates electricity.

Key milestones and attributes associated with this technology include:

—EBR–II is a sodium test reactor with 30 years of successful operation at the Argonne National Laboratory, which provides a significant base of technical data;
—The Energy Policy Act of 1992 authorized the building of a sodium-cooled recycling reactor;
—The 2002 DOE GEN IV Roadmap rated the sodium-cooled reactor ahead of the other five GEN IV concepts;
—Most recently the Global Nuclear Energy Partnership, with four industrial teams including GEH, all agreed that a sodium-cooled reactor was needed to fully recycle all the transuranics in used nuclear fuel;
—A GEN IV sodium-cooled reactor vessel can be fabricated in the United States today; and
—This technology uses small modular reactors suitable for smaller electrical grids.

Earlier this year, President Obama directed the Secretary of Energy to establish the Blue Ribbon Commission on America's Nuclear Future to make recommendations for developing a safe, long-term solution to managing the Nation's used nuclear fuel and nuclear waste. The highly respected members of the Commission have already started their work and will provide a final report to the President within the next 2 years. GEH has requested an opportunity to engage with the Commission to discuss the benefits of full-recycling and the establishment of recycling centers. Some of the benefits of recycling that we will outline include:

—Reducing the required storage time of used nuclear fuel by over 99.99 percent, from greater than 1 million years to several hundred years;
—Using the current U.S. inventory of 60,000 metric tons of used nuclear fuel to meet the electricity generation demands of the United States for over 100 years if recycled within a high energy GEN IV reactor (using 2008 U.S. electricity generation data); and
—Using the U.S. inventory of depleted uranium that is discarded during the enrichment process that has the potential to meet the electricity generation demands of the United States for over 900 years if recycled within a sodium-cooled GEN IV reactor (using 2008 U.S. electricity generation data).

While GEH believes the PRISM is an excellent technology, we acknowledge that it is not the only technology and will encourage the Commission to embrace the concept of recycling rather than endorse a particular technology. GEH supports establishing advanced recycling centers in the regions where the reactors stand and where consumers have paid into the Nuclear Waste Fund.

TOWARD A NEW GEN IV POLICY

GE has worked with the U.S. Government to develop civilian nuclear power technology since the beginning of the U.S. nuclear program. There was extraordinary creativity in fashioning novel arrangements to meet the demands of nuclear development; Congress established the Joint Committee on Atomic Energy, and industry established standards and professional societies such as the American Nuclear Society to support those standards. These Government/private sector approaches represented triumphs of pragmatism over ideology and of substance over form.

Over the past decade, Congress has been responsive and creative in supporting the national laboratories and universities as they investigate the sustainable nuclear fuel cycle. This focus on education and research has played a significant role in the large increase of graduates in nuclear related fields, and must continue so that the industry is prepared for the future.

Our current challenges (waste solutions and plutonium disposition) and opportunities for low carbon electricity call for policymakers to take a fresh look at how to fast track the building of sodium-cooled recycling reactors.

GEH believes that in order to sustain long-term development of full-recycling, the United States must learn from our foreign allies (U.K., France, and Japan) regarding best practices from the modified open fuel cycle approach (reprocessing). But we must also stand on our own in support of an even more innovative full-recycling technology.

It is critical to recognize that the United States is falling behind in developing innovative nuclear technologies. China and India are in the process of building sodium-cooled GEN IV reactors, which are expected to be the drivers in their development of sustainable nuclear fuel cycles. Without a similar long-term policy, the United States can expect to place third, at best in the near future.

Before I conclude my remarks, I want to shift gears a little and mention an additional innovative nuclear technology that GEH is pursuing in the United States-Global Laser Enrichment. This new method of enriching uranium for peaceful purposes is being developed in the United States under strict oversight by the NRC and the Department of Energy. If the testing of the GLE technology continues to return the positive results we have seen thus far, we will soon build the first commercial facility in Wilmington, NC, adding hundreds of high paying jobs and providing our U.S. customers with a competitively priced, domestic supply of enriched fuel for their power plants.

SUMMARY OF RECOMMENDATIONS

The advanced nuclear power technology developed at GEH is a vital part of GE's clean energy portfolio. The world needs the innovative energy technology solutions America has to offer, and America needs them too.

Safe, reliable base-load electricity generated without producing greenhouse gas emissions is needed to meet the heavy demands of industrial and residential users. Congress and the public have endorsed the expansion of nuclear power in the United States, understanding the energy independence and job growth potential of this low-carbon power generation technology. The helpful provisions in the Energy Policy Act of 2005, including loan guarantees have helped set the stage for a nuclear power renaissance.

We must continue the great tradition of the Government and private sectors working in partnership to enable nuclear energy to grow. Our recommendations for this subcommittee for investments in an abundant and responsible long-term energy supply, for weapons plutonium disposition and for addressing used nuclear fuel using full-recycling are to support:

—Competitively awarded industry-led licensing project(s) for sodium-cooled recycling reactor(s).
—Reenergize the domestic manufacturing and sodium research and development base by competitively awarding the manufacture and siting of two GEN IV sodium recycling reactor vessels to support the licensing project.
—Expand the weapons disposition program to include converting weapons material into fuel for disposition in a sodium-cooled recycling reactor.
—Funding the President's budget request for the nuclear energy programs including an additional $36 billion in loan guarantees, Reactor Concepts R&D, Fuel Cycle R&D and the Nuclear Energy Enabling Technology program.

The Nation faces a choice today: should we continue down the same path that we have been on for the last 30 years with a repository-only solution, should we take the path of our allies and adopt reprocessing, or should we lead nuclear innovation with full-recycling? By building a sodium-cooled recycling project, we can lead the transformation to full-recycling, use a previously untapped energy source, and provide another path for weapons plutonium disposition.

Thank you. This concludes my formal statement. I would be pleased to answer any questions you may have at this time.

Senator DORGAN. Dr. Loewen, thank you very much.

Mr. Sharp, first of all, I appreciate your testimony. I think there is an understanding that much of what we need to do requires additional funding, research, and commitment to have a consistent scientific inquiry in a range of areas. For example, decarbonizing the use of coal, it is pretty clear to me we are going to continue to use coal in this country's future, but we need to use it differently and will. But to get to that point, we are going to need to make investments.

How do you think that is going to progress? There is a big group down at the White House starting yesterday trying to figure out how you cut back spending and find additional revenues to reduce the budget deficit. So this is not a very easy time in which to accomplish that which you believe need to be done.

Mr. SHARP. Well, what you raise is the problem of how to get persistent policy, and of course, our past experience is it is up and down and that means we do not advance in a number of ways.

Let me just first back up. Just investing in research does not guarantee the product comes out, but we still need to do this, especially on carbon capture and storage because of the critical role of coal. Obviously, if you turn to a system of cap and trade, you have some additional possibilities for funding because you are generating in the private market value which is in the allowances, for example, that can be used to fund this because I think one of the things—all these initiatives taken in 2005 and 2007 and in the stimulus package—any of them based on appropriations are bound to run into severe pressure on them in the next 3 to 5 years because of the deficit. I do not see any other way you folks can manage that. That does not mean they are all abandoned, but this has been the historic problem.

So one of the virtues of the carbon tax, which is difficult to sell I realize, or the cap and trade system is that they at least generate either in the private sector or in the public sector some kind of value that can be directed toward these goals.

Senator DORGAN. Without having a long discussion about it, those who are working on climate change in the Senate breathlessly announced that cap and trade is dead. So whatever the alternative may or may not be. I personally believe there should be a price on carbon, and I would support a carbon fee. I think we should cap carbon and price carbon. I understand that, but I do not support cap and trade and would not.

Mr. SHARP. Well, I understand that announcement, Senator, but I might just say my impression of the Kerry-Graham-Lieberman is that while they are not any longer supporting an economy-wide cap and trade system, that they have something with a different name called the "cap on the electric utilities sector," which is where we had the experience of SO_2. It has the same function.

Senator DORGAN. You are right, of course. I was simply describing what their announcement was.

Mr. SHARP. Right.

Senator DORGAN. You are absolutely correct that in that area, it is cap and trade.

Mr. Fri, you indicated in your testimony that with respect to the research that is being done in energy and has been done now for some while from the Ford administration forward, that almost all of the benefits from this research came from four programs. You talk about the total Federal cost of the three efficiency programs being $12 million and producing $30 billion in economic benefits. What that implies, without saying it, is a lot of the research, of course, does not amount to anything, and some of the research and perhaps some of the research that is the least costly research can provide huge benefits.

Is it not the case that, in terms of finding a way to make fuel from thin air, as we described earlier, or trying to find the right way to decarbonize coal—we held a hearing on beneficial use of carbon, which I am very interested in—in order to reach these areas and find some positive conclusions to research, you are going to have to, perhaps, go down a lot of blind alleys? Therefore, a lot of that money will not be effectively spent, but that is just the nature of research. Is it not?

Mr. SHARP. It is the nature of research, of course, and you cannot expect everything to be a winner, much less a home run like those little efficiency programs. But looking at those three programs, as I suggested in my testimony, tells you something about what you should look for when you are planning research, and in those three cases, there was a clear private market for more efficient refrigerators, for low-emissivity windows, and electronic ballasts to fluorescent light bulbs. Those were the three programs, plenty of private market out there. There was in each case a fairly specific market barrier, not even a technology barrier that needed to be removed that would let the private market move that new technology to market. And that is the lesson I think you need to draw in terms of planning and funding research, is to be disciplined about the two crucial questions. If you are successful, is there likely to be a market and what barrier can be removed by Federal action that will allow the private sector to get that technology to market? Now, even with those rules, you are not going to win every one, but I think you can avoid some of the blind allies.

Senator DORGAN. Mr. Loewen, your testimony is exclusively about nuclear energy, and that has been a part of what we have done, although we have not built new plants for a long, long while. I think everyone concedes—you described the President's comments—and myself and others concede that nuclear power is going to be a part of our future and we are going to see additional plants built.

The concept of this hearing is a broader look at what aspirations we have for an energy mix and the development of additional energy sources, given that nuclear is going to be a part of that. Have you done work and studies in other areas? Do you have some comments about the larger energy mix going forward 20, 40, 50 years from now?

Dr. LOEWEN. Yes. Senator Dorgan, my role is as a Chief Engineer for a company that sells nuclear powerplants. I work for a larger company that also sells a wide portfolio of energy products. And our chairman, Mr. Immelt, came to Washington, DC in 2005 and announced the ecoimagination project, and that has really started our company to look at green energy sources across the spectrum of our suite of technologies.

The reason why I drilled down so far in the details on this particular nuclear technology is that it is using a completely different source of energy input than we have from our current nuclear power plants. And that is where I see with your chart up there with the wood piles and all these different pictures depicting how we changed, you could have a picture where you are using all those canisters that are in Oak Ridge, Tennessee and Portsmouth, Ohio and Paducah, Kentucky of the depleted uranium, and that becomes an energy source. So that was where I was trying to provide the committee kind of that broader look, that this is an energy source that we have not tapped into yet.

Senator DORGAN. I want to ask Senator Alexander to inquire further.

As I said, I am very interested in beneficial use of carbon because, Mr. Sharp, you and Mr. Fri both described the need to restrain carbon. I think most everyone understands that now. Tell me your assessment of the promise of beneficial use of carbon.

We know in North Dakota, you can put CO_2 down into an oil well and enhance oil recovery. But there are a lot of other breathless ideas out there that are trying to demonstrate at scale a solution for the beneficial use of carbon, actually bringing the price of carbon down to near zero if they find the right beneficial use. What is your assessment of that?

Mr. SHARP. Well, I am the wrong person to ask. I honestly do not know.

Obviously, enhanced oil recovery is a known operational thing, but that will never use the large quantities that we need to sequester. But I certainly think it is well worth us spending some incentive money on finding out in the research area whether some of these things can pan out.

Again, one of the biggest questions for all of these kind of things that we face is the scale of what we are ultimately talking about is gigantic, whether it is in oil, gas, electricity, or whatever. And when we talk about these things, the important reason to go multiple ways on these technologies is precisely because few of them end up being able to scale up to do what we need.

So I do not have an answer on this. Maybe Bob Fri has a——

Senator DORGAN. We had a scientist from Sandia testify at one of our hearings, and she said, change your mind set a little bit, which I thought was interesting. We think of carbon as a problem. Think of carbon as a product and how would you use the product, a very different approach for a scientist.

Mr. Fri.

Mr. FRI. That is right. There are certainly a lot of great ideas out there about ways of using carbon in an agricultural setting and others that would make it a valuable resource and we ought to explore those.

But Phil Sharp is right. The portfolio that we are dealing with has two dimensions, maybe more. But one is scale. If we cannot ultimately scale something up to a point where it makes a substantial difference in a very large energy system, then it can be of some help, but we really do need the scale. And the other is timing in the sense there are some things we know how to do now and if we are serious about particularly climate change, we really need to start doing them.

And there are a lot of very good ideas about what we might be able to do in the future, and we need to pick the ones of those that are going to be game-changers. Some of the uses of carbon that have been suggested do have the scale properties and could be game-changers and I think are worth support.

Mr. SHARP. Senator, if I just add a note. Part of this goes to how effective different kinds of policies are. You folks have a responsibility—you have done it—of investing in these kinds of technologies. But going back to Mr. Fri's articulation of the need for market incentives, if you put in place in this country a carbon constraint policy, that is likely in and of itself to at least produce in the marketplace a number of incentives which tell somebody at Sandia and everywhere else you build it and they will come because if it works, we will be sucking it into the marketplace. It will not stay on the shelf.

Senator DORGAN. Thank you very much.

Senator Alexander.

Senator ALEXANDER. Mr. Chairman, this has been a very interesting hearing.

Mr. Fri, as I understood your comments, you are saying every now and then we ought to review what we are doing in research and make sure it is appropriate.

And then we were talking a little bit. The Senator and Mr. Sharp were talking about, well, where we are going to get the money for this research.

To make this topical, I think Secretary Salazar is going to announce today that the Federal Government is going to approve the Cape Wind project which has put wind the size of Manhattan Island in Nantucket Sound.

Mr. Fri, if you were persuaded that the Energy Information Administration figures show that our subsidies for wind today are 25 times as much per megawatt hour as subsidies for all other forms of electricity combined and that to produce 20 percent of our electricity from wind would cost taxpayers $170 billion over 10 years, would you think that a wiser use of some of that money might be for research into other areas such as advanced batteries or photovoltaic cells or the carbon capture ideas that we were talking about?

Mr. FRI. I suppose the short answer is yes, to some extent. I think that the wind experience has actually been a success story with a lesson associated with it. The success story is we do now have some considerable amount of wind capacity in the United States. It is a promising technology which is, even without the production tax credit, becoming economically competitive in certain regions.

The lesson goes back to something Mr. Sharp was saying and that is we tended to have a production tax credit one year and then not the next year and then back again. And that kind of jerking the system around does not lead to an efficient use of resources. It is better in my judgment to moderate the level of resource commitment and be more consistent about doing it each and every year until you get the job done.

Senator ALEXANDER. It produces 1.3 percent of our electricity, and it is going to cost us—we have already committed $30 billion to it.

Mr. Sharp, I noticed the President has appointed you to the Nuclear Security Commission which is a very distinguished group of people. I am very pleased with what he has done there with the Nuclear Regulatory Commission.

I was doing some quick math in my head. And you know that I have been at your forum talking about the renewable energy sprawl, and we have had a lot of talk about scale today. The Cape Wind project would cover an area the size of Manhattan Island. It would produce about one-tenth the amount of electricity that one reactor would on 1 square mile, and the reactor electricity would be more reliable at a cheaper cost and cost taxpayers a lot less. Is that an appropriate thing to consider as we go forward?

Mr. SHARP. Well, I certainly think that is one of the factors that will and should be considered as we go forward. I would simply say, as you can appreciate, that I personally believe we need and should have more nuclear power, especially if we are confronting the climate change issue. But I think the larger energy picture requires a broad mix, and so we want to be careful not just to say we only will go with this one, but not with that one.

However, if I can resort to your previous question, I do think ultimately over time, when we decide to subsidize an infant industry, we must have an exit strategy, and there has got to be a point at which we are as consumers confronted with what the real costs are.

Now, I think in the developmental stage, there is a justification for the Government, just as I think on the nuclear power for testing out these new reactors—what we are really testing is whether the regulatory system and the construction process and the management of it can be done in an effective and timely manner—should have loan guarantees for the Government to do that, but not for loan guarantees forever for nuclear, any more than a subsidy forever on wind.

Senator ALEXANDER. And if we have an interest in low carbon energy production, would it not make more sense to have a low-carbon energy standard rather than a renewable energy standard that picks and chooses particular forms?

Mr. SHARP. Yes.

Senator ALEXANDER. Mr. Fri, do you agree with that?

Mr. FRI. Yes. Whether it is by regulatory means or economic incentive means, the broader the application, the more people you get trying to innovate, the more success you are going to have in showing up with something that really works.

Senator ALEXANDER. Thank you.

And Mr. Chairman, if I could ask Mr. Loewen just one question in my time, thank you for coming today.

The President talked in his State of the Union Address about a new generation of nuclear reactors, and he may have been talking about more of the same kind we already build. But as we talk about the 500-mile battery for an electric car and cutting the cost of photovoltaic cells by a factor of 4, we should also be talking about how do we do a better job of recycling used nuclear fuel in a way that reduces its mass, makes it easier to store, and does not isolate plutonium. The reactor on which you are working is one that does that. How soon do you think that reactor could be commercially available in the United States?

Dr. LOEWEN. Thank you, Senator Alexander. That is a question that I have been asked a lot.

Senator ALEXANDER. Probably by people in your own company.

Dr. LOEWEN. Yes, on the second day of employment.

The initiatives that I outlined in both my written and oral testimony are not really about the technology. It is not really about the cost. It is about gaining that sort of confidence to reduce the risk. So broadly, our vision is how we reduce that risk. So that is where we see starting a licensing process now, tomorrow. And in that context, now we harness the intellectual capital of our universities and our national laboratories. So in that licensing process, when a vendor like General Electric submits it to the Nuclear Regulatory Commission, that is open and transparent, and when we get questions for additional information, some of those questions would be more appropriate for the national laboratory to answer or a researcher at a university. Then those get fed back so that then we feel comfortable about this technology, with that license in hand, then I can come before this subcommittee and say this is how much it is going to cost because it is a difficult thing to do right now with the licensing risk.

Then the other one is let us build a reactor vessel that is a test stand. It does not need a license. It gets filled with water. We put that at a university. We put another one at a national laboratory and fill that full of sodium, and that becomes a place that we can get some of the answers that we need in the licensing process.

So to answer your question simply, sir, we could start tomorrow with those incremental steps to gain that confidence so that we can bring this technology forward.

Senator ALEXANDER. Thank you, Mr. Chairman.

Senator DORGAN. Senator Alexander, thank you very much.

Let me just say again I support some additional nuclear energy in this country, and my hope is that my colleagues and others will support finding ways to get clean, less expensive energy where the sun shines and the wind blows. That, it seems to me, will be an inexhaustible source of cheap, clean energy in the future, provided that we bring to bear on that our best scientific minds. We have made a lot of progress in wind energy, I might say.

But I think we have really disserved wind energy and some others with what we have done on the production tax credit. Consider what we did with oil. I think it was 1916 we said to people, you want to look for oil and gas in this country, God bless you. That is what this country wants you to do, and we are going to put in place significant tax incentives for you to do that, very significant, permanent, long-term tax incentives. That is what we said to those who looked for oil and gas, and I have supported most of that.

In 1992, we said to people who want to produce wind energy that we are going to put together a production tax credit. We will let it expire three or four times over the next 20–30 years. We will extend it six times, short-term, stutter, start, and stop. I mean, you want to shut off investments in something that is promising, that is a quick way to do it.

I happen to think that we ought to pick some of these areas—nuclear would be fine, as well as wind and solar—and say here is where America is headed. Here is what we aspire to achieve for the next decade. Count on it. Believe in it. Invest in it.

Now, Europe, taking a look at solar and wind energy, has a much longer commitment, but also has a commitment that diminishes as the technologies improve and there is less need for the incentives.

So we can and should be much smarter in a wide range of these areas. Yes, nuclear, but also wind and solar and renewables as well.

CONCLUSION OF HEARING

So this has been, I think, a very interesting hearing. We appreciate the work all three of you are doing and appreciate your testimony today.

This hearing is recessed.

[Whereupon, at 11:58 a.m., Wednesday, April 28, the hearing was concluded, and the subcommittee was recessed, to reconvene subject to the call of the Chair.]

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