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FUTURE OF COAL

HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

TO

RECEIVE TESTIMONY ON THE "FUTURE OF COAL" REPORT RECENTLY PUBLISHED BY THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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FUTURE OF COAL

THURSDAY, MARCH 22, 2007

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 2:33 p.m., in room SD–364, Dirksen Senate Office Building, Hon. Jeff Bingaman, chairman, presiding.

OPENING STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR FROM NEW MEXICO

The CHAIRMAN. Thank you all very much for being here. Why don't we go ahead with the hearing? I should tell everyone that Senator Domenici is coming in a few minutes. He's involved, with several other members of the committee, in the mark-up of the supplemental Appropriation Bill, which they're doing in the Appropriations Committee, and so that's a priority item that's going to make some of them late.

But, the purpose of this hearing today is to try to clarify people's thoughts about the future of coal. The basis for the discussion, of course, is the recently-released report from MIT, giving conclusions and recommendations about the future of coal, based on an extensive review of the literature describing the current state of coal technology.

As the title to this report makes clear, the underlying premise of the report is that we are quickly entering a period where greenhouse gas emissions will be a primary determining factor in choosing our energy sources. The concept was also reflected in the recent report of the Electric Power Research Institute, Electricity Technology in a Carbon-Constrained Future.

Both of these reports reflect a growing sentiment in the public, both here and abroad, that the current path that we are on is not sustainable. The final shape of the policy that we are going to employ to control greenhouse gases is not clear. I've been working with others here in the Senate to flesh out ideas about how we can go forward. But, I do think that the discussion has moved beyond the question of whether we should constrain carbon, to more important questions of how we should do so, and when.

What we lack, so far, in this area is not technological ability or investment interest, but the political will to move ahead and develop a framework that will allow these technologies to flourish. As I see it, a policy framework for coal needs to have as a minimum of two things. First, we need to give a clear price signal to markets on the value of adding greenhouse gases to the atmosphere, or the cost of adding those greenhouse gases to the atmosphere. Without this, it will never make good economic sense to spend the extra capital in emission controls or to invest in the necessary control technology.

Second, I believe we need to accelerate the research and development, and importantly the demonstration, of large-scale carbon capture and storage technologies. This report explains, in some depth, this topic of carbon capture and storage and how central it is to the future of coal in the United States and in our future energy policy.

Several of us here on the committee have been trying to take the lead in the Senate to outline some practical steps that can be taken to begin answering these questions. Earlier this month, Senator Salazar and Bunning introduced a bipartisan bill, S. 731, The National Carbon Dioxide Storage Capacity Assessment Act. There are five other Senators, including myself and Senator Tester, who are on the committee, as cosponsors.

That bill outlines a process for determining potential geologic formations for the storage of carbon dioxide. I want to thank both of them for their leadership and their initiative.

Today, Senator Domenici and I are introducing a bill that would complement that earlier bill, and this bill is called the DOE Carbon Capture and Storage Research, Development, and Demonstration Act. The bill will improve and expand carbon capture and storage program that we created as part of the 2005 Energy Bill. Specifically, it will build on DOE's regional carbon sequestration partnerships, to ensure that we have the answers that we need for this key part of our energy future. We have a number of cosponsors on that legislation. I'm told Senators Tester, Bunning, Salazar, Obama, and Webb have all cosponsored the bill.

I'd like to inform colleagues that we will hold a legislative hearing on those two carbon sequestration bills in the reasonably near future, both to examine their specific provisions and to hear from experts on what other steps we should be taking in the Senate to deal with these issues. It's obviously an important piece of the puzzle, and I hope a good first step toward even more legislation to set us on a sustainable path forward in a carbon-constrained world.

So, this hearing should be a very good introduction to the issues and a basis upon which we can begin legislative work here in the committee. Again, I thank our very distinguished panel of witnesses for their presence here today. Why don't we go right ahead and start with testimony? Then when Senator Domenici comes, he may have an opening statement at that point.

But I'll start on my left with Professor John Deutch who is co-chair of this study, a Professor of Chemistry at MIT and a former high-ranking official here in the Government in various important capacities. I've had the good fortune to work with him in many of those capacities and welcome him back to the Congress.

With him is Ernie Moniz who is, of course, also co-chair of the study and a professor of physics and engineering systems at MIT, and former Deputy Secretary of Energy.

Bryan Hannegan, who's the vice president for environment at EPRI, the Electric Power Research Institute in Palo Alto, thank you very much for being here.

Dan Lashof, who is a frequent testifier to our committee, a welcome one, the deputy director of the climate center for the Natural Resources Defense Council in New York, thank you very much for being here.

Professor Deutch, why don't you go right ahead? We will hear from each of you, if you can summarize your comments, and then we will have some questions.

[The prepared statements of Senators Bingaman, Salazar, and Sanders follow:]

PREPARED STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR FROM NEW MEXICO

Thank you all for coming here to testify today and give us your thoughts on the future of coal. The basis for our discussion today is a recently released report by MIT giving their conclusions and recommendations based on an extensive review of the literature describing the current state of coal technology.

The title of the report is, "The Future of Coal; Options for a Carbon Constrained World." As this title makes clear, the underlying premise of this report is that we are quickly entering a period where greenhouse gas emissions will be a primary determining factor in choosing our energy sources. This concept also was reflected in the recent report from the Electric Power Research Institute, "Electricity Technology in a Carbon-Constrained Future."

It seems to me, that both of these reports reflect a growing sentiment among the public, both here and abroad, that the current path we are on is unsustainable. The final shape of the policy we will employ to control greenhouse gases is unclear. I, and others here, have some ideas about how we might go forward, but we seem to have moved beyond the question of "if," to the more important questions of "how" and "when."

What we have lacked so far in this area is not technological ability or investment interest but the political will to develop a framework that will allow these technologies to flourish. And there are clearly opportunities in coal technologies. Considering the abundant coal resources we have here and the scale of the energy challenge we face in the future it is imperative that we do all we can to stimulate innovation to make coal use compatible with our carbon constrained world.

As I see it, a policy framework for coal must, at a minimum do two things: First, we must give a clear price signal to markets on the value of adding greenhouse gasses to the atmosphere. Without this, it will never make economic sense to spend the extra capital in emissions controls or to invest in control technologies. Second, I believe we need to accelerate the research, development, and—importantly—the demonstration of large-scale carbon capture and storage technologies.

As this report explains in some depth, the topic of carbon capture and storage is central to the future of coal in the United States and our future energy policy. That is why a number of Members of this Committee have been taking the lead here in the Senate to outline the practical steps that we must take to answer the questions that surround carbon capture and storage technologies and to develop a consensus on how they should be implemented.

Earlier this month, Senators Salazar and Bunning introduced a bipartisan bill, S. 731, the National Carbon Dioxide Storage Capacity Assessment Act of 2007, with 5 other Senators, including myself and Senator Tester on this committee. That bill outlines a process for determining potential geological formations for the storage of carbon dioxide. I want to thank them both for their leadership and initiative. Today, Senator Domenici and I are introducing a bill to complement the Salazar-Bunning bill. Our bill is called the DOE Carbon Capture and Storage Research, Development, and Demonstration Act of 2007.

This bill will improve and expand the carbon capture and storage program that we created at the Department of Energy in the Energy Policy Act of 2005. Specifically, it will build on DOE's regional carbon sequestration partnerships to ensure that we have the answers we need for this key element of our energy future. I am pleased to have a number of co-sponsors from both sides of the aisle on this bill, as well.

I would like to inform my colleagues here that we will hold a legislative hearing on those two carbon sequestration bills in the near future, both to examine their specific provisions and to hear from experts what other steps we should be taking here in the Senate to advance the technology and utilization of carbon sequestration.

This is obviously an important piece of the puzzle and I hope a good first step towards even more legislation to set us on a sustainable path forward in a carbon constrained world.

Today's hearing provides a good introduction to the issues and an informational base for that legislative work here in the committee. I'd like to thank all of you for your efforts in bringing us this information and I look forward to your views as we develop policy for the future use of coal.

PREPARED STATEMENT OF HON. KEN SALAZAR, U.S. SENATOR FROM COLORADO

Thank you Mr. Chairman and Ranking Member Domenici.

My home state of Colorado is endowed with many natural resources, including vast coal resources. Coal is our most abundant domestic energy source. It provides more than 50% of our nation's electricity needs, and America has enough coal to last more than 200 years. Unfortunately, CO_2 pollution from coal combustion is a main cause of global warming, which threatens my state's water resources, our economy, and our quality of life.

Fortunately, as the MIT "Future of Coal" Study shows, there seems to be more than one way to reconcile coal use with protecting our climate, through new technologies such as Integrated Gasification Combined Cycle (IGCC) with Carbon Capture and Storage. I am proud of the work this Committee did in the Energy Policy Act of 2005 to promote new advanced coal technologies. We need low-carbon technologies like coal gasification and ultra-supercritical generation, with carbon capture and storage, to continue to power our homes and businesses without exacerbating the problems associated with global warming.

Mr. Chairman, I believe that even in a carbon constrained economy, our use of coal from domestic sources will continue to grow. Indeed, the MIT Study suggests (as the Energy Information Administration has previously reported) that even with a price on carbon (starting at $25 per ton of CO_2 emitted) coal use over the study period (through 2050) would go up by between 20% and 60% if carbon capture and storage technologies are deployed. Corresponding CO_2 emissions from coal plants would be reduced by a half from today's levels. In short, the new coal technologies that are the subject of this report offer a way to secure the future of coal in a carbon constrained world.

My understanding is that all the elements of IGCC are known—there are dozens of gasification plants in operation in several industries. Likewise, companies are already doing geologic carbon sequestration. For example, in the oil fields we're using CO_2 for enhanced oil recovery.

As the MIT report indicates, there is sufficient scientific evidence to conclude that carbon sequestration is a viable option. To ensure that it is technically feasible, several large-scale demonstrations must be conducted. Simultaneously, liability issues must be addressed and a regulatory structure developed to insure the success of this technology.

The report also recommends, and together with Chairman Bingaman and several of our colleagues on this Committee, I have introduced legislation that would start us on the path to large-scale sequestration by directing the U.S. Geological Survey to conduct a national assessment of our sequestration capacity. Specifically, this national assessment would evaluate the potential capacity and rate of carbon sequestration in all possible sites throughout the United States, and would evaluate the various risk levels involved.

Carbon sequestration also has the potential to enhance the recovery capabilities of certain oil, gas, and coal-bed reservoirs, increasing the efficiency with which we extract these important fossil resources.

The Department of Energy has already established seven regional carbon sequestration partnerships. These partnerships have vital experience and understanding about the potential for storing carbon dioxide. Our legislation will build upon the existing work of these partnerships, and create a national database accessible to the public on the potential storage sites across the United States—enabling companies to make cost-effective decisions needed to make sequestration a viable option.

Last month in the Finance Committee Montana's Governor, Brian Schweitzer, also endorsed the future of coal. Montana has one-third of all the coal deposits in America—8 percent of all the coal in the world. But the Governor recognizes the signs of global warming in the west. "We don't get as much snow in the high country as we used to . . . and the runoff starts sooner in the spring. The river I've been fishing over the last 50 years is now warmer in July by five degrees than 50 years ago, and it is hard on our trout population."

Governor Schweitzer knows the only way we'll be able to use our coal reserves is if we can burn coal without emitting the CO_2. I agree and look forward, Mr. Chairman, to working with you and our colleagues in the Congress to help American companies—in partnership with government—take advantage of opportunities to lead the world in developing new clean coal technologies.

The report states that one of the major challenges we face is to develop, deploy and demonstrate commercially viable technologies for CCS. The report recommends federal spending of $500 to $550 million per year for 10 years on R&D and another $300 million per year over 10 years on "first of a kind" demonstrations of carbon capture and storage technologies. I will work with Senator Dorgan and you, Mr. Domenici, to make sure DOE has the necessary funding to invest in low- or zero-emission gasification and liquefaction technologies, and in developing the technologies necessary to sequester the carbon dioxide. Working together, we can identify the best technologies and move down the innovation curve faster to ensure coal is a part of this country's clean energy future.

PREPARED STATEMENT OF HON. BERNARD SANDERS, U.S. SENATOR FROM VERMONT

Chairman Bingaman, Ranking Member Domenici, we now live in a carbon-constrained world, or one in which carbon should be constrained in our production of energy. I thank the authors of this MIT study that is the topic of today's hearing for educating us on this issue.

Vermonters look forward to a world where we are not addicted to fossil fuels, including coal, because coal brings with it mountain top removal, acid mine drainage, and air pollution, including global warming gases. It also results in the concentration of wealth and power in the hands of corporations that for over a century have been known for their ruthless disregard for human dignity. We look forward to a country and a world where energy efficiency and renewable energy are the principal, if not the only, ways we power our society. To the extent that this study assists in bringing that cleaner future to our people, it is welcomed.

I am concerned that many of the coal plants that are in the process of being permitted/constructed today are using old technology which is not easily retro-fitted with Carbon Capture and Storage (CCS) technology. Therefore, we may be locking ourselves into a more expensive solution when we should be requiring Integrated Gasification Combined Cycle (IGCC) technology, now, even without CCS, so that when this technology is better demonstrated, we can easily install it on coal plants equipped to accept it.

I also want to thank the other witnesses from the Electric Power Research Institute and the Natural Resource Defense Council for their analyses of this study and their perspectives on coal and CCS.

STATEMENT OF JOHN M. DEUTCH, INSTITUTE PROFESSOR, DEPARTMENT OF CHEMISTRY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MA

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

As I came here this afternoon, I realized that it was almost to the day and certainly to the month, that I first appeared in front of this committee, 30 years ago. That's how old I am. So, I want to tell you, it's good to be back, but it started 30 years ago, and Senator Domenici was here for that hearing.

Let me very briefly point to six or seven main conclusions or points about our Future of Coal in a carbon-constrained world. These are the main conclusions that I think should be of interest to the committee, and I know that my friend, Ernie Moniz, will add a few points after that.

The first is that a significant carbon charge is required to give the market signals to permit us to stabilize greenhouse gas emissions, let's say, by mid-century. That market signal, whether it's in the form of a carbon charge through attacks or through a capture-rate system, has three effects.

The first effect, is it reduces demand significantly for energy, for electricity. It shifts from carbon-rich carbon, high-carbon sources of electricity and other fuels to low-carbon fuels—for example, wind or nuclear power.

Very importantly, it opens the door to new technologies, which make coal use a carbon-free emissions, so it has those three effects. Less demand, a shift to lower carbon-intensity fuels, and new technologies such as carbon capture and sequestration. Our estimate is the level of charge necessary is about $30 per ton of CO_2, which would add 20 to 25 percent to the retail price of electricity for U.S. consumers.

Our second principle conclusion is that carbon capture and sequestration is the critically-enabling technology to prepare coal for the future. Carbon capture and sequestration permits the use of coal to capture the CO_2 that is used, that is formed in combustion, its pressurization, and transportation to a sequestration or storage site.

Our highest priority recommendation and objective is to recommend three to five at-scale—that means 1 million ton per year—sequestration projects in different geologies in the United States, managed in such a manner that they demonstrate the practical—the practical, the practical—practical demonstration of this technology with respect to economics, with respect to technical performance, and very importantly, an accompanying regulatory framework that will command public confidence.

Each one of those projects would cost about $15 million a year, if they are properly instrumented with the appropriate monitoring and verification, plus the cost of CO_2, but in our minds, doing that now, immediately, provides a practical option for coal, going forward in the future. If carbon capture and sequestration is available, our estimate is there will be more coal use, even with a very, very severe carbon-control policy, because carbon capture and sequestration will be economically viable.

Our third point is that it is too early to pick a technology winner for coal use. As you know, Mr. Chairman, there are two leading technologies for use in coal today. One is pulverized coal—you would have oxygen-driven pulverized coal plants if there was carbon capture and sequestration—or integrated gasification-combined cycle. These are the two large alternatives that are presently on the menu today.

In our view these technologies should be pursued, and there are other interesting technologies as well, that should be pursued, and it is too early for anyone—an investor—to pick a technology winner. Depending upon coal type and upon circumstances, depending upon how much technology advance there will be, depending about all these matters, one project or another may choose to use a particular gassifier or a particular pulverized coal plant.

The next point, Mr. Chairman, is that the 2005 Energy Act authorizes Government assistance to a wide range of coal technology projects. We believe that Federal assistance should only be given to coal projects with CO_2 capture and sequestration. That whether it's pulverized coal plant, whether it's an IGCC fuel plant, whether it's a synthetic fuels plant, whether it's a retro-fit of some kind of plant, no matter how it's done, we think it's appropriate and necessary for the Government to provide such assistance to show the private investment community that these technologies are practical, but it is important that it be done with carbon capture and sequestration. There is not the same justification for Federal assistance to these kinds of technologies where there is not carbon capture and sequestration.

This leads me to my next point, that it is our engineering judgment that the prospects for retro-fitted plants, which are designed for one purpose—to later do carbon capture and sequestration, or to do pre-investment for plants that you're building today for one purpose, assuming that you can easily retro-fit them for carbon capture later—but that window of opportunity is very narrow, indeed. It is likely to be quite expensive and difficult to do the retrofit. The reason is quite easy to explain—a plant with a carbon capture and sequestration is a very different plant than a plant that has been built for optimum performance without carbon capture and sequestration. The notion that you can just bolt on a device which will do the carbon capture for you ignores the many other changes in the processes that have to take place to make it work.

So, our view is the push for Government assistance today should be where there is unknown. The unknown is in the integration of carbon capture and sequestration to the efficient operation of a carbon capture, fishing operation to that conversion, coal-conversion plant.

Mr. Chairman, there's also another problem which we see and draw to your attention, and that is the possibility of a perverse incentive today for man, many people, to commit to a coal-conversion plant, without CO_2 capture today under the expectation that such plants will be grandfathered, that they will not be subject to any future carbon constraints that may be placed, they will be granted, for example, granted emission allowances, or granted waivers from emission taxes in the future. We believe that such grandfathering loopholes should be closed, with enough notification to the industry, so that you don't catch people unaware, or else you're going to find people building many plants in anticipation of a carbon-control regime.

My final remark has to do with the worldwide prospects for stabilization of carbon emissions. We want to recognize that dealing with global warming requires global adherence to emission constraints. The real issue here is what will be happening going forward, not in the United States or in Europe or the developed world where we see the economies, but what will happen in the large, emerging, rapidly growing economies, which are projected to be the biggest users of coal, and the biggest emitters of greenhouse gases in the future.

I will remind you that, last year, China put online the equivalent of 80 large coal plants. None of them, of course, with carbon capture and sequestration. Their electricity use is projected to grow at three or four times the rate of increase of the United States or of Europe, or OECD countries, in general.

So some way must be found of reaching an accommodation with these emerging economies, or else the actions that we take will have no significant effect on greenhouse gases, on global warming worldwide. We are making very slow progress at that step of engaging those countries, and finding a way to come to some sort of an agreement with them about what will be the control of these emissions going forward.

Our study did a particular in-depth look about the challenges facing China, if they were even to consider doing such a CO_2 constraint policy, adopting them and then implementing them. There are very good reasons why they believe they should be given a much longer, a different set of rules for the developing countries, but if we don't come together about some set of incentives for these countries to adopt carbon capture and sequestration, the actions we take will not prove productive in controlling greenhouse gas emissions.

The central message of this study is that the demonstration of technical, economic and institutional features for carbon capture and sequestration at commercial scale and coal combustion and coal-conversion plants will give policymakers and the public the confidence that practical carbon mitigation options exist. It will shorten the deployment time and reduce the costs of carbon capture and sequestration to occur, should a carbon emission and coal policy be adopted, and I think inevitably it's going to be. Third, it will maintain opportunities for the lowest cost, and most widely available energy form, coal, to be used to meet the world's pressing energy needs in an environmentally acceptable manner.

Thank you very much, Mr. Chairman. I look forward to your questions, and the questions from the members.

[The joint prepared statement of Mr. Deutch and Mr. Moniz follows:]

JOINT PREPARED STATEMENT OF JOHN M. DEUTCH, INSTITUTE PROFESSOR, DEPARTMENT OF CHEMISTRY, AND ERNEST J. MONIZ, CECIL AND IDA GREEN PROFESSOR OF PHYSICS & ENGINEERING SYSTEMS, CO-DIRECTOR, LABORATORY FOR ENERGY AND THE ENVIRONMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MA

Mr. Chairman, and members of the committee, thank you for the opportunity to appear before you today to summarize some of the key findings and recommendations in the MIT study on the future of coal. We carried out the study with eleven colleagues from various disciplines, over a three-year period, with the benefit of advice from an external group with diverse perspectives. We request that the Executive Summary of the report be entered into the record.

The study examines the role of coal as an energy source in a world where constraints on carbon emissions are adopted to mitigate global warming. Our first premise is that the risks of global warming are real and that the United States and other governments should and will take action to restrict the emission of carbon dioxide and other greenhouse gases.

Our second and equally important premise is that coal will continue to play a large and indispensable role in a greenhouse gas constrained world.

Our purpose is to identify the measures that should be taken to assure the availability of demonstrated technologies that would facilitate the achievement of carbon emission reduction goals while continuing to rely on coal to meet a significant fraction of the world's energy needs.

Carbon dioxide capture and sequestration (CCS) is the critical technology enabler for this purpose, and the priority objective with respect to coal should be the successful large-scale demonstration of the technical, economic, and environmental performance of the technologies that make up all of the major components of a large-scale integrated CCS system—capture, transportation, and storage.

The United States and other nations may need a vast scale of carbon dioxide sequestration. By mid-century, annual sequestration of several gigatonnes of carbon dioxide is the scale needed for a major impact on climate change mitigation, given the expectation that coal use will grow substantially. This translates into sequestration of the CO_2 emissions from many hundreds of utility scale plants worldwide.

Each plant will need to capture millions of metric tonnes of CO_2 each year. Over a fifty-year lifetime, one such plant would inject about a billion barrels of compressed CO_2 for sequestration. We have confidence that megatonne scale injection at multiple well-characterized sites can start safely now, but an extensive program is needed to establish public confidence in the practical operation of large scale sequestration facilities over extended periods and to demonstrate the technical and economic characteristics of the sequestration activity.

An important additional objective of the demonstration program is to create an explicit and rigorous regulatory process that gives the public and political leaders confidence in effective implementation of very large scale sequestration. A regulatory framework needs to be defined for sequestration projects including site selection, injection operation, and eventual transfer of custody to public authorities after a period of successful operation.

Present government and private sector sequestration projects are inadequate to demonstrate the practical implementation of large scale sequestration on a timely basis.

Thus we believe that the highest priority should be given to a program that will demonstrate CO_2 sequestration at megatonne scale in several geologies, following "bottom-up" site characterization. For the United States, this means about three megatonne/year projects with appropriate modeling, monitoring and verification (MMV), focusing on deep saline aquifers. Each demonstration project should last about eight to ten years. We estimate the cost for the total program to be about $500M over a decade, not including the cost of CO_2 acquisition. The CO_2 costs are likely to be considerable and highly variable depending on the acquisition strategy (natural reservoirs, capture from existing plants, supply from large scale demonstrations of new coal combustion and conversion plants).

In addition to the value of the scientific and engineering data that will emerge from this sequestration demonstration program, we should not underestimate the value of demonstrating the ability to successfully manage the program over an extended time. Such practical implementation experience will be important for public confidence in committing to very large sequestration over many decades.

To explore the prospect of very large scale sequestration, our study employed the Emissions Prediction and Policy Analysis (EPPA) model, developed at MIT, to prepare scenarios of global coal use and CO_2 emissions under various assumptions about the level and timing of CO_2 emissions pricing, whether through a tax, a cap and trade system, or some other mechanism.

An important threshold is the CO_2 price that leads to economic choices that result in stabilization of CO_2 emissions. The economic adjustments caused by a CO_2 charge are reduced energy use, a shift to lower-carbon emitting technology, improved efficiency of new and existing coal power plants, and importantly introduction of CCS. The EPPA model and our engineering analysis of alternative coal technologies suggests that a carbon charge of approximately $30/tonne-$CO_2$ is needed (most of this comes from capture, not sequestration). However, if the CO_2 emissions price remains low compared with this threshold price for an extended period, CO_2 emissions are significantly higher and CCS plays a minor role in reducing cumulative CO_2 emissions in this half-century. The CCS demonstration program needs to be carried out with urgency or the United States runs the danger of adopting a carbon constraint policy without a practical alternative for use of coal.

Our highest priority recommendation is that the Congress, the Department of Energy, and other private and public sector entities work to launch as soon as possible a sequestration demonstration program with the characteristics identified above, including those associated with development of the regulatory system. A sense of urgency has been absent and this needs to change.

Our second recommendation is for the U.S. government to provide incentives to several alternative coal combustion and conversion technologies that employ CCS. At present, Integrated Gasification Combined Cycle (IGCC) is the leading candidate for electricity production with CO_2 capture because it is estimated to have lower cost than pulverized coal with capture. However, neither IGCC nor other coal technologies have been demonstrated with CCS at large scale.

It is critical that the government RD&D program not pick a technology "winner" for several reasons. First, technology advances will undoubtedly lower the cost of all coal utilization technologies with capture—IGCC, pulverized coal, and potentially novel approaches. Some advances, such as much lower cost oxygen separation from air, could remove the IGCC cost advantage. Second, there are very different coal types (high ash content, high moisture content, . . .) and local conditions for specific projects that affect technology choice.

Indeed, the DOE program needs considerable strengthening and diversification in looking at a range of basic enabling technologies that can have major impact in the years ahead, particularly in lowering the cost of coal use in a carbon-constrained world. This work needs to be done at laboratory or process development unit scale, not as part of large integrated system demonstrations.

Both industry and the government would benefit from an extensive modeling and simulation effort in order to compare alternative technologies and integrated systems as well as to guide development. A significant increase in the DOE coal RD&D program is called for, as well as some restructuring.

Government assistance is needed for a portfolio of coal combustion and conversion demonstration projects with CO_2 capture—IGCC; oxyfuel retrofits; coal to synthetic natural gas, chemicals and fuels are examples. Given the technical uncertainty and the current absence of a carbon dioxide emissions charge, there is no economic incentive for private firms to undertake such projects at any appreciable scale. The DOE coal program is not on a path to address our priority recommendations—enabling technology, sequestration demonstrations, coal combustion and conversion demonstrations with capture. The level of funding falls far short of what is required and the program, perhaps as a result, is imbalanced.

The flagship project FutureGen is consistent with our priority recommendation to initiate integrated demonstration projects at scale. However, we are concerned that the project needs more clarity in its objectives. Specifically, a project of this scale and complex system integration should be viewed as a demonstration of commercial viability at a future time when a meaningful carbon policy is in place. Its principal call on taxpayer dollars is to provide information on such commercial viability to multiple constituencies, including the investment community. To provide high fidelity information, it needs to have freedom to operate in a commercial environment.

We believe that the Congress should work with the Administration to clarify that the project objectives are commercial demonstration, not research, and reach an understanding on cost-sharing that is grounded in project realities and not in arbitrary historical formulas. In thinking about a broader set of coal technology demonstrations, including the acquisition of the CO_2 needed for the sequestration demonstration projects, we suggest that a new quasi-government corporation should be considered.

The 2005 Energy Policy Act contains provisions that authorize federal government assistance for coal plants containing advanced technology projects with or without CCS. We believe this assistance should be directed only to plants with CCS, both new plants and retrofit applications on existing plants.

There is the possibility of a perverse incentive for early investment in coal-fired power plants without capture, whether pulverized coal or IGCC, in the expectation that the emissions from these plants would potentially be "grandfathered" by the grant of free CO_2 allowances as part of future carbon emission regulations and that (in unregulated markets) they would also benefit from the increase in electricity prices that will accompany a carbon control regime. Congress should act to close this "grandfathering" loophole before it becomes a problem.

Success at capping CO_2 emissions ultimately depends upon adherence to CO_2 mitigation policies by large developed and developing economies. We see little progress to moving towards the needed international arrangements. Although the European Union has implemented a cap-and-trade program covering approximately half of its CO_2 emissions, the United States has not yet adopted mandatory policies at the federal level. U.S. leadership in emissions reduction is a likely prerequisite to substantial action by emerging economies, and recent developments in the American business sector and in Congress are encouraging.

A more aggressive U.S. policy appears in line with developing public attitudes. Our study has polled the American public, following a similar poll conducted for the earlier MIT study on nuclear power. Americans now rank global warming as the number one environmental problem facing the country, and seventy percent of the American public think that the U.S. government needs to do more to reduce greenhouse gas emissions. Willingness to pay to solve this problem has grown 50% over the past three years.

The situation faced by large, rapidly growing, emerging economies is difficult. We studied a number of cases in China, looking at the "real" decision-making process for construction and operation of coal plants in several provinces.

These case studies suggest that it will be some time until China (or India) is willing and able to mitigate CO_2 emissions. We examined, with the EPPA model, the consequences of a lagged compliance with CO_2 mitigation measures by non-OECD countries. While a long lag, say 40-50 years, precludes any realistic possibility of meeting prudent global greenhouse gas concentrations, we found that a more modest lag, say 10 years, is potentially manageable from the point of view of incremental accumulated emissions. That is, the challenge of stabilizing emissions is exacerbated but not qualitatively altered.

This suggests a step-by-step international approach to the climate challenge, one that requires U.S. leadership both in advancing meaningful carbon policy and in demonstrating as early as possible the effectiveness and cost performance of technologies such as sequestration.

Absent substantial reductions in CO_2 emissions relative to "business-as-usual" expectations, substantial global warming will occur. At some point, nations would then face accepting the high economic cost and social disruption of adapting to climate change or the more problematic prospect of geo-engineering the climate by active measures. We do not dismiss the possibilities of adaptation and/or geo-engineering. But we do believe that it is less risky and ultimately less costly for the U.S. to lead the way in adopting emissions constraints today and in developing and demonstrating the technologies that will constrain emissions without significantly impacting economic development.

Mr. Chairman, thank you again for inviting our testimony. We appreciate the leadership of this committee in moving forward our nation's approach to global warming risks, and we welcome further discussion.

The CHAIRMAN. Thank you very much.

Professor Moniz, we're glad to have you here, thank you.

STATEMENT OF ERNEST J. MONIZ, CECIL AND IDA GREEN PROFESSOR OF PHYSICS AND ENGINEERING SYSTEMS, CO-DIRECTOR, LABORATORY FOR ENERGY AND THE ENVIRONMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MA

Mr. MONIZ. Thank you, Mr. Chairman.

I cannot claim this is my 30th-year anniversary, only my 10th.

Mr. DEUTCH. Not bad, not bad.

Mr. MONIZ. Given the obvious conclusion about John and me.

Mr. Chairman and members of the committee, thank you for the opportunity. What I will do is, since John has given this kind of overview of the report, just emphasize three features, briefly.

One is there is sometimes some confusion over the words "large-scale" and "sequestration." And I think that's partly because, there are in some senses, three different uses of the word. One is of the mega-ton per-year scale, associated with a utility-sale plant, one plant. Another is the lifetime accumulation of emissions from one utility-scale plant, which is then on the 100-mega-ton scale, or equivalently, billion barrels of compressed CO_2 sequestration. The third is the giga-ton scale, which is where we have to get to, say, by mid-century, for sequestration to be one of the technologies making a large impact in mitigating climate change risks.

I think the important thing to emphasize, so there's no confusion, is that we feel very, very confident about the wisdom of going ahead now with those mega-ton per-year projects. And while the program described in the Report, and by John, practical implementation will be essential for generating public confidence, generating the regulatory regimes needed to reach those other very large cumulative scales for large plants, and for the globe.

Second point would be a brief statement about the Department of Energy RD&D program. First, we believe that the program is under-funded, and perhaps as a consequence, rather unbalanced. We need a much more aggressive, what I would call, basic science and engineering effort, in terms of looking for the breakthrough technologies, at bench-scale, and at process development unit-scale. That could be transforming in the future.

These are things like oxygen separation, advanced capture technologies, to give a whole list of them—these are not getting the attention that we will need, to really get new ideas and new cost reduction some decades down the road.

Second is that the sequestration program that John just described, is of course, in some sense, our highest priority for immediate implementation, and we welcome the bill that you just announced, that you filed today for sequestration, and of course would be delighted to help in any way that we can to help shape those programs, to address the key issues.

Third, is we also recommend that we need a portfolio of coal technology-demonstration programs. Starting with IGCC—I'm sorry, always with capture—starting with IGCC, it makes perfect sense. But we also need to be thinking about a demonstration program, for example, of an oxygen-firing retro-fit of an existing plant; of a coal-to-synthetic natural gas plant, or a coal-to-chemicals plant. We need a portfolio.

Those demonstration projects themselves may be the sources of the possibly very expensive carbon dioxide needed for the sequestration demonstrations. On the other hand, we should not have the sequestration demonstrations hostage to exquisite timing of these demonstration projects to the sequestration projects.

We believe these large projects should have a clear focus on demonstration of commercial viability as the point of these demonstration programs. Large, billion dollar-integrated programs are not the place for "research," they are for demonstrating commercial viability, and as one supports those programs, it will be very important to provide high-fidelity information, which means having the projects run in as commercial a manner as possible. We can delve into that in more detail.

Finally, my third point, very briefly, is that another aspect of the study was to look at a continuation of our polling of the American public, that started with our earlier report, and there we would just note one fact that emerged, and that is that in 3 short years between the two polls, climate change went from the bottom of the list to the top of the list in terms of environmental concerns of the American public, and that was associated as well, with the public's willingness to contemplate, frankly, paying a somewhat larger amount than they were several years ago for addressing climate change.

Consequently, of course, we look forward to the continued leadership of you, Mr. Chairman, and the committee as you move forward on climate change legislation. Thank you. We also look forward to questions.

The CHAIRMAN. Thank you very much.

Mr. Hannegan, we're glad to have you here.

STATEMENT OF BRYAN HANNEGAN, VICE PRESIDENT, ENVIRONMENT, ELECTRIC POWER RESEARCH INSTITUTE, PALO ALTO, CA

Mr. HANNEGAN. Thank you, Mr. Chairman, and members of the committee.

I'm Bryan Hannegan, vice president, environment at the Electric Power Research Institute, a non-profit, collaborative, R&D organization, headquartered in Palo Alto, California.

EPRI appreciates the opportunity to provide testimony to the committee on the MIT report, and it's a great personal honor for me to be back in this committee room, and on this side of the witness table.

My comments today reflect our Institute's work with our talented scientists and engineers who are working on the many issues associated with electric power generation and use.

But today I want to focus my comments on two subjects. First, I want to provide to you EPRI's view on the MIT report which, at the outset, I want to say we believe is an important foundation on which to consider future energy policy.

Second, I want to highlight some of the recent work that we've done. You mentioned in your opening statement, Mr. Chairman, emphasizing the importance of CO_2 capture and storage, as part of an overall low-cost, low-carbon portfolio of options that we'll need to address climate change.

As you're well aware, coal currently provides half or over half of the electricity used in the United States, and most of the forecasts show that this will continue to be dominant in our energy future. By displacing otherwise-needed imports of natural gas or fuel oil, coal plays a critical role in our energy security, and it helps address our trade deficit with respect to energy.

The challenge is this, though. By 2030 EIA projects that total electricity demand in the United States will go up by 40 percent. At the same time as we think about dealing with climate change, we're looking at a substantial reduction in our future greenhouse gas emissions, and we want to do that in a way that allows for continued economic growth, and the benefits that all of the energy that we use, provides.

I want to stress to the committee, that this is not a trivial matter. It implies a substantial change in the way that we produce and consume electricity, all throughout our economy. The technologies like we'll discuss today on carbon capture and storage from coal are just one part of a necessarily economy-wide solution that includes greater efficiency at the end-use, increasing renewables, more efficient use of natural gas, and expanded role for nuclear power and similar transformations in all of our other sectors from transport to commercial and residential use.

It's this context in which I encourage you to consider the MIT study that my colleagues here just recently summarized. EPRI agrees with many of the study's main points, but we differ on a couple.

In particular, we agree that carbon capture and storage is going to be a critically enabling technology for coal going forward, and as Professor Deutch noted in his comments, the key will be the successful demonstration of CCS at the large-scale—one million tons of CO_2 per year. We believe this is important for both pre-combustion, as well as post-combustion technologies. Both pulverized coal as we know it today in the United States, and IGCC technologies going forward. We also must demonstrate storage in a variety of geologies, to take advantage of the full richness that we have available here in the United States.

As I mentioned, we agree with MIT's view that we should avoid choosing between coal technology options. While the technology for pulverized coal is well-established, the method for capturing and storing the CO_2 from those plants is not, and needs significant demonstration work.

But, in contrast, while there are proven methods for capturing and storing the CO_2 from IGCC, the plants that we're thinking about building, going forward, will have larger components, and a degree of integration that has not yet been demonstrated affordably and reliably at a commercial scale. In that vein, we disagree with comments in the MIT Report, limiting the application of your DOE programs to just IGCC; we think there's a role for pulverized coal for capture and storage going forward.

Both of these areas are going to require work to reduce the cost penalty and energy demands associated with current coal technologies, and we view the existing FutureGen programs, and the regional carbon sequestration programs at DOE, as good examples in this regard.

But others are needed, and we also think that many of the programs at DOE do need to significantly increase their scope, and accelerate the schedules of the work that they're doing to enable CCS capability as soon as possible.

In our view, however, an even greater impediment than the technology, than the financing, the even greater impediment to expanded CCS may be the development of public acceptance and the regulatory and legal frameworks going forward. Absent a consistent and predictable approach to siting and permitting facilities that have carbon capture and storage, the capital costs and the risks associated with these projects will simply be too large to allow them to move forward.

There are also questions of ownership of the stored CO_2, the liability when it leaks—if it leaks—back into the atmosphere, and questions regarding the environmental fate of the CO_2 once you put it in the ground. These issues bear further study and work at EPRI is underway, but more work needs to be done.

Let me make another point about the MIT study—we disagree with their view that pre-investment in capture-ready features is categorically un-economic. In many ways, whether or not you're retro-fitting an existing plant or you're building a new plant with an eye toward capture and storage, that's going to be a decision that's dictated by the availability of the technology, how soon you think limits on CO_2 emissions will come—in the event that the limits become more likely, the prospect of pre-investment could become worthy of consideration. But if you do it in the near future, it's a higher-cost option of compliance with CO_2 limits going forward.

Let me turn now to the recent work that we've done at EPRI that illustrates the promise of CCS as part of the solution to satisfying our energy needs in an environmentally responsible manner. Mr. Chairman, you mentioned our electricity technology in a carbon-constrained future work, and it does suggest that with aggressive R&D, demonstration, and deployment of advanced energy technologies, and more importantly, with aggressive assumptions on how those technologies can be deployed, we can slow down and halt the increase in CO_2 emissions from the electric sector, and then eventually reduce them, even as we simultaneously meet the increased demand for electricity.

However, as shown on this chart, I note that the pace at which we can do so, using EPRI's professional judgment and technical expertise, is substantially slower than some of the proposals that have been discussed in this body, and some that have been envisioned by this committee.

The chart to my right shows the net change in CO_2 emissions, relative to EIA's base case in their 2007 annual energy outlook, that results from specific technology deployment targets identified in seven areas, from NG sufficiency at the top in blue, down to plug-in hybrid vehicles and distributed energy resources at the bottom, in purple.

As I mentioned, the most encouraging aspect of the study is, that as we move toward 2030, we see CO_2 emissions from the electric sector can be falling fairly dramatically. However—and I must stress this—it will require a long-term commitment of billions of dollars in energy research, development, and deployment in every aspect of electric generation, transmission and consumption. It will not be cheap, and it will not be easy to accomplish.

As you see on the chart, the largest area there is in orange, and that's carbon capture and storage. We believe that those technologies offer the greatest promise, particularly if—as we assume in our work—you apply them to every new coal plant coming online after 2020.

As my colleagues from MIT have just pointed out, this is not an all-assured, given the technology development that we're engaged in, and the pace at which we expect things to come about.

Let me make one final point about our work. We've done some preliminary economic analysis, looking at the cost of achieving the emissions trajectory implied by the grey area both with, and without, capture and storage and advanced nuclear technologies, and we estimate that the cost to the U.S. economy without those technologies roughly triple, to a total of $2 trillion over 50 years, if you don't have capture and storage, and if you don't have advanced nuclear. They triple relative to the cost that would be incurred if you did have those technologies. Instead of having carbon capture and storage, and nuclear at the ready, you would instead meet the grey emissions requirement, by massive fuel-switching to natural gas, and price-induced conservation, driven by very large carbon prices, in our economic model.

The bottom line of this work suggests that as you consider legislation going forward, you should probably take into account the pace at which you expect technologies to be deployed realistically and cost-effectively in the economy. If you have a constraint before technology, you may incur larger costs than if you had the technology before you applied the constraint.

In summary, we're continuing with further technical and economic analysis on this work, and I'd be pleased, Mr. Chairman, to update the committee as our work evolved in the weeks and months ahead. I want to thank you and Senator Domenici, and your colleagues on the committee for the opportunity to speak, and I look forward to your questions.

[The prepared statement of Mr. Hannegan follows:]

PREPARED STATEMENT OF BRYAN HANNEGAN, VICE PRESIDENT, ENVIRONMENT, ELECTRIC POWER RESEARCH INSTITUTE

Thank you, Mr. Chairman, Ranking Member Domenici, and Members of the Committee. I am Bryan Hannegan, Vice President—Environment for the Electric Power Research Institute (EPRI), a non-profit, collaborative R&D organization headquartered in Palo Alto, California. EPRI appreciates the opportunity to provide testimony to the Committee on the MIT "Future of Coal" report, and it is a great personal honor for me to be back in this Committee room on this side of the witness table. My comments today reflect the work of the talented scientists and engineers we have working across our Institute on the many issues associated with electric power generation and use.

I want to focus my comments today on three subjects: (1) EPRI's views on the MIT report, which we believe provides an important foundation on which to consider future energy policy; (2) a detailed view from EPRI on the principal challenges facing coal-based generation in the decades ahead; and (3) highlights of some recent analytical work that EPRI has published emphasizing the importance of advanced coal technologies as part of an overall low-cost, low-carbon portfolio of options to reduce carbon dioxide emissions associated with climate change.

BACKGROUND

Coal currently provides over half of the electricity used in the United States, and most forecasts of future energy use in the United States show that coal will continue to have a dominant share in our electric power generation for the foreseeable future. Coal is a stably priced, affordable, domestic fuel that can be used in an environmentally responsible manner. Through development of advanced pollution control technologies and sensible regulatory programs, emissions of criteria air pollutants from new coal-fired power plants have been reduced by more than 90% over the past three decades. And by displacing otherwise needed imports of natural gas or fuel oil, coal helps address America's energy security and reduces our trade deficit with respect to energy.

By 2030, according to the Energy Information Administration, the consumption of electricity in the United States is expected to increase by approximately 40% over current levels, at the same time, to responsibly address the risks posed by potential climate change, we must substantially reduce the greenhouse gas emissions intensity of our economy in a way which allows for continued economic growth and the benefits that energy provides. This is not a trivial matter—it implies a substantial change in the way we produce and consume electricity. Technologies to reduce CO_2 emissions from coal will necessarily be one part of an economy-wide solution that includes greater end-use efficiency, increasing renewable energy, more efficient use of natural gas, expanded nuclear power, and similar transformations in the transportation, commercial, industrial and residential sectors of our economy. In fact, our work at EPRI on climate policy has consistently shown that non-emitting technologies for electricity generation will likely be less expensive than technologies for limiting emissions of direct fossil fuel end uses in other sectors. Paradoxically, as we seek greater limits on CO_2 across our economy, our work at EPRI suggests we will see greater amounts of electrification—but only if the technologies to do so with near-zero emissions are at hand.

THE MIT STUDY

Let me first make some general remarks about the MIT study which is the topic of today's hearing. I should note that while none of the EPRI staff were formally involved in the development of the report, we did comment on earlier drafts of it provided to us by the study's authors. In addition, our former President and CEO, Kurt Yeager, served on the study's Advisory Committee.

We agree with many of the main points of the MIT study:

- In particular, we agree with the study's main finding that CO_2 capture and sequestration (CCS) will be the critical enabling technology that provides for continued coal use even as we reduce our CO_2 emissions.
- We agree that the key to proving CCS capability is the demonstration of CCS at large-scale (>1 million tons CO_2/year) for both pre-and post-combustion capture with storage in a variety of geologies. The scope of the program described in the MIT report is appropriate.
- We share the view expressed by the MIT report that absent these successful demonstrations at the large scale, CCS will be confined to a narrow set of uses for enhanced oil recovery, and coal's share of future electricity production will decline dramatically as a result.

- We concur with the MIT report that we should avoid choosing between coal technology options—rather, we should foster a "portfolio of technology options".
  - —While there are well proven methods for capturing CO_2 resulting from coal gasification, IGCC plants will have larger components and a degree of integration that has not been demonstrated at the commercial scale.
  - —In contrast, PC technology is well proven commercially in the power industry, and here the need is for demonstration of post combustion capture at a commercial and affordable scale.
- We agree that there will inevitably be additional costs associated with CCS. EPRI's latest estimates suggest that the levelized cost of electricity (COE) from new coal plants (IGCC or supercritical PC) designed for capture, compression, transportation and storage of the CO_2 will be 50-80% higher than the COE of a conventional supercritical PC (SCPC) plant.
- EPRI's technical assessment work indicates that the preferred technology and the additional cost of electricity for CCS will depend on the coal type, location and the technology employed.
  - —Without CCS, supercritical pulverized coal (SCPC) has an advantage over IGCC. However, the additional CCS cost is generally lower with IGCC than for SCPC.
  - —Some studies show an advantage for IGCC with CCS with bituminous coal, but with lignite coal SCPC with CCS is more generally preferred. With sub-bituminous coals, SCPC with CCS and IGCC with CCS appear to show similar costs.
- At the same time, our initial work with post-combustion CO_2 capture technologies suggests we can potentially reduce the current 30% energy penalty associated with CCS to something closer to 10% over the longer-term. Improvements in IGCC plants offer the same potential for reducing cost and energy penalty as well.
- We also concur with MIT's assessment of the need to consider the entire integrated system for capture, transportation and storage of CO_2 at scale, and note that the existing FutureGen program is one good example of how this can be done. FutureGen is recognized around the world as a meaningful carbon sequestration project, and it has become a model for similar projects in other parts of the world. Others are needed, and we welcome the recent 10 MW pilot plant and the 200-MW plant announcement by AEP in that regard.
- We believe that the greater impediment to expanded CCS may be the development of public acceptance and suitable regulatory and legal frameworks. Absent a consistent and predictable approach to siting and permitting facilities for the transport and storage of CO_2, the capital costs and risks associated with these projects will likely prevent them from moving forward. The question of ownership of the stored CO_2 and the liability for any release or leakage is also not well understood. And most notably, the environmental fate of the captured and stored CO_2 is also an open scientific area worth further study.
- We see value in the approach taken by the various DOE Regional Carbon Sequestration Partnerships and do not agree with MIT's assessment that these existing programs are "completely inadequate". However, we do see the need to significantly accelerate the schedules and increase the scope of these programs to allow large scale tests and demonstrations of the full range of CCS technologies.
- We view the question of whether to retrofit an existing coal-based plant for CCS as a matter of economics and reliability: if the technologies exist to do so at a cost low enough to keep the plant in operation reliably, the owner may incorporate CCS retrofits particularly as they make additional modifications to the system to meet new stringent air pollution controls. EPRI is initiating analytical work in this area to better understand the potential for retrofits on existing coal-based generation units.
- With respect to the construction of new coal-based generation units, we disagree with the MIT report's categorical conclusion that pre-investment in "capture-ready" features is uneconomic. EPRI views this as a matter of perception on when and how restrictions on CO_2 emissions may occur: as the prospect of limits becomes more likely, such pre-investment becomes more worthy of consideration.
- The rapid pace of expansion in global coal generation capacity (105 GW added in China last year alone) underscores the need to focus on enabling large-scale CCS technology as soon as possible, regardless of discussions on domestic or international policy frameworks to reduce CO_2 emissions.

In the paragraphs that follow, we provide further detail on EPRI's view of the critical needs for coal-based generation in a carbon-constrained world.

INCREASING COAL PLANT EFFICIENCY

In the 1950s and '60s, the United States was the world's pioneer in power plants using thermodynamically efficient "supercritical" and "ultra-supercritical" steam conditions. Exelon's coal-fired Eddystone Unit 1, in service since 1960, still boasts the world's highest steam temperatures and pressures. Because of reliability problems with some of these early units, U.S. designers retreated from the highest supercritical steam conditions until the 1980s and '90s when international efforts involving EPRI and U.S., European, and Japanese researchers concentrated on new, reliable materials for high-efficiency pulverized coal plants. Given the prospect of potential CO_2 regulations (and efforts by power producers to demonstrate voluntary CO_2 reductions), the impetus for higher efficiency in future coal-based generation units has gained economic traction worldwide. In fact, the majority of new pulverized coal (PC) plants announced over the last two years will employ high-efficiency supercritical steam cycles, and several will use the ultra-supercritical steam conditions heretofore used only overseas (aside from Eddystone).

EPRI is working with the Department of Energy, the Ohio Coal Development Office, and major equipment suppliers on an important initiative to qualify a whole new class of nickel-based "superalloys," which will enable maximum steam temperatures to rise from an ultra-supercritical steam temperature of 1100 °F to an "advanced" ultra-supercritical steam temperature of 1400 °F. Combined with a modest increase in steam pressure, this provides an efficiency gain that reduces a new plant's carbon intensity (expressed in terms of CO_2 emitted per megawatt-hour (MWh)) by about 20% relative to today's state-of-the-art plant. If capture of the remaining CO_2 is desired, improved efficiency will also reduces the required size of any necessary equipment.

However, realization of this opportunity will not be automatic—in fact, it will require a renewed, sustained R&D commitment and substantial investment in demonstration facilities to bring new technologies to market. The European Union has embraced such a strategy and is midway through its program to demonstrate a pulverized coal plant with 1300 °F steam conditions, which was realistically planned as a 20-year activity.

Efficiency improvements will also be important for other coal power technologies. The world's first supercritical circulating fluidized-bed (CFB) plant is currently under construction in Poland. The greatest increase in efficiency for integrated gasification combined cycle (IGCC) units will come from increases in the size and efficiency of the gas turbines and improvements in their ability to handle hydrogen rich "syngas" that would be produced in IGCC plants designed for CO_2 capture.

CO_2 CAPTURE TECHNOLOGY

Carbon capture and storage (CCS) technologies can be feasibly integrated into virtually all types of new coal-fired power plants, including IGCC, PC, CFB, and variants such as oxy-fuel combustion. For those constructing new plants, it is unclear which type of plant would be economically preferred if it were built to include carbon capture. All have relative competitive advantages under various scenarios of available coal types, plant capacity, location, sales of by-products, etc.

Although carbon capture appears technically feasible for all coal power technologies, it poses substantial engineering challenges (requiring major investments in R&D and demonstrations) and comes at considerable cost. However, analyses by EPRI and the Coal Utilization Research Council suggest that once these substantial investments are made, the cost of CCS becomes manageable, and ultimately coal-based electricity with CCS can be cost competitive with other low-carbon generation technologies.

Post-combustion CO_2 separation processes (placed after the boiler in the power plant) are currently used commercially in the food and beverage and chemical industries, but these applications are at a scale much smaller than that needed for power producing PC or CFB power plants. These processes themselves are also huge energy consumers, and without investment in their improvement, they would reduce plant electrical output by as much as 30% (creating the need for more new plants). CO_2 separation processes suitable for IGCC plants are used commercially in the oil and gas and chemical industries at a scale closer to that ultimately needed, but their application necessitates development of modified IGCC plant equipment, including additional chemical process steps and gas turbines that can bum nearly pure hydrogen.

EPRI's most recent cost estimates suggest that for PC plants, the addition of CO_2 capture using the currently most developed technical option, amine solvents, along with drying and compression, pipeline transportation to a nearby storage site, and underground injection, would add about 60-80% to the net present value of life-cycle costs of electricity (expressed as levelized cost of electricity, or COE, and excluding storage site monitoring, liability insurance, etc.). This translates into a potentially large hike in consumers' electric bills.

The COE cost premium for including CO_2 capture in IGCC plants, along with drying, compression, transportation, and storage, is about 40-50%. Although this is a lower cost increase in percentage terms than that for PC plants, IGCC plants initially cost more than PC plants. Thus, the bottom-line cost to consumers for power from IGCC plants with capture may be comparable to that for PC plants with capture.

A utility's choice between these technologies will depend on available coals and their physical-chemical properties, desired plant size, the CO_2 capture process and its degree of integration with other plant processes, plant elevation, the value of plant co-products, and other factors. For example, IGCC with CO_2 capture generally shows an economic advantage in studies based on low-moisture bituminous coals. For coals with high moisture and low heating value, such as sub-bituminous and lignite coals, a recent EPRI study shows PC with CO_2 capture being competitive.

It should be noted that IGCC plants (like PC plants) do not capture CO_2 without substantial plant modifications, energy losses, and investments in additional process equipment. As noted above, however, the magnitude of these impacts could likely be reduced substantially through aggressive investments in R&D. Historical experience with the development of environmental control technologies for today's power plants suggests that technological advances from "learning-by-doing" will likely lead to significant cost reductions in CO_2 capture technologies as the installed base of plants with CO_2 capture grows. An International Energy Agency study led by Carnegie Mellon University suggested that overall electricity costs from plants with CO_2 capture could come down by 15% relative to the currently predicted costs after about 200 systems were installed. Furthermore, despite the substantial cost increases for adding CO_2 capture to coal-based IGCC and PC power plants, their resulting cost-of-electricity is still usually less than that for natural gas-based plants at current and forecasted natural gas prices.

Engineering analyses by EPRI, DOE, and the Coal Utilization Research Council suggests that costs could come down faster through CO_2 capture process innovations or, in the case of IGCC plants, fundamental plant improvements—provided sufficient RD&D investments are made. EPRI pathways for reduction in capital cost and improvement in efficiency are embodied in two companion RD&D Augmentation Plans developed under the collaborative CoalFleet for Tomorrow program. Efforts toward reducing the cost of IGCC plants with CO_2 capture will focus on adapting more advanced and larger gas turbines for use with hydrogen-rich fuels, lower-cost oxygen supplies, improved gas clean-up, advanced steam cycle conditions, and other activities.

For PC plants, the progression to advanced ultra-supercritical steam conditions will steadily increase plant efficiency and reduce CO_2 production. Improved solvents are expected to greatly reduce post-combustion CO_2 capture process. EPRI is working to accelerate the introduction of novel, alternative CO_2 separation solvents with much lower energy requirements for regeneration. Such solvents—for example, chilled ammonium carbonate—could reduce the loss in power output imposed by the CO_2 capture process from about 30% to about 10%. A small pilot plant (5 MW-thermal) is being designed for installation at a power plant in Wisconsin later this year; success there would warrant a scale-up to a larger pilot or pre-commercial plant. An EPRI timeline (compatible with DOE's timeframe) for the possible commercial introduction of post-combustion CO_2 capture follows.

The introduction of oxy-fuel combustion may allow further reductions in CO_2 capture costs by allowing the flue gas to be compressed directly, without any CO_2 separation process and reducing the size of the supercritical steam generator. Boiler suppliers and major European and Canadian power generators are actively working on pilot-scale testing and scale-up of this technology.

EPRI stresses that no single advanced coal generating technology (or any generating technology) has clear-cut economic advantages across the range of U.S. applications. The best strategy for meeting future electricity needs while addressing climate change concerns and economic impact lies in developing multiple technologies from which power producers (and their regulators) can choose the one best suited to local conditions and preferences.

Assuring timely, cost-effective coal power technology with CO_2 capture entails simultaneous and substantial progress in RD&D efforts on improving capture processes and fundamental plant systems. EPRI sees the need for government and industry to pursue these and other pertinent RD&D efforts aggressively through significant public policy and funding support. Early commercial viability will likely come only through firm commitments to the necessary R&D and demonstrations and through collaborative arrangements that share risks and disseminate results.

TRANSPORTATION AND GEOLOGIC STORAGE

Geologic sequestration of CO_2 has been proven effective by nature, as evidenced by the numerous natural underground CO_2 reservoirs in Colorado, Utah, and other western states. CO_2 is also found in natural gas reservoirs, where it has resided for millions of years. Thus, evidence suggests that depleting or depleted oil and gas reservoirs, and similar "capped" sandstone formations containing saltwater that cannot be made potable, are capable of storing CO_2 for millennia or longer. Geologic sequestration as a strategy for reducing CO_2 emissions is being demonstrated in numerous projects around the world.

Three relatively large projects—the Sleipner Saline Aquifer CO_2 Storage (SACS) project in the North Sea off of Norway; the Weyburn Project in Saskatchewan, Canada; and the In Salah Project in Algeria—together sequester about 3 to 4 million metric tons of CO_2 per year, which approaches the output of just one typical 500 megawatt coal-fired power plant. With 17 collective years of operating experience, these projects suggest that CO_2 storage in deep geologic formations can be carried out safely and reliably. Furthermore, CO_2 injection technology and subsurface behavior modeling have been proven in the oil industry, where CO_2 has been injected for 30 years for enhanced oil recovery (EOR) in the Permian Basin fields of west Texas and Oklahoma. Regulatory oversight and community acceptance of injection operations are well established.

In the United States, DOE has an active R&D program (the "Regional Carbon Sequestration Partnerships") that is mapping geologic formations suitable for CO_2 storage and conducting pilot-scale CO_2 injection validation tests across the country. These tests, as well as most commercial applications for long-term storage, will compress CO_2 to a liquid-like "supercritical" state to maximize the amount stored per unit volume underground. As a result, virtually all CO_2 storage applications will be at least a half-mile deep, helping reduce the likelihood of any leakage to the atmosphere, which would defeat the purpose of sequestering the CO_2 in the first place.

DOE's Regional Carbon Sequestration Partnerships represent broad collaborative teaming of public agencies, private companies, and non-profits; they would be an excellent vehicle for conducting larger "near-deployment scale" CO_2 injection tests to prove specific U.S. geologic formations, which EPRI believes to be one of the keys to commercializing CCS for coal-based power plants. Evaluations by these. Regional Partnerships and others suggest that enough geologic storage capacity exists in the United States to hold several centuries' worth of CO_2 emissions from coal-based power plants and other stationary sources. However, the distribution of suitable storage formations across the country is not uniform: some areas have ample storage capacity whereas others appear to have little or none.

Thus, CO_2 captured at some power plants would be expected to require pipeline transportation for several hundred miles to suitable injection locations, which may be in other states. While this adds cost, it doesn't represent a technical hurdle because CO_2 pipeline technology has been proven in oil field FOR applications. As CCS is applied commercially, EPRI expects that early projects would take place at coal-based power plants near sequestration sites or an existing CO_2 pipeline. As the number of projects increases, regional CO_2 pipeline networks connecting multiple sources and storage sites would be needed.

There is still much work to be done before CCS can implemented on a scale large enough to significantly reduce CO_2 emissions into the atmosphere. In addition to large-scale demonstrations at U.S. geologic formations, many legal and institutional uncertainties need to be resolved. Uncertainty about long term monitoring requirements, liability, and insurance is an example. State-by-State variation in regulatory approaches is another. Some geologic formations suitable for CO_2 storage underlie multiple states. For private companies considering CCS, these various uncertainties translate into increased risk.

THE PROMISE OF CCS

Recent EPRI work has illustrated the necessity and the urgency to develop carbon capture and storage (CCS) technologies as part of the solution to satisfying our energy needs in an environmentally responsible manner. Our "Electricity Technology in a Carbon-Constrained Future" study, which I am pleased to have led, suggests that with aggressive R&D, demonstration, and deployment of advanced electricity technologies, it is technically feasible to slow down and stop the increase in U.S. electric sector CO_2 emissions, and then eventually reduce them over the next 25 years while simultaneously meeting the increased demand for electricity. However, even under the most aggressive technology assumptions, the pace at which we can do so is substantially slower than that envisioned under several of the pending bills currently before this Committee and the Congress as a whole.

To develop this analysis, we compiled data on the currently and likely future cost and performance of various electricity technologies from our Technical Assessment Group work, various public-private technology R&D roadmaps, and expert opinions from academia, industry, and the NGO community in the published literature. From this information, EPRI established specific technology deployment targets in seven areas: efficiency, renewables, nuclear generation, advanced coal generation, carbon capture and storage (CCS), plug-in hybrid electric vehicles (PHEV) and distributed energy resources. We then calculated the net change in CO_2 emissions from the electric sector which would result from achieving each of those technology targets compared to the underlying assumptions in the Base Case of the 2007 Annual Energy Outlook published by the Energy Information Administration (EIA). The results are shown in Figure 1.*

The most encouraging aspect of the study is that, as we move toward 2030, CO_2 emissions levels from the U.S. electric sector can begin falling fairly dramatically. However, this will require the long-term commitment of billions of dollars in energy research, development and deployment in every aspect of electric generation, transmission and consumption. It will not be cheap, nor will it be easy to accomplish. While one could argue that CO_2 reductions from some of these targets could be slightly higher or somewhat lower, the overall picture is clear—we can get to a low-carbon future, but only with substantial consistent investment, smart policy choices and a realistic timeline.

Of the seven options we analyzed, we believe that the greatest reductions in future U.S. electric sector CO_2 emissions are likely to come from applying CCS technologies to nearly all new coal-based power plants coming on-line after 2020. In fact, the longer we delay in developing the capability to deploy CCS technologies that can be deployed at a commercial scale, the longer we will have to wait for the resulting substantial reductions in CO_2 and correspondingly, reductions in the risk of future climate change.

Furthermore, preliminary economic work conducted by EPRI to extend this study shows that absent both CCS and advanced nuclear technologies, achieving these aggressive CO_2 emissions reductions would be extremely costly. We estimate that the costs to the U.S. economy would roughly triple—to nearly $2 trillion over the next 50 years—compared to costs if CCS and advanced nuclear technologies were commercially available. This large difference in economic cost arises from the lack of low-cost, low-carbon technologies to reduce future CO_2 emissions growth on a large scale: in a world without CCS and nuclear, we rely instead on massive fuel switching to natural gas (with attendant price increases and import dependence) and on price-induced conservation driven by very large carbon prices (which would more than likely trigger any "safety valve" set in legislation). Our preliminary economic work suggests that the timeline for any cost-effective program of CO_2 emissions reductions should be dictated by our expectation of technology development and deployments in the decades ahead.

We are continuing with further technical and economic analysis, and we expect to release our final economic analysis later this year. I would be pleased to update the Committee as our work evolves in the weeks and months ahead.

The CHAIRMAN. Thank you very much.

Mr. Dan Lashof is our final witness on this panel, and we're glad to have you here.

STATEMENT OF DANIEL A. LASHOF, PH.D., CLIMATE CENTER SCIENCE DIRECTOR, NATURAL RESOURCES DEFENSE COUNCIL, NEW YORK, NY

Mr. LASHOF. Thank you very much, Mr. Chairman. It's a pleasure to be back before the committee.

* Graphic has been retained in committee file.

Members of the committee, I am Daniel Lashof, I am the science director, and deputy director of the Climate Center at the Natural Resources Defense Council.

Mr. Chairman, I went to school at the other end of Massachusetts Avenue from the esteemed professors from MIT, so I dare not really question the technical judgments that they make about the readiness of carbon capture and storage technology. I do have some questions about the completeness of their policy recommendations, which I'll come to in a minute.

But, indeed, I agree strongly with their first premise, which is simply that the risks of global warming are real, and the United States and other countries need to take action to restrict emissions of carbon dioxide and other global warming pollutions, that certainly is essential.

They're finding that retro-fitting existing coal plants with carbon capture and storage, whether they be integrated gasification plants, or more conventional pulverized coal plants, would be very complex and expensive, and unlikely to occur. It is also a very important finding in my view.

Third, I agree with their conclusion that mega-ton scale injection at multiple wealth characterized sites can happen safely now. Indeed, that conclusion is also shared by Dr. Julio Friedman of Lawrence Livermore National Lab, who testified before the House Energy & Commerce Committee last month, that the technology, the understanding of the geology for doing carbon capture is at a stage where we should really start learning more by doing it, rather than just doing research in a laboratory mode.

Fourth, I agree strongly with many of their policy conclusions, including one that Profession Deutch mentioned, which is that Federal assistance for coal projects should only go to projects that actually incorporate carbon capture and storage, as a central part of their design.

But I do have some issues with the policy recommendations; in particular, I believe that they are incomplete. In my view, the most important policy recommendation stemming from their technical analysis is that Congress should immediately require that any new coal-fired power plants be designed and operated with carbon capture and storage, starting right away. Their analysis shows that is technically feasible, and it is very important to establish that as a policy matter.

The reason it's so important is that if you take a typical 500–megawatt coal plant, and build it without carbon capture and storage, emissions are about 4 million tons of CO_2 a year—that plant can be expected to operate for 50 years or more. That means it's a commitment to emitting 200 million tons of CO_2 into the atmosphere over its lifetime. Simply put, the 100 or so conventional coal plants that are on the drawing board in the United States and the thousands or more that are on the drawing boards worldwide—if they are built without carbon capture and storage, it will make it impossible to meet the climate protection goals that I know you share, Mr. Chairman.

In one conclusion of the MIT Report that I think has been widely misinterpreted, their analysis finds that the private sector does not now have the incentive to build plants that have carbon capture and storage technology built into them, and that's true. But that's precisely why Congress needs to act. It needs to create a legal requirement that future coal plants have this technology.

Some may suggest that we don't need to have a specific performance standard for new coal plants if we have an overall cap-and-trade system—let the price go in there, and if people want to build plants without carbon capture, they have to pay for the permits, that should be enough. But the MIT study shows why I don't think that is enough. They conclude that the price of carbon allowances has to reach about \$30 per ton of CO_2, before carbon capture and storage technology would be the economic choice. That's a relatively high number.

Indeed the EIA analysis, which was the last time I was before the committee, considering their analysis of your discussion draft proposal, concluded that because of the price caps that were built into that proposal, at least through 2030, there would be no investment in carbon capture and storage, driven economically by the private sector. So, even with more stringent caps, there's no guarantee that the price of CO_2 allowances would quickly reach the point where the private sector would choose to build new plants with carbon capture and storage built in.

So, I think there would be a large risk that we would see dozens, if not hundreds, of additional plants built in the United States that would then commit us over 50 years or more to excessive levels of CO_2 emissions that would be very difficult to control in the future.

Certainly, your leadership with Senator Boxer in putting developers on notice that shouldn't expect to get any grandfathered allowances if they go ahead and build plants without carbon capture and storage, I think, has been very, very important. But, I don't think that, by itself, is enough. Because even without the expectations of grandfathered allowances, without a carbon price of \$30 a ton or higher, many utilities may conclude that they should just go ahead and try to build plants quickly, and get their money out before the price of allowances goes very high.

An additional policy idea, I would suggest, to go along with a CO_2 new source performance standard for new power plants, is a low-carbon generation obligation. This would require that an increasing fraction of all of the electricity generated by coal, come from plants that employ carbon capture and storage. The idea behind this, as a complement to a new source performance standard, is to spread the cost and the risk of building this new technology across the coal-based industry, rather than concentrating only on the developers of new plants. So, I think that's an idea I would urge you to consider.

Finally, to address Professor Deutch's point about the need to deal with the many power plants that are being built in China and at a somewhat slower pace in India, but a really, truly dizzying pace in China, building conventional coal plants. I think it's really essential for the international community to step up and develop a dedicated fund that would pay for the incremental costs of building those plants with carbon capture and disposal as soon as possible, so as they're building out that infrastructure, it's built in a way that's consistent with where we need to go on global warming.

It's actually a commitment that the international community made, in principle, back in 1992 at Rio, and it's never been fulfilled. Now is the time to step up, we have the technology that this report and others show that we know how to keep the CO_2 out of the atmosphere, by putting it underground, starting now. So in my view, there's no time like the present—let's get started. Thank you.

[The prepared statement of Mr. Lashof follows:]

PREPARED STATEMENT OF DANIEL A. LASHOF, PH.D., CLIMATE CENTER SCIENCE DIRECTOR, NATURAL RESOURCES DEFENSE COUNCIL, NEW YORK, NY

INTRODUCTION

Thank you for the opportunity to share my views regarding MIT's "Future of Coal" report.[1] My name is Daniel A. Lashof, and I am the science director of the Climate Center at the Natural Resources Defense Council (NRDC). I was a coauthor (with David Hawkins and Robert Williams) of a September 2006 Scientific American article titled "What to do about Coal." David Hawkins of NRDC served on the advisory committee for the MIT study and NRDC has prepared a brief response to the MIT report, which is attached to my testimony and available online.[2]

NRDC is a national, nonprofit organization of scientists, lawyers and environmental specialists dedicated to protecting public health and the environment. Founded in 1970, NRDC has more than 1.2 million members and online activists nationwide, served from offices in New York, Washington, Los Angeles and San Francisco.

CAPTURING AND SEQUESTERING CARBON IS POSSIBLE TODAY

MIT's report on the Future of Coal correctly recognizes the imperative for prompt action on global warming and the critical role that use of carbon dioxide (CO_2) capture and geologic storage (CCS) must play in reconciling protection of the climate with expected global dependence on coal. Yet the report's examination of policies to promote immediate deployment of CCS systems is incomplete and it fails to address the most urgent problem facing U.S. policymakers: what CO_2 performance requirements should be applied to proposed new coal power plants?

While the facts set forth in the report provide ample justification for a recommendation to require all proposed new coal plants to capture CO_2 for geologic disposal, the report is silent on this question.

Rather than recommending performance requirements to capture and store CO_2 from all new coal plants, the report proposes an incomplete policy response that would likely fail to prevent the construction of new high-emitting coal plants and result in much larger taxpayer costs and higher abatement costs when climate protection policies are adopted. The report recommends that government grants be made to energy companies to fund use of CO_2 capture at a few new coal plants, that government fund several large-scale geologic injection projects, and that Congress not "grandfather" new proposed power plants from future CO_2 control legislation. While each of these recommendations is a useful complement to a direct requirement for new coal plants to use CCS, by themselves they are inadequate.

Some industry proponents of old-technology coal plants that will not capture CO_2 have claimed that the MIT study suggests that CCS systems are not ready for use at proposed new coal plants. In contrast, the report itself states that there is no reason for Congress to delay adoption of a carbon emission control policy and finds that construction of new supercritical pulverized coal plants without CCS "will raise the cost of future CO_2 control." One reason is that retrofits of plants built without CCS are not likely. The MIT report finds that: "[. . .], retrofitting an existing coal-fired plant originally designed to operate without carbon capture will require major technical modification, regardless of whether the technology is SCPC or IGCC." (Executive Summary, p. xiv) Yet the report fails to recommend (or even discuss) the most obvious direct policy measure a requirement that new coal plants employ CCS.

IS CCS READY FOR NEW COAL PLANTS TO USE TODAY?

While the Findings and Recommendations chapter of the MIT report states there is no reason for Congress to delay adoption of a carbon emission control policy and finds that construction of new supercritical pulverized coal plants without CCS "will

[1] Online at http://mit.edu/coal/.
[2] Online at www.nrdc.org/globalWarming/coal/contents.asp.

raise the cost of future CO_2 control," the report's Executive Summary discusses the choice of whether to apply CCS from the point of view of private sector developers, concluding that it is difficult to choose between Integrated Gasification Combined Cycle (IGCC) technology and supercritical pulverized coal (SCPC) technology.

The critical flaw in this discussion, which I expect will be widely quoted by conventional coal plant developers, is that it implies that the only rational approach to new coal plant investments is to permit private developers to choose between two different types of coal plants, both of which release their CO_2 rather than capturing it. However, the premise of significantly delayed requirements to control CO_2 emissions that underlies this discussion is inconsistent with other findings in the report that CCS is ready for application today and that there is no reason for Congress to delay adoption of limits on CO_2 emissions.

Is it technically feasible for new coal power plants to capture and sequester their carbon? The MIT study itself supports an affirmative answer. The study finds that commercial capture systems exist:

> Of the possible approaches to separation [with pulverized coal plants], chemical absorption with amines, such as monoethanolamine (MEA) or hindered amines, is the commercial process of choice. (page 24)
>
> In applying CO_2 capture to IGCC [. . .] a weakly CO_2-binding physical solvent, such as the glymes in Selexol, can be used to separate out the CO_2. Reducing the pressure releases the CO_2 and regenerates the solvent, greatly reducing the energy requirements for CO_2 capture and recovery compared to the MEA system. (page 34)

The study also finds that "large-scale CO_2 injection projects can be operated safely" (Executive Summary, p. xii). Dr. Julio Friedman of Lawrence Livermore National Laboratory agrees. Testifying before the House Energy and Commerce Committee on March 6, 2007, Dr. Friedman concluded that:

> Opportunities for rapid deployment of [geological carbon sequestration] GCS exist in the U.S. There is enough technical knowledge to select a safe and effective storage site, plan a large-scale injection, monitor CO_2, and remediate and mitigate any problems that might arise (e.g., well-bore leakage). This knowledge derives from over 100 years of groundwater resource work, oil and gas exploration and production, studies of geological analogs, natural gas storage site selection and operation, and hazardous waste disposal. A careful operator could begin work today at a commercial scale and confidently select and operate a site for 30 to 50 years. (pages 6-7)

The MIT study notes that existing projects do not employ the rigorous monitoring that is needed for a fully implemented CCS program and that permitting regulations need to be written. However, if begun now, these requirements can be developed in a few years, shorter than the period required to plan, finance, and build new coal plants now in preliminary development stages. Such requirements will need to be adopted to carry out the large demonstration injection projects recommended by the report in any case. As the report states, "What is needed is to demonstrate an integrated system of capture, transportation, and storage of CO_2, at scale. This is a practical goal but requires concerted action to carry out" (Executive Summary, p. xi) Rather than carry out a set of demonstrations unconnected to newly built coal plants, the obvious alternative is to integrate the construction of new coal plants with the initial large-scale injection projects.

CONCLUSION

The MIT study does not examine in any detail the key issue surrounding new coal plant construction: would it be better to vent CO_2 from new coal plants in the next decade or two rather than capture it. The report notes that if significant new coal capacity without CCS is built the costs of CO_2 control programs would increase for all. Another outcome, not discussed in the report, is that such new coal investments will be cited by their owners as reasons to delay the pace of programs to limit CO_2 emissions. That result would foreclose options to stabilize CO_2 concentrations at adequately protective levels.

While the authors of the MIT report decline to say so directly, the information presented in the report supports a straightforward policy recommendation: Congress should require planned new coal plants in the United States to employ CCS without further delay.

Natural Resources Defense Council's Response to MIT's 'Future of Coal' Report

By David Hawkins and George Peridas, Natural Resources Defense Council

ABOUT NRDC

The Natural Resources Defense Council is an international nonprofit environmental organization with more than 1.2 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in New York City, Washington, D.C., Los Angeles, San Francisco, and Beijing. Visit us at www.nrdc.org. NRDC President: Frances Beinecke; NRDC Director of Communications: Phil Gutis; NRDC Publications Director: Alexandra Kennaugh; NRDC Editor: Lisa Goffredi.

SUMMARY

MIT's report on the Future of Coal correctly recognizes the imperative for prompt action on global warming and the critical role that use of carbon dioxide (CO_2) capture and geologic storage (CCS) must play in reconciling protection of the climate with expected global dependence on coal. Yet the report's examination of policies to promote immediate deployment of CCS systems is incomplete and it fails to address the most urgent problem facing U.S. policymakers: what CO_2 performance requirements should be applied to proposed new coal power plants?

While the facts set forth in the report provide ample justification for a recommendation to require all proposed new coal plants to capture CO_2 for geologic disposal, the report is silent on this question.

Rather than recommending performance requirements to capture and store CO_2 from all new coal plants, the report proposes an incomplete policy response that would likely fail to prevent the construction of new high-emitting coal plants and result in much larger taxpayer costs and higher abatement costs when climate protection policies are adopted. The report recommends that government grants be made to energy companies to fund use of CO_2 capture at a few new coal plants, that government fund several large-scale geologic injection projects, and that Congress not "grandfather" new proposed power plants from future CO_2 control legislation. While each of these recommendations is a useful complement to a direct requirement for new coal plants to use CCS, by themselves they are inadequate.

Based on leaks of early drafts of the report's executive summary, industry proponents of old-technology coal plants that will not capture CO_2 are already claiming the MIT study suggests that CCS systems are not ready for use at proposed new coal plants. MIT's Howard Herzog, one of the MIT study participants, in a November 2006 presentation, provides a more accurate summary of the facts:

> Is CCS feasible? Yes, all major components of a carbon capture and sequestration system are commercially available today. Why is CCS use limited today? It is almost always cheaper to emit to the atmosphere than sequester. Therefore, opportunities are limited to niche areas until carbon policies are put in place.

The report states there is no reason for Congress to delay adoption of a carbon emission control policy and finds that construction of new supercritical pulverized coal plants without CCS "will raise the cost of future CO_2 control." Yet the report fails to recommend (or even discuss) the most obvious direct policy measure—a requirement that new coal plants employ CCS.

Is CCS Ready for New Coal Plants to Use Today?

While the Findings and Recommendations chapter of the MIT report states there is no reason for Congress to delay adoption of a carbon emission control policy and finds that construction of new supercritical pulverized coal plants without CCS "will raise the cost of future CO_2 control," the report's Executive Summary inconsistently suggests that the choice of whether to apply CCS should be left to private sector developers:

> From the standpoint of a power plant developer, the choice of a coal-fired technology for a new power plant today involves a delicate balancing of considerations. On the one hand, factors such as the potential tightening of air quality standards for SO_2, NO_X, and mercury, a future carbon charge, or the possible introduction of federal or state financial assistance for IGCC would seem to favor the choice of IGCC. On the other hand, factors such as near-term opportunity for higher efficiency, capability to use lower cost

> coals, the ability to cycle the power plant more readily in response to grid conditions, and confidence in reaching capacity factor/efficiency performance goals would seem to favor the choice of super critical pulverized coal (SCPC). Other than recommending that new coal units should be built with the highest efficiency that is economically justifiable, we do not believe that a clear preference for either technology can be justified. (Executive Summary, p. xiv)

The critical flaw in this excerpt, which we expect will be widely quoted by conventional coal plant developers, is that it implies that the only rational approach to new coal plant investments is to permit private developers to choose between two different types of coal plants, both of which release their CO_2 rather than capturing it. However, the premise of significantly delayed requirements to control CO_2 emissions that underlies this discussion is inconsistent with other findings in the report that CCS is ready for application today and that there is no reason for Congress to delay adoption of limits on CO_2 emissions.

Is it technically feasible for new coal power plants to capture and sequester their carbon? The MIT study itself supports an affirmative answer. The study finds that commercial capture systems exist:

> Of the possible approaches to separation [with pulverized coal plants], chemical absorption with amines, such as monoethanolamine (MEA) or hindered amines, is the commercial process of choice. (page 24)
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The study also finds that "large-scale CO_2 injection projects can be operated safely" (Executive Summary, p. xii). The study notes that existing projects do not employ the rigorous monitoring that is needed for a fully implemented CCS program and that permitting regulations need to be written. However, if begun now, these requirements can be developed in a few years, shorter than the period required to plan, finance, and build new coal plants now in preliminary development stages. Such requirements will need to be adopted to carry out the large demonstration injection projects recommended by the report in any case. As the report states, "What is needed is to demonstrate an integrated system of capture, transportation, and storage of CO_2, at scale. This is a practical goal but requires concerted action to carry out" (Executive Summary, p. xi) Rather than carry out a set of demonstrations unconnected to newly built coal plants, the obvious alternative is to integrate the construction of new coal plants with the initial large-scale injection projects.

CAPTURING AND SEQUESTERING CARBON IS POSSIBLE TODAY

Capture of Carbon From Power Plants

The 2005 Intergovernmental Panel on Climate Change (IPCC) special report on Carbon Dioxide Capture and Storage groups processes to capture or separate CO_2 from power plant gas streams into three categories: post-combustion, pre-combustion and oxyfuel combustion. Today pre-combustion capture is the most economic option but other approaches show promise as well.

Pre-combustion capture is applicable to processes that gasify coal. Coal gasification is widely used in industrial processes, such as ammonia and fertilizer production around the world. Hundreds of such industrial gasifiers are in operation today. Integrated Gasification Combined Cycle (IGCC), used for electric power production, is a relatively recent development—about two decades old and is still not widely deployed.

Commercially demonstrated systems for pre-combustion capture from the coal gasification process are used in industrial plants to separate CO_2 from natural gas and to make chemicals such as ammonia. Due to lack of CO_2 control policies, most such systems simply release the separated CO_2 to the air. An example where the CO_2 from coal gasification is actually captured rather than vented is the Dakota Gasification Company plant in Beulah, North Dakota, which captures and pipelines more than one million tons of CO_2 per year from its lignite gasification plant to an oil field in Saskatchewan. ExxonMobil's Shute Creek natural gas processing plant in Wyoming, which strips CO_2 from sour gas and pipelines several million tons per year to oil fields in Colorado and Wyoming, is another large industrial example.

Today's pre-combustion capture approach is not applicable to the installed base of conventional pulverized coal in the United States and elsewhere. However, it is ready today for use with IGCC power plants. The oil giant BP has already announced an IGCC project with pre-combustion CO_2 capture at its refinery in Carson, California. The MIT executive summary statement that "[t]here is no operational experience with carbon capture from coal plants and certainly not with an integrated sequestration operation." (Executive Summary, p. xiii), is not correct as the Dakota Gasification plant shows.

The principal obstacle for broad application of pre-combustion capture to new power plants is not technical, it is economic: under today's laws it is cheaper to release CO_2 to the air rather than capturing it. The MIT report states that "at present Integrated Gasification Combined Cycle (IGCC) is the leading candidate for electricity production with CO_2 capture because it is estimated to have lower cost than pulverized coal with capture" (Executive Summary, p. xiii). This is backed up in the main body of the study, which quotes the respective costs of electricity from a supercritical pulverized coal plant with capture and an IGCC with capture as 7.69 cents/kWh and 6.52 cents/kWh (p. 30).

Commercial post-combustion CO_2 capture systems have been applied to very small portions of flue gases from a few coal-fired power plants in the United States that sell the captured CO_2 to the food and beverage industry. However, industry analysts and the MIT report state that today's systems, based on publicly available information, involve much higher costs and energy penalties than the principal demonstrated alternative, pre-combustion capture. New and potentially less expensive post-combustion concepts have been evaluated in laboratory tests and some, such as ammonia-based capture systems, are scheduled for small pilot-scale tests in the next few years. Under normal industrial development scenarios, if successful such pilot tests would be followed by larger demonstration tests and then by commercial-scale tests. These and other approaches should continue to be explored.

Oxyfuel combustion is also in the early stages of development. Pilot studies for oxyfuel processes have been announced. As with post-combustion processes, absent an accelerated effort to leapfrog the normal commercialization process, it could be significant number of years before such systems begin to be deployed broadly in commercial application.

Capturing emissions from new power plants is perfectly feasible. Is it possible then to sequester the CO_2 in geologic formations? We examine that question below.

Sequestration of Carbon in Geologic Formations Is Possible

We have a significant experience base for injecting large amounts of CO_2 into geologic formations. For several decades oil field operators have received high pressure CO_2 for injection into fields to enhance oil recovery, delivered by pipelines spanning as much as several hundred miles. Today in the United States a total of more than 35 million tons of CO_2 are injected annually in more than 70 projects. In addition to this enhanced oil recovery experience, there are several other large injection projects in operation or announced. The longest running of these, the Sleipner project, began in 1996. But the largest of these projects injects on the order of 1 million tons per year of CO_2, while a single large coal power plant can produce about 5 million tons per year. And of course, our experience with human-made injection projects does not extend for the 1,000-year or more period that we would need to keep CO_2 in place underground for it to be effective in helping to avoid dangerous global warming. Accordingly, the public and interested members of the environmental, industry, and policy communities rightly ask whether we can carry out a large-scale injection program safely and assure that the injected CO_2 will stay where we put it.

Do we have a basis today for concluding that injected CO_2 will stay in place for the long periods required to prevent its contributing to global warming? The IPCC report concluded that we do, stating that "[o]bservations from engineered and natural analogues as well as models suggest that the fraction retained in appropriately selected and managed geologic reservoirs is very likely to exceed 99 percent over 100 years and is likely to exceed 99 percent over 1,000 years."

The MIT study itself states that:

> [although substantial work remains to characterize and quantify these mechanisms, they are understood well enough today to trust estimates of the percentage of CO_2 stored over some period of time—the result of decades of studies in analogous hydrocarbon systems, natural gas storage operations, and CO_2-EOR. [. . .] Additional work will reduce the uncertainties associated with long-term efficacy and numerical estimates of storage volume capacity, but no knowledge gaps today appear to cast doubt on the fundamental likelihood of the feasibility of CCS. [. . .] Our overall judgment is that the prospect for geologic CO_2 sequestration is excellent. We base this judgment on 30 years of injection experience and the ability of the earth's crust to trap CO_2. (p. 44)

Although the report notes the existence of open issues about large-scale deployment, meaning a sequestration program on the order of billions of tons per year, Chapter 4 of the report makes clear that these issues are not obstacles to commencing numerous multimillion tonne per year injection projects today. Rather, the issues mentioned are ones that should be addressed to allow a large-scale program to be implemented in an economically optimized fashion.

The report makes recommendations that include a comprehensive nationwide survey by the United States Geological Survey to map out storage capacity, the development of a regulatory framework for CCS, the adoption of long-term liability regimes for storage sites, and the acceleration of large-scale sequestration projects of at least 1 million tonnes of CO_2 annually. All of these recommendations can be implemented before the commissioning of new coal power plants now in the development stage.

The Cost of CCS

CCS costs more than conventional power generation. Significantly more capital and equipment is required and the energy penalty that accompanies plants that capture and sequester their carbon is not trivial. However, deployment of CCS will have a minimal effect on the power sector, end-consumers, and the economy as a whole.

With today's off-the-shelf systems, estimates are that the production cost of electricity at a coal plant with CCS could be as much as 40 percent higher than at a conventional plant that emits its CO_2. But the impact on average electricity prices of introducing CCS now will be very much smaller due to several factors.

First, power production costs represent about 60 percent of the price that end-consumers pay for electricity—the rest comes from transmission and distribution costs. Second, coal-based power, which would initially be the source that would utilize CCS, represents just over half of U.S. power consumption. Third, and most important, even if we start now, CCS would be applied to only a small fraction of U.S. coal capacity for some time. Thus, with a properly designed trading approach, the incremental costs on the units equipped with CCS could be spread over the entire coal-based power sector or possibly across all fossil capacity depending on the choices made by Congress. Based on CCS costs available in 2005 we estimate that a low-carbon generation obligation large enough to cover all forecasted new U.S. coal capacity through 2020 could be implemented for about a 2 percent increase in average U.S. retail electricity rates.

The MIT study notes that absent a value for carbon there is no economic reason from the firm's perspective to employ CCS outside niche markets like enhanced oil recovery. However, the study does not demonstrate, or even argue, that a prompt deployment program would result in economically infeasible impacts on electricity prices. The added costs of CCS therefore do not constitute an argument that prompt deployment for new capacity now in the planning pipeline would be economically infeasible.

Regulations Needed for CCS

A regulatory framework is absolutely necessary to assure that CCS does not pose any significant risk to human health or the environment, to assure it is performed to high standards, and to enable the widespread adoption of the technology.

The MIT study clearly calls for such a framework to be developed, and should be commended for doing so:

> An explicit and rigorous regulatory process that has public and political support is prerequisite for implementation of carbon sequestration on a large scale. This regulatory process must resolve issues associated with the definition of property rights, liability, site licensing and monitoring, ownership, compensation arrangements and other institutional and legal considerations. Regulatory protocols need to be defined for sequestration projects including site selection, injection operation, and eventual transfer of custody to public authorities after a period of successful operation.[. . .] These issues should be addressed with far more urgency than is evidenced today (Executive Summary, p. xii).

With concerted effort by an agency with jurisdiction and capability, which we believe is the U.S. EPA, a regulatory framework for CCS can be in place in a few years. For new plants that are closer to construction, there will likely be a need for interim requirements and those should be set forth without further delay.

POLICIES TO PROMOTE CCS

The MIT study recommends government grants to support installation of CO_2 capture at several new coal plants (p. 100).

Although this policy recommendation may make sense as a complement to a requirement for new coal plants to use CCS, by itself it is inadequate and likely to lead to wasted taxpayer expenditures.

Research and development funding as well as direct government subsidies can be useful in assisting a technology's widespread adoption, but cannot substitute for the incentive that a genuine commercial market for CO_2 capture and storage systems will provide to the private sector. Government assistance needs to go hand in hand with policies that will make the adoption of low-carbon generation technologies mandatory. The amounts of capital that the private sector can spend to optimize CCS methods will almost certainly always dwarf what government will provide with taxpayer dollars. To mobilize those private sector dollars, Congress needs a stimulus more compelling than the offer of modest handouts for research.

We have a model that works: intelligently designed policies to limit emissions cause firms to invest money to find better and less expensive ways to prevent or capture emissions.

Where a technology is already competitive with other emission control techniques, for example, sulfur dioxide scrubbers, a cap and trade program like that enacted by Congress in 1990, can result in more rapid deployment, improvements in performance, and reductions in costs. However, a CO_2 cap and trade program by itself may not result in deployment of CCS systems as rapidly as we need. Many new coal plant design decisions are being made literally today. Depending on the pace of required reductions under an emissions cap, a firm may decide to build a conventional coal plant and purchase credits from the cap and trade market rather than applying CCS systems to the plant. Although this may appear to be economically rational in the short term, it is likely to lead to higher costs of CO_2 control in the mid and longer term if substantial amounts of new conventional coal construction leads to ballooning demand for CO_2 credits.

Moreover, delaying the start of CCS until a cap and trade system price is high enough to produce these investments delays the broad demonstration of the technology that the United States and other countries need if, as seems likely, we continue substantial use of coal. The more affordable CCS becomes, the more widespread its use will be throughout the world, including in rapidly growing economies like China and India. But the learning and cost reductions for CCS that are desirable will come only from the experience gained by building and operating the initial commercial plants. The longer we wait to ramp up this experience, the longer we will wait to see CCS deployed here and in countries like China.

Accordingly, we believe the best policy package is a hybrid program that combines the breadth and flexibility of a cap and trade program with well-designed performance measures focused on key technologies like CCS. One such performance measure is a CO_2 emissions standard that applies to new power investments. California enacted such a measure in SB1368 in 2006. It requires new investments for sale of power in California to meet a performance standard that is achievable by coal with a moderate amount of CO_2 capture.

Another approach is a low-carbon generation obligation for coal-based power. Similar in concept to a renewable performance standard, the low-carbon generation obligation requires an initially small fraction of sales from coal-based power to meet a CO_2 performance standard that is achievable with CCS. The required fraction of sales would increase gradually over time and the obligation would be tradable. Thus, a coal-based generating firm could meet the requirement by building a plant with CCS, by purchasing power generated by another source that meets the standard, or by purchasing credits from those who build such plants. This approach has the advantage of speeding the deployment of CCS while avoiding the "first mover penalty." Instead of causing the first builder of a commercial coal plant with CCS to bear all of the incremental costs, the tradable low-carbon generation obligation would spread those costs over the entire coal-based generation system. The builder of the first unit would achieve far more hours of low-carbon generation than required and would sell the credits to other firms that needed credits to comply. These credit sales would finance the incremental costs of these early units. This approach provides the coal-based power industry with the experience with a technology that it knows is needed to reconcile coal use and climate protection and does it without sticker shock.

MISINTERPRETATIONS OF THE MIT REPORT

Some have misread the MIT to suggest that additional research and development is required before we could apply CCS to coal plants now being designed. For example, a recent press report cited a leaked draft of the report's executive summary as follows: "[the study] concludes in a draft version that it is not clear which technology—the so-called integrated gasification combined cycle or pulverized coal—will allow for the easiest carbon capture, because so much engineering work remains to be done". This reference confuses two different issues: is CCS demonstrated today versus which approach to CCS may ultimately prove to be most effective and economical. As discussed above, the MIT report makes clear that demonstrated CCS methods exist today although private firms will not employ them absent a subsidy or a CO_2 emissions performance requirement.

The report urges that no single approach like IGCC should be anointed as the ultimate best system for use of coal with CCS. Adoption of policies that set a CO_2 performance standard now for new plants will not anoint IGCC as the technological winner since alternative approaches can be employed when they are ready. If the alternatives prove superior to IGCC and pre-combustion capture, the market will reward them accordingly. Setting the policy now will create the market that will stimulate competition among competing approaches.

Some industry developers who are seeking approval to build conventional CO_2 emitting coal plants already have misstated the report's conclusions as justifying their attempts to build new plants without CCS. For example, Sithe Global Power LLC, the developer of the proposed Desert Rock power plant, in a January 2007 brochure, cites the then unreleased report to imply that the report raises questions about "the viability of sequestration technologies".

> Even if carbon capture technologies become available and affordable, many unanswered questions remain about the viability and impacts of sequestering carbon dioxide. While some technologies in the oil and gas industries use carbon sequestration today for additional development, no long-term storage data is currently available. An upcoming study from energy experts at the Massachusetts Institute of Technology (MIT) to be released in February 2007 is likely to cast further doubt on the viability of sequestration technologies. While Sithe Global and other developers believe the future is promising, carbon sequestration issues still remain a largely unknown factor because of these concerns.

In fact, the MIT report states the authors' "confidence that large-scale CO_2 injection projects can be operated safely," even though current modeling, monitoring, and verification methods do not resolve all relevant technical issues. (Executive Summary, p. xii). Chapter 4 of the report, which discusses geologic storage in detail, states that

- geologic trapping mechanisms "are understood well enough today to trust estimates" made by the IPCC that more than 99 percent of injected CO_2 will likely be retained for at least 1,000 years; and
- "no knowledge gaps today appear to cast doubt on the fundamental likelihood of the feasibility of CCS." (p. 44)

CONCLUSION: TIME IS OF THE ESSENCE

The study does not examine in any detail the key issue surrounding new coal plant construction: would it be better to vent CO_2 from new coal plants in the next decade or two rather than capture it. The report notes that if significant new coal capacity without CCS is built the costs of CO_2 control programs would increase for all. Another outcome, not discussed in the report, is that such new coal investments will be cited by their owners as reasons to delay the pace of programs to limit CO_2 emissions. That result would foreclose options to stabilize CO_2 concentrations at adequately protective levels.

The report does state that there is no reason for Congress to delay action to limit CO_2 emissions during the CCS demonstration program recommended by the study authors. There are ample reasons to avoid any such delay. If CO_2 performance standards for U.S. coal plants were to be delayed until after the completion of the three to five recommended large-scale sequestration demonstrations, and other countries followed suit, it is likely that broad CCS would not happen until another 20 years of coal capacity had been constructed—an amount of new capacity about as large as current global coal capacity. If that amount of sunk investment in non-capture coal capacity is made, either CO_2 control programs will be much more costly, as the study notes, or worse, politicians will simply fail to put in place effective programs to protect against a climate catastrophe.

The die is being cast for that catastrophe today, not decades from now. Decisions being made today in corporate board rooms, government ministries, and congressional hearing rooms are determining how the next coal-fired power plants will be designed and operated. Power plant investments are enormous in scale, more than $1 billion per plant, and plants built today will operate for 60 years or more. The International Energy Agency (IEA) forecasts that more than $5 trillion will be spent globally on new power plants in the next 25 years. Under IEA's forecasts, more than 1,800GW of new coal plants will be built between now and 2030—capacity equivalent to 3000 large coal plants, or an average of ten new coal plants every month for the next quarter century. This new capacity amounts to 1.5 times the total of all the coal plants operating in the world today.

The astounding fact is that under IEA's forecast, 7 out of every 10 coal plants that will be operating in 2030 don't exist today. That fact presents a huge opportunity—many of these coal plants will not need to be built if we invest more in efficiency; additional numbers of these coal plants can be replaced with clean, renewable alternative power sources; and for the remainder, we can build them to capture their CO_2, instead of building them the way our grandfathers built them.

If all 3,000 of the next wave of coal plants are built with no CO_2 controls, their lifetime emissions will impose an enormous pollution lien on our children and grandchildren. Over a projected 60-year life these plants would likely emit 750 billion tons of CO_2, a total, from just 25 years of investment decisions, that is 30 percent greater than the total CO_2 emissions from all previous human use of coal.

The MIT report concludes that retrofits of plants built without CCS are not likely: "[. . .], retrofitting an existing coal-fired plant originally designed to operate without carbon capture will require major technical modification, regardless of whether the technology is SCPC or IGCC." (Executive Summary, p. xiv)

The IPCC stated in February 2007 that the warming of the plant's climate system is "unequivocal", and that it is attributable to anthropogenic greenhouse gas emissions with more than 90 percent probability. Meanwhile, in its April 2007 release, the Panel reportedly will warn of starvation, water shortages, disease, floods, extinctions, and increased death rates, claiming that "[c]hanges in climate are now affecting physical and biological systems on every continent." We must begin decreasing our greenhouse gas emissions now. The modest costs of deploying CCS today are completely overshadowed by the costs and risks of not doing so.

While the authors of the MIT report decline to say so directly, the information presented in the report supports a straightforward policy recommendation: Congress should require planned new coal plants in the United States to employ CCS without further delay.

The CHAIRMAN. Thank you very much. Thank you all.

We'll do 5-minute rounds here, and let me start and ask a few questions.

Let me ask Professor Deutch and Professor Moniz: on the issue of whether or not there's going to be the capacity to actually capture and sequester—the capturing, I guess, is not the tough part, it's the sequestering that's more difficult, as I understand it. We have, as you said, Professor Deutch, 80 new coal plants constructed in China last year. We've got lots of coal plants ourselves, there are lots of coal plants around the world. Is it realistic to think that once this technology is perfected and commercialized on a large scale, that we then have the capacity, and geologic formations, to really sequester all of this carbon? It just strikes me that you've got a lot of carbon going into the atmosphere now, and I'm just wondering if all of that's going to be going into geologic formations in the future, and do we have enough of them?

Mr. DEUTCH. Mr. Chairman, the first point is, that we believe there is a vast capacity in deep saline aquifers in the United States for the foreseeable storage of this CO_2 material. One of the recommendations of our study is, however, to do a bottom-up review, in this country, and elsewhere in the world, to really tie down what these capacities are. Our expectation is that the same will be found for China. India, on the other hand, has less-capable geology. But, we do think in the United States that storage capacity exists, and through some accidental piece of good fortune, which I don't usually encounter, the places where we have coal plants, the places where these deep saline aquifers exist, are more or less close by. So, it's not vast distances.

The second point I would like to make is that I don't think it is only the process of injection and monitoring the storage cites in this report. We need practical experience with the capture part, where we really haven't done any work on capture from a coal plant. We need experience with the pressurization and transportation, and we need the coal-integrated system put together, in a regulatory framework. That practical experience is important.

What about the pace? Yes, it's a huge scale, as Ernie emphasized; yes, it will take time to make those investments; but I want to remind you that since the Congress put in new source performance standards on criteria pollutants, the coal industry and the utilities have shown a tremendous capacity to meet those more stringent environmental requirements. I am convinced that given time, and given the support, that the coal industry will gradually be able to introduce this into the operation of the United States.

The CHAIRMAN. Let me just to try to better understand what people are recommending going forward here.

As I understand, in the MIT Report that you've described, the recommendation there is that we should immediately, or as soon as we can, change the law or provide that Federal assistance will only go to projects that incorporate this capture and sequestration technology, coal projects.

Mr. DEUTCH. That's correct, Mr. Chairman, but let me emphasize, that we think it should be an array of projects.

The CHAIRMAN. Right.

Mr. DEUTCH. It should not just be IGCC——

The CHAIRMAN. Right, it——

Mr. DEUTCH. It should be all sorts of projects.

The CHAIRMAN. Yes, use all possible technologies, but use capture and sequestration.

Mr. DEUTCH. Each one of them would have to have capture and sequestration——

The CHAIRMAN. Right.

Mr. DEUTCH [continuing]. Integrated in their design and operation.

The CHAIRMAN. That's your recommendation for what we do right now.

Now, I understand that we've got a different set of ideas, Dr. Hannegan. You said that EPRI's view was that beginning in 2020, you would anticipate we would have in place a requirement that carbon capture and sequestration be used if additional coal plants are to be constructed, as I understood it. Is that right?

Mr. HANNEGAN. Actually, Mr. Chairman, it was one assumption that we made under the scenario here to the right. It was not—EPRI is a 501(c)(3) non-profit, it doesn't make policy recommendations per se—it was just one element of assuming, as would be assumed in the case of the MIT study, that if we invest substantially in the carbon capture and storage technologies, and we work on deploying them and developing them at a commercial scale, our technical work shows that the earliest that they could be within the range of economic assistance to be commercializable on their own, is in the 2020 timeframe. Once you start from moving at the current pilot scale that we're seeing today, through to some of the new announcements by AEP and others of a 200–megawatt project, just within the last week, to by the time you get to a commercial scale where you've tested and run that, and you develop the supporting regulatory structures, the earliest that we see it could be widespread, in terms of its availability, is by 2020.

Let me say one other thing, and that is: we disagree with MIT's view that you should only limit support to those projects that have carbon capture and storage built in. Those certainly should be preferred, because CO_2 capture and storage is a necessary option, as we've demonstrated going forward, but there are issues associated with so-called Ultra Super Critical Pulverized Coal Plants, which are pushing temperatures and pressures that we've never done in the real world. Also with respect to IGCC at scale—I mentioned in my testimony—there's a level of sophistication and integration that hasn't been demonstrated above the two pilot programs at DOE.

The CHAIRMAN. My time has run out, maybe I'll come back and ask some additional questions in the second round.

Senator Domenici, did you want to go ahead with a statement, or questions, or did you want me to skip over and call someone else? What's your preference?

Senator DOMENICI. I'm going to do what's most accommodating to you all.

The CHAIRMAN. I think we're happy to hear your statement and questions at this point, if you're ready.

Senator DOMENICI. I won't have any questions, but I do have a statement.

STATEMENT OF HON. PETE V. DOMENICI, U.S. SENATOR FROM NEW MEXICO

Senator DOMENICI. First of all, I don't know what it is, Senator Bingaman, I don't get to see these two guys—Deutch and Moniz very often. One would think that they are actually hiding out in some foreign country and just show up every now and then and peek at us, because they look so different. I mean, they're getting grey, bald-headed——

[Laughter.]

Senator DOMENICI. I mean, the whole thing, huh?

Mr. MONIZ. Shall we go?

Senator DOMENICI. Do you guys work together or at different places?

Mr. DEUTCH. Senator, I remember how you looked 30 years ago, too.

[Laughter.]

Senator DOMENICI. Well, Senator Bingaman tells me I still look pretty good.

[Laughter.]

Senator DOMENICI. Anyway, I have been waiting for an occasion to express myself the way I'm going to here in just a little bit, and I thought it might be good to do it today, where you guys could come down hard on me, and when you go outside afterwards, you can say, "That's really bad, what he said," but——

First, I want to thank Senator Bingaman for scheduling this hearing on this very important topic. Make no mistake about it: we must recognize that the use of American coal in electricity generation is essential to our Nation's energy independence and security. At present, half of our electricity is generated from coal, and the EIA estimates that by 2030, 57 percent of our electricity will be derived from coal. Nobody can be sitting around that's worried about the products that come from burning coal, and be cavalier about that reality.

With these numbers in mind, it is clear that for us to make progress, we must make significant advancements in clean coal technology. I believe it would be unwise for the United States to move forward without also working to get China and India as full partners in the capture and sequestration of carbon dioxide. That includes getting their financial support for these efforts.

When the technology is proven at the scale needed to capture and sequester carbon dioxide, it will be critical for them to fully participate in the implementation of that technology. To do otherwise could negatively impact the U.S. economy and our global competitiveness. I don't think one can see that any other way.

The United States has led the effort, but unless China, and the other coal-using countries participate in this work with both human capital and financial resources, it is unlikely that we will be able to address global climate change in a reasonable, fair and effective manner.

China controls the world's third-largest coal reserves, and is expected to account for more than half of the global growth in coal over the next 25 years. I want to read that again. China controls the world's third-largest coal reserves, and is expected to account for more than half the global growth in coal supply and demand over the next 25 years.

In approximately 2 years, China will pass us as the world's leader in carbon dioxide emissions. By 2025, China will emit twice as much carbon dioxide as the United States. Remember, it is not American Climate Change we are facing, it is Global Climate Change, and it requires global cooperation and participation for a global solution.

I expect that Professors Deutch and Moniz will tell us that it makes a significant difference in reducing the world's carbon emissions, but other major coal-using and -producing countries have to participate in finding solutions. I find The Future of Coal Report interesting, and I'm ready to support major research, development, and development projects in this area. It is clear that we need to gain a better understanding of how to best enhance the efficiency of our future, and our future coal-fired power plants, to reduce carbon dioxide emissions.

We also need to better understand how to best capture and sequester carbon, and to deal with the technological, economical, and potential infrastructure and liability challenges that we face in large-scale carbon sequestration.

All of these are issues that the MIT Report can help us better understand. Having the answer to these questions will be important so we don't put our country at economic risk or at competitive disadvantage.

I believe the Report does a good job of pointing out many of the issues that need to be addressed to help Congress thoughtfully address coal and its future. I thank the Chairman for holding the hearing. I look forward to working with him and others as we move forward in a very, very formidable task ahead of us.

Thank you very much.

The CHAIRMAN. Professor Deutch, did you want to respond?

Mr. DEUTCH. Thank you very much, Mr. Chairman, I'll be very brief.

Senator, in my opening remarks I made it very clear, and the report is quite clear, that you're quite right, this is a global problem, and if there's not a way of finding the large, emerging economies, like India and China, have them constrain their CO_2 emissions, climate change doesn't get better. It is a judgment question on which I have my own view—very, very great reservations about: should the United States or Europe or the developed world, in general, go forward—when should it go forward?—unless you have it locked up tight when the emerging economies will go forward. We have some information about what would happen if there was a lag-time. You must find a way to lock up the emerging economies on this question as well, or else you're only going to be paying money, and not improving the climate.

The CHAIRMAN. Senator Bunning, why don't you go ahead?

Senator BUNNING. Thank you very much, Mr. Chairman. Thank you all for being here. Since you have two of the largest coal-producing States in the United States here represented in Senator Thomas and myself—Kentucky and Wyoming—we have a deep and abiding interest in what's going on with coal. We appreciate your report.

Your report emphasizes demonstration of new technologies. One of the technologies I believe that is most promising is coal-to-liquid fuels. I have introduced legislation to provide Government incentives in the form of tax credits and planning loans for the first few coal-to-liquid facilities. I believe these plants, aside from easing our dependence on foreign oil, will help push gas, coal gasification technology into the mainstream, much like that which has been done in South Africa.

Would you support this kind of a demonstration program?

Mr. DEUTCH. Senator, our Report and our comments here are quite clear that synthetic fuels—gases or liquids—would certainly be candidates for us in these early demonstration projects, but with carbon capture——

Senator BUNNING. Carbon sequestration—oh, yes.

Mr. DEUTCH. I might say in this regard that there's an advantage——

Senator BUNNING. We have that in the bill.

Mr. DEUTCH. But, it's an advantage with synthetic liquids, because you're making oxygen in the—you have to make the oxygen to do the synthetic fuel, so you don't have that extra cost that you have in electricity generation.

Senator BUNNING. I'm also one of the co-sponsors of the bill for the other program where we find out how we can store and place the carbon that we sequester.

Mr. DEUTCH. Yes, Senator.

Senator BUNNING. I have a question for, is it Don or Dan?

Mr. LASHOF. Dan.

Senator BUNNING. I know the NRDC has opposed coal-to-liquid technology, but I see your organization supports coal gasification for electricity. Is that correct, or incorrect?

Mr. LASHOF. Well, Senator, we believe that carbon capture and storage is a critical technology, if coal is going to be a viable energy technology in the electric sector, and we support Government funding for carbon capture and disposal associated with electricity generation.

The problem we have with coal-to-liquids is that, when we're looking at the need to reduce the CO_2 emissions that cause global warming by, on the order of 80 percent over the next 50 years, we need to be moving from transportation fuels that rely on petroleum to fuels that have fundamentally lower greenhouse gas emissions over the fuel cycle, from well to wheels.

The problem with coal-to-liquids is, even with carbon capture and storage, you still end up, at best, with a fuel that has about the same emissions, or a little bit higher emissions, than from conventional gasoline. The reason for that is that the tailpipe emissions are basically the same, you're producing a hydrocarbon fuel that is essentially equivalent to diesel.

Senator BUNNING. The Air Force would disagree with you.

Mr. LASHOF. No, I don't think so. I know the Air Force is very interested in using Fischer-Tropes liquids derived from coal in their jets, and the emissions from the jets would be about the same as—their CO_2 emissions would be essentially identical——

Senator BUNNING. They have testified before me, or have come to visit with me, and that is not their position.

Mr. LASHOF. Well, and——

Senator BUNNING. Because the fuel burns cooler, it's better for the engines, and with a mixture of some type of petroleum, it doesn't emit near the emissions that a regular jet would emit if it used petroleum-based fuel.

Mr. LASHOF. Well, I'd be happy to review their testimony and——

Senator BUNNING. That's all right.

Mr. LASHOF [continuing]. Further to the record, but the, my understanding——

Senator BUNNING. You ought to visit with them.

Mr. LASHOF. Yes, well, we've talked to them, and I know that they also say that we should have carbon capture and storage with that technology.

Senator BUNNING. Yes, they have.

Mr. LASHOF. I think that's very helpful.

With respect, Senator, I think that the bill, as it was introduced, allows for support for the carbon capture and disposal portion, but does not require that that be incorporated——

Senator BUNNING. Well, we've changed it to require it.

Mr. LASHOF. I think that's definitely a step in the right direction. I certainly appreciate that.

Senator BUNNING. Well, we appreciate all of you being here.

My time is expired, Mr. Chairman, go right ahead.

The CHAIRMAN. Thank you very much.

Senator Salazar.

Senator SALAZAR. Thank you very much, Chairman Bingaman, for holding this very important hearing. I would just make a comment that I, too, come from a State that is a coal-producing State—Colorado—and I know that on our Western slope, we produce some of the high-quality coal that is very important to our economy. We share that same interest with Wyoming and Kentucky and other States that are coal-producing States.

I also think that inevitably what's going to happen is we will continue to grow in how much coal we ultimately use, simply because of the fact that it is so available, and I think your report shows that.

I would ask you to comment, and I know you did this on your report—in terms of the possibilities that we have with respect to both IGCC, as well as with respect to carbon sequestration. This committee has been very supportive of moving forward with demonstration projects, IGCC—I know there are a number of projects out there that are already up and running, and a number that are being planned.

I also would like you to comment on how it is that we can move the ball further forward, in terms of carbon sequestration. There's legislation which Senator Bunning, and I, and others on this committee are moving forward with to try to get a good assessment of the geologic formations of the country, so that we can determine where the best places are for us to be able to do carbon sequestration.

So, I'd like, really, a comment from the panel on two issues—one, how far along are we on IGCC, and is there anything that we can do here in the Congress to try to speed up that effort for the United States, and two, what more can we do in terms of the carbon sequestration programs that we've talked about?

Mr. MONIZ. Senator Salazar, first of all, I'd like to respond as a person who spends time on the banks of the Conejos, in your part of the country.

Senator SALAZAR. I will say, if I was to ask anybody here where that river is, you and I probably are the only ones who know where that river is.

Mr. MONIZ. Twenty-five miles west of Antonito.

Senator SALAZAR. It's a beautiful river.

Mr. MONIZ. The first question on IGCC: first, I do want to repeat something that my colleague, John Deutch said earlier, and that is that we feel it's very important to explore alternative technologies, but with what we know today, and with some more experience, IGCC right now does look to be the lowest cost technology with capture, so the idea of moving forward with a major integrated demonstration of IGCC and carbon capture is one we endorse.

We would add, in terms of what the Congress can do—we would note that the current plans with FutureGen are moving along too slowly, and I believe the Congress should provide clarity that the object of that, and other, large-scale, integrated demonstrations, is to demonstrate commercial viability and one should guide the project execution along those lines. There are various issues, in terms of reliance, on historical formulas, for cost-sharing, that I think deserve re-examination, but that would certainly help that go forward, while one also, hopefully, plans for a broader portfolio of integrated demonstration projects with capture, with other technologies.

For example, the issues of retro-fitting pulverized coal plants with oxygen firing could be a very interesting and important demonstration, given our large installed base.

Senator SALAZAR. Let me ask you, just in terms of moving forward to the point where we have commercial viability with respect to these demonstration projects: I know that there are a number of demonstration projects out there, including one that is being planned for Colorado, that I very much support. From your point of view, are those demonstration projects headed in the direction that we will be able to examine the commercial viability of IGCC?

Mr. MONIZ. Well, I think first of all, of course, there is no operating large-scale coal plant with carbon capture and sequestration. We believe that this is a technical challenge, to demonstrate that integrated system of IGCC with capture. We believe there should be public funding to support it. The question will be in the practical implementation: is the project going to be executed in the way that provides, if you like, high-fidelity information, let's say, to the investment community?

Senator SALAZAR. Which is the best of the IGCC demonstration projects currently underway?

Mr. MONIZ. Well, I would not cast judgment on that——

Senator SALAZAR. Give me two or three that you would recommend that some of us might go——

Mr. MONIZ. If we talk about FutureGen as the obvious candidate right now, with Federal support, we would say that we need to have fewer chefs in the kitchen—streamline it, and focus it on commercial viability. There's some very good people involved in that project—I mean, Mike Mudd, who is heading that, is a terrific person. I believe we have to, for example, make sure we're not falling into a trap of lots of Federal procurement rules, et cetera, that can compromise the value of the commercial information.

We can discuss that in more detail. If I may just answer briefly, the sequestration part—I'd just say that I think in our report, I believe we provide the elements of an aggressive, appropriate road map to really resolve the key issues of sequestration, including site characterization, monitoring, verification, modeling, support for a regulatory regime, and demonstration of practical implementation, on about a 10–year time period with, what I would consider to be relatively modest funds. That, I think, is something that, on this panel, we have all agreed with. It calls for a relatively small number of focused projects, at well-characterized sites.

Senator SALAZAR. Thank you, Professor.

My time is up.

Mr. HANNEGAN. Mr. Chairman, if I may offer a slightly different view to the Senator's question regarding IGCC, we at EPRI, the Electric Power Research Institute, published a study just within the last year for the city of San Antonio that looked at the comparison in cost between an IGCC using Powder River Basin coal, against a supercritical pulverized coal plant, and we actually found that the costs for each are comparable within the margin of uncertainty.

So, one of the messages out of that study, which I'd be happy to add to the record, if that's desirable, is that we ought not to get caught up just necessarily on IGCC when it comes to carbon capture and storage. That in some cases, particularly for lignite coals, pulverized coal technologies are actually more affordable and just as effective in terms of creating a CO_2 stream that can be scrubbed out and stored. The choice of a technology between IGCC, oxy-fuel, and pulverized coal is really a horse race. In that IGCC technology itself is not quite mature, but capturing the CO_2 is. Pulverized coal technology is mature, but capturing the CO_2 is not. So there are different aspects of those problems that should both be advanced as part of a comprehensive research program.

Senator SALAZAR. All right. Thank you.

The CHAIRMAN. Senator Corker.

Senator CORKER. Mr. Chairman, thank you for this testimony, and thank all of you for being here. You know, our State, the State of Tennessee has had companies who have shown tremendous leadership in clean coal technologies, and we're obviously very supportive of that, and hope it'll continue.

As I listen to the complexities that are going to be with us in the future—capture and sequestration, and just the unknowns that we have in that regard—and then we talk about the projected percentage of electricity that's going to be generated through coal, which is already a huge factor here in our country now—as you look at these additional requirements and complications, if you will, to make sure that it's environmentally friendly, how does it compare with this additional expense—sequestration and capture—to nuclear power?

Mr. DEUTCH. Senator, if we had a carbon charge, or an additional price for the capture and sequestration as we estimate it, it would make nuclear power—if it works as well as it's supposed to—cheaper, and our expectation would be in the presence of a carbon charge, nuclear power would become more economical than coal with carbon capture as a base load generation source.

Nevertheless, the amount of nuclear power that will be used here and elsewhere in the world is not limitless, and will be both, for many reasons, will be only part of the mix, and so coal will still have a role to play.

Senator CORKER. What are some of the reasons that it won't be more expensive? The use of nuclear, after all this is done, and if, in fact there's some policy put in place to limit carbon—why is nuclear not going to be more pervasive?

Mr. DEUTCH. In 2003, we did a similar study at MIT in the future of nuclear power, and we looked very, very carefully at the rate at which nuclear power might penetrate between now and mid-century, that's for the next 50 years, we didn't try and go beyond that.

There are a variety of reasons—including the length of time it takes to construct these plants, the kind of skills that are available for doing it, which would, in our judgment, limit the amount of nuclear power, you might say, to the most favorable circumstances to about a factor of three between now and mid-century. That's a great expansion, that would be an expansion from roughly 100 big-scale plants in the United States, to 300, and we think that that's about as much as you can expect from nuclear power. We'd be delighted if it was more, but right now, we're still just talking about adding that first nuclear power plant.

I might mention in the case of China, which is very aggressively pushing nuclear power, they're expecting, I think, about 20 plants over the next 10 years; meanwhile they're putting in 80 coal plants a year. So, I think we would like to move forward on nuclear, but we shouldn't overestimate the speed at which it's going to happen. We still need to have progress on waste management, sir. We still have to assure that everybody has the highest safety standards. We have to assure that the non-proliferation considerations are kept in worldwide.

So, we're all for nuclear power in my world, but I think we have to be realistic about how fast it can come in.

Mr. HANNEGAN. Senator, I actually have a couple of charts over here that go directly to your question of competitiveness between the two fuels.

We actually did a study about a year ago looking at the different generation options that face a utility CEO when they start thinking about siting their next plant. In fact, the premise of your question—if I could get the other one, the 2010 one, just put that up—the chart that's being shown now, along the bottom axis, the cost of carbon moves from zero dollars, where it is today, to $10, $20, $30 on over to $50, and you can see how—for each of the colored curves on the chart, the costs of factoring in carbon constraints into those technologies, change the levelized cost of electricity and simply divide by 10 there to get a sense of cents per kilowatt hour.

We show that once you get even a modest carbon charge on the coal technologies—pulverized coal in red, and IGCC in sort of the purple—that nuclear line, which is the flat line at about 5.5 cents per kilowatt hour, really begins to be the most economic.

That raises a point that I wanted to make, with respect to my colleagues' comment that carbon capture and storage is here and you can do it today. You certainly can, and if you do it at $30 per ton, which is the figure in the MIT study, you see quickly that the red and the purple line curves are even above natural gas combined cycle at $6 per million cubic feet. They're certainly beginning to become comparable with wind power at today's technologies. So there's no guarantee that if we were to start pricing carbon at that level, people would necessarily continue to build coal. They might actually fuel switch to other things, and I think you have to take that into account.

The second chart that I have here, actually reflects what we think these costs will look like in 10 or 15 years' time. If you invest in an aggress of about $2 billion per year in addition to over what you see today, research program that develops and deploys these new technologies, and in contrast to the previous chart, you see how all of those pixie sticks—if you will—collapse onto the relatively the same low-cost, low-carbon portfolio and that's even including the cost of capture.

This just goes to our main point, that if you allow time for the RD&D to go forward, as the MIT report describes, and you don't force the implementation of CO_2 capture and storage immediately, you'll actually get more emissions reductions later on, at a lower cost, and that will be better for the economy.

Mr. MONIZ. May I just add one point, Senator Corker? That is that I agree with what Bryan has said, but should also be cautious that, for example, these projections of, let's say, nuclear power costs, do have assumptions built in about, for example, a reduction of capital costs that has not been demonstrated, as well as issues about how it's financed. So, really our view is, I think, well as John said, our view is that we're going to have multiple technologies deployed, they will be site-specific, regulatory-specific, choices that will affect cost. These are going to be—what we see today—they're all going to be in the mix, if we can solve the key problems.

The CHAIRMAN. Senator Thomas.

Senator THOMAS. Thank you, Mr. Chairman.

Thank you, gentlemen. I certainly appreciate your work on this.

Mr. Deutch and Mr. Moniz. Your report calls for three to five large demonstration power plants, and this and that. The Energy Bill we passed in section 413 calls for ones in the West. Do you share our opinion, on the advantage of mine-mouth generation, and how do you think these technologies would work in the West?

Mr. DEUTCH. We're certain that these technologies, again choosing from the menu of available technologies, would work in the West. There's a lot to be said for mine-mouth facilities.

Once again, we're not trying to specify technologies, we're not trying to specify locations, we're saying that the key thing is, to make coal usable, if there are carbon constraints, and the key step to take is to do the sequestration piece. The kind of technology you'd use on Western coals or at the mine-mouth, we don't know how that's going to turn out.

Senator THOMAS. No.

Mr. DEUTCH. It should go forward as the markets set.

Senator THOMAS. Yes, well, the market's currently setting the price of shipping coal to the East more than the value of the coal. So, that gets a little difficult.

You emphasized the importance of not picking technological winners and losers. But, you recommend no Federal assistance be provided unless it has carbon sequestration involved. There are some technologies that are closer to commercial availability rather than that. Isn't your study exactly warning the Government against moving forward with these other technologies, as well?

Mr. DEUTCH. No, Senator, I think that the point is that we don't believe that the taxpayer dollars should be used to subsidize technologies which are commercial, or very close to commercial. We believe that the technologies without carbon-captured sequestration, such as IGCC without carbon capture, or even supercritical pulverized coal are sufficiently close to commercialization, that private industry and private investors will go forward with those projects without Government assistance, assuming that the regulatory uncertainty of the carbon charge is not present.

But there's no amount of money that you can spend of the taxpayer to get rid of that regulatory uncertainty in their mind. Where we do see Government assistance justified is when there is technology uncertainty; you have to show and demonstrate its technical performance, its economic cost, and environmental acceptability. Then we think the assistance——

Senator THOMAS. I think there's a real question, and I've talked about this at the White House and this and that. I don't think anyone quarrels with the notion that down the road we're going to see some alternative sources and all these kinds of things. But that's a ways down the road. We're going to have 10, 15 years of demand for energy.

So, it seems to me we have to sort of balance between encouraging and giving incentives to the production of power that we'll have in this shorter term, as we wait for the longer term. We get so wrapped up in research that we won't be able to turn on the lights, if we aren't careful. Do you agree with that, Dr. Hannegan?

Mr. HANNEGAN. Well, there's a certain role for both, Senator. We see a very valuable role for the Federal Government to be involved in things that are very much at the pilot scale, at the "can we do it" scale. Then, the role of the public-private partnerships, like FutureGen, to say, "OK, we've done it in the laboratory, now can we do it at the real-world at some scale, which is not quite commercial, but it's larger than the bench top?"

Then, the question is, at what point does that partnership segue way into private-only funding and commercialization of the technology? I think EPRI's view is slightly different than that of the MIT report, in that we don't see IGCC and supercritical pulverized coal technologies, yet, at commercial scale as reliable and affordable as, you know, I think you would like them to be for folks on Wall Street not to put a risk premium on the investments, for State regulators to see them as the low-cost alternatives when companies come to make proposals, as they have. They've been turned away in favor of a tried-and-true technology.

So, I think there's still some barrier there between where we see those coal technologies today, and where you would want them to be to call them fully commercializable. I mean, there's a role for research, but there's also a role for incentives. I think the Energy Bill got that right.

Mr. MONIZ. Senator.

Senator THOMAS. I hope so, because there's a demand that's going to be there.

Yes, sir.

Mr. MONIZ. I'm sorry, I just wanted to add a comment. One is to clarify something which, to make it absolutely clear in terms of the MIT report, makes it very clear that our statement about the issue of subsidies, of assistance only for plants with capture. I just want to emphasize: that applies to commercial projects or large-scale integration demonstrations. It certainly does not apply to research and development, which needs to go across a very broad set of technologies.

Then the issue is one of, frankly, prioritization of what is not an issue of taxpayers' dollars, and we certainly do not believe that there are technical grounds for arguing for additional public subsidy of plants without capture. I remind you, the taxpayers have paid for development of these technologies, Tampa Bay, IGCC, etc. So, it's really a question of—and certainly costing too much is not a valid argument for public assistance. So, I think we need to be just very hard-nosed in our prioritization of where these public dollars go.

Senator THOMAS. Yes, I understand it's really saying we have to balance between research in the future and meeting the needs of the next 5 years, 10 years from now.

Thank you, Mr. Chairman.

The CHAIRMAN. Senator Domenici.

Senator DOMENICI. I just want to depart from what would be the most directed kinds of questions, to discussion with any of you about the technology of sequestration.

First, am I right in assuming that large-scale sequestration, including in the definition that this includes putting the CO_2 away, permanently? Am I right in assuming that that is a very difficult technology to achieve, and that it may be awhile before we can get our hands around that and get it applied? John Deutch?

Mr. DEUTCH. Senator, my answer to that would be, no, it is not a difficult technology. It is, however, extremely demanding because of the scale of it to implement it successfully and responsibly and have it work. This is not magnetic fusion. This is making sure that you have the process in place to capture, transport, and do it right. So, you need examples of that.

Mr. MONIZ. May I add a comment, Senator?

That is that I do think it's important, personally, that we not think in terms of the word permanent. I mean, permanent is good, but we should also keep in mind that, you know, one might have percent, per-century "leakages." Well, that buys us an enormous amount of time, in terms of the CO_2 budget. In the 23rd century, we are likely to have a very different set of options, maybe even fusion, in terms of carbon-free technology. So, I think it's very important that we not fall into the trap of thinking that it must be "proved" to be permanent forever.

Mr. LASHOF. If I could——

Senator DOMENICI. Yes.

Mr. LASHOF [continuing]. A couple things. All right, Senator Domenici. You know, I think it's worth noting a couple things in terms of the way the technology is.

First of all, and we haven't mentioned, the U.S. oil industry is putting 30 million tons of CO_2 a year underground right now for enhanced water recovery. They have a very good track record of safety in doing that over the last 20 or 30 years. Now, they haven't done that with the idea of keeping the carbon underground permanently, or for a century time scale, but the incremental monitoring and verification requirements that are needed to ensure that that CO_2 is staying underground are not that challenging.

There's also three large-scale CO_2 sequestration—geologic sequestration projects going around the world, one Weyburn, Saskatchewan, one in Sleipner, as the Norway project, and one in Algeria. So, there is, at scale, some already significant experience. So, in my view, you know—the oil industry spent 100 years perfecting the technology to understand those reservoirs and get oil out of the ground. And what we're really asking them to do is turn their seismic technology upside down and figure out how to put some CO_2 back underground.

It's a technically challenging thing to do, but it's not something that is beyond what we can do, starting right away. So, I think the way to move forward on this is to get experience, to actually do this at scale, at commercial plants. BP for one, is proposing to do this in California with a fully integrated system, with a power plant that would generate 500 megawatts. It's using petroleum coke, rather than coal, but the technology is essentially the same.

Mr. MONIZ. Senator, I'll be brief. I wish it were as easy as my colleague from NRDC indicates. We have a handful of projects that are currently sequestering a million tons per year, or so, of CO_2. One 500–megawatt coal-fire power plant, releases on the order of three to four times that amount. That's one plant. Over the next 25 years, EIA's forecast expects to add, I've roughed out some numbers here, 300–gigawatts, so about 600 new coal-fired power plants under their base forecast. If I take that 4 million tons per year and I multiply it by 600 plants, I get 2.4 billion tons of carbon that has to go in, compared to the 30 million that the oil and gas industry is using today. It's a vastly different order of magnitude and it's that scale of the challenge which I think is really daunting in terms of bringing this technology to market.

Senator DOMENICI. That's how you see it, too?

Mr. DEUTCH. No, it's not the way I see it. First of all, I think that the comparison with the EOR, with Enhanced Oil Recovery, is a poor one for a variety of reasons. The regulatory requirements for doing EOR injection are done under the water; it's completely different.

The fact of the matter is, if you look at some of these—and it's a subject I know a little bit about—these fields have been crunched up a lot. So while you learn something from these projects, the fact is you should get no comfort from EOR in terms of the large scale that we have to anticipate. You get no comfort because the capacity's not there. Worldwide, you could do all the EOR, you aren't going to do anything, you're going to have to use saline aquifers.

The second thing is, one of the best tables in our report is a report that looks at these three projects—Weyburn, Sleipner, and In Salah in Algeria—and it says, "Here's the instrumentation that is present in those three sites. And, here is the instrumentation we think would be needed to have a proper sequestration project." They're vastly different, vastly different. So to get this, the instrumentation to do the monitoring, just not seismic, it is a lot of other instruments that you want, and the modeling and simulation to make sure you know what's going on, it is a demanding job. Since we don't—we want to make sure we get public confidence that this is working right, we're going to do it right, and you can not work off of these things. You've got to do these projects carefully.

Mr. MONIZ. That monitoring, that John described, must be used in these projects to inform the regulatory development.

Mr. HANNEGAN. Senator, one last point, as hard as this sounds to go from three projects at 1 million tons each to 2.4 or so billion by 2030, we absolutely have to do this if we're going to address CO_2

emissions from the electric power sector in a significant way. It's the largest contributor in the work that we've done at EPRI, and I don't think anybody out there disagrees that it's got to play a significant role. The sooner we're able to prove up these technologies, the sooner we're able to realize the benefits with respect to climate change.

Senator DOMENICI. Thank you very much.

The CHAIRMAN. Senator Corker had one final question, and then we will dismiss the panel and conclude the hearing, but go right ahead.

Senator CORKER. Many of your assumptions—all of your assumptions, I think—have talked about a carbon charge. You don't have to worry about winners and losers. We do, but what is the most efficient way to, if a carbon charge is implemented, to implement one, the most efficient way to not have unintended consequences. Many of the cap-and-trade policies that we look at, you know, they can have a lot of unintended consequences. What is the most efficient way, in your estimation, to have a carbon charge that has the desired outcome?

Mr. HANNEGAN. Senator, let me be clear about the work that we've done. We don't make any assumptions in EPRI's analysis about how the cost comes about. But there is going to, inevitably, be an extra cost associated with capturing and storing the CO_2 from a coal-fired power plant compared to just venting it into the atmosphere. There will always be a cost, that will be unavoidable. Through technology we can reduce that cost from about 50 to 80 percent extra today, down to a much more manageable level and that's what we think we can do with R&D.

While we didn't envision the kinds of policies that would get you there, you can choose from a range of things from tax incentives and loan guarantees and the other, sort of, assistance that we've seen in the past, to things like a cap-and-trade program. We at EPRI have done some work looking at—if you went a certain direction, how would you design it economically in an optimal sense—but I think that's probably a topic that deserves a full hearing in and of itself.

Mr. DEUTCH. Senator, my goofy economist colleagues tell me that the clear answer to this question is a cap and trade system. Assuming that you tell me how you're going to allocate the allowances initially. Having been in that world, I know how hard that is. There are winners and losers in that and there are plenty of people I've spoken to who have strong views about their rights to have allowances and the other guys' rights not to have allowances. So, that's the first thing.

But, I want to say that we should remember that this is a global problem and what will work for us is going to be a lot harder to do in India or China where they don't have an internal market structure to make this go through. So, we have to keep in mind exactly the point you make, what works for us isn't necessarily going to work for the rest of the world, especially the emerging world, which Senator Domenici quite points out has to be a player. So, this is a complicated process.

I, personally, believe for a lot of reasons, that we would be much better advised to have a tax, rather than a cap-and-trade system.

It might evolve over time into a cap-and-trade system, but I think your life would be easier if we had a tax, and in our world.

Mr. MONIZ. I would just add a comment that, first of all, we should stress that the MIT report specifically avoids talking about how a carbon policy would be implemented, so——

Senator CORKER. It keeps you more popular.

Mr. MONIZ. However, I will put myself in your colleagues' camp of certainly feeling that a tax system, a carbon tax system is more straightforward, more easily implementable. I would just add one other point. That is, there's a lot of merit, although it does not resolve, certainly, all of your distributional problems. Nevertheless, a revenue neutral tax——

Mr. DEUTCH. Yes.

Mr. MONIZ [continuing]. Would be the thing to consider. My personal—this is purely personal—favorites would be that that revenue neutrality would come from some combination of payroll taxes and corporate taxes.

Mr. LASHOF. Senator, if I can——

The CHAIRMAN. Let's take one more view and then we'll——

Mr. LASHOF. Senator Bingaman's had days-long workshops on this topic, so we won't go into great detail. But, I just want to state, for the record, that my view is that a cap-and-trade system is the most efficient way to do it, because it puts the emphasis on where it needs to be, which is the quantity of global warming pollution going into the atmosphere, which we need to drive down over time in order to prevent dangerous global warming.

Certainly, there are issues about the impacts of that, and who would win and who would lose, and I think those do have to be carefully considered and addressed through the way in which the emission allowances are allocated and, probably the most efficient way to do that is to auction the allowances and use the revenue from that to potentially reduce other taxes, or to help put some of this new technology that's needed to meet the cap, effectively, into the field.

Again, there's, you know, we could spend a long time talking about how to design that, but I think the basic concept is, if you want to solve global warming, you need to reduce the amount of global warming pollution, so, putting a cap on how much goes into the atmosphere and allowing trading of allowances is an efficient way to do that.

Mr. HANNEGAN. Mr. Chairman, if I may make one quick point? If you do the R&D to get to a point where you've got those technologies, like we show on the chart over there, you'll notice those curves are relatively flat. In other words, they're insensitive to the carbon price that you're charging. Because they're non-emitting, and so, one of the things I'd argue is that, ultimately if you're investing in the R&D, how you choose amongst those technologies—be it coal, wind, nuclear, what have you—will now become more of a function of what makes sense for you at your site and for your utilities; you're making investments in the electric sector. And, some of the design issues that have come up may, perhaps, be less important with a robust technology program.

The CHAIRMAN. Well, thank you all very much. This is very useful testimony and we thank you for the report and the, both reports, the EPRI report as well.

We will conclude the hearing with that. Thank you.

[Whereupon, at 4:06 p.m., the hearing was adjourned.]

APPENDIX

Responses to Additional Questions

Responses of Daniel A. Lashof to Questions From Senator Bingaman

Question 1. You believe that carbon capture technology is available today to such an extent that Congress should require it on any new power plant. This raises two issues:

Who should bear the risk associated with including these technologies that have not yet been demonstrated at the scale of a commercial power plant?

Answer. All elements of CO_2 capture, compression, transportation and storage have been demonstrated individually, and in some cases in combination. Even though capture of CO_2 at a power plant at the scale required has not yet taken place, the technology is for all intents and purposes the same as that deployed at synthetic fuels plants where it is currently commercially deployed. Consequently, we believe that the owner(s) or operator(s) of the capture, transportation and storage facilities should be respectively responsible for assuring that the facility operates in compliance with regulations during their lifetime. After site closure and decommissioning, separate provisions may be appropriate, bearing in mind that the transient nature of corporations may not allow them to hold responsibility in perpetuity.

Question 2. Who should pay the additional capital costs or energy costs of capture and sequestration if there is not yet a market price for greenhouse gasses?

Answer. The additional costs should be spread over the coal-fired power-generation sector. This could be accomplished through a Low Carbon Generation Portfolio Standard, whereby a small and increasing portion of coal-fired generation would be required to meet an emissions level equivalent to an advanced CO_2 capture plant. A credit trading program would allow generators to meet the standard in the most cost-effective way.

Question 3. The study authors indicate that a regulatory framework is needed to oversee site selection for CO_2 injection, injection operations, and for long term monitoring and management. At what level, state, federal, or a combination, do you see this framework being introduced?

Answer. USEPA should regulate CCS. The agency has authority under the Safe Drinking Water Act, and has already issued guidances for small scale injection projects. However, a much more comprehensive framework is needed. We believe that the existing Underground injection Control Program model is a good one: USEPA sets federal requirements and minimum standards, allowing states to tailor or implement these by requesting primacy with administrative and financial support from USEPA. A common federal framework is essential to steer the regulations. Moreover, some states will have neither the ability nor the desire to regulate CCS. However, some issues such as pore space ownership and liability are bound to differ from state to state. State frameworks are therefore also necessary, as long as they adhere to the minimum federal standards.

Response of Daniel A. Lashof to Question From Senator Sanders

Question 4. If the Congress adopts your suggestion that no new coal plants be built unless they incorporate Carbon Capture and Storage, what practical effect would that have on coal plants now in the permitting queue?

Answer. The plants in the permitting phase would need to incorporate capture technologies into their design. For proposed gasification plants this would be a significant but reasonable modification. For proposed conventional pulverized coal plants this may require a complete redesign. Utilities and regulators would need to evaluate the added costs of the new design and determine whether energy efficiency and/or renewable energy investments would be more cost effective than continuing with plans to build coal-fired generation.

RESPONSE OF DANIEL A. LASHOF TO QUESTION FROM SENATOR SALAZAR

Question 5. The U.S. Climate Change Technology Program Strategic Plan shows that capturing CO_2 emissions from fossil fuel plants and disposing of it in deep geologic formations is a critical technology for preventing global warming. For this to become a commercially and legally viable option for mitigating greenhouse gas emissions, a robust and transparent regulatory framework for CO_2 injection deep underground will need to be put in place in the immediate future. Is EPA currently devoting the resources necessary to develop this framework in a timely manner? And what is the timeframe in which this should be developed?

Answer. USEPA has only dealt with small-scale injections so far. A more robust regulatory framework is needed for commercial scale projects. The agency is not moving at a pace that we consider satisfactory, nor devoting the necessary resources. Large, commercial-scale CCS projects are imminent. The development of regulations is likely to span several years. If we start now, we have a chance of having workable regulations by the time the first CCS plants are commissioned. We are already late in commencing the regulatory process. Congress should direct EPA to devote the resources necessary to complete the regulations in a timely fashion.

RESPONSES OF DANIEL A. LASHOF TO QUESTIONS FROM SENATOR DOMENICI

Question 6. A recent NRDC press release on the Future of Coal in a Carbon Constrained World Report said:

> The report's examination of policies to promote immediate deployment of CCS systems is incomplete and it fails to address the most urgent problem facing U.S. policymakers: what CO_2 performance requirements should be applied to proposed new power plants.

Mr. Lashof, am I correct to say that traditionally the Natural Resources Defense Council has been an ardent supporter of the environmental laws of this country?

Answer. Absolutely—For more than three decades, NRDC has fought successfully to defend wilderness and wildlife and to protect clean air, clean water and a healthy environment.

Question 7. Am I also correct to say that the Natural Resources Defense Council would expect the government to complete a full National Environmental Policy Act assessment before it undertakes a proposal to transport and inject the amounts of CO_2 recommended for injection in the MIT report?

Answer. Yes, we would expect an environmental impact assessment to be carried out before the injections of large volumes of CO_2 in the subsurface.

Question 8. Given your organization's historic stance that ground disturbing activities be fully analyzed, how is it that the NRDC can conclude that Congress should direct all new coal fired power plants include CCS in the face of MIT's statement that: "The central message of our study is that demonstrations of technical, economic, and institutional features of carbon capture and sequestration at commercial scale coal combustion and conversion plants, will give policymakers and the public confidence that a practical carbon mitigation control option exists"?

Answer. NRDC has been following CCS technology for many years now. Consensus exists among experts that, although we need to amass additional knowledge and clarify certain areas, no major technical barriers exist in deploying this technology in a way that safeguards human health and the environment. The barriers are economic and regulatory and policy related. Indeed, the MIT states in the same report:

> Although substantial work remains to characterize and quantify these [trapping] mechanisms, they are understood well enough today to trust estimates of the percentage of CO_2 stored over some period of time—the result of decades of studies in analogous hydrocarbon systems, natural gas storage operations, and CO_2-EOR. Specifically, it is very likely that the fraction of stored CO_2 will be greater than 99% over 100 years, and likely that the fraction of stored CO_2 will exceed 99% for 1000 years. Moreover, some mechanisms appear to be self-reinforcing. Additional work will reduce the uncertainties associated with long-term efficacy and numerical estimates of storage volume capacity, but no knowledge gaps today appear to cast doubt on the fundamental likelihood of the feasibility of CCS.

The key words in your question and the MIT statement that you quote are "give policymakers and the public confidence". The experts have already made up their mind on the matter: they see no showstoppers in the way of large-scale deployment. They are simply recommending a handful of demonstrations with federal involvement to illustrate this to the wider public. We second the suggestion and stress the urgency with which these should be carried out.

If performed under adequate regulatory oversight and according to best practices (which emphasizes USEPA's role in preparing a regulatory framework), we are confident that the risks associated with CCS are dwarfed by the risks associated with venting to the atmosphere 100% of the CO_2, produced by coal plants for the foreseeable future.

Question 9a. If a utility came to Congress today and said they are willing to include CCS, untested as it is, to a proposal for a new Integrated Gasification Combined Cycle (IGCC) or Supercritical Pulverized Coal (SCPC) plant would the Natural Resource Defense Counsel support full sufficiency from all federal environmental laws to get the carbon capture and sequestration technology implemented?

Answer. No.

Question 9b. If the answer is no:

Given your unwillingness to provide sufficiency to speed the process of CCS and NRDC's longstanding demands that the National Environmental Policy Act be strictly adhered to, why should Congress legislate a Carbon Sequestration standard without really knowing what the environmental impacts of such a standard might be?

Answer. The NEPA process is site-specific. We do not believe that the safety or efficacy of CCS in general will be proved or disproved following NEPA review. We believe that a great deal is known about the potential environmental impacts of a CCS standard if it is implemented and overseen properly. While we have high confidence that CCS can be conducted in an environmentally sound manner, it is still essential to adhere to existing laws and to examine projects on a case-by-case basis to understand local impacts. The NEPA process is also essential in reassuring local and other stakeholders about the merits and safety of a project. Earning public acceptance is crucial in siting CCS projects, and attempting to avoid the NEPA process would likely lead to hostile reactions that would actually slow the process of implementing CCS.

RESPONSES OF DANIEL A. LASHOF TO QUESTIONS FROM SENATOR BUNNING

Question 10. I know the NRDC has opposed coal-to-liquid technology. But I have also seen your organization support coal gasification for electricity. I understand that your position is coal-to-liquid technology will increase CO_2 emissions "well-to-wheels" or "mine-to-wheels" as is more appropriate and you recommend moving to hydrogen and ethanol transportation fuels. But I believe America can not transition to a zero-carbon economy overnight. And as corn prices have shown us, we can not fuel the entire country on corn ethanol. Coal-to-liquid technology will be a bridge for the next decades until we have a new, cleaner technology. For example, a coal-to-liquid plant, using off-the-shelf carbon capture and sequestration technology and a 10 percent cellulosic biomass blend in the coal feedstock, would reduce carbon emissions compared to gasoline by 30 percent. This is a huge reduction. Not to mention that it will provide coal-based electricity with carbon capture technology already built in and a gasification system ready to promote cellulosic fuels. Given all these advantages, what will it take for you to support coal-to-liquid fuel?

Answer. Liquefying coal to turn it into transportation fuels is an inefficient and extremely carbon intensive process. Without carbon sequestration it would result in well-to-wheel emissions that are double those of petroleum-derived fuels. Even with carbon sequestration, the most authoritative studies show that emissions would still be higher than from conventional diesel fuel or gasoline. The process is also very costly, and a liquid coal industry cannot develop without federal support. We consider this an unwise use of taxpayers' money, particularly because it is incompatible with the need to curb greenhouse gas emissions. Analyses show that the development of a liquid coal industry would make carbon mitigation under a cap & trade regime much more expensive, and also start using underground CO_2 storage capacity at rapid rates. We also have no evidence that developers are intending to use biomass feedstocks or carbon capture AND sequestration from the outset in these plants. There are cheaper, cleaner and easier ways to break our oil addiction than liquefying coal. If coal is to be used to replace gasoline, generating electricity for use in plug-in hybrid vehicles (PHEVs) can be far more efficient and cleaner than making liquid fuels. In fact, a ton of coal used to generate electricity used in a PHEV will displace more than twice as much oil as using the same coal to make liquid fuels, even using optimistic assumptions about the conversion efficiency of liquid coal plants.[1] The difference in CO_2, emissions is even more dramatic. Liquid coal produced with CCS and used in a hybrid vehicle would still result in lifecycle greenhouse gas emissions of approximately 330 grams/mile, or ten times as much as the 33 grams/mile that could be achieve by a PHEV operating on electricity generated in a coal-fired power plant equipped with CCS.[2]

NRDC does not support coal gasification as an end in itself. Rather we believe that coal gasification can facilitate CCS, which is an essential technology for reducing CO_2 emissions from powerplants.

Question 11. The Air Force testing program has shown that because of the properties of fischer-tropsch fuel, such as lower burn temperature and weight, jets that use that fuel will emit less CO_2 compared to existing jet fuels. This is on top of their confirmation of a significant reduction of other pollutants such as sulfur and particulate matter. Are you aware of these beneficial characteristics of CTL fuel compared to existing fossil fuels?

Answer. We are aware of these characteristics, but they do not take into account the CO_2 emissions associated with these fuels over their entire life cycle. These are still far worse than petroleum based fuels.

Question 12. The MIT study indicates that with new technologies, we could reduce the CO_2 emissions of our current coal power fleet by 20%. Yet the study recommends that no government funds for used for Research for existing coal power plants. Given the long life-cycle of a plant and the report's conclusion that coal will continue to be used well into the future, do you think it makes sense to incentivize technology retrofits that reduce CO_2 emissions?

Answer. The most pressing need is to ensure that no NEW plants get built without capturing their CO_2 emissions from the outset. As the MIT report points out, retrofitting requires major overhaul and large expenses. By building conventional plants we risk locking ourselves into several decades' worth of new emissions, and into added costs of CO_2 control. In the case of very old and inefficient plants, a new plant might be economically preferable to a retrofit. In the case of a more recent build, this might not be the case. We do believe research to reduce the costs of all types of carbon capture should be funded, but under no circumstances should it be used as an excuse for postponing action and not utilizing technologies that are available to us now.

Question 13. The report also highlights that China and India will be building hundreds of new coal-fired generation units in the coming decade using old technology. Regardless of whether of not these countries agree to limit CO_2 emissions, they will have a huge need for retrofit emissions technology. The report, however, recommends no government support for developing this technology. Why do you oppose the government supporting emission reducing technology for use here in America and abroad?

Answer. Although we do not speak for MIT, it is not our understanding that the report recommends that no funds be spent on retrofit technology research—on the contrary, the report states that:

> The U.S. 2005 Energy Act contains provisions that authorize federal government assistance for IGCC or pulverized coal plants containing advanced technology projects with or without CCS. We believe that this assistance should be directed only to plants with CCS, both new plants and retrofit applications on existing plants.

We agree with this statement, and stress the need to fund research that leads to real and measurable emission reductions. In the case of CCS, sequestering CO_2 is a necessary requirement. Federal money needs to be used wisely, and as a trigger for much larger private sector investment.

Question 14. The MIT Study indicates that China alone will account for more than half of the global growth in coal supply and demand in the next 25 years. Why do you think China would be willing to participate in a carbon capture and sequestration scheme like the one the report proposes within the next ten years?

Answer. As we understand it, the report proposes "negotiating a global agreement featuring delayed adherence to a carbon charge for developing economies", not a carbon capture and sequestration scheme. In other words, developed countries should lead by legislating comprehensive carbon policies and specific emission limits. We

[1] Assumes production of 84 gallons of liquid fuel per ton of coal, based on the National Coal Council report. Vehicle efficiency is assumed to be 37.1 miles/gallon on liquid fuel and 3.14 miles/kWh on electricity.

[2] Assumes lifecycle greenhouse gas emission from liquid coal of 27.3 lbs/gallon and lifecycle greenhouse gas emissions from an IGCC power plant with CCS of 106 grams/kWh, based on R. Williams et al., paper presented to GHGT-8 Conference, June 2006.

believe that developed countries will need to transfer their technological know-how to developing countries in a concerted way if emissions are to be curbed in time. China understands that global warming is a serious threat to its food supply and water supply, among other concerns. With effective leadership by the United States and active engagement with China we believe that China and other developing countries will participate appropriately in international efforts to prevent dangerous global warming.

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