S. Hrg. 110–174

CLEAN COAL TECHNOLOGY

HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

TO

RECEIVE TESTIMONY ON RECENT ADVANCES IN CLEAN COAL TECHNOLOGY, INCLUDING THE PROSPECTS FOR DEPLOYING THESE TECHNOLOGIES AT A COMMERCIAL SCALE IN THE NEAR FUTURE

AUGUST 1, 2007

Printed for the use of the
Committee on Energy and Natural Resources

U.S. GOVERNMENT PRINTING OFFICE

38–602 PDF WASHINGTON : 2007

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
Fax: (202) 512–2250 Mail: Stop SSOP, Washington, DC 20402–0001

COMMITTEE ON ENERGY AND NATURAL RESOURCES

JEFF BINGAMAN, New Mexico, *Chairman*

DANIEL K. AKAKA, Hawaii
BYRON L. DORGAN, North Dakota
RON WYDEN, Oregon
TIM JOHNSON, South Dakota
MARY L. LANDRIEU, Louisiana
MARIA CANTWELL, Washington
KEN SALAZAR, Colorado
ROBERT MENENDEZ, New Jersey
BLANCHE L. LINCOLN, Arkansas
BERNARD SANDERS, Vermont
JON TESTER, Montana

PETE V. DOMENICI, New Mexico
LARRY E. CRAIG, Idaho
LISA MURKOWSKI, Alaska
RICHARD BURR, North Carolina
JIM DEMINT, South Carolina
BOB CORKER, Tennessee
JOHN BARRASSO, Wyoming
JEFF SESSIONS, Alabama
GORDON H. SMITH, Oregon
JIM BUNNING, Kentucky
MEL MARTINEZ, Florida

ROBERT M. SIMON, *Staff Director*
SAM E. FOWLER, *Chief Counsel*
FRANK MACCHIAROLA, *Republican Staff Director*
JUDITH K. PENSABENE, *Republican Chief Counsel*

CONTENTS

STATEMENTS

	Page
Alix, Frank, Chief Executive Officer, Powerspan, Portsmouth, NH	55
Barrasso, Hon. John, U.S. Senator From Wyoming	30
Bauer, Carl O., Director, National Energy Technology Laboratory, Department of Energy	2
Bingaman, Hon. Jeff, U.S. Senator From New Mexico	1
Corker, Hon. Bob, U.S. Senator From Tennessee	75
Craig, Hon. Larry E., U.S. Senator From Idaho	40
Domenici, Hon. Pete V., U.S. Senator From New Mexico	35
Dorgan, Hon. Byron L., U.S. Senator From North Dakota	38
Fehrman, Bill, President, Pacificorp Energy, Salt Lake City, Utah	64
Hollinden, Jerry, Representative, The National Coal Council, Louisville, KY	11
Langley, Don C., Vice President and Chief Technology Officer, the Babcock and Wilcox Companies, Barberton, OH	46
Perlman, Andrew Chief Executive Officer, Great Point Energy, Cambridge, MA	49
Phillips, Jeffrey N., Program Manager, Advanced Coal Generation, Electric Power Research, Institute, Charlotte, NC	15
Rosborough, Jim, Commercial Director, Alternative Feedstocks, the Dow Chemical Company, Midland, MI	59
Salazar, Hon. Ken, U.S. Senator From Colorado	32
Sessions, Hon. Jeff, U.S. Senator From Alabama	43
Tester, Hon. Jon, U.S. Senator From Montana	45

APPENDIX

Responses to additional questions	83

CLEAN COAL TECHNOLOGY

WEDNESDAY, AUGUST 1, 2007

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

The committee met, pursuant to notice, at 9:28 a.m. in room SD–366, Dirksen Senate Office Building, Hon. Jeff Bingaman, chairman, presiding.

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

The CHAIRMAN. OK, why don't we start the hearing. I'm informed Senator Domenici is going to be a little late, but that we should proceed without him and he will catch up once he gets here.

Let me just make a few comments, and then we have two excellent panels this morning. We'll just start with panel one, but let me make these comments first.

Thank you all very much for coming. We're hoping to learn more about the latest advances in clean coal technology as part of this hearing. This is a very important subject that the committee is spending a lot of time on this year. This is the third hearing we've had on coal, so far this year. I think it's important that we try to understand the policy, and what the right policy should be, with regard to this very important resource.

Coal-fired generation supplies over half, or about half of the electricity that we consume in the United States. The Energy Information Administration predicts that that share will at least stay constant and perhaps even increase over the next 20 to 30 years. Coal is likely to remain a prominent part of our energy supply, both because it's cheap and because it's abundant.

Importantly, it is also true that in other countries, particularly the fast-developing countries of India and China. They have an unprecedented demand for energy. China, for example, has plans to build over 500 new coal-fired power plants in the coming years, that we know about. It's estimated that a new plant opens there every few weeks, or every week is the estimate, every week to ten days.

If this expansion is accomplished using the sub-critical pulverized coal technology that we still use predominantly here and throughout the world, the implications for solving our global warming problems are serious.

The United States, largely through the good works of the National Laboratories, has been a leader in the development of clean coal technology. Over the last few decades technologies have been produced and policies have been implemented, to significantly reduce emissions of pollutants, such as sulfur dioxide and nitrogen oxides and mercury. The next challenge is to deal with the issue of carbon dioxide emissions from coal generation. Today, those emissions are roughly double the emissions produced from burning natural gas.

We've reached some measure of consensus around the Congress that global warming is a problem we need to address. I think where we lack consensus is on how to address it. I expect that we will be having debates on that subject even before this session of the Congress is over. I think what we need to be doing in the interim, of course, is determining how we can go about reducing emissions and what timeframe we need to follow.

This latter point of timing is very important, not only because of the pace of construction in India and in China that I mentioned, but also, when we do arrive at an approach to regulating green house gas emissions that puts a price on carbon dioxide, we need to try to have technologies identified that can be deployed.

Given a long lead time of five to 10 years between design and operation that we have seen for many of these projects, one could imagine a scenario where it could be actually decades before these technologies would be determined to be commercially viable and ready for widespread deployment. So, we need to avoid that, if at all possible.

I hope that in addition to developing these advanced technologies, we can collectively come up with some creative ways to compress the timeframe for commercial deployment of the technologies. I hope some of the testimony today will help us with regard to that.

Let me just introduce the first panel. Carl Bauer, who is the Director of the National Energy Technology Laboratory in Morgantown, West Virginia is here. Thank you for being here, Carl.

Jerry Hollinden, who is the Senior Vice President of Power Business Line, URS Corporation in Louisville, Kentucky. Thank you for being here.

Jeffrey Phillips, who's the Program Manager for Advanced Coal Generation with EPRI out of Charlotte, North Carolina. Thank you for being here.

So, why don't you folks go right ahead? Senator Barrasso and I will hear your testimony and then have some questions.

STATEMENT OF CARL O. BAUER, DIRECTOR, NATIONAL ENERGY TECHNOLOGY LABORATORY, DEPARTMENT OF ENERGY

Mr. BAUER. Thank you, Mr. Chairman, members of the committee. Obviously, with the introduction, Senator, you obviously are well-informed, as is the committee, and we thank you for your interest.

Economic prosperity in the United States over the past century has relied heavily on the abundance of fossil fuels in North America. Making full use of this domestic asset in a responsible manner has been, and will be, an essential part of how our country fulfills its energy requirements, minimize the detrimental environmental impacts, and positively contributes to National security and well being.

Given current technologies, coal prices, and the rates of consumption, the United States has approximately a 250-year supply of coal available. Coal-fired power plants supply over half of our electricity, and are essential to continue to do so through at least the mid-century. Several overarching issues characterize the current energy situation in the United States: environmental quality, energy affordability, and supply security. A resolution of these challenges depends in part from the development and deployment of technologies that are the result of design and implementing a timely and properly tiered researched development and demonstration strategy.

DOE is developing a portfolio of technologies that will lead to cost-effective, near-zero atmospheric emissions technologies, including green house gases. But both the future and existing fleet of coal-based energy plants. The RD&D program is divided into a coal R&D program and a demonstration component.

The success of the clean coal R&D will ultimately be judged by the extent to which emerging technologies get deployed in domestic and international marketplaces. Deploying technologies into the international marketplace requires that the technologies address environmental and operational performance requirements, as well as financial challenges relative to the ability of plants to dispatch or sell its electricity at an acceptable place in the auction, which characterizes the access to the market needed to gain adequate return on investment for the utilities.

This includes, in the regulated market, the ability to recover cost in the rate-base, the technical and financial risks associated with the deployment of new coal technologies are key factors in determining whether they will achieve success in the marketplace, and are often difficult to overcome for new technologies seeking to make entry.

In 1985, the Congress authorized DOE to initiate the clean coal technology demonstration program to provide additional impetus to move technologies from the laboratories to the marketplace. This program evolved into the power plant improvement initiative and then to the clean coal power initiative at present. The purpose of this cost-shared program was to develop and demonstrate at commercial scale, innovative technologies that would help industry to meet the strict environmental requirements, and yet not impinge on the economy of the United States.

More than 20 technologies from the program have achieved commercial success in technologies that are related to low-NO_X burners, selective catalytic reduction, flue gas desulphurization, fluid-bed combustion, and now mercury. The National Research Council estimated that these technologies have yielded sales totaling more than $27 billion. Announcements of the third solicitation under CCPI is planned in this year. The focus is on carbon capture and storage technologies. Fossil Energies core R&D program provides for the development of new cloth and environmentally effective approaches to use coal at predemonstration scale. These include advanced research, advanced turbines and hydrogen turbines, carbon sequestration and capture, fuel cells gasification, hydrogen and fuels production, and innovation for existing plants. Details on these programs are in my written testimony. Today, nearly three out of every four coal- burning power plants in this country, is equipped with technologies that can trace their roots back to the clean coal technology program.

For example, the current generation of low-NO_X burners alone, is a major clean coal story. Nearly $1.5 billion of these burners have been sold and installed. Selective catalytic reduction now costs half what it did in the 1980's and systems are on order or under construction for 30 percent of the coal-fired power plants. Flue gas scrubbers are a third of their cost compared to the 1970's and are more reliable, less costly, and more efficient. Fluidized- bed technology development in the core coal R&D program was first demonstrated in that program and has recorded global sales of over $10 billion. In Tampa, Florida and West Terra Haute, Indiana, the first pioneering full-size coal gasification power plants, IGCCs, have opened a new pathway for the next generation of clean fuel flexible power plants.

More recently within the coal R&D program, the carbon sequestration regional partnerships have brought an enormous amount of capability and experience together to work on the challenge of both infrastructure development and storing huge volumes of CO_2 underground permanently. Together with DOE, the partnerships secure the active participation of more than 500 entities representing more than 350 industrial companies, engineering firms, State agencies, non-governmental organizations, and other supporting organizations.

The partnerships are conducting field tests to validate the efficacy of carbon capture and storage technologies and a variety of geologic and terrestrial storage sites throughout the United States and Canada. Extensive data information gathered during the initial stages of the project, of the seven partnerships, identified the most promising opportunities for carbon sequestration in their regions and are performing 25 geologic field sites and 11 terrestrial field tests.

In conclusion, DOEs clean coal R&D program has a successful track record and a promising future that will ultimately lead to pollution-free coal plants.

Mr. Chairman and members of the committee, this completes my statement and I'd be happy to take any questions you have.

[The prepared statement of Mr. Bauer follows:]

PREPARED STATEMENT OF CARL O. BAUER, DIRECTOR, NATIONAL ENERGY TECHNOLOGY LABORATORY, DEPARTMENT OF ENERGY

Thank you Mr. Chairman and Members of the Committee. I appreciate this opportunity to provide testimony on the Department of Energy's (DOE's) Clean Coal Research and Development (R&D) Program.

The economic prosperity of the United States over the past century has been built upon an abundance of fossil fuels in North America. The United States' fossil fuel resources represent a tremendous national asset. Making full use of this domestic asset in a responsible manner enables the country to fulfill its energy requirements, minimize detrimental environmental impacts, and positively contribute to national security.

Given current technologies, coal prices, and rates of consumption, the United States has approximately a 250-year supply of coal available. Coal-fired power plants supply about half of our electricity and are expected to continue to do so through mid-century. Because electricity production increases at a rate of about 2% per year, the rate of coal use will increase proportionally. However, the continued use of this secure domestic resource will be dependent on the development of cost-effective technology options to meet both economic and environmental goals, including the reduction of greenhouse gas emissions.

ENERGY ISSUES FACING THE UNITED STATES

Several overarching issues characterize the current energy situation in the United States. Their resolution depends in part on designing and implementing a timely and properly tailored research, development, and demonstration strategy, which could help sustain economic growth in the United States. The major issues are energy affordability and supply security, and environmental quality.

ENERGY AFFORDABILITY AND SUPPLY SECURITY

The availability of affordable energy has been instrumental in helping establish the United States' economic engine. The relatively recent escalation in energy prices, particularly in oil and natural gas, stem, in large measure, from the global competition for these energy resources. In particular, as economies in China, India, and other countries in the developing world expand to meet the demands of their huge populations, their impact on world markets will increase through increased competition for oil and gas supplies. Further complicating this issue are socio-political and other influences that can affect the energy market.

Despite gains in energy efficiency and projected conservation, stemming in part from higher prices, the Energy Information Agency (EIA) projects that the U.S. will require increasing amounts of energy through 2030, the last year that EIA models. Even after accounting for growing contributions from renewable energy and nuclear, our domestic coal resources will be required to provide an affordable portion of our growing needs.

ENVIRONMENTAL QUALITY

All fossil fuels incorporate carbon and all contain, to greater or lesser degrees, undesirable components, such as sulfur, nitrogen, and other trace elements, that can potentially harm the earth's biota.

It has long been recognized that coal-fired power plants emit sulfur and nitrogen containing compounds that combine with the moisture in the atmosphere to produce acid rain, and even acid snow. The generation of acid rain is not limited to local regions around the power plant. These acid forming emissions are often carried over hundreds to thousands of miles by wind currents where they are deposited to earth through rain or snow. In addition to sulfur and nitrogen compounds, coal power plants are also known to emit particulates that can, if unmitigated, lead to harmful health effects.

Air toxics is a term used to describe atmospheric pollutants that, if unmitigated, can also cause serious health effects. Air toxics include heavy metals, volatile organics, dioxins, and mercury. Relative to fossil fuel use, mercury has been the focus of recent attention and regulatory action. Mercury health effects are still being investigated but have, thus far, been linked to neurological, cardiovascular, and respiratory illnesses.

Currently, there is growing consensus that increased levels of greenhouse gases in the atmosphere, primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons, are linked to climate change. In this connection, fossil fuel use has been identified as a major source of anthropogenic greenhouse gas emissions, particularly carbon dioxide, into the atmosphere. Slowing the growth of anthropogenic greenhouse gas emissions has become an important concern.

The production of electricity using fossil, nuclear, and renewables requires large quantities of water and produces waste byproducts. In the United States, thermoelectric power plants utilize more than 130 billion gallons of water per day. With water supply and availability issues becoming more acute across the major growth areas of the United States, the energy industry will need to take bold steps to conserve water, while meeting all environmental requirements. Coal-fired power plants also produce more than 120 million tons of solid waste byproducts each year. While 40% of these are re-used in various markets, the remainder is deposited into landfills and requires careful management and monitoring to prevent harmful environmental impacts.

Ensuring environmental quality is not a simple matter. Environmental requirements are becoming increasingly stringent and require new technologies to address the challenges of regulatory compliance. The use of fossil fuels is clearly essential for the foreseeable future. Therefore, industry, and where appropriate in collaboration with the public sector and others, must reduce the environmental impact of utilization of these fuels.

HOW IS DOE RESPONDING TO THE ISSUES

The Office of Fossil Energy (FE) recognizes the complex energy challenges facing America today. Its programs are directly responding to the issues laid out above, as well as to the direction provided by Congress and the Administration. To ensure a secure energy future for the United States, the Nation must commit to energy efficiency and renewable energy, but it also must promote the cleaner and more productive use of domestic energy resources, including coal, oil, and natural gas. The following key thrusts in Fossil Energy's research portfolio will lead the way in enhancing energy security from fossil fuels.

Near-Zero Atmospheric Emissions Energy.—DOE is spearheading an R&D effort called FutureGen that will utilize technology developments from the core R&D program to provide near-zero atmospheric emissions clean coal power plants—including carbon capture and sequestration—that could ultimately be built at costs comparable to current day technology. Together with its supporting technologies for reducing all criteria pollutants, FutureGen will help to ensure that coal-fired power plants meet the most stringent environmental requirements.

Climate Change.—DOE conducts R&D that contributes to expanding the options for meeting near-term greenhouse gas intensity goals, set by President Bush in the Global Climate Change Initiative. By meeting the near-term intensity goals, the longer-term goal of atmospheric greenhouse gas stabilization will become more achievable. Federal investment in climate change mitigation technologies has one overriding benefit: a broad suite of such technologies can expand the menu of future policy choices, both domestically and internationally. Without technology advances, the choice of future greenhouse-gas-reducing technologies may be limited to those that are either prohibitively expensive or require massive overhauls to existing infrastructure.

ROLE OF PUBLIC INVESTMENT IN R&D

America's fossil fuel industry is a mature industry made up of thousands of small companies and major corporations. The strategic role of the Federal Government in FE R&D is to develop technology options that can benefit the public by addressing market failures. More specifically, FE carries out high-risk, high-value R&D that can:

- Accelerate the development of new energy technologies beyond the pace that would otherwise be dictated by normal market or regulatory forces.
- Expand the slate of beneficial energy options beyond those likely to be developed by the private sector on its own.
- Potentially result in revolutionary "breakthrough" technologies that achieve environmental, efficiency, and/or cost goals well beyond those currently pursued by the private sector.

The Federal R&D program is working to provide advanced technology options that are significantly more effective and affordable than today's limited set of fossil energy technologies. The success of this activity could not only benefit current power stations but also strengthen the technical foundation for the next generation of coal-fueled power plants—serving to preserve energy diversity and strengthen domestic energy security. The Federal presence in this type of R&D may also provide scientifically sound data for future governmental regulatory and policy decisions.

Similarly, the current uncertainty regarding future regulation of CO_2 is not conducive to significant private-sector investment in greenhouse gas mitigation technologies. The Federal R&D program, therefore, is developing a wide range of potential carbon mitigation approaches—such as carbon sequestration—that can be used by the private sector for future investment opportunity.

Every year, DOE conducts a benefit analysis to quantify and highlight the significant economic and energy-sector benefits attributable to R&D programs. Estimated impacts on oil and gas production, oil imports, power generation technology market penetration, carbon intensity, and fuel prices are the basis for estimating economic, environmental, and energy security benefits from FE's R&D programs.

PRIVATE-SECTOR R&D ISSUES

Within the electric power industry, R&D investments have been historically modest. The National Science Foundation estimates utility-funded R&D at $114 million in 2001. Nationally, the production of electricity consumes over 40 quadrillion British thermal units of energy a year. Sixty-nine percent of this energy is contributed by fossil fuels and coal is the largest single such contributor of all the fossil resources. However, over 65% of that potential energy in that coal is lost in the process of generation. Thus, the Nation has an obvious interest in increasing the efficiency of electricity generation, and thereby reducing harmful emissions while allowing the continued use of its most abundant fossil resource—coal. The regulations of the Clean Air and Water Acts, as well as the goals of the Clear Skies Initiative, as embodied in the Clean Air Interstate Rule and the Clean Air Mercury Rule, give utilities the incentives to provide the necessary level of R&D needed to achieve these goals. Where the incentives do not exist, government may have a role.

CLEAN COAL TECHNOLOGY

DOE's Office of Fossil Energy is devoted to ensuring that the Nation can continue to rely on clean, affordable energy from traditional fuel resources. This mission is accomplished through a mix of internal and external R&D efforts that concentrate the expertise and talents of thousands of public- and private-sector scientists, engineers, technicians, and other research professionals. The Department is developing a portfolio of cost-effective near-zero atmospheric emissions technologies, including greenhouse gases, for the future fleet of coal-based energy plants. The RD&D Program is divided into a demonstration component and a core R&D program.

DEMONSTRATION PROGRAM

The success of Clean Coal R&D will ultimately be judged by the extent to which emerging technologies get deployed in domestic and international marketplaces. The technical and financial risks associated with the deployment of new coal technologies are key factors determining whether they will achieve success in the marketplace.

In 1985, the Congress authorized DOE to initiate the Clean Coal Technology Demonstration Program to provide additional impetus to move technology from the laboratory to the marketplace. The purpose of the program was to develop and demonstrate, at commercial scale, a family of innovative technologies that would help industry to meet the strict environmental requirements that were ultimately contained in the Clean Air Act Amendments of 1990. The Program was developed as a Government/industry cost-shared partnership and DOE's cost share was limited to a maximum of 50% of the funding for each participating project.

The first projects were started in 1987. These projects were selected in the first of five rounds of competition. Over the course of the program, 34 projects have been completed. The total cost of these five rounds was approximately $3.3 billion, with DOE contributing approximately $1.3 billion. In 2001, a solicitation for a follow-on to the original five rounds was issued. This program was called the Power Plant Improvement Initiative (PPII), and it resulted in six projects, of which four are finished, one is still active, and one was withdrawn. The total value of the five implemented PPII projects was approximately $71 million, with DOE contributing approximately $32 million.

The program that followed PPII is the Clean Coal Power Initiative (CCPI). Solicitations issued in 2002 and 2004 resulted in a total of 10 projects, eight of which are active, one is not yet started, and one was withdrawn. The value of the CCPI projects is approximately $2.7 billion, with the DOE contribution set at $530 million. The CCPI and the earlier programs are referred to collectively as the Clean Coal Technology Demonstration Program (the Program).

More than 20 technologies from the Program have achieved commercial success in technologies related to low-NO_x burners, selective catalytic reduction, flue gas desulfurization, and fluidized-bed combustion. It is difficult to determine how much commercialization of these technologies would have happened absent the DOE assistance.

FUTURE DEMONSTRATION PROGRAM

Announcement of the third solicitation under CCPI is planned in FY 2007. Its focus is on carbon capture and storage technologies. This current round specifically targets advanced coal based systems and subsystems that capture or separate carbon dioxide for sequestration or for beneficial uses. Round 3 is also open to any coal-based advanced carbon capture technologies that result in co-benefits with respect to efficiency, environmental, or economic improvements potentially capable of achieving CCPI coal technology performance levels specified in Title IV of the Energy Policy Act of 2005.

DOE is interested in demonstrating advanced technologies not currently deployed in the marketplace—specifically technologies capable of producing electricity alone or in any combination with heat, fuels, chemicals, or hydrogen. Prospective projects must, however, ensure that coal is used for at least 75% of the fuel energy input to the process and that electricity is at least 50% of the energy-equivalent output from the technology demonstration.

DOE is currently developing large-scale field tests of geologic carbon sequestration, on the order of 1 million metric tons of CO_2 per year, and is looking for the best way to structure the requirements of the current announcement to allow demonstration projects under CCPI to integrate with the sequestration field tests.

CORE COAL R&D PROGRAM

The Office of Fossil Energy's core coal R&D program provides for the development of new cost-and environmentally-effective approaches to coal use, approaches at pre-demonstration scale. It includes Advanced Research, Advanced Turbines, Carbon Sequestration, Fuel Cells, Gasification, Hydrogen and Fuels, and Innovations for Existing Plants, which are described in more detail below.

ADVANCED RESEARCH

The Advanced Research Program is a bridge between basic research and the development and deployment of innovative systems capable of creating highly efficient and environmentally benign power- and energy-production systems. Research objectives include resolving the technology barriers that enable improvements to emerging power systems as well as fundamental research on novel technologies that can be utilized in clean energy production. The objective of the program is to support development of critical enabling technologies to make it possible for the line programs to achieve their goals of developing advanced, coal-based power systems for affordable, efficient, near-zero atmospheric emissions power generation. Example developments include high-temperature materials, revolutionary sensors and controls, and advanced computing/visualization techniques.

ADVANCED TURBINES

The Advanced Turbine Program consists of a portfolio of laboratory and field R&D projects focused on performance-improvement technologies with great potential for increasing efficiency and reducing emissions and costs in coal-based applications. The Program focuses on the combustion of pure hydrogen fuels in MW-scale turbines greater than 100 MW size range and the compression of large volumes of CO_2. Since advanced turbines will be fuel flexible, capable of operating on hydrogen or syngas, they will make possible electric power generation in gasification applications configured to capture CO_2.

CARBON SEQUESTRATION

The Carbon Sequestration Program consists of a portfolio of laboratory and field R&D focused on technologies with great potential for reducing greenhouse gas emissions. Most efforts focus on capturing carbon dioxide from large stationary sources such as power plants, and sequestering carbon dioxide in geologic formations. The Program also addresses the control of fugitive methane emissions, which is another potent greenhouse gas. Carbon sequestration is a key component of the President's strategy to slow the growth of greenhouse gas emissions, as well as several National Energy Policy goals targeting the development of new technologies. It also supports the goals of the Framework Convention on Climate Change and other international collaborations to reduce greenhouse gas intensity and greenhouse gas emissions. The programmatic timeline is to demonstrate a portfolio of safe, cost-effective greenhouse gas capture, storage, and mitigation technologies at the pre-commercial scale by 2012, leading to demonstration and substantial deployment and market penetration beyond 2012. These greenhouse gas mitigation technologies could help slow greenhouse gas emissions in the medium term. They also provide potential for ultimately stabilizing and reducing greenhouse gas emissions in the United States.

FUEL CELLS

Fuel cells could help support the efficiency and emission targets of future power plants, such as FutureGen. The 50% higher heating value target is challenging, and fuel cells can clearly facilitate achieving this target when used as the main power block, possibly in combination with a turbine. In order to ensure the ability to site future power plants in any state in the country, low emissions of criteria pollutants will be required. Fuel cell emissions are well below current and proposed environmental limits. Fuel cells could play a significant part in energy security. Their modular nature permits use in central or distributed generation with equal ease. Rapid response to emergent energy needs is enhanced by the modularity and fuel flexibility of fuel cells. The ultimate goal of the program is the development of low-cost large (>100 MW) fuel cell power systems that will produce affordable, efficient, and environmentally friendly electrical power from coal with greater than 50% higher heating value (HHV) efficiency, including integrated coal gasification and carbon dioxide separation processes and capture at least 90% of the CO2 emissions from the system. The cost goal for fuel cells in coal systems is to achieve a ten-fold reduction in the fuel cell system cost.

FUTUREGEN

FutureGen is a $1 billion Government-industry initiative to design, build, and operate an advanced, coal-based, Integrated Gasification Combined-Cycle (IGCC) power plant to:

- Co-produce electricity and hydrogen;
- Achieve near-zero atmospheric emissions, with geological sequestration of carbon dioxide;
- Demonstrate system integration of cutting edge technologies; and
- Chart a technological pathway toward an energy future in which near-zero atmospheric emissions clean coal power plants can be designed, built, and operated at a cost that is no more than 10% above the cost of non-sequestered systems.

Coal continues to face environmental challenges relative to other energy sources. The near-zero atmospheric emissions concept spearheaded by FutureGen is vital to the future viability of coal as an energy resource, particularly in light of growing climate change concerns. Coal is abundant, secure, and relatively inexpensive when compared to other energy sources. With near-zero atmospheric emissions, coal could not only produce baseload electricity, but also help germinate a hydrogen energy economy.

GASIFICATION

Gasification is a pre-combustion pathway to convert coal or other carbon-containing feedstocks into synthesis gas, a mixture composed primarily of carbon monoxide and hydrogen; the synthesis gas, in turn, can be used as a fuel to generate electricity or steam, or as a basic raw material to produce hydrogen, high-value chemicals, and liquid transportation fuels. DOE isdeveloping advanced gasification technologies to meet the most stringent environmental regulations in any state and facilitate the efficient capture of CO_2 for subsequent sequestration—a pathway to "near-zero atmospheric emissions" coal-based energy. Gasification plants are complex systems that rely on a large number of interconnected processes and technologies. Advances in the current state-of-the-art, as well as development of novel approaches, could help reveal the technical pathways enabling gasification to meet the demands of future markets while contributing to energy security.

HYDROGEN AND FUELS

DOE developed the Hydrogen Posture Plan to integrate and implement the technology needed to achieve the Hydrogen Economy. The Hydrogen from Coal Program was initiated in fiscal year 2004 to support the President's Hydrogen Fuel Initiative, DOE's goals in the Hydrogen Posture Plan, and the FutureGen project. The mission of the Hydrogen from Coal Program is to develop advanced technologies through joint public and private RD&D to facilitate the transition to the hydrogen economy through central production of gaseous hydrogen.

INNOVATIONS FOR EXISTING PLANTS

Over the past three decades, the existing fleet of coal-fired power plants has made significant strides in reducing air emissions, minimizing impacts on water quality and availability, and managing solid byproducts. As the coal-based electric utility sector enters the 21st century, it will be faced with additional environmental issues such as mercury, nitrogen oxide, air toxics, and acid-gas emissions control requirements, constraints on water availability needed for plant cooling and other purposes, and decreasing space available to dispose of the solid residues from coal combustion. The Innovations for Existing Plants subprogram supported technology development in anticipation of regulatory limits that are now being implemented through the Clean Air Interstate Rule and the Clean Air Mercury Rule. These rules were promulgated in 2005, giving the private sector an incentive to develop the technologies required to reduce their pollutant emissions. Because the government role in development of these technologies has shifted to the private sector, the Innovations for Existing Plants subprogram is no longer needed.

CONCLUSION

Today, nearly three out of every four coal-burning power plants in this country are equipped with technologies that can trace their roots back to the Clean Coal Technology Program. Approaches demonstrated through the program include coal processing to produce clean fuels, combustion modification to control emissions, post-combustion cleanup of flue gas, and repowering with advanced power generation systems. These efforts helped accelerate production of cost-effective compliance options to address environmental issues associated with coal use. Relative to carbon capture and storage, DOE is making significant progress in developing the technologies and infrastructure needed for deployment of these technologies in a future carbon-constrained world. The following are some examples of clean coal successes that were developed in part with DOE support:

- The current generation of low-NO_X burners alone is a major clean coal success story. Nearly $1.5 billion of these burners have been sold. Selective catalytic reduction now costs half what it did in the 1980s and systems are on order or under construction for 30 percent of U.S. coal-fired plants.
- Flue gas scrubbers are a third of their cost in the 1970s, and they are more reliable, less costly and more efficient due to innovations developed and tested in Clean Coal Technology Program.
- Fluidized bed technology developed in the core coal R&D program and first demonstrated in the program has recorded global sales of over $10 billion.
- In Tampa, Florida, and West Terre Haute, Indiana, the first pioneering, full-size coal gasification power plants have opened a new pathway for the next generation of clean, fuel-flexible power plants. This was made possible through demonstration projects under the Clean Coal Technology Program.
- A number of the commercial demonstration projects have received technology achievement awards. These include the Tidd pressurized fluidized-bed combustion project by Ohio Power Company; Babcock & Wilcox Company low-NOx/cell burner project; Pure Air Lake's advanced flue gas desulfurization project; and Southern Company Services' CT-121 flue gas desulfurization project.
- Advanced coal preparation work previously conducted at NETL's onsite research facilities is now standard practice in the energy industry in achieving product quality specifications for sulfur emissions compliance, as well as reductions of other air pollutants including mercury and other trace elements.
- Work sponsored by the clean coal program continues to look at mercury and multi-pollutant controls for coal-fired boilers. Operation of the TOXECON™ process, which could offer coal-fired power plants a low-cost retrofit option for reducing mercury emissions by up to 90%, was initiated at the We Energies Presque Isle Power Plant in Marquette, Michigan. This project demonstrates the first full-scale commercial mercuryemission-control system for permanent operation.
- The Carbon Sequestration Atlas of the United States and Canada, developed by NETL, the Regional Carbon Sequestration Partnerships (Partnerships), and the National Carbon Sequestration Database and Geographical Information System, contains information on stationary sources for CO_2 emissions, geologic formations with sequestration potential, and terrestrial ecosystems with potential for enhanced carbon uptake, all referenced to their geographic location to enable matching sources and sequestration sites.
- CO_2 capture technology is being developed for solvent, sorbent, membrane, and oxycombustion systems that, if successfully developed, would be capable of capturing greater than 90 percent of the flue gas CO_2 at a significant cost reduction when compared to state-of-the-art, amine-based capture systems. Research and systems analysis have identified potential cost reductions of 30-45% for the capture of CO_2. In addition, ionic liquid membranes and absorbents are being developed for capture of CO_2 from power plants. Ionic liquid membranes have been developed at NETL for pre-combustion applications that surpass polymers in terms of CO2 selectivity and permeability at elevated temperatures.
- Field projects have demonstrated the ability to "map" CO_2 injected into an underground formation at a much higher resolution than previously anticipated and confirmed the ability of perfluorocarbon tracers to track CO_2 movement through a reservoir. DOE-sponsored research has also led to the development of the U-Tube sampler, which was developed for and successfully deployed at the Frio test site in Texas. This novel tool is used to obtain geochemical samples of both the water and gas portions of downhole samples at in situ pressure.

- The Carbon Sequestration Regional Partnerships have brought an enormous amount of capability and experience together to work on the challenge of infrastructure development. Together with DOE, the Partnerships secured the active participation of more than 500 individuals representing more than 350 industrial companies, engineering firms, state agencies, non-governmental organizations, and other supporting organizations.
- The Partnerships are conducting field tests to validate the efficacy of carbon capture and storage technologies in a variety of geologic storage sites throughout the U.S. and Canada. Using the extensive data and information gathered during the initial stages of the project, the seven Partnerships identified the most promising opportunities for carbon sequestration in their Regions and are performing 25 geologic field tests.

In conclusion, DOE's Clean Coal R&D Program has a successful track record and a promising future that will ultimately lead to coal plants with near-zero atmospheric emissions.

Mr. Chairman, and Members of the Committee, this completes my statement. I would be happy to take any questions you may have at this time.

The CHAIRMAN. OK, thank you very much.

Mr. Hollinden, why don't you go right ahead, please.

STATEMENT OF JERRY HOLLINDEN, REPRESENTATIVE, THE NATIONAL COAL COUNCIL

Mr. HOLLINDEN. Good morning, Mr. Chairman. My name is Jerry Hollinden and today I'm testifying on behalf of the National Coal Council.

The Council is a Federal Advisory Committee to the Secretary of Energy. Council membership is by personal appointment of the Secretary and included representatives from across the broad spectrum of the coal and energy industry. All members volunteer their time and expertise to the Secretary on issues that he requests the Council to address.

By letter dated June 26, 2006, Secretary Bodman requested that the Council conduct a study of technologies available to avoid or capture and store carbon dioxide emissions, especially those from coal-fired power plants. Additionally the Secretary requested that the Council recommend a technology-base framework for mitigating green house gas emissions from those plants.

The Council accepted the Secretary's request, formulated a workgroup of about 45 experts in the field, and on June 7 of this year submitted their report to Secretary Bodman.

Today, I will summarize the key findings and recommendations of that study and I have attached a copy of the full report to my testimony for the record.

The report includes four major findings. One, coal must continue its vital and growing role in energy production in the United States, supplying more than 50 percent of the Nation's electricity. Two, reducing carbon dioxide emissions presents a significant technological challenge, but the coal industry has a proven record of successfully meeting such challenges and stands ready to meet this one as well. Three, it is imperative that research, development, and demonstration efforts move forward quickly on a portfolio of technologies to reduce our capture and store carbon dioxide emissions. Four, public/private support for technologies to reduce our capture and store carbon dioxide is critical to the energy independence and security of the United States.

As indicated by today's hearings, the Council understands that Congress intends to address carbon management. In that context, it is imperative that the Nation immediately accelerate deployment of technologically and economically favorable high-efficiency advanced coal combustion, coal liquefaction, and gasification technologies. In addition, it is critical to accelerate development, demonstration, and deployment of carbon dioxide reduction and carbon capture and storage technologies to control and sequester carbon dioxide emissions from these advanced coal-based technologies.

With this in mind, the Council made the following recommendations to Secretary Bodman. One, work closely with other appropriate agencies within the Federal Government to streamline—not eliminate as some have accused the Council of recommending—but streamlining the long, costly, and complicated permitting process for siting, building, and operating coal power plants and associated carbon dioxide capture, storage, and facilities.

Two, significantly increase funding across the full spectrum of carbon capture and storage technologies, including the capture, compression, transportation, storage, and monitoring, so as to ensure that the expectations for carbon dioxide capture and storage will be met on the local, State, and national levels.

Three, determine the legal liabilities associated with carbon capture and storage.

Four, increase funding of the regional carbon sequestration partnerships to adequately finance large- scale carbon dioxide storage projects in a number of different geological formations, such as deep saline reservoirs.

Five, support research projects that cover a wide variety of capture technologies, including those that capture less than 90 percent of emissions, because they are in the early stages of a technology maturation process.

Six, pursue a large-scale demonstration project to spur development of ultra-supercritical pulverized coal technology for electricity generation.

Seven, ensure Integrated Gasification Combined Cycle technology has been completely and efficiently integrated into a large-scale power plant and carbon capture and storage system.

As I stated earlier, the Secretary also asked the Council to recommend a framework for doing this. To do this, necessary actions would be. In the near-term, efficiency improvements at existing power plants should be expedited. For the mid-term, advanced clean coal technology, such as IGCC and ultra-supercritical combustion, must be given public support in the form of cost and permitting incentives and financial support for initial demonstrations so that they can succeed in the marketplace. In the long-term, technology for carbon capture and storage, including storage sites and related infrastructure, must be developed and demonstrated over the next 10 years.

Thank you, Mr. Chairman. I will be happy to answer any questions you or the committee members may have.

[The prepared statement of Mr. Hollinden follows:]

PREPARED STATEMENT OF JERRY HOLLINDEN, REPRESENTATIVE, THE NATIONAL COAL COUNCIL

Good morning, Mr. Chairman. My name is Jerry Hollinden and today I am testifying on behalf of The National Coal Council. The Council is a federal advisory committee to the Secretary of Energy. Council membership is by personal appointment of the Secretary and includes representatives from across the broad spectrum of the coal and energy industry. Council members include senior executives from coal producers, shippers and users as well as consultants, conservation groups, Native Americans, university faculty members, State government officials, lawyers, boiler manufacturers, architect/engineers and large electricity consumers. All members volunteer their time and expertise to the Secretary on issues that he requests the Council to address.

By letter dated June 26, 2006 Secretary Samuel Bodman requested that the Council "conduct a study of technologies available to avoid, or capture and store, carbon dioxide emissions—especially those from coal-fired power plants." Additionally, the Secretary requested that the Council recommend "a technology-based framework for mitigating greenhouse gas emissions from those plants."

The Council accepted the Secretary's request, formulated a working group of about 45 experts in the field, and on June 7, 2007 submitted their report to Secretary Bodman.

Today I will summarize the key findings and recommendations of that study, and I have attached a copy of the full report* to my testimony for the record.

The report includes four major findings:

1. Coal must continue its vital and growing role in energy production in the United States, supplying more than 50 percent of the nation's electricity.
2. Reducing carbon dioxide emissions presents a significant technological challenge, but the coal industry has a proven record of successfully meeting such challenges and stands ready to meet this one as well.
3. It is imperative that research, development and demonstration efforts move forward quickly on a portfolio of technologies to reduce or capture and store carbon dioxide emissions.
4. Public-private support for technologies to reduce or capture and store carbon dioxide is critical to the energy independence and security of the United States.

As indicated by today's hearing, the Council understands that Congress intends to address carbon management. In that context, it is imperative that the nation immediately accelerate deployment of technologically and economically favorable high-efficiency advanced coal combustion, coal liquefaction and gasification technologies. In addition, it is critical to accelerate development, demonstration and deployment of carbon dioxide reduction and carbon capture and storage technologies to control and sequester carbon dioxide emissions from these advanced coal-based technologies. These technologies will be implemented as they become available, affordable and deployable.

With this in mind the Council made the following recommendations to Secretary Bodman. The Department of Energy, acting in coordination with other federal agencies and states, should:

1. Work closely with other appropriate agencies within the federal government to streamline the long, costly and complicated permitting process for siting, building and operating power plants and associated carbon dioxide capture, transportation and storage facilities. Please note that the recommendation is to "streamline" this process, not eliminate it, as some have accused the Council of recommending. A cooperative approach by DOE and EPA on rules such as New Source Review, the Clean Air Interstate Rule and the Clean Air Mercury Rule, for example, would be extremely helpful.
2. Significantly increase funding across the full spectrum of carbon capture and storage technologies—including capture, compression, transportation, storage and monitoring—so as to ensure that the expectations for carbon dioxide capture and storage will be met on the local, state and national levels.
3. Create a team to lead an engineering program for testing multiple carbon management and storage technologies at power plant scale within the next five years.
4. Determine the legal liabilities associate with carbon capture and storage. This includes resolving ownership issues and responsibility for stored carbon dioxide in the event of leakage, and implementing long-term monitoring of storage facilities.
5. Increase funding of the Regional Carbon Sequestration Partnerships to adequately finance large-scale carbon dioxide storage projects in a number of different geologic formations, such as deep saline reservoirs and enhanced coal

* Document has been retained in committee files.

bed methane recovery. Current projects are focused strongly on enhanced oil recovery applications which enable lower total cost, but further work needs to be done to prove the viability of other kinds of projects so as to represent a spectrum of geology in areas where carbon dioxide is generated.

6. Support research projects that cover a wide variety of capture technologies, including those that capture less than 90 percent of the emissions because they are in the early stages of the technology maturation process. Carbon capture rates will increase as these technologies mature, and these technologies should not be abandoned today simply because they cannot immediately meet high capture expectations early in their development cycle.

7. Pursue a large scale demonstration project to spur development of ultra-supercritical pulverized coal technology for electricity generation. Extremely high temperatures and pressures (1400 degrees F; 5,000 psi) are required to achieve high plant efficiency, which require the development of new alloys and components.

8. Integrated Gasification Combined Cycle (IGCC) technology has not been completely and efficiently integrated into a large-scale power plant and carbon capture and storage system. Significantly more work will be required to do this. While this technology is considered commercially available in the chemical industry, the carbon dioxide capture process and acid gas clean up systems being designed for large scale deployment in power plants still constitutes a first-generation application.

9. Promote significant additional research and demonstration projects related to the transportation and safe storage of carbon dioxide. This would include:

a. Developing accepted performance standards or prescriptive design standards for the permanent geological storage of carbon dioxide.

b. Fostering the creation of uniform guidelines for site selection, operations, monitoring and closure of storage facilities.

c. Ensuring creation of a federal entity to take title to, and responsibility for, long-term post-closure monitoring of underground storage, liability and remediation at all carbon dioxide management sites.

d. Facilitating development of an economic, efficient and adequate infrastructure for transportation and storage of captured carbon dioxide.

e. Creating a legal framework to indemnify all entities that safely capture, transport and store carbon dioxide.

f. Creating clear transportation and storage rules that provide incentives to business models that will encourage the development of independent collection pipelines and storage facilities.

10. Consider undertaking 3-5 projects at a scale of about 1 million tons per year of carbon dioxide injection to understand the outstanding technical challenges and to demonstrate to the public that long-term carbon dioxide storage can be achieved safely and effectively.

As I stated earlier, the Secretary also asked the Council to recommend a framework for mitigating greenhouse gas emissions from coal-based generating plants. This framework is simple conceptually but difficult in terms of marshalling the requisite financial commitments, resolving legal and regulatory uncertainties, and instituting appropriate risk-sharing mechanisms. Necessary actions include:

Near Term.—Efficiency improvements at existing plants should be expedited. This can be achieved both technically and economically, but regulatory barriers must be addressed including the New Source Review process. In such cases, New Source Review should not be required for plant efficiency improvements that reduce carbon dioxide emissions with no subsequent increase in sulfur dioxide or oxides of nitrogen emissions increases.

Mid Term.—Advanced clean coal technologies such as IGCC and ultra-supercritical combustion must be given public policy support in the form of cost and permitting incentives and financial support for initial demonstrations so they can succeed in the marketplace. Legal questions about liability for long term storage must be addressed. Continued progress on FutureGen will be very important in these matters.

Long Term.—Technology for carbon capture and storage, including storage sites and related infrastructure, must be developed and demonstrated over the next 10 years. Several major carbon capture and storage projects must be started as soon as possible in order to achieve commercialization within the next 15 years. Oxygen firing technologies are designed specifically for carbon capture and will not develop independently of storage and infrastructure.

Ideally, all of this will be done in the context of public-private partnerships to more quickly bring these technologies to a state of commercial deployment.

Within 15 years, a suite of carbon capture technologies and storage facilities must become commercially available and affordable. When that happens, the coal-based electricity generation industry will be able to build these technologies into new plants and retrofit them at existing plants, where appropriate. In the long run, when these technologies become available in the marketplace, other nations using coal can also access them at a more reasonable cost.

Thank you, Mr. Chairman. I will be happy to answer any questions you or other Committee members may have.

The CHAIRMAN. Thank you very much.

Mr. Phillips, go right ahead.

STATEMENT OF JEFFREY N. PHILLIPS, PROGRAM MANAGER, ADVANCED COAL GENERATION, ELECTRIC POWER RESEARCH INSTITUTE, CHARLOTTE, NC

Mr. PHILLIPS. Mr. Chairman, I'd like to thank you and your colleagues for inviting me to speak to you on behalf of our institute. As you can imagine, it's a little difficult to cover all the contents of our report in 5 minutes.

So I just want to give you the highlights, which are, we have some good news and some bad news. We also have some more good news and some more bad news, and we have some additional bad news. So, if you're keeping track, it's two good and three bad. But the game is not over yet, and with a concerted public/private partnership, we believe that the outcome for coal and the carbon-constrained future can still be positive.

Now, the first good news is that any new coal plant built today has the capability to achieve extremely low emissions of the so-called criteria pollutants—NO_X, SO_x, and so forth—while also operating at a significantly higher efficiencies than the existing coal plants in the United States.

Now, most of the coal plants we have here were built in the 1950s, 1960s, and 1970s and a lot of folks think that coal power is old technology and can't be improved. We've been building automobiles since the early 1900s and automotive technology is still improving. Similarly, today's new coal plants are as different from those built 30 years ago as 2007 electric hybrid car is from a 1975 AMC Pacer. I would have said Gremlin, which is what I grew up with, but I think Pacer is more humorous.

While the higher efficiency of today's new plants means that they will produce less CO_2 per megawatt-hour than the existing fleet, our analysis of the electric power sector shows that in order to get the sector CO_2 emissions back down to 1990 levels by 2030, it's going to take more than just building more efficient coal plants.

That's where my first bad news comes in. While several technologies that can capture CO_2 emissions from coal power plants are ready to be demonstrated today, our analysis shows that they will significantly increase the cost of electricity. Capturing 90 percent of the CO_2 from either a pulverized coal, or an IGCC power plant increases the cost of power by up to 80 percent.

So adding CO_2 capture would greatly increase the operating cost of a plant well above that of one that doesn't capture CO_2. This means that a plant with CO_2 capture will fall down the dispatch order and it will reduce the amount of time that that plant is called on to operate and consequently, it will reduce the amount of CO_2

that's actually captured. So some means to induce CO_2 capture without economically penalizing the owner of the power plant needs to be devised. If not, CO_2 capture technology of any type will not be fully utilized.

My other good news is, that while the impact of capturing CO_2 today is significant, we have identified R&D pathways for both pulverized coal and IGCC that could dramatically reduce the cost of CO_2 capture. The Joint Kirk-EPRI Roadmap issued last year, shows that with appropriate R&D and demonstrations, technology for CO_2 capturing coal plants built in 2025 could lead to only a 10 percent increase in the cost of electricity.

The other bad news is, that at current levels of funding for coal R&D, we'll never get there by 2025. In fact, we might not even get there by 2045. Getting a broad portfolio of cost-effective capture technologies will require substantially increased—although not unprecedented—investments in R&D from both government and industry, on an unwavering basis over the next 20 plus years. Now toward this end, EPRI is now developing and marshalling support for an ambitious set of industry-led projects to address the R&D challenge.

Now, I want to emphasize that whenever you try out new technologies, you're bound to run into glitches and reliability is going to suffer. Consequently, we recommend following a "walk before you run" strategy, which means we'll try out these systems on a few plants, perhaps not at full scale to limit the cost. Let us fall on our bottoms a few times, dust ourselves off, figure out what went wrong, get the kinks out, before we start widespread deployment.

My final bad news is that even if we were able to drive the cost of capturing CO_2 to zero tomorrow, it's highly unlikely that any power plant owner will inject CO_2 into deep reservoirs given the current uncertainty over the regulations and liability of deep geologic storage of CO_2.

Now, I'm confident that our nation's engineers and scientists can solve the challenge of capturing CO_2 at economically acceptable costs, but we need help from you on the legal issues.

So in summary, today's new coal power plants are cleaner and more efficient than the existing fleet. Today's CO_2 capture technology will increase wholesale electricity prices by up to 80 percent, but we've identified a clear technology pathway that could decrease that to only 10 percent by 2025. Unfortunately, the funding for the development of that path is sadly inadequate. Finally, we engineers need some legal experts to help us sort out the rules for deep geologic storage of CO_2.

Thank you and I'll be happy to take your questions.

[The prepared statement of Mr. Phillips follows:]

PREPARED STATEMENT OF JEFFREY N. PHILLIPS, PH.D., PROGRAM MANAGER, ADVANCED COAL GENERATION, ELECTRIC POWER RESEARCH INSTITUTE, CHARLOTTE, NC

INTRODUCTION

I am Jeff Phillips, Program Manager for Advanced Coal Generation for the Electric Power Research Institute (EPRI). EPRI is a non-profit, collaborative R&D organization with principal offices in Palo Alto, California, and Charlotte, North Carolina, where I work. EPRI appreciates the opportunity to provide testimony to the Subcommittee on the topic of carbon capture and sequestration.

BACKGROUND

Coal is the energy source for half of the electricity generated in the United States. Even with the aggressive development and deployment of alternative energy sources, numerous forecasts of energy use predict that coal will continue to provide a major share of our electric power generation throughout the 21st century. Coal is a stably priced, affordable, domestic fuel that can be used in an environmentally responsible manner. Criteria air pollutants from all types of new coal power plants have been reduced by more than 90% compared with plants built 40 years ago. With the development and deployment of CO_2 capture and storage (CCS) technologies, coal power becomes part of the solution to satisfying both our energy needs and our global climate change concerns. However, a sustained RD&D program at heightened levels of investment and resolution of legal and regulatory unknowns for long-term geologic CO_2 storage will be required to achieve the promise of clean coal technologies. EPRI sees crucial roles for both industry and governments in aggressively pursuing collaborative RD&D over the next 20+ years to create a portfolio of commercially self-sustaining, competitive advanced coal power generation and CO_2 capture and storage technologies.

The potential return on this investment is enormous. EPRI's "Electricity Technology in a Carbon-Constrained Future" study suggests that it is technically feasible to reduce U.S. electric sector CO_2 emissions over the next 25 years while meeting the increased demand for electricity, with the largest single contribution to emissions reduction coming from application of CCS technologies to new coal-based power plants coming on-line after 2020. Economic analyses of scenarios to achieve the study's emission reduction goals show that a 2030 U.S. energy mix including advanced coal technologies with CCS results in electricity at half the cost of a 2030 energy mix without coal with CCS. In the case with advanced coal with CCS, the U.S. economy is $1 trillion larger than in the case without coal and CCS, with a much stronger manufacturing sector. A previous EPRI economic study based on financial market "options" principles produced a similar result, estimating the added cost to U.S. consumers through 2050 of not having coal's price-stabilizing influence on the electricity system at $1.4 trillion (present value basis).

The portfolio aspect of advanced coal and CCS technologies must be emphasized because no single advanced coal 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 minimizing economic disruption lies in developing multiple technologies from which power producers (and their regulators) can choose the option best suited to local conditions and preferences. When it comes to CCS technology, there is no "silver bullet," but we can develop "silver buckshot."

Toward this end, four major technology efforts related to CO_2 emissions reduction from coal-based power systems must be undertaken:

1. Increased efficiency and reliability of integrated gasification combined cycle (IGCC) power plants.
2. Increased thermodynamic efficiency of pulverized-coal (PC) power plants.
3. Improved technologies for capture of CO_2 from coal combustion-and gasification-based power plants.
4. Reliable, acceptable technologies for long-term storage of captured. CO_2

Identification of mechanisms to share RD&D financial and technical risks and to address legal and regulatory uncertainties must take place as well.

In short, a comprehensive recognition of all the factors needed to hasten deployment of competitive, commercial advanced coal and CO_2 capture and storage technologies—and implementation of realistic, pragmatic plans to overcome barriers—is the key to meeting the challenge to supply affordable, environmentally responsible energy in a carbon-constrained world.

ACCELERATING RD&D ON ADVANCED COAL TECHNOLOGIES WITH CO_2 CAPTURE AND STORAGE—INVESTMENT AND TIME REQUIREMENTS

A typical path to develop a technology to commercial maturity consists of moving from the conceptual stage to laboratory testing, to small pilot-scale tests, to larger-scale tests, to multiple full-scale demonstrations, and finally to deployment in full-scale commercial operations. For capital-intensive technologies such as advanced coal power systems, each stage can take years or even decades to complete and each sequential stage tends to entail increasing levels of investment. As depicted in Figure 1,* several key advanced coal power and CCS technologies are now in (or approaching) an "adolescent" stage of development. This is time of particular vulnerability in the technology development cycle, as it is common for the expected costs of full-scale application to be higher than earlier estimates when less was known about scale-up and application challenges. Public agency and private funders can become disillusioned with a technology development effort at this point, but as long as fundamental technology performance results continue to meet expectations, and a path to cost reduction is clear, perseverance by project sponsors in maintaining momentum is crucial. Unexpectedly high costs at the mid-stage of technology development have historically come down following market introduction, experience gained from "learning-by-doing," realization of economies of scale in design and production as order volumes rise, and removal of contingencies covering uncertainties and first-of-a-kind costs. An International Energy Agency study led by Carnegie Mellon University observed this pattern in the cost over time of power plant environmental controls and has predicted a similar reduction in the cost of power plant CO_2 capture technologies as the cumulative installed capacity grows.[1] EPRI concurs with their expectations of experience-based cost reductions and believes that RD&D on specifically identified technology refinements can lead to greater cost reductions sooner in the deployment phase.

Of the coal-based power generating and carbon sequestration technologies shown in Figure 1, only supercritical pulverized coal (SCPC) technology has reached commercial maturity. It is crucial that other technologies in the portfolio—namely ultra-supercritical (USC) PC, integrated gasification combined cycle (IGCC), CO_2 capture (pre-combustion, post-combustion, and oxy-combustion), and CO_2 storage—be given sufficient support to reach the stage of declining constant dollar costs before society's requirements for greenhouse gas reductions compel their application in large numbers.

Figure 2* depicts the major activities in each of the four technology areas that must take place to achieve a set of robust solutions to reduce CO_2 emissions from coal power systems. This framework should be considered as a whole rather than as a set of discrete tasks. Although individual goals related to efficiency, CO_2 capture, and CO_2 storage present major challenges, significant challenges also arise from complex interactions that occur when CO_2 capture processes are integrated with gasification-and combustion-based power plant processes.

REDUCING CO_2 EMISSIONS THROUGH IMPROVED COAL POWER PLANT EFFICIENCY

Improved thermodynamic efficiency reduces CO_2 emissions by reducing the amount of fuel required to generate a given amount of electricity. A two-percentage point gain in efficiency provides a reduction in fuel consumption of roughly 5% and a similar reduction in CO_2 output. Depending on the technology used, improved efficiency can also provide similar reductions in criteria air pollutants, hazardous air pollutants, and water consumption.

A "typical" 500 MW (net) coal plant emits about 3 million metric tons of CO_2 per year. The annual power output and emissions of the current U.S. coal fleet are roughly equivalent to 600 such plants. The contributions attributable to individual plants vary considerably with differences in plant steam cycle, coal type, capacity factor, and operating regimes. For a given fuel, a new supercritical PC unit built today might produce 5–10% less CO_2 per megawatt-hour (MWh) than the existing fleet average for that coal type.

With an aggressive RD&D program on efficiency improvement, new ultra-supercritical (USC PC) plants could reduce CO_2 emissions per MWh by up to 25% relative to the existing fleet average. Significant efficiency gains are also possible for IGCC plants by employing advanced gas turbines and through more energy-efficient oxygen plants and synthesis (fuel) gas cleanup technologies.

EPRI and the Coal Utilization Research Council (CURC), in consultation with DOE, have identified a challenging but achievable set of milestones for improvements in the efficiency, cost, and emissions of PC and coal-based IGCC plants. The EPRI-CURC Roadmap projects an overall improvement in the thermal efficiency of state-of-the art generating technology from 38–41% in 2010 to 44–49% by 2025 (on a higher heating value [HHV] basis; see Table 1). The ranges in the numbers are not simply a reflection of uncertainty, but rather they underscore an important point about differences among U.S. coals. The natural variations in moisture and ash content and combustion characteristics between coals have a significant impact

* Figures 1-12 have been retained in committee files.

[1] IEA Greenhouse Gas R&D Programme (IEA GHG), "Estimating Future Trends in the Cost of CO_2 Capture Technologies," 2006/5, January 2006.

on efficiency. The best efficiencies are possible with bituminous coals, a mid-range value is applicable to subbituminous coals, and the low end of the range is for lignite. Thus, an equally advanced plant might have a two percentage point lower efficiency on subbituminous coal, such as Wyoming and Montana's Powder River basin, relative to Pennsylvania and West Virginia's Pittsburgh #8. The efficiency for the same plant using lignite from North Dakota or Texas might be two percentage points even lower than that for subbituminous coal. Any government incentive program with an efficiency-based qualification criterion should recognize these inherent differences in the attainable efficiencies for plants using different ranks of coal.

As Table 1 indicates, technology-based efficiency gains over time will be offset by the energy required for CO_2 capture. Nevertheless, aggressive pursuit of the EPRI-CURC RD&D program offers the prospect of coal plants with CO_2 capture in 2025 that have net efficiencies meeting or exceeding current-day power plants without CO_2 capture.

Table 1—Efficiency Milestones in EPRI-CURC Roadmap

	2010	*2015*	*2020*	*2025*
PC & IGCC Systems (Without CO_2 Capture)	38–41% HHV	39–43% HHV	42–46% HHV	44–49% HHV
PC & IGCC Systems (With CO_2 Capture*)	31–32% HHV	31–35% HHV	33–39% HHV	39–46% HHV

*Efficiency values reflect impact of 90% CO_2 capture, but not compression or transportation.

NEW PLANT EFFICIENCY IMPROVEMENTS—IGCC

Although IGCC is not yet a mature technology for coal-fired power plants, chemical plants around the world have accumulated a 100-year experience base operating coal-based gasification units and related gas cleanup processes. The most advanced of these units are similar to the front end of a modern IGCC facility. Similarly, several decades of experience firing natural gas and petroleum distillate have established a high level of maturity for the basic combined cycle generating technology. Nonetheless, ongoing RD&D continues to provide significant advances in the base technologies, as well as in the suite of technologies used to integrate them into an IGCC generating facility.

Efficiency gains in currently proposed IGCC plants will come from the use of new "FB-class" gas turbines, which will provide an overall plant efficiency gain of about 0.6 percentage point (relative to IGCC units with FA-class models, such as Tampa Electric's Polk Power Station). This corresponds to a decrease in CO_2 emissions rate of about 1.5%.

Figure 3* depicts the anticipated timeframe for further developments identified by EPRI's CoalFleet for Tomorrow® program that promise a succession of significant improvements in IGCC unit efficiency. Key technology advances under development include: larger capacity gasifiers (often via higher operating pressures that boost throughput without a commensurate increase in vessel size); integration of new gasifiers with larger, more efficient G- and H-class gas turbines; use of ion transport membrane (ITM) and/or other more energy-efficient technologies in oxygen plants; warm synthesis gas cleanup and membrane separation processes for CO_2 capture that reduce energy losses in these areas; recycle of liquefied CO_2 to replace water in gasifier feed slurry (reducing heat loss to water evaporation); and hybrid combined cycles using fuel cells to achieve generating efficiencies exceeding those of conventional combined cycle technology. Improvements in gasifier reliability and in control systems also contribute to improved annual average efficiency by minimizing the number and duration of startups and shutdowns.

Larger, Higher Firing Temperature Gas Turbines.—For plants coming on-line around 2015, the larger size G-class gas turbines, which operate at higher firing temperatures (relative to F-class machines) can improve efficiency by 1 to 2 percentage points while also decreasing capital cost per kW capacity. The H-class gas turbines, coming on-line in the same timeframe, will provide a further increase in efficiency and capacity.

Ion Transport Membrane—Based Oxygen Plants.—Most gasifiers used in IGCC plants require a large quantity of high-pressure, high purity oxygen, which is typically generated on-site with an expensive and energy-intensive cryogenic process. The ITM process allows the oxygen in high-temperature air to pass through a membrane while preventing passage of non-oxygen atoms. According to developers, an ITM-based oxygen plant consumes 35–60% less power and costs 35% less than a cryogenic plant. EPRI is performing a due diligence assessment of this technology in advance of potential participation in technology scale-up efforts.

Supercritical Heat Recovery Steam Generators.—In IGCC plants, hot exhaust gas exiting the gas turbine is ducted into a heat exchanger known as a heat recovery steam generator (HRSG) to transfer energy into water-filled tubes producing steam to drive a steam turbine. This combination of a gas turbine and steam turbine power cycles produces electricity more efficiently than either a gas turbine or steam turbine alone. As with conventional steam power plants, the efficiency of the steam cycle in a combined cycle plant increases when turbine inlet steam temperature and pressure are increased. The higher exhaust temperatures of G-and H-class gas turbines offer the potential for adoption of more-efficient supercritical steam cycles. Materials for use in a supercritical HRSG are generally established.

Synthesis Gas Cleaning at Higher Temperatures.—The acid gas recovery (AGR) processes currently used to remove sulfur compounds from synthesis gas require that the gas and solvent be cooled to about 100°F, thereby causing a loss in efficiency. Further costs and efficiency loss are inherent in the process equipment and auxiliary steam required to recover the sulfur compounds from the solvent and convert them to useable products. Several DOE-sponsored RD&D efforts aim to reduce the energy losses and costs imposed by this recovery process. These technologies (described below could be ready—with adequate RD&D support—by 2020:

- The Selective Catalytic Oxidation of Hydrogen Sulfide process eliminates the Claus and Tail Gas Treating units along with the traditional solvent-based AGR contactor, regenerator, and heat exchangers by directly converting hydrogen sulfide (H_2S) to elemental sulfur. The process allows for a higher operating temperature of approximately 300°F, which eliminates part of the low-temperature gas cooling train. The anticipated benefit is a net capital cost reduction of about $60/kW along with an efficiency gain of about 0.8 percentage point.
- The RTI/Eastman High Temperature Desulfurization System uses a regenerable dry zinc oxide sorbent in a dual loop transport reactor system to convert H_2S and COS to H_2O, CO_2, and SO_2. Tests at Eastman Chemical Company have shown sulfur species removal rates above 99.9%, with 10 ppm output versus 8000+ ppm input sulfur, using operating temperatures of 800–1000°F. This process is also being tested for its ability to provide a high-pressure CO_2 byproduct. The anticipated benefit for IGCC, compared with using a standard oil-industry process for sulfur removal, is a net capital cost reduction of $60–90 per kW, a thermal efficiency gain of 2–4% for the gasification process, and a slight reduction in operating cost. Tests are also under way for a multi-contaminant removal processes that can be integrated with the transport desulfurization system at temperatures above 480°F.

Liquid CO_2-Coal Slurrying for Gasification of Low-Rank Coals.—Future IGCC plants may recycle some of the recovered liquid CO_2 to replace water as the slurrying medium for the coal feed. This is expected to increase gasification efficiency for all coals, but particularly for low-rank coals (i.e., subbituminous and lignite), which have high inherent moisture content. The liquid CO_2 has a lower heat of vaporization than water and is able to carry more coal per unit mass of fluid. The liquid CO_2-coal slurry will flash almost immediately upon entering the gasifier, providing good dispersion of the coal particles and potentially yielding dry-fed gasifier performance with slurry-fed simplicity.

Slurry-fed gasification technologies have a cost advantage over conventional dry-fed fuel handling systems, but they suffer a large performance penalty when used with coals containing a large fraction of water and ash. EPRI identified CO_2 coal slurrying as an innovative fuel preparation concept 20 years ago, when IGCC technology was in its infancy. At that time, however, the cost of producing liquid CO_2 was too high to justify the improved thermodynamic performance.

To date, CO_2-coal slurrying has only been demonstrated at pilot scale and has yet to be assessed in feeding coal to a gasifier, so the estimated performance benefits remain to be confirmed. The concept warrants consideration for future IGCC plants that capture and compress CO_2 for storage, as this will substantially reduce the incremental cost of producing a liquid CO_2 stream. It will first be necessary, however, to update previous studies to quantify the potential benefit of liquid CO_2 slurries with IGCC plants designed for CO_2 capture. If the predicted benefit is economically advantageous, a significant amount of scale-up and demonstration work would be required to qualify this technology for commercial use.

Fuel Cells and IGCC.—No matter how far gasification and turbine technology advance, IGCC power plant efficiency will never progress beyond the inherent thermodynamic limits of the gas turbine and steam turbine power cycles (along with lower limits imposed by available materials technology). Several IGCC–fuel cell hybrid power plant concepts (IGFC) aim to provide a path to coal-based power generation with net efficiencies that exceed those of conventional combined cycle generation.

Along with its high thermal efficiency, the fuel cell hybrid cycle reduces the energy consumption for CO_2 capture. The anode section of the fuel cell produces a stream that is highly concentrated in CO_2. After removal of water, this stream can be compressed for sequestration. The concentrated CO_2 stream is produced without having to include a water-gas shift reactor in the process (see Figure 4*). This further improves the thermal efficiency and decreases capital cost. IGFC power systems are a long-term solution, however, unlikely to see full-scale demonstration until about 2030.

Role of FutureGen.—The FutureGen Industrial Alliance and DOE are building a first-of-its-kind, near-zero emissions coal-fed IGCC power plant integrated with CCS. The commencement of full-scale operations is targeted for 2013. The project aims to sequester CO_2 in a representative geologic formation at a rate of at least one million metric tons per year.

The FutureGen design will address scaling and integration issues for coal-based, zero emissions IGCC plants. In its role as a "living laboratory," FutureGen is designed to validate additional advanced technologies that offer the promise of clean environmental performance at a reduced cost and increased reliability. FutureGen will have the flexibility to conduct full-scale and slipstream tests of such scalable advanced technologies such as:

- Membrane processes to replace cryogenic separation for oxygen production.
- An advanced transport reactor sidestream with 30% of the capacity of the main gasifier.
- Advanced membrane and solvent processes for H_2 and CO_2 separation.
- A raw gas shift reactor that reduces the upstream clean-up requirements.
- Ultra low-NO_X combustors that can be used with high-hydrogen synthesis gas.
- A fuel cell hybrid combined cycle pilot.
- Challenging first-of-a-kind system integration.
- Smart dynamic plant controls including a CO_2 management system.

Figure 5* provides a schematic of the "backbone" and "research platform" process trains envisioned for the FutureGen plant.

Figure 6* summarizes EPRI's recommended major RD&D activities for improving the efficiency and cost of IGCC technologies with CO_2 capture.

NEW PLANT EFFICIENCY IMPROVEMENTS—ADVANCED PULVERIZED COAL

Pulverized-coal power plants have long been a primary source of reliable and affordable power in the United States and around the world. The advanced level of maturity of the technology, along with basic thermodynamic principles, suggests that significant efficiency gains can most readily be realized by increasing the operating temperatures and pressures of the steam cycle. Such increases, in turn, can be achieved only if there is adequate development of suitable materials and new boiler and steam turbine designs that allow use of higher steam temperatures and pressures.

Current state-of-the-art plants use supercritical main steam conditions (i.e., temperature and pressure above the "critical point" where the liquid and vapor phases of water are indistinguishable). SCPC plants typically have main steam conditions up to 1100°F. The term "ultra-supercritical" is used to describe plants with main steam temperatures in excess of 1100°F and potentially as high as 1400°F.

Achieving higher steam temperatures and higher efficiency will require the development of new corrosion-resistant, high-temperature nickel alloys for use in the boiler and steam turbine. In the United States, these challenges are being address by the Ultra-Supercritical Materials Consortium, a DOE R&D program involving Energy Industries of Ohio, EPRI, the Ohio Coal Development Office, and numerous equipment suppliers. EPRI provides technical management for the consortium.

It is expected that a USC PC plant operating at about 1300°F will be built during the next seven to ten years, following the demonstration and commercial availability of advanced materials from these programs. This plant would achieve an efficiency of about 45% (HHV) on bituminous coal, compared with 39% for a current state-of-the-art plant, and would reduce CO_2 production per net MWh by about 15%.

Ultimately, nickel-base alloys are expected to enable stream temperatures in the neighborhood of 1400°F and generating efficiencies up to 47% HHV with bituminous coal. This approximately 10 percentage point improvement over the efficiency of a new subcritical pulverized-coal plant would equate to a decrease of about 25% in CO_2 and other emissions per MWh.

Figure 7* illustrates a timeline developed by EPRI's CoalFleet for Tomorrow® program to establish efficiency improvement and cost reduction goals for USC PC plants with CO_2 capture.

UltraGen USC PC Commercial Projects.—EPRI and industry representatives have proposed a framework to support commercial projects that demonstrate advanced PC technologies. The vision entails construction of two commercially operated USC PC power plants that combine state-of-the-art pollution controls, ultra-supercritical steam power cycles, and innovative flue gas scrubbing technologies to capture CO_2.

The UltraGen I plant will use the best of today's proven ferritic steels, while UltraGen II will be the first plant in the United States to feature new, nickel-based alloys that are able to withstand the higher temperatures involved. UltraGen I will feature an approximately quarter-scale CO_2 capture system demonstration using the best established technology. This system will be about 15 times the size of the largest system operating on a coal-fired boiler today. UltraGen II will double the size of the CO_2 capture system, and may demonstrate a new class of chemical solvent if one of the emerging low-energy processes has reached a sufficient stage of development. Both plants will demonstrate ultra-low emissions. Both UltraGen demonstration plants will dry and compress the captured CO_2 for long-term geologic storage and/or use in enhanced oil or gas recovery operations. Figure 8* depicts the proposed key features of UltraGen I and II.

To provide a platform for testing and developing emerging PC technologies, the program will allow for technology trials at existing sites as well as at the sites of new projects. It is expected that the UltraGen projects will be commercially operated units dispatching electricity to the grid. The differential cost to the host utility for demonstrating these improved features are envisioned to be offset by tax credits and funds raised by an industry-led consortia formed through EPRI.

The UltraGen projects represent the type of "giant step" collaborative efforts that need to be taken to advance PC technology to the next phase of evolution and assure competitiveness in a carbon-constrained world. Because of the time and expense for each "design and build" iteration for coal power plants (3 to 5 years not counting the permitting process and ~$2 billion), there is no room for hesitation in terms of commitment to advanced technology validation and demonstration projects.

The UltraGen projects will resolve critical barriers to the deployment of USC PC technology by providing a shared-risk vehicle for testing and validating high-temperature materials, components, and designs in plants also providing superior environmental performance.

Figure 9* summarizes EPRI's recommended major RD&D activities for improving the efficiency and cost of USC PC technologies with CO_2 capture.

Efficiency Gains for the Existing PC Fleet.—Many subcritical units in the existing U.S. fleet will continue to operate for years to come. Replacing these units en masse would be economically prohibitive. Their flexibility for load following and provision of support services to ensure grid stability makes them highly valuable. With equipment upgrades, many of these units can realize modest efficiency gains, which, when accumulated across the existing generating fleet could make a sizeable difference.

These upgrades depend on the equipment configuration and operating parameters of a particular plant and may include:

- turbine blading and steam path upgrades.
- turbine control valve upgrades for more efficient regulation of steam.
- cooling tower and condenser upgrades to reduce circulating water temperature, steam turbine exhaust backpressure, and auxiliary power consumption.
- cooling tower heat transfer media upgrades.
- condenser optimization to maximize heat transfer and minimize condenser temperature.
- condenser air leakage prevention/detection.
- variable speed drive technology for pump and fan motors to reduce power consumption.
- air heater upgrades to increase heat recovery and reduce leakage.
- advanced control systems incorporating neural nets to optimize temperature, pressure, and flow rates of fuel, air, flue gas, steam, and water.
- optimization of water blowdown and blowdown energy recovery.
- optimization of attemperator design, control, and operating scenarios.
- sootblower optimization via "intelligent" sootblower system use.

IMPROVING CO_2 CAPTURE TECHNOLOGIES

The laws of physics and chemistry impose inherent limits on the extent of CO_2 reductions that can be achieved through efficiency gains alone. Further reductions in CO_2 emissions will require pre-combustion or post-combustion CO_2 capture technologies and the storage of separated CO_2 in locations where it can be kept away from the atmosphere for centuries or longer.

Albeit at considerable cost, CO_2 capture technologies can be integrated into all coal-based power plant technologies. For existing plants, specific plant design features, space limitations, and various economic and regulatory considerations will determine whether retrofit-for-capture is feasible. For both new plants and retrofits, there is a tremendous need (and opportunity) to reduce the energy required to remove CO_2 from fuel gas or flue gas. Figure 10* shows a selection of the key technology development and test programs needed to achieve a goal of commercial CO_2 capture technologies for advanced coal combustion-and gasification-based power plants at a progressively shrinking constant-dollar levelized cost-of-electricity premium. Specifically, the target is premium of about $6/MWh in 2025 (relative to plants at that time without capture) compared with an estimated 2010 cost premium of perhaps $40/MWh (not counting the cost of transportation and storage). Such a goal poses substantial engineering challenges and will require major investments in RD&D to reduce the currently large net power reductions and efficiency (operating cost) penalties associated with CO_2 capture technologies. Achieving this goal will allow power producers to meet the public demand for stable electricity prices while reducing CO_2 emissions to address climate change concerns.

PRE-COMBUSTION CO_2 CAPTURE (IGCC)

IGCC technology allows for CO_2 capture to take place via an added fuel gas processing step at elevated pressure, rather than at the atmospheric pressure of post-combustion flue gas, permitting capital savings through smaller equipment sizes as well as lower operating costs.

Currently available technologies for such pre-combustion CO_2 removal use a chemical and/or physical solvent that selectively absorbs CO_2 and other "acid gases," such as hydrogen sulfide. Application of this technology requires that the CO in synthesis gas (the principal component) first be "shifted" to CO_2 and hydrogen via a catalytic reaction with water. The CO_2 in the shifted synthesis gas is then removed via contact with the solvent in an absorber column, leaving a hydrogen-rich synthesis gas for combustion in the gas turbine. The CO_2 is released from the solvent in a regeneration process that typically reduces pressure and/or increases temperature.

Chemical plants currently employ such a process commercially using methyl diethanolamine (MDEA) as a chemical solvent or the Selexol and Rectisol processes, which rely on physical solvents. Physical solvents are generally preferred when extremely high (>99.8%) sulfur species removal is required. Although the required scale-up for IGCC power plant applications is less than that needed for scale-up of post-combustion CO_2 capture processes for PC plants, considerable engineering challenges remain and work on optimal integration with IGCC cycle processes has just begun.

The impact of current pre-combustion CO_2 removal processes on IGCC plant thermal efficiency and capital cost is significant. In particular, the water-gas shift reaction reduces the heating value of synthesis gas fed to the gas turbine. Because the gasifier outlet ratios of CO to methane to H_2 are different for each gasifier technology, the relative impact of the water-gas shift reactor process also varies. In general, however, it can be on the order of a 10% fuel energy reduction. Heat regeneration of solvents further reduces the steam available for power generation. Other solvents, which are depressurized to release captured CO_2, must be re-pressurized for reuse. Cooling water consumption is increased for solvents needing cooling after regeneration and for pre-cooling and interstage cooling during compression of separated CO_2 to a supercritical state for transportation and storage. Heat integration with other IGCC cycle processes to minimize these energy impacts is complex and is currently the subject of considerable RD&D by EPRI and others.

Membrane CO_2 Separation.—Technology for separating CO_2 from shifted synthesis gas (or flue gas from PC plants) offers the promise of lower auxiliary power consumption but is currently only at the laboratory stage of development. Several organizations are pursuing different approaches to membrane-based applications. In general, however, CO_2 recovery on the low-pressure side of a selective membrane can take place at a higher pressure than is now possible with solvent processes, reducing the subsequent power demand for compressing CO_2 to a supercritical state. Membrane-based processes can also eliminate steam and power consumption for regenerating and pumping solvent, respectively, but they require power to create the pressure difference between the source gas and CO_2-rich sides. If membrane technology can be developed at scale to meet performance goals, it could enable up to a 50% reduction in capital cost and auxiliary power requirements relative to current CO_2 capture and compression technology.

POST-COMBUSTION CO_2 CAPTURE (PC AND CFB PLANTS)

The post-combustion CO_2 capture processes envisioned for power plant boilers draw upon commercial experience with amine solvent separation at much smaller scale in the food and beverage and chemical industries and upon three applications of CO_2 capture from a slipstream of exhaust gas from circulating fluidized-bed (CFB) units.

These processes contact flue gas with an amine solvent in an absorber column (much like a wet SO_2 scrubber) where the CO_2 chemically reacts with the solvent. The CO_2-rich liquid mixture then passes to a stripper column where it is heated to change the chemical equilibrium point, releasing the CO_2. The "regenerated" solvent is then recirculated back to the absorber column, while the released CO_2 may be further processed before compression to a supercritical state for efficient transportation to a storage location.

After drying, the CO_2 released from the regenerator is relatively pure. However, success CO_2 removal requires very low levels of SO_2 and NO_2 entering the CO_2 absorber, as these species also react with the solvent. Thus, high-efficiency SO_2 and NO_X control systems are essential to minimizing solvent consumption costs for post-combustion CO_2 capture. Extensive RD&D is in progress to improve the solvent and system designs for power boiler applications and to develop better solvents with greater absorption capacity, less energy demand for regeneration, and greater ability to accommodate flue gas contaminants.

At present, monoethanolamine (MEA) is the "default" solvent for post-combustion CO_2 capture studies and small-scale field applications. Processes based on improved amines, such as Fluor's Econamine FG Plus and Mitsubishi Heavy Industries' KS–1, are under development. The potential for improving amine-based processes appears significant. For example, a recent study based on KS–1 suggests that its impact on net power output for a supercritical PC unit would be 19% and its impact on the levelized cost-of-electricity would be 44%, whereas earlier studies based on suboptimal MEA applications yielded output penalties approaching 30% and cost-of-electricity penalties of up to 65%.

Accordingly, amine-based engineered solvents are the subject of numerous ongoing efforts to improve performance in power boiler post-combustion capture applications. Along with modifications to the chemical properties of the sorbents, these efforts are addressing the physical structure of the absorber and regenerator equipment, examining membrane contactors and other modifications to improve gas-liquid contact and/or heat transfer, and optimizing thermal integration with steam turbine and balance-of-plant systems. Although the challenge is daunting, the payoff is potentially massive, as these solutions may be applicable not only to new plants, but to retrofits where sufficient plot space is available at the back end of the plant.

Finally, as discussed earlier, deploying USC PC technology to increase efficiency and lower uncontrolled CO_2 per MWh can further reduce the cost impact of post-combustion CO_2 capture.

Chilled Ammonia Process.—Post-combustion CO_2 capture using a chilled ammonia-based solvent offers the promise of dramatically reducing parasitic power losses relative to MEA. In the process currently under development and testing by Alstom and EPRI, respectively, CO_2 is absorbed in a solution of ammonium carbonate, at low temperature and atmospheric pressure, and combines with the $NaCO_3$ to form ammonium bicarbonate.

Compared with amines, ammonium carbonate has over twice the CO_2 absorption capacity and requires less than half the heat to regenerate. Further, regeneration can be performed under higher pressure than amines, so the released CO_2 is already partially pressurized. Therefore, less energy is subsequently required for compression to a supercritical state for transportation to an injection location. Developers have estimated that the parasitic power loss from a full-scale supercritical PC plant using chilled ammonia CO_2 capture could be as low as 10%, with an associated cost-of-electricity penalty of just 25%. Following successful experiments at 0.25 MW_e scale, Alstom and a consortium of EPRI members are constructing a 1.7 MW_e pilot unit to test the chilled ammonia process with a flue gas slipstream at We Energies' Pleasant Prairie Power Plant.

Other "multi-pollutant" control system developers are also exploring ammonia-based processes for CO_2 removal.

OXY-FUEL COMBUSTION BOILERS

Fuel combustion in a blend of oxygen and recycled flue gas rather than in air (known as oxy-fuel combustion or oxy-combustion) is gaining interest as a viable CO_2 capture alternative for PC and CFB plants. The process is applicable to virtually all fossil-fueled boiler types and is a candidate for retrofits as well as new power plants.

Firing coal only with high-purity oxygen would result in too high of a flame temperature, which would increase slagging, fouling, and corrosion problems, so the oxygen is diluted by mixing it with a slipstream of recycled flue gas. As a result, the flue gas downstream of the recycle slipstream take-off consists primarily of CO_2 and water vapor (although it also contains small amounts of nitrogen, oxygen, and criteria pollutants). After the water is condensed, the CO_2-rich gas is compressed and purified to remove contaminants and prepare the CO_2 for transportation and storage.

Oxy-combustion boilers have been studied in laboratory-scale and small pilot units of up to 3 MW_t. Two larger pilot units, at ~10 MW_e, are now under construction by Babcock & Wilcox (B&W) and Vattenfall. An Australian-Japanese project team is pursuing a 30 MW_e repowering project in Australia. These larger tests will allow verification of mathematical models and provide engineering data useful for designing pre-commercial systems. The first such pre-commercial unit could be built at SaskPower's Shand station near Estevan, Saskatchewan. SaskPower, B&W Canada, and Air Liquide have been jointly developing an oxy-combustion SCPC design, and a decision on whether to proceed to construction is expected by late 2007, with a target in-service date of 2011–12.

CO_2 TRANSPORT AND GEOLOGIC STORAGE

Application of CO_2 capture technologies implies that there will be secure and economical storage or beneficial uses that can assure CO_2 will be kept out of the atmosphere. The most developed approach for large-scale CO_2 storage is injection into deep, well-sealed geological formations, including depleted or partially depleted oil and gas reservoirs and similar geologically sealed "saline formations" (porous rocks filled with brine that is impractical for desalination). Partially depleted oil reservoirs provide the added benefit of enhanced oil recovery (EOR). [EOR is used in mature fields to recover additional oil after standard extraction methods have been used. When CO_2 is injected for EOR, it causes residual oil to swell and become less viscous, allowing some to flow to production wells, thus extending the field's productive life.] Although EOR can help the economics of CCS projects, EOR sites are ultimately too few and too geographically isolated to accommodate much of the CO_2 from large-scale industrial CO_2 capture operations. In contrast, saline formations are available in many—but not all—U.S. locations.

Natural underground CO_2 reservoirs in Colorado, Utah, and other western states testify to the effectiveness of long-term geologic CO_2 storage. CO_2 is also found in natural gas reservoirs, where it has resided for millions of years. Thus, evidence suggests that depleted or near-depleted oil and gas reservoirs, and similarly "capped" saline formations will be ideal for storing CO_2 for millennia or longer. Geologic sequestration as a strategy for reducing CO_2 emissions from the atmosphere is currently being demonstrated in several projects around the world. Three larger-scale projects—Statoil's Sleipner Saline Aquifer CO_2 Storage project in the North Sea off of Norway; the Weyburn Project in Saskatchewan, Canada; and the In Salah Project in Algeria—together sequester about 3–4 million metric tons of CO_2 per year, which collectively approaches the output of just one typical 500 MW coal-fired power plant. With 17 collective operating years of experience, these projects have thus far demonstrated that CO_2 storage in deep geologic formations can be carried out safely and reliably. Statoil estimates that Norwegian greenhouse gas emissions would have risen incrementally by 3% if the CO_2 from the Sleipner project had been vented rather than sequestered.[2]

Table 2 lists a selection of current and planned CO_2 storage projects as of early 2007, including those involving EOR.

Table 2—Select Existing and Planned CO_2 Storage Projects as of Early 2007

PROJECT	CO_2 SOURCE	COUNTRY	START	Anticipated amount injected by:		
				2006	2010	2015
Sleipner	Gas. Proc.	Norway	1996	9 MT	13 MT	18 MT
Weyburn	Coal	Canada	2000	5 MT	12 MT	17 MT

[2] http://www.co2captureandstorage.info/project__specific.php?project__id=26

Table 2—Select Existing and Planned CO_2 Storage Projects as of Early 2007—Continued

PROJECT	CO_2 SOURCE	COUNTRY	START	Anticipated amount injected by:		
				2006	2010	2015
In Salah	Gas. Proc.	Algeria	2004	2 MT	7 MT	12 MT
Snohvit	Gas. Proc.	Norway	2007	0	2 MT	5 MT
Gorgon	Gas. Proc.	Australia	2010	0	0	12 MT
DF-1 Miller	Gas	U.K.	2009	0	1 MT	8 MT
DF-2 Carson	Pet Coke	U.S.	2011	0	0	16 MT
Draugen	Gas	Norway	2012	0	0	7 MT
FutureGen	Coal	U.S.	2012	0	0	2 MT
Monash	Coal	Australia	NA	0	0	NA
SaskPower	Coal	Canada	NA	0	0	NA
Ketzin/CO_2 STORE	NA	Germany	2007	0	50 KT	50 KT
Otway	Natural	Australia	2007	0	100 KT	100 KT
TOTALS				***16 MT***	***35 MT***	***99 MT***

Source: Sally M. Benson, "Can CO_2 Capture and Storage in Deep Geological Formations Make Coal-Fired Electricity Generation Climate Friendly?" Presentation at Emerging Energy Technologies Summit, UC Santa Barbara, California, February 9, 2007. [Note: Statoil has subsequently suspended plans for the Draugen project and announced a study of CO_2 capture at a gas-fired power plant at Tjeldbergodden. BP and Rio Tinto have announced the coal-based "DF-3" project in Australia.]

Enhanced Oil Recovery.—Experience relevant to CCS comes from the oil industry, where CO_2 injection technology and modeling of its subsurface behavior have a proven track record. EOR has been conducted successfully for 35 years in the Permian Basin fields of west Texas and Oklahoma. Regulatory oversight and community acceptance of injection operations for EOR seem well established.

Although the purpose of EOR is not to sequester CO_2 per se, the practice can be adapted to include CO_2 storage opportunities. This approach is being demonstrated in the Weyburn-Midale CO_2 monitoring projects in Saskatchewan, Canada. The Weyburn project uses captured and dried CO_2 from the Dakota Gasification Company's Great Plains synfuels plant near Beulah, North Dakota. The CO_2 is transported via a 200 mile pipeline constructed of standard carbon steel. Over the life of the project, the net CO_2 storage is estimated at 20 million metric tons, while an additional 130 million barrels of oil will be produced.

The economic value of EOR with CCS represents an excellent opportunity for initial geologic sequestration projects like Weyburn. In addition, "next generation" CO_2-EOR processes could boost U.S. technically recoverable oil resources by 160 billion barrels.[3]

CCS IN THE UNITED STATES

A DOE-sponsored R&D program, the "Regional Carbon Sequestration Partnerships," is engaged in mapping U.S. geologic formations suitable for CO_2 storage. Evaluations by these Regional Partnerships and others suggest that enough geologic storage capacity exists in the United States to hold several centuries' production of CO_2 from coal-based power plants and other large point sources.

The Regional Partnerships are also conducting pilot-scale CO_2 injection validation tests across the country in differing geologic formations, including saline formations, deep unmineable coal seams, and older oil and gas reservoirs. Figure 11* illustrates some of these options. These tests, as well as most commercial applications for long-term storage, will use CO_2 compressed for volumetric efficiency to a liquid-like "supercritical" state; thus, virtually all CO_2 storage will take place in formations at least a half-mile deep, where the risk of leakage to shallower groundwater aquifers or to the surface is less likely to occur.

[3] http://www.adv-res.com/pdf/Game__Changer__Document.pdf

After successful completion of pilot-scale CO_2 storage validation tests, the Partnerships will undertake large-volume storage tests, injecting quantities of ~1 million metric tons of CO_2 or more over a several year period, along with post-injection monitoring to track the absorption of the CO_2 in the target formation(s) and to check for potential leakage.

The EPRI–CURC Roadmap identifies the need for several large-scale integrated demonstrations of CO_2 capture and storage. This assessment was echoed by MIT in its recent Future of Coal report, which calls for three to five U.S. demonstrations of about 1 million metric tons of CO_2 per year and about 10 worldwide.[4] These demonstrations could be the critical path item in commercialization of CCS technology. In addition, EPRI has identified 10 key topics where further technical and/or policy development is needed before CCS can become fully commercial:

- Caprock integrity
- Injectivity and storage capacity
- CO_2 trapping mechanisms
- CO_2 leakage and permanence
- CO_2 and mineral interactions
- Reliable, low-cost monitoring systems
- Quick response and mitigation and remediation procedures
- Protection of potable water
- Mineral rights
- Long-term liability

Figure 12* summarizes the relationship between EPRI's recommended large-scale integrated CO_2 capture and storage demonstrations and the Regional Partnerships' "Phase III" large-volume CO_2 storage tests.

CO_2 TRANSPORTATION

Mapping of the distribution of potentially suitable CO_2 storage formations across the country, as part of the research by the Regional Partnerships, shows that some areas have ample storage capacity while others appear to have little or none. Thus, implementing CO_2 capture at some power plants may require pipeline transportation for several hundred miles to suitable injection locations, possibly in other states. Although this adds cost, it does not represent a technical hurdle because long-distance, interstate CO_2 pipelines have been used commercially in oilfield EOR applications. Nonetheless, EPRI expects that early commercial CCS projects will 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 industrial sources and storage sites will be needed.

POLICY-RELATED LONG-TERM CO_2 STORAGE ISSUES

Beyond developing the technological aspects of CCS, public policy need to address issues such as CO_2 storage site permitting, long-term monitoring requirements, and liability. CCS represents an emerging industry, and the jurisdiction for regulating it has yet to be determined.

Currently, efforts are under way in some states to establish regulatory frameworks for long-term geologic CO_2 storage. Additionally, stakeholder organizations such as the Interstate Oil and Gas Compact Commission (IOGCC) are developing their own suggested regulatory recommendations for states drafting legislation and regulatory procedures for CO_2 injection and storage operations.[5] Other stakeholders, such as environmental groups, are also offering policy recommendations. EPRI expects this field to become very active soon.

Because some promising sequestration formations underlie multiple states, a state-by-state approach may not be adequate. At the federal level, the U.S. EPA published a first-of-its-kind guidance (UICPG # 83) on March 1, 2007, for permitting underground injection of CO_2.[6] This guidance offers flexibility for pilot projects evaluating the practice of CCS, while leaving unresolved the requirements that could apply to future large-scale CCS projects.

LONG-TERM CO_2 STORAGE LIABILITY ISSUES

Long-term liability of storage sites will need to be assigned before CCS can become fully commercial. Because CCS activities will be undertaken to serve the public good, as determined by government policy, and will be implemented in response

[4] http://web.mit.edu/coal/The__Future__of__Coal.pdf
[5] http://www.iogcc.state.ok.us/PDFS/CarbonCaptureandStorageReportandSummary.pdf
[6] http://www.epa/gov/safewater/uic/pdfs/guide__uic__carbonsequestration__final-03-07.pdf

to anticipated or actual government-imposed limits on CO_2 emissions, a number of policy analysts have suggested that the entities performing these activities should be granted a large measure of long-term risk reduction.

RD&D INVESTMENT FOR ADVANCED COAL AND CCS TECHNOLOGIES

Developing the suite of technologies needed to achieve competitive advanced coal and CCS technologies will require a sustained major investment in RD&D. As shown in Table 3, EPRI has estimated that an expenditure of approximately $8 billion will be required in the 10-year period from 2008–17. The MIT Future of Coal report estimates the funding need at up to $800–850 million per year, which approaches the EPRI value. Further, EPRI expects expected that an RD&D investment of roughly $17 billion will be required over the next 25 years.

Investment in earlier years may be weighted toward IGCC, as this technology is less developed and will require more RD&D investment to reach the desired level of commercial viability. As interim progress and future needs cannot be adequately forecast at this time, the years after 2023 do not distinguish between IGCC and PC.

Table 3—RD&D Funding Needs for Advanced Coal Power Generation Technologies with CO_2 Capture

<table>
<tr><th></th><th>2008–12</th><th>2013–17</th><th>2018–22</th><th>2023–27</th><th>2028–32</th></tr>
<tr><td>Total Estimated RD&D Funding Needs
(Public + Private Sectors)</td><td>$830M/yr</td><td>$800M/yr</td><td>$800M/yr</td><td>$620M/yr</td><td>$400M/yr</td></tr>
<tr><td>Advanced Combustion, CO_2 Capture</td><td>25%</td><td>25%</td><td>40%</td><td rowspan="2">80%</td><td rowspan="2">80%</td></tr>
<tr><td>Integrated Gasification Combined Cycle (IGCC), CO_2 Capture</td><td>50%</td><td>50%</td><td>40%</td></tr>
<tr><td>CO_2 Storage</td><td>25%</td><td>25%</td><td>20%</td><td>20%</td><td>20%</td></tr>
</table>

By any measure, these estimated RD&D investments are substantial. EPRI and the members of the CoalFleet for Tomorrow® program, by promoting collaborative ventures among industry stakeholders and governments, believe that the costs of developing critical-path technologies for advanced coal and CCS can be shouldered by multiple participants. EPRI believes that government policy and incentives will also play a key role in fostering CCS technologies through early RD&D stages to achieve widespread, economically feasible deployment capable of achieving major reductions in U.S. CO_2 emissions.

The CHAIRMAN. Well, thank you all very much for your testimony. I think it's very useful.

Let me just start and do 5 minutes of questions and we'll give everyone a chance to ask some questions here and see if we want to do a second round after that.

Let me ask you, Mr. Hollinden, first. I know one of your recommendations here relates to ultra- supercritical pulverized coal and how, I think you say, we should pursue a large-scale demonstration project to spur development of ultra-supercritical pulverized coal technology.

We had a hearing with the folks from MIT, John Doitch and Ernie Menise, I believe testified. I got the impression from that hearing that they thought that ultra- supercritical technology had been demonstrated in various parts of the world, that they're using it in Germany today, they're using it in Japan, they're using it in various places. We have not used it for a variety of reasons, but why do we need to reinvent the wheel? Why can't we take the technology that has been demonstrated elsewhere in the world and put it into application here? Or am I confused about whether it's been demonstrated?

Mr. HOLLINDEN. Well, there's a lot of forms of supercritical. There's supercritical, ultra-supercritical, and advanced ultra-supercritical. We're talking about advanced ultra-supercritical here, so there may just be a difference in the terminology that we're using here.

For instance, a conventional plant would operate at 35 percent, maybe, efficiency. A supercritical plant might operate at 39, an ultra-supercritical at 42 to 44 and the advanced ultra-supercritical at 48. We're looking at the advanced ultra-supercritical. I think that the MIT people were talking about the ultra-supercritical plants.

The CHAIRMAN. So you're saying that what you're talking about seeing demonstrated at commercial scale has not been demonstrated at the commercial scale as yet.

Mr. HOLLINDEN. That's correct.

The CHAIRMAN. Anywhere in the world?

Mr. HOLLINDEN. That's correct.

The CHAIRMAN. Am I right, though, that even for the ultra-supercritical that gets you to 42 percent, we have not implemented or used that technology to the extent it's been used elsewhere in the world?

Mr. HOLLINDEN. Yes, sir. That's correct.

The CHAIRMAN. Why is that? Why are we so behind some of these other industrial countries in doing that?

Mr. HOLLINDEN. You know, as representative of the National Coal Council, you know, our study here was related to CO_2 control. So, I feel like that, you know, I could answer that as, from my, according to me——

The CHAIRMAN. Yes, go right ahead.

Mr. HOLLINDEN [continuing]. Not, for the Council—

The CHAIRMAN. Don't, just give us your own perspective on it.

Mr. HOLLINDEN. You know, I came out of the coal industry, I mean, I worked for Tennessee Valley Authority for a number of years, I've been involved in coal. In the early days, these technologies were not very reliable. So, you know, in the United States we put plants on, coal was cheap and we wanted the plants to run. So we put on technologies that ran very effectively, very reliably without much interest, I shouldn't say interest, but much need for efficiency because coal was so cheap. So, it didn't make a whole lot of difference.

The CHAIRMAN. So efficiency was much less of a priority than reliability?

Mr. HOLLINDEN. Absolutely, absolutely.

The CHAIRMAN. So, we didn't really put much pressure on, or much priority on getting the most efficient possible plant?

Mr. HOLLINDEN. That is the way it is today, too.

The CHAIRMAN. Right. OK.

Mr. Phillips, let me ask you—you made reference to the dispatch order and the fact that even if we were to build some of these highly efficient plants, the reductions in emissions would not be that great because they would be very far down in the dispatch order. I thought that's what I heard you say.

Mr. PHILLIPS. That's right, yes.

No—one of the reasons why those costs increased so much is that, for instance, in a pulverized coal plant you're going to be using almost 30 percent of the plant's output to compress the CO_2 and put it in the pipeline. So therefore, the overall, the effective efficiency of the plant goes down dramatically and because of that the operating costs of the plant for a given amount of megawatts is higher.

So, just to get the lowest cost electricity, the way it's run now, you know, the cheapest plant goes on first, the second cheapest second, and so forth. So these plants would be further down the dispatch order, unless there's some kind of an incentive for them to capture that CO_2 and put it in the ground. So, that's what I was talking about. We're probably looking at something on the order of $20 a ton or so.

The CHAIRMAN. The dispatch order is currently and historically determined on the basis on what gets you the cheapest power?

Mr. PHILLIPS. That's correct. Particularly in our deregulated States where there's a, you know, competitive generation. It's simply a matter of who bids the lowest. They get picked first.

The CHAIRMAN. What if there were a change in policy that got us to a point where we had a dispatch order that was dictated by how you get the fewest emissions?

Mr. PHILLIPS. Well, that would certainly change things.

The CHAIRMAN. Would that significantly incentivize development of these technologies in a way that they are not currently incentivized, or use of these technologies, I guess?

Mr. PHILLIPS. Right. I haven't really looked into the details. I'm more of a technologist than a policy person, so I can't say specifically, but obviously right now, the way the situation is, there's not an incentive and so any type of mechanism that did make an incentive would obviously be a help.

The CHAIRMAN. All right. I've used my time.

Senator Domenici, go right ahead.

All right. Senator Craig, you, would you? I've got a list here.

Senator CRAIG. I was going to say, I was not here first, Mr. Chairman.

The CHAIRMAN. OK.

I guess Senator Barrasso was next. Excuse me, I got out of order here. Go ahead.

STATEMENT OF HON. JOHN BARRASSO, U.S. SENATOR FROM WYOMING

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

As you know, Wyoming produces more coal than any other State, almost 500 million tons of coal, and people in Wyoming are familiar with the unit trains, the 100 cars carrying coal out of the State. As they talked, for every four cars, three are carrying coal, and one is carrying water, because that's how it is until it gets to be used.

People, as consumers, want affordable energy, and we've become more dependent on international sources of energy, and the more we can do to become energy independent, I think the better it is for our Nation, and clearly, the better it is for my State.

The technology needs to be there, for efficiency, so that we can generate more electricity from the same amount of coal, but the people of Wyoming would agree that we're at a unique position now. I've been in the legislature in Wyoming, legislators have been to the mines, have seen the technology, we have an entire Wyoming infrastructure authority, looking at some of the things that are important to us, as a State, because we think we can be very helpful in making the Nation energy independent.

In a program called Leadership Wyoming, for 7 years in a row, people travel around the State, bipartisan, looking at what we can do, and we look at coal technology, coal-to-gas, coal-to-liquids—ways to convert coal into electricity and then build the transmission line to move the energy in a more efficient way.

When I look at this—and you say you want to try to find the right incentives for the carbon dioxide, one of the thoughts is, carbon dioxide can be used for enhanced oil recovery from oil wells, and you know, if you could get the technology so that, in a place where you have oil wells, like Wyoming, and you have coal, like Wyoming, and the carbon dioxide can be used from one to the other, than the carbon dioxide can be pumped into the wells to enhance, and gain more energy.

I guess the first question would be—wouldn't Wyoming be the best place in the world to do all of these things? Even though you're all from the East Coast?

The additional question is, how do we get this done? I mean, you're looking for incentives, but we need to get this technology advanced, throwing a lot of money at it in 1 year isn't going to solve it in a year. There's a *Wall Street Journal* article yesterday, Australia Pushes Clean Coal, there, you know, coal reserves in Australia and in the United States, in China—is America going to have to lead the world in coming up with the technology, and then sharing it internationally with some of these others? What's the best way to get that done?

Mr. BAUER. I appreciate your insights, Senator. The question—obviously EOR is probably one of the early places that we can use CO_2. In fact, one of the issues and challenges of EOR, is where do you get the CO_2, so most of the EOR, to date, in the country has been using naturally occurring CO_2, and most of it has been in the Permian basin.

Anthropogenic CO_2 is about three to four times as expensive, and that puts a chill on the economics around EOR. So, having an abundant supply of CO_2 that was at cost, substantially more competitive than it presently is from man-made, would be very helpful.

So, that leads to your question about capturing CO_2, and using it effectively. I think the simple answer to that is yes, but right now, the policy and dynamics around capture that don't really foster that effort, it's purely a marketplace decision, and as you're probably aware, the gasification facility in North Dakota sends EOR up to the Weyburn Facility in Canada, to do EOR. That CO_2 pipeline was invested in by DOE, the Federal Government, to evaluate how does that work? It's been very, very, profitable for the company, and I think the information we've gathered about large-scale injection of CO_2 has been very helpful.

I don't know if that helps you with your answer, but I think that capture technology that will get the economics down to capturing and separating CO_2 is an essential part, just as Jeff was talking about, as far as just dealing with electricity costs.

Senator BARRASSO. It just seems, Mr. Chairman, that so much has to do with BTUs, and how to capture the energy, and how to do it in a clean, efficient way, and I think that we can really go a long way, when you just look at the amount of coal resources that are available in this Nation. I mean, there is this source of energy, and the more that we can do, and the more that we can encourage, you know, as a Government, to put clean coal, and all those technologies, coal liquification into gas, into liquids, the better it's going to be for our Nation, and our own energy independence.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you very much.

Senator Salazar.

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

Senator SALAZAR. Thank you. Thank you very much, Chairman Bingaman, and Senator Domenici for holding this hearing. I remember our committee hearings on the Energy Policy Act of 2007, whatever the name is, that we just passed. The dialog that we had in this committee with Senator Thomas, Senator Barrasso, and Senator Tester who, and others who were very interested in the coal issue, and how we can deal with the most abundant resource that we have here in America today, and try to use it as one of those items on the menu that gets us to address the very critical energy issues that our country faces.

Today, as I understand, we're looking at—based on the latest oil prices, $72 per barrel, and I think we're going to continue to see a robust agenda on the part of the United States Congress, to try to figure out ways of moving forward toward energy independence. I've always said those drivers are not only National security and economic, but they also now have to do with our environmental security here as a country, and that seems to be the challenge with respect to how we move forward with coal resources.

So, my question to you has to do with respect to how we might be able to reconcile the use of coal with the challenge that we face, regarding global warming, and how, specifically we might be able to use coal-powered energy for hybrid plug-in vehicles. I think two-thirds of our oil today is currently used for transportation. Plug-in hybrids, I think, have a tremendous opportunity in terms of dealing with the transportation issue, and it also seems to me to provide a great opportunity for our coal resources and our coal industry to be able to produce electricity and to sequester the carbon from those plants.

So, I'd just like, starting with you, Carl, going through and commenting how the hybrid plug-in technology is also related to what we do with coal development and carbon sequestration.

Mr. BAUER. I think it's an astute observation, Senator, we did a study at NETL just recently in looking at the alternatives to liquid transportation fuels, and plug-in hybrids was one of the areas that we thought was a way to reduce the dependency on the imports, or the demand on fuel liquids.

So, obviously that increases the demand for electricity, and 50 percent of electricity comes from coal. I would suggest that the large base load plants—nuclear and coal—as well as renewable portfolios, would have an opportunity to contribute more to transportation fuel offset.

So, back to your question—how does coal deal with that? Or even natural gas combined cycles, when you have a CO_2 issue? Again, we go back to having good, solid technology for capture at a lower economic cost, and the ability and the regulatory framework for decisions to be made in the marketplace to take that CO_2 captured and put it someplace for storage, long-term, or we're looking at trying to find ways to use CO_2 as a product, not just as a waste problem.

So, for example, we're stimulating algae growth to see what we can do to get more efficiency out of the carbon by creating biodiesel from the algae. That adds to the offset of the carbon, and provides electricity for plug-ins, and you have two ways of addressing liquid fuels that way.

Senator SALAZAR. Mr. Hollinden.

Mr. HOLLINDEN. The National Coal Council did not look at hybrid coal technologies, so I would be speaking for myself, as opposed to the Council. If that's OK?

Senator SALAZAR. Go ahead, give me a quick remark and then we'll go with someone else.

Mr. HOLLINDEN. I think one of the overriding issue that I have with all of these technologies, is a continued negative press we get with "dirty coal." You know, and it doesn't help our communities, when they hear this, that coal continues to be dirty. Every time we pick up a paper, we hear of "dirty coal" and "clean gas."

In fact, when these clean coal technologies, advanced coal combustion technologies, gasification technologies are implemented in 15, 10 or 15 years with CO_2 control, they're going to be cleaner than gas. It's never put in the paper like that.

Senator SALAZAR. Well, let me——

Mr. HOLLINDEN. I think our folks need to understand, our people need to understand——

Senator SALAZAR. [continuing]. Let me just say this, Jerry, from my point of view, we have struggled in this committee, many of us come from coal-rich States, and I do, and I support the coal industry in my State. How we reconcile the development and use of our coal with the environmental realities of the consequence of coal, is something that we all struggle with.

It seems to me that so long as transportation consumes two-thirds of our energy, it's going to continue to be a National security driver that all of us are going to agree, we need to do something with. So, I would encourage you and the National Coal Council and others to look at how we use coal in connection with our transportation needs, and specifically looking at plug-in hybrids.

Jeff, can you just make a quick comment on it?

Mr. PHILLIPS. Yes, EPRI has been looking at plug-in hybrids for quite awhile, and in fact, we just issued a joint report with NRDC on the impact of plug-in hybrids on overall emissions in the United States economy, and it shows that indeed, this is a favorable pathway.

I mean, when you think about it, as costly as it may be to put CO_2 capture on the back end of a coal plant, it would be even more costly to put it on the back end of an automobile.

If you look at a future electric power sector that is decarbonized with solar/wind, solar and coal plants with carbon capture, we basically will have a carbon-free fuel that you could, then, to run your automobiles.

Senator SALAZAR. OK. Thank you.

Mr. PHILLIPS. I think it's a very wise policy to pursue.

Senator SALAZAR. My time is up. Thank you.

[The prepared statement of Senator Salazar follows:]

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

I want to thank Chairman Bingaman and Ranking Member Domenici for holding today's hearing on clean coal technologies, and efforts to capture and store carbon dioxide. I am proud of our achievements on clean coal technologies in the Energy Policy Act of 2005 and on carbon sequestration in the Energy Savings Act of 2007. There is more work to do, however, particularly given the very real near-term as well as longer-term opportunities for carbon capture and storage and the commercial deployment of advanced coal utilization technologies. So I appreciate the efforts of Chairman Bingaman, Ranking Member Domenici, and the committee staff putting this hearing together.

My home state of Colorado is endowed with many natural resources, including vast coal resources. In Colorado, 71% of the electricity we produce is generated with coal. Colorado consumed 18.9 million tons of coal in 2004, generating 37.5 million megawatts of electricity. Most of this coal comes from Colorado, but some of it is from Wyoming.

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, there seems to be more than one way to reconcile coal use with protecting our climate, through new low-carbon technologies such as Integrated Gasification Combined Cycle (IGCC), Oxycoal and ultra-supercritical combustion technologies. In addition, advancements in capturing carbon and safely sequestering it underground will allow our country to use coal, and at the same time reduce CO_2 emissions. I am proud of the work this Committee did in the Energy Savings Act of 2007 to promote research, development and deployment of carbon capture and sequestration technologies, and to do an assessment of our nation's carbon storage capacity. What we learn from the national assessment may be valuable in determining optimal locations to place coal gasification and other new power plants to put them near areas where the CO_2 emissions can be safely sequestered.

Advances in technology indicate that a coal plant using combined cycle technology, carbon capture and storage, and biomass as part of the fuel source can result in far lower greenhouse gas emissions. It is my understanding that even some coal-to-liquid processes can use up to 30% biomass in the feedstock, which reduces the CO_2 emissions from the process. The use of a renewable fuel like biomass in these plants presents a great opportunity to allow for an expanded use of coal without adding to global warming.

I also believe plug-in hybrid electric vehicles present an important opportunity to utilize coal—to make electricity—as a source of transportation fuel, and thus to displace large quantities of petroleum-based transportation fuels. Because two-thirds of our transportation fuels are derived form petroleum products, plug-in hybrid electric vehicles powered by electricity generated from renewable sources and from advanced coal power plants with carbon capture and storage will enable us to achieve greater energy security, economic security and environmental security in this country.

Thank you Chairman Bingaman and Ranking Member Domenici for holding today's hearing so that we can learn more about how our country's greatest fossil fuel resource can be used to power our homes and businesses as well as to fuel our automobiles.

The CHAIRMAN. Senator Domenici. Senator Craig. Either one, whoever wants to go.

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

Senator DOMENICI. All right, thank you. Thank you very much, Mr. Chairman.

Let me say that it's very, very important that a hearing like this one occur. We must go before our Congress, and before the people of this country the facts about coal, and coal in our future.

Incidentally, if you wonder what deep thoughts I was exchanging views with the man on my left and the man on my right, in case you wonder, the three of you, I was telling him, each of them, that you are dressing much better these days.

[Laughter.]

Senator DOMENICI. Mr. Salazar, I was talking about the coal industry being dressed up in pretty good attire these days, there must be that there's something good on the horizon. In any event, I'm with you.

I wanted to ask some questions, panel one. Carl—the Department of Energy's goal is, "To develop by 2012, fossil fuel systems with 90 percent CO_2 recapture, 99 percent storage, at less than a 10 percent increase in the cost of energy." I've noticed that the National Coal Council makes a clear recommendation in their report to the Secretary that technologies should not be abandoned today, just because they can not immediately meet high capture expectations, early in their development cycle.

Can you explain this concept in greater detail? It is an important one—to what extent do the existing clean coal programs at the Department account for it?

Mr. BAUER. Thank you, Senator. Yes, I will attempt to clarify that.

I believe what the National Coal Council is recommending, and what the Department of Energy and National Energy and Technology do in the implementation of fossil program, it's R&D, so it wouldn't be R&D if we knew the answer, we'd just go and do it.

As we go through R&D, we do systems analysis of the research, as well as the application, to see that if the technology would, in fact, work, would it be economically viable, so that someone would buy it and put it to work? Because they have to go back into the dispatch rate base.

However, having said that, it depends on what stage of development the technology is in. Early in the technology, an analysis that suggests it doesn't work, may suggest why—from the economic standpoint—it wouldn't be acceptable, and that could then be resolved with further technical efforts. So, instead of abandoning that approach, it's wise to recognize the issue, and see how that issue can be further dealt with, technologically, so that technology does come forward.

It's also important for us to have multiple paths forward, because as they go down the line, go to the races, not all of them are going to make it to the other end, but the more opportunities we have to get to the other end within the budget allowance, it makes good decisions to get there. It also, chronologically speaking, gets us to technological solutions, sooner, and I hope that helps, Senator.

Senator DOMENICI. You got it.

In terms of our ability to retrofit the existing coal fleet for CO_2 capture and storage, we must account, not only for predictable increases in electricity demand, but also the inevitable losses in the output of existing plants that seek to incorporate and capture technologies.

What implications do you believe this trend will have for the pace at which carbon dioxide capture, and existing plants, can be achieved? Even once those technologies have reached commercial availability? Carl, you want to do it?

Mr. BAUER. OK, I'll take that on.

I think that, again, as Jeff alluded in his testimony—if we were just to, for example, to quickly provide an insight to this. If we were to take today, and then Congress put into law, and regulations were in effect, they would say that we have to capture half of the CO_2 from the existing fleet.

Right now, our calculations suggest, on existing technology, that would be about a 15 percent reduction in delivery of electricity, 15 percent reduction in the efficiency at the end point of delivery.

That translates to the need, if you want to deliver the same amount of electricity that we presently have—when you think about with the plug-ins, you need more—that would mean we need 42 gigawatts of additional power capacity to offset the loss of power required to deal with the CO_2 capture and sequestration challenge of taking 50 percent of the CO_2 from the existing fleet, and putting it into sequestration.

That's a huge—42 gigawatts, coupled with all the other growth that we need—is a huge amount of power to generate, or to replace, figuring a plant takes 6 to 8 years to get through permitting and construction, whether it's nuclear or coal, those are pretty ideal times. It's probably more like 8 to 10 years, natural gas combined cycle, if we're lucky, 3 to 4 years, but then for every 25 gigawatts of gas, you need another 1 trillion cubic feet of natural gas supply.

So, the challenge is very surmountable, and the economic impacts. By the way, if we did that, our numbers predict about an increase to about $85 a megawatt, compared to existing fleet, presently $25 megawatt as of older plants. So, it's a substantial economic, not just technological challenge.

Senator DOMENICI. Thank you very much.

Mr. PHILLIPS. Can I also respond to that, Senator?

Senator DOMENICI. Jeffrey, it's your question, your answer, too.

Mr. PHILLIPS. Yes, well, EPRI recently put out what we call our Prism Analysis, or some people call it our wedge chart, which shows how we could remove CO_2 from the emissions of the electric power sector using various projects, and in that analysis we show that you could drop down to 1990 CO_2 emission levels by 2030, and in that analysis, we did not assume any retrofitting of CO_2 capture. Only CO_2 capture on new coal plants.

Now, we're also doing very aggressive things on the energy use side—better efficiencies in the homes, increases in solar and wind usage, increases in nuclear power, and higher efficiency for existing plants. That was the one retrofit that we said was, you can go back into existing plants and improve their efficiency, and reduce emissions by maybe 5 percent just doing that.

The problem with retrofitting is that some plants, it might be cost-effective, other plants, they've already had so many other things retrofitted to them, that you'd have to put the CO_2 capture stuff on the other side of the highway, and it would get very, very costly.

Senator DOMENICI. Thank you very much.

Thank you, Mr. Chairman.

[The prepared statement of Senator Domenici follows:]

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

Good morning, I want to thank the Chairman for scheduling this important hearing. Coal is our most affordable and abundant fossil fuel. We generate over half of our electricity with coal. But coal is a versatile feed-stock as well, and electricity is not the only product we can make from it. During our recent energy debate, there was a desire to support new alternative uses of coal. However, there was stiff resistance to those efforts, largely based on concerns about the cleanliness of coal.

The term itself, "clean coal", is a moving target, however. Its definition, and the technology needed to meet that definition, has evolved over time. We have devoted significant resources over the years to making coal clean. We now find ourselves focused primarily on carbon dioxide and its impact on global climate change. In that context, we can, and should, continue to make coal cleaner.

It is important to do so, given that coal accounts for nearly one third of our carbon dioxide emissions. This effort will be undertaken at a massive scale, and it will be a challenging one.

To provide perspective, consider that the amount of coal produced during a typical week this month would, if shipped by rail, fill 2,100 trains with 100 cars each and stretch across 2000 miles—that's two-thirds the width of the entire United States. We use nearly 1.2 billion tons of coal per year, and that figure is expected to increase with time. The challenge presented by the environmental improvements we seek is equally significant, but I believe we are up to that challenge.

In 1989, our country was generating 1,583 billion kilowatt hours of electricity from coal. By 2005 that figure had increased by 27 percent to 2,013 billion kilowatt hours per year.

During those same 16 years, the emissions we have traditionally used to define clean coal went down significantly. Sulfur dioxide decreased by 48 percent per unit of power generated, and nitrous oxide went down 66 percent.

We do not owe this progress to a purely regulatory approach, but to innovators and investors who have cooperated with the federal government to develop and commercialize better technologies.

We have always sought to cushion the blow associated with environmental limitations through public-private partnerships, and the case of carbon dioxide should not be an exception. The task before us now is to continue—and expedite—this historical trend of environmental improvement.

Today, we will hear from witnesses to clarify the appropriate definition of what "clean" coal is. We must know what technologies can be deployed to meet this definition and when they will be available. Make no mistake—this will be expensive, so we must also know the costs in order to minimize the financial burden passed along to consumers.

This conversation must take place in the context of our nation's environmental, economic and energy security priorities. In all 3 of these categories, it is in our best interest to expand, not limit, our future use of clean coal.

I thank the witnesses for appearing today and look forward to hearing their testimony.

The CHAIRMAN. Thank you.

Senator Dorgan.

STATEMENT OF HON. BYRON L. DORGAN, U.S. SENATOR FROM NORTH DAKOTA

Senator DORGAN. Mr. Chairman, Thank you very much. It's interesting that we meet during a week when oil is at $78 a barrel, and are now talking about coal, which of course, is our most abundant resource. It's also interesting that all of these hearings have changed, because we've come to an intersection that's a new road for us, and a new intersection. We are not going to talk about coal development in the future, without talking about climate change and CO_2 capture and sequestration.

The question on that is not whether, it is how, and when? Because only addressing how and when, only then will we be able to—in my judgment—have full use of the most abundant resource that we have.

I wanted to mention a couple of things. Senator Domenici and I chair the Appropriations Committee that funds these projects and accounts, and Senator Domenici has chaired that same Subcommittee on Appropriations, and now, is now the Ranking Member. For example, we have—carbon sequestration in 2007, we had $100 million. The Administration has requested in their 2008 budget, $79 million. We put in $132 million. So, the Administration was proposing 20 percent less than we actually spent in 2007.

Advanced research, about the same, almost a third less. You know, a range of these accounts are not being funded the way—one would expect if this is a priority, than you boost funding in research, especially in these areas of carbon capture and sequestration. That has not been the case.

We have, however, increased that funding in our subcommittee, believing it's a priority.

I want to mention one more thing, and then I'm going to ask you a question. In North Dakota, most of you know we have the nations only coal gasification plant, we make synthetic natural gas from lignite coal. We also have built a pipeline to the oil fields in Alberta to transport CO_2. We capture about 50 percent of the CO_2, we send it to Alberta, Canada, they invest it in their oil wells, to increase productivity of marginal oil wells.

Now, I read recently that there are—and I don't know whether this is a good report—but I read that some suggest that there are over 200 billion barrels of oil that remain as residual oil in partially produced wells, or mature oil fields. By contrast, for example, the Saudis, we believe, have reserves of around 270 billion—that's the largest reserve in the world. This 200 billion would be about 10 times of what we expect our reserved to be.

If that's the case, and if we can find beneficial use of carbon sequestration, by investing in these oil fields, and dramatically increasing the supply of domestic oil, we'll have done a lot of things that are important: unlocked our ability to use coal, dramatically improved our capability to increase oil supplies, and also protected our air shed.

That's why this hearing is so unbelievably important. Because, I mean, it will determine what kind of energy future we have, if we get these things right. I'm not certain, by the way, Future Gen is the right approach, by building one huge plant. I think there are many ways to try to figure out, how you combine various technologies, and evaluate what the combination of various technologies mean, in terms of practical capability for the future? We've sort of loaded this into one big wagon and said, "All right, we're going forward with this big wagon." I'm not so sure that we shouldn't have broken it into a number of different parts.

Having said all that, let me ask—are the three of you optimistic, or pessimistic, or have mixed feelings about the proposition of our being able to really find the methods of capture and sequestration which unlocks our ability to use this resource? Do you feel optimistic we can do this in a reasonable timeframe, and do it well, Carl?

Mr. BAUER. I'm very optimistic we can do that. I think we've already had, through the regional partnerships, and the National Laboratories and the universities that have been engaged heavily in this, as well as the oil and gas industry, which has been doing EOR for a long time, a lot of information that indicates carbon capture and storage, the storage part is very doable. We know we can do capture today, the problem with capture today is the economics around it, can we afford to do it today at the price that it would drive our electricity price in this country? Electricity and GDP seem to run very parallel to each other, as opposed to energy, which is slightly lower, because we are much more efficient at using our energy.

So, I believe the answer is yes, we can do that. Having the regulatory framework for an industry that doesn't do that as a normal cause is important for them to make the business decisions and be able to build it into the rate base, or whatever approvals they have to go with the Commissioners.

I also believe we have capture and separation technologies that over the next decade will substantially improve the costs, and get toward the DOE goals. I can go over those another time, but I believe so.

Just as one sidelight to the EOR—for all of the EOR that's been done in this country to date, we have only produced 1 billion barrels of oil from EOR. So, the Senator's right—there is a 200 billion barrels, or if you go down below 5,000 feet, there's probably 400 billion barrels that are possible, that could be recovered, however, that's technologically possible, not economically viable without better technology or cheaper CO_2.

Senator DORGAN. Are the others optimistic?

Mr. HOLLINDEN. Yes, I am, too. From a different perspective, I'm with an architect engineering company, and you know, over the last 30 years, every challenge that's been thrown at the coal and utility industry has been met, whether it's been SO_2, whether it's been NO_X, whether it's been particulates, now it's mercury——

Senator DORGAN. Mercury.

Mr. HOLLINDEN [continuing]. Now we're looking at CO_2, you know? I mean, we can bring the solutions, you know, to the table. I mean, that's what we're here for, and, as engineering companies, and developers, and as my colleague just said—it's a function of cost, and risk today of these technologies.

Remember, we can develop CO_2 removal, quickly, but that CO_2 has to go somewhere. I think we've got to remember that we've got to do this simultaneously. We've got to be developing sequestration technology at the same time we're developing CO_2 control. Because, we can be removing CO_2, and have no place to put it. It's a lot different from the SO_2 removal, and NO_X in there, where you can put sulfur dioxide material, you know, in wall board plants on the ground. You remove CO_2, and you haven't demonstrated a place to put it, you know, you have to shut that facility down.

Senator DORGAN. Jerry, you complained about not getting good press for the coal industry, I'd remind you that the statement—bad news travels halfway around the world before good news gets its shoes on. It's something we understand here, and I understand, I understood your complaint.

Mr. Phillips.

Mr. PHILLIPS. Yes, Senator, I am also optimistic, but it's going to take a sustained effort. I told some engineering students at Virginia Tech, this is your moon shot, this is your generation's moon shot, that's the level of effort that it will take to make this happen. We did put a man on the moon, and we did it in 10 years. We're talking about something that we need to do in 20 years, it can happen, and I think that EOR is going to be a very key bridge to making that happen.

Because, as you point out, you can make money from that. I used to work in the oil business, and so I'll give you a general rule of thumb—take the price of oil in dollars, per barrel, divide that by 2, and that's the price in dollars per ton that the oil industry should be willing to pay for CO_2 in enhanced oil recovery. So that's if it's $73 today, then that's what—about $36.5 per ton.

Now, unfortunately, those numbers right there are based on technology that's probably going to cost us $50 a ton. So, it doesn't quite cover the cost, but it sure covers a lot. If we could use that, his, Carl Bauer's program has done an analysis that shows that if we just captured CO_2 from half of the new power plants that are built between now and 2025, use it for enhanced oil recovery, we could double United States domestic oil production.

Senator DORGAN. That's a very important piece of information. I've gone over my time, but I thank the Chairman.

Thank you very much.

The CHAIRMAN. Thank you very much.

Senator Craig.

STATEMENT OF HON. LARRY E. CRAIG, U.S. SENATOR FROM IDAHO

Senator CRAIG. Well, in that very exciting concept, Jeff, you excited me more when you talked about your desire to have an AMC Pacer. I, too, wanted one.

[Laughter.]

Mr. PHILLIPS. I had to settle for a Gremlin.

Senator CRAIG. I didn't even get that far.

Well, we were farming and ranching in those days, and there was no money in cattle, so my dad and I couldn't afford even the Gremlin, let alone the Pacer.

[Laughter.]

Senator CRAIG. That's probably why I drive a Honda Element today. Something in my mental background that would suggest I kind of like big boxes.

[Laughter.]

Senator CRAIG. Anyway, having said that, you talk about the legal challenges, the good news, the bad news, and the bad news/good news——

Mr. PHILLIPS. Yes.

Senator CRAIG. Walk us through the ultimate legal challenges that you see that we can be players in that continue to allow the technology and the industry to move in the directions we want it to move in.

Mr. PHILLIPS. All right, well, one of the biggest things is just, just, you know, who owns the CO_2 once it goes into the ground, who's going to be liable if it starts to leak back out——

Senator CRAIG. The Big Belch, in other words.

Mr. PHILLIPS. Yeah, or it finds a stray oil well that we didn't know about, and it starts coming up there, are you liable to pay money? Or are you just liable to fill up the hole? Do you have to capture additional CO_2 somewhere else and put that in the ground?

You know, and then there's, you know, the usual silly things that you're going to expect, that somebody's, you know, rose bushes die, and they attribute that because of the, you put CO_2 in the ground 50 miles away. Those kind of things need to be addressed also.

Senator CRAIG. Those are serious things, at the same time, as a percentage of the whole, what percent of the impediment exists in those legal questions today? In your mind?

Mr. PHILLIPS. It's enormous, it's hard to overstate it. Two things that bankers and insurance companies don't like is uncertainty. Right now, that's all we have when it comes to geologic sequestration of CO_2, because we haven't done very much of it, nobody really knows what could be the consequences. Nobody knows what the rules are. If I put CO_2 underground in the ground that I own, and it goes over to the ground you own, do I have to pay you money for that? Right? I mean, all of these things have to be taken—EOR. We've got the pipeline up in North Dakota, they allow 1 percent of sulfur in that CO_2. The pipeline down in Texas, they allow 10 parts per million. What's the basis for those two? What am I supposed to design my plant to be able to do? We need some——

Senator CRAIG. So you need uniformity.

Mr. PHILLIPS [continuing]. We need some uniformity.

Senator CRAIG. You need certainty.

Mr. PHILLIPS. We just need to know what the rules are going to be.

Senator CRAIG. Legal structure brings that.

Mr. PHILLIPS. Right.

Senator CRAIG. OK.

Mr. PHILLIPS. I think that the liability question, I think if we're going to ask power companies to put CO_2 underground for the public good, that we need to provide some kind of a mechanism to say, "OK, if you follow the rules, and do this the way we want you to, you know, you're now exempted from liability after you've met all of those requirements."

Senator CRAIG. I want to thank Senator Dorgan in his new role as chairman of that subcommittee that he spoke of for funding sequestration R&D. I think that's extremely valuable as we continue to move this spectrum forward.

Having said that, recently the Senate passed an Energy Act of 2007, and in that Act was a section related to carbon capture and sequestration demonstration project at the Capitol Power Plant. I looked at that and thought, "Gee, that's a nice political feel-good." Is it realistic to take one of these old plants in the heart of a capitol city and practice any form of reasonable sequestration? Or carbon capture? Or is that simply a waste of money? Maybe that's a question too hard for you to go to.

Where should we be doing this kind of R&D, other than in our Nation's Capitol. Out in Wyoming?

Mr. PHILLIPS. I know two Senators who would——

Senator CRAIG. Jerry and Carl, I'm not going to let you off now——

[Laughter.]

Senator CRAIG. We put Jeff on the hook, why don't you respond to that? The latter part of the question?

Mr. BAUER. I appreciate the latter part, not the first part.

Senator CRAIG. I'm sure you do.

Mr. BAUER. I believe that the plan that we have going forward is a very solid plan. Because, as Jeff was talking about, some of the legal constraints, there's also the acceptance constraints. Part of the regional partnership issue is, getting the States—I mean, let's face it, this is done locally. We can decide here in Washington what we think is the right thing to do, but the people who have to put it to work and live with it are out there where they live.

So, part of the regional partnership was both to collect the scientific and technical information required to ensure that this was right and safe in that scale, and to identify the places that it could be done, and it covers 97 percent of the country's most probable places, and power and industrial CO_2 production, so it's covering a broad spectrum of opportunity, and to get the regulators, the State officials, the citizens, the academia of the State and region actively involved so they can understand it, so as this becomes law, and as it becomes regulation, they have already engaged in the process, and so we can continue to move forward, for those of us who got involved in applying CIRCLA and RICLA, we know we went through a decade of legal battles about doing things, because we didn't get people comfortable about what was being done, and there were tremendous battles.

This is an important issue, to move it forward requires extensive large-scale demonstrations and scientific and technical work around that, but it also requires the work of the people in the area to understand what's going on, so that they feel comfortable and acceptable risk around this whole issue.

So I think, the question you ask is really, we need to do it out in the States, and the States that have the highest probability of using CO_2 capture are the ones that have substantial industrial CO_2 generation, or power generation CO_2, and do have reservoirs. In fact, that's what the regional partnerships represent, and have aggressively got companies to put money up.

The regional partnerships don't just live off the largesse of the Federal dollars, there is a tremendous amount of investment from the private sector with them. So, I think we're getting a tremendous move forward in accelerating the process of acceptance and understanding how to do it legally right there.

Senator CRAIG. Mr. Chairman, and Senator Domenici, the reason that I ask that question—while I understand sometimes we do things that are politically "feel-goods," the reality is that siting some of these facilities is not unlike how we're siting new reactor generator facilities. The easier siting comes where they are, and where there is, in my opinion, a feeling of understanding on the part of the populace, as it relates to the need to site.

Case in point, we had a company try to site a major coal—it would have been a merchant generator, a major coal plant in Idaho, 2 years ago. Right by the rail, had its water, could have used Wyoming coal, and the State of Idaho said no. The people said no. Now, I won't suggest that it made the siting possibility, opportunity may not have been handled as well as it could have been, but the reality was, and it goes back to what Senator Dorgan is saying, there was a great opportunity here, but it probably occurs where it already is, from a standpoint of acceptance and understanding, and the issue of cleanliness, i.e. non-emitting, is paramount now, in the minds of most Americans. We've got to get this thing done, and the only way we're going to do it is in partnerships and investment to get us off from an 80 percent escalated cost. That's unacceptable.

Thank you.

The CHAIRMAN. Thank you very much.

Senator Sessions has been waiting, why don't we go ahead and have you ask your question. Then Senator Tester, and then we have a vote at 10:35, at least that's what I've been informed, so maybe we can conclude the questions of these remaining two Senators, and then finish with this panel before we go to vote.

Senator Sessions.

STATEMENT OF HON. JEFF SESSIONS, U.S. SENATOR FROM ALABAMA

Senator SESSIONS. The Economist Report of June 2, reports that coal produces 50 percent of America's electricity, 70 percent of India's, 80 percent of China's, it's widely distributed around the globe, noting that China is adding coal-fired, powered plants at a remarkable rate. Two 500–megawatt coal-fired power plants are starting up every week in China, which is each year, they're adding more than Britain has, total. So, coal is a real factor in everything that we must think about, as we consider electricity for the future.

There was a book by, Mr. Chairman, I believe it's Jacquard, a Canadian who analyzed all of this, and global warming, and concluded that fossil fuels capture is the best way, long-term, for America, for the world, to meet our global warming, and energy needs. So, I don't know where we are. We certainly have a lot of coal.

Let me ask you first, Mr. Bauer, if you have concluded in the next, say 20 years from today, if you produced clean coal with capture, and nuclear-generated electricity, what would be the relative cost of those two, do you have any idea?

Mr. BAUER. I would submit that if the research that has been done, and the technologies that are coming forth, implement, in today's dollars, let's say, we would see, hopefully we'd be meeting our goals of maybe 10 percent to 15 percent increase in electricity, assuming that the demand for electricity doesn't outstrip the supply, and then we get into market dynamics of supply and demand.

I think the same thing is true on nuclear power, I happen to come from a nuclear power background earlier in my career, and both opportunities for power generation are substantial base load contributors that, up and running, keep chugging along and generating. So, for coal, CO_2 capture at a decent price, and CO_2 sequestration being understood and utilized, I think the prices will stay in a very marginal area, and we have plenty of sequestration and storage opportunity, according to the USGS reports, and our analysis of that.

Senator SESSIONS. So, my, my, I guess a consumer goes and pays his bill, he doesn't expect a great difference between clean coal cost of electricity and a nuclear base load cost of electricity?

Mr. BAUER. I think if you look—one of the problems that I question is a fact of materials availability. If you look at both GE's comments on the meeting with Hitachi, and merging to make power plants, they raise their price from the merger a year ago to now by 50 percent, all based on concrete and steel availability. That's an issue we're not talking about, but that is a big issue of building power plants, capturing CO_2, and building nuclear power plants that is really going to drive that price up.

Now, if we can get that back under control and balanced by rebuilding our capability to produce—a different issue, I know, Senators—then I think the prices can come back into operation and construction that are reasonable to what we experienced today, a little higher because of having to do additional things. The fact that we're down to about 20 percent of what original scrubber technology cost today, at this, the inflated dollars, should suggest we have the same opportunity to go forward with improved technology, and it becoming ever less expensive.

Senator SESSIONS. One of the things I think we would need to ask, and maybe, Mr. Phillips would have an idea or any of the others, it seems to me that there are certain areas of the country more capable of storing CO_2 than others. A Federal mandate that requires that, do you have any idea—is that true? Should there be any compensations for areas not able to do so?

Mr. PHILLIPS. It's certainly true that there is some areas that don't have good areas underground for storing CO_2, unfortunately, my State of North Carolina is one of them, we'll have to send a pipeline over the Appalachian Mountains to find a good location, maybe we can send it all the way down to Alabama if you'll let us. Whether there should be compensation for that, I don't know, but I think it speaks to your first question, which is, we can't do it all with carbon capture from coal power plants, we can't do it all from nuclear, we can't do it all with renewables, there is no silver bullet, what we need is silver buck shot—we've got to try it all.

[Laughter.]

Senator SESSIONS. Mr. Chairman, I know your time, I'll yield back, thank you, sir.

The CHAIRMAN. I think the vote is about half over, so let me move, go to Senator Tester.

STATEMENT OF HON. JON TESTER, U.S. SENATOR FROM MONTANA

Senator TESTER. Thank you, Mr. Chairman.

So that means your answer is going to have to be very concise.

I think this is for Carl—the Future Gen project is a—appears to be a pretty decent project, public/private partnership for zero emissions. It appears to be going slower than what I thought. Give me your perspective, tell me what you think on where it's at as far as moving along, and tell us what we can do to help push it along.

Mr. BAUER. It was an easy question, at least.

Senator TESTER. See if you can do that in 15 seconds or less.

Mr. BAUER. The Future Gen Project, actually, is moving along for a general coal-type utility project, pretty much as they normally do. So, it seems slow, but that is a real sense of what it takes to build these large plants. It has some conditional issues about finding the State and location to put the CO_2 in, which has added to the timeframe. We're hoping that a selection of site will be completed by the end of the calendar year, and that by next year, assuming Appropriations and everyone agrees to go forward to the larger money about actual design and building, design work is going on right now, will continue on the schedule to still meet our goal of testing by 2012, and proving that sequestration works at large scale. How do we imperil that will also be proving the sequestration side for the regional partnerships.

FutureGen also is to prove that the theory about capturing CO_2 inexpensively from IGC, running hydrogen turbines which don't run anywhere today, all of the issues about gas cleanup and the economics will also be improved in the integration and balance of plants. Those are big challenges that are often lost in the discussion of CO_2 capture that that FutureGen Project is also going to try to answer.

Senator TESTER. Is there anything we can do to push it forward, or do you think it's adequately moving the way it is?

Mr. BAUER. I think the progress is being made in a very timely manner, I do think that, you know, the continued funding and recognition of funding will be there, helps the industry decide they want to put their shoulder to it and keep pushing, rather than kind of going along wondering if they should make the investment. I know that's a big challenge for the country.

Senator TESTER. Thank you, Mr. Chairman. We've got to go.

The CHAIRMAN. All right.

Let me thank all three of you, this has been very useful. We have one other panel that we will return to in about 10, 15 minutes, and resume the hearing.

Thank you, we're on recess for that period.

[Recess.]

The CHAIRMAN. Why don't we go ahead with the second panel. I apologize to everybody for the long delay. They had various problems on the Senate floor getting a second vote accomplished.

This second panel, let me just introduce the people here.

Mr. Don Langley, who is the Vice President and Chief Technology Officer with Babcock & Wilcox Companies in Barberton, Ohio.

Mr. Andrew Perlman, who's Chief Executive Officer with Great Point Energy in Cambridge, Massachusetts.

Frank Alix, who is Chief Executive Officer with Powerspan in Portsmouth, New Hampshire.

Jim Rosborough, who's Commercial Director for Alternative Feedstocks with Dow Chemical Company.

Bill Fehrman, who's the President of PacifiCorp Energy in Salt Lake.

Thank you all for being here and why don't you each take about 5 minutes and summarize your main points. We will put your full statements in the record.

Mr. Langley, go right ahead.

STATEMENT OF DONALD C. LANGLEY, VICE PRESIDENT AND CHIEF TECHNOLOGY OFFICER, THE BABCOCK AND WILCOX COMPANY, BARBERTON, OH

Mr. LANGLEY. Chairman Bingaman, distinguished members, thank you for the honor to testify before you today. My name is Don Langley and I'm the Vice President and Chief Technology Officer for the Babcock and Wilcox Company, a provider of advanced pulverized coal boiler technology and all types of environmental control equipment for the electric power industry.

I'm here today to talk about carbon capture and storage technology or CCS technology for use in the electric power industry. We and other technology providers are actively developing a variety of CCS solutions for coal power plants. While these multiple tracks require different development lead times, commercialization is not too far in the future. With appropriate policy, that is policy that does not pre-select winners, I believe our industry will deliver a variety of technologies for carbon management.

Among other options, there are two in particular that I'd like to discuss. B&W is leading the effort toward commercializing oxy-fuel or what we call oxy-coal combustion technology for carbon dioxide capture. Starting this month we are running privately funded, large-scale oxy-coal tests at our 30 megawatt thermal test facility in Ohio. We're also conducting a feasibility study with American Electric Power to examine retrofitting oxy-coal to an existing plant and we're working intensely with Saskatchewan Power, who seeks to build a new 300 megawatt plant, utilizing oxy-coal combustion for both power and enhanced oil recovery. The oxy-coal combustion approach also holds promise of near-zero emissions, including almost complete elimination of NO_X, mercury, and SO_x.

Another area where we are actively working, is improving the efficiency of plants by raising steam temperatures. As with the rest of the industry, and really all across the economy, efficiency improvement pays dividends. B&W's goal is to increase efficiency such that CO_2 emission levels for a new plant would be 30 percent below today's fleet, the average of today's fleet. This can help our cause in two ways.

First, replacing older, least efficient plants in the existing fleet would allow us to continue to meet energy demands with less CO_2 output. But I think even more interesting, this advanced process applied in conjunction with CCS technology will reduce the amount of CO_2 needing to be captured, thereby lowering costs for carbon capture and improving total plant economics.

Oxy-coal and efficiency gains are two examples of our technology initiatives and now I want to make a few points about deployment. MIT's future of coal report recommends building field demonstration projects that capture and store about one million tons of CO_2 per year, with a projected cost share of $2 to $3 billion. This multiple project approach is then the first key enabling step leading to commercial-scale early deployment projects with roll-out of commercial projects with CCS then to follow. We agree with MIT's recommendations and this is what I would say is putting first things first.

Why this is important can be seen in an example roll-out scenario. One deployment scheme, one that the NRDC is advocating consideration of, is a performance standard, whereby over a 10-year period, 10 to 15 percent of the power generation from coal is required to be from low emitting sources. The result would be avoidance of about 400 million tons per year of CO_2, while still meeting rising energy demands.

I calculate that if this deployment occurred as a new capacity, up to 100 new 660-megawatt plants would be required. The investment then would be about $300 billion. My point is, that to enable this type of investment, a solid technology platform must be in place. To do that, we must do first things first.

Finally, the timing of this technology roll-out and managing expectations is crucial to ensuring long-term success. B&W believes large at-scale CCS-based demonstration projects can be on the ground and operating in the 2012 to 2014 timeframe. We think this is consistent DOE–EPA efforts to enable geologic storage around 2012. We then project that we could be ready for a large-scale roll-out with commercial performance guarantees around 2018 to 2019 and offer serious carbon storage from coal plants beginning in, perhaps, 2020. I understand that this timeline will be disappointing to some, but the risk associated with an ill-conceived or rush initial deployment of CCS technology is time lost for successful storage efforts in the future, lower storage levels in the aggregate, and ultimately higher costs. We have to get the long-term program right and not rush the short-term learning. We believe if we proceed in a thoughtful and deliberate way, we as an industry, can and will deliver.

Again sir, thank you for the honor of testifying today.

[The prepared statement of Mr. Langley follows:]

PREPARED STATEMENT OF DONALD C. LANGLEY, VICE PRESIDENT AND CHIEF TECHNOLOGY OFFICER, THE BABCOCK & WILCOX COMPANY, BARBERTON, OH

Chairman Bingaman, Mr. Domenici, and Members of the Committee: My name is Don Langley and I am the Vice President and Chief Technology Officer of The Babcock & Wilcox Company. The Babcock and Wilcox Company, headquartered in Barberton, Ohio is a provider of supercritical pulverized coal boiler technology and a leading provider of all types of environmental control equipment for the electric utility industry, as well as for the renewable biomass natural resource sector.

I am pleased to testify before you today on critical aspects of delivering carbon capture and storage, or CCS technology for the coal-based electric utility industry. It is well recognized that the utilization of coal is an important element of a national strategy to ensure energy independence. It is also well recognized that to achieve meaningful greenhouse gas emission reductions, a portfolio of technologies will be required, including clean coal, solar, nuclear, wind, and biomass to name a few. The power providers also need options within each of these technologies to suit their specific needs, such as fuel. We would advocate then that it is necessary to avoid legislative provisions that would explicitly or implicitly pick winners in this important competition. Given certainty on performance requirements for clean coal and a clear need for CCS, a free and open market with healthy competition stands the best chance to deliver technology in a cost effective manner.

I would start with some overview points. B&W recognizes the value of striving for carbon neutral energy sources, understands the tasks before us to mitigate carbon emissions, and willingly accepts the challenge. We have invested over $100 million over the last five years to develop innovative technology paths forward. We, and other technology providers, are actively developing a variety of climate-friendly solutions for coal power plants. While the multiple tracks require different development lead times, the commercialization trajectories are not too far out into the future. Substantial R&D support and incentives will be needed to attain the interim goal of getting at scale, first-of-a-kind plants on the ground. By "at scale", I mean plants capturing and storing something like one-million tons per year. It is our opinion that the pathway forward consists of establishing these at-scale field demonstration projects, followed by early deployment, commercial scale units with special considerations, such as incentives, all leading to a large scale rollout of clean coal with CCS. Whether this pathway is structured by policy or allowed to occur naturally, these important steps must by completed to enable the investment required to support a large scale rollout of new technology. We must do first things first, the large scale R&D, and not attempt to do second things first by moving directly to large project incentives for projects with high deployment risk. It is important that policy recognize these important steps, and with appropriate policy, our industry will deliver a variety of technologies for carbon management. That is, policy that does not pick winners and addresses first things first is crucial.

B&W is pursuing a variety of carbon-friendly technologies. I would like to discuss two of them.

B&W is leading the effort toward commercializing oxy-coal combustion technology for carbon dioxide capture. Oxy-coal technology utilizes nearly pure oxygen instead of air in the combustion process which then produces concentrated stream of CO_2 that can be stored geologically or used for enhanced oil recovery (EOR). Starting this month, we are running large scale oxy-coal tests that we privately funded at our 30 MWth R&D facility. This work is being funded by B&W, American Air Liquide, EPRI and a group of ten interested power generating companies. Battelle is also supporting the project with input on geologic storage parameters. We are also conducting a feasibility study with American Electric Power to examine retrofitting oxy-coal to an existing plant; and we are working intensely with SaskPower in Saskatchewan, who seek to build a new 300 MW plant using oxy-coal combustion for power and enhanced oil recovery. In addition to capturing almost all the plant's carbon dioxide, the oxy-coal combustion approach also holds the promise of near zero emissions, including almost complete elimination of mercury, NO_x and SO_2 emissions. Insuring that R&D programs or commercial deployment incentives are not structured to pick winners at the onset will then allow us to continue to move this technology forward, further develop the compression and storage aspects and deploy it along side other promising technologies. We have every reason to believe that commercially deployed oxy-coal combustion systems will be cost competitive or less costly than IGCCs designs when IGCC systems are finally configured to capture CO_2.

Another area we are actively working is improving the efficiency of power plants. Efficiency improvements pay dividends in almost all scenarios. The aggregate efficiency of the existing coal fleet is nominally 31%. Increasing the temperature and pressure of the steam in a combustion plant increases the power generation efficiency. A modern ultra-supercritical combustion plant can achieve efficiencies on the order of 38 to 40%, thereby reducing CO_2 output by 16 to 18% on a specific, pounds per megawatt hour basis. B&W has set the goal and identified the technology roadmap for driving combustion plant efficiency even higher, to 45 percent, using very high temperature designs which would reduce the CO_2 produced per unit of energy by perhaps 30%. This can help our cause in two ways. First, replacing the older, least efficient plants in the existing fleet would allow us to continue to meet energy needs with less CO_2 output. Additionally, this very high temperature process in conjunction with CCS will reduce the amount of CO_2 needing to be captured, lower the capital investment and the operating costs for carbon capture, benefit the overall plant economics, and justify accelerated implementation. We have been receiving some support from the DOE for this activity as the alloy materials required must be certified for public use and will be used by all the technology providers. To continue to develop this technology, we will need as an industry, to construct a materials test center that will conduct advanced, component based research for the shared benefit of all technology providers. This important R&D function is worthy of funding considerations and we will be soliciting for this support in R&D funding plans.

These are two examples of the investment B&W is making to redefine Clean Coal Technology. We believe that MIT, as articulated in the Future of Coal report, has it mostly right with recommendations for extensive, at-scale field demonstration projects, each of which would capture and sequester about one million tons of CO_2 per year. The at-scale project approach is the key enabling step that would lead to accelerated commercial scale early deployment projects, followed by a large scale rollout of plants with CCS.

We need to do first things first. For example, NRDC is advocating consideration of a proposed performance standard approach whereby, over a ten year period, 10 to 15% of the generation from coal is required to be low emitting power. I calculate that, if this goal were to be attained by building new capacity, up to 100 new, 660MW plants would need to be built, representing an investment approaching $300 billion in today's dollars. This is a worthy goal as this approach would remove upwards of 400 million tons per year of CO_2 from the sector emissions while still meeting rising energy demands. My point is that to enable this type of investment, a solid technology platform must be in place and we must do the first things first. We agree with MIT that only $2 to $3 billion would be required to fund this large scale R&D and one million tons of CO_2 per year at-scale field demonstrations. The sooner we start, the sooner we can get to the point where we are storing carbon dioxide in earnest.

Finally, the timing of this technology rollout and managing expectations is crucial, particularly if we are to ensure long term success. B&W believes large at-scale CCS based demonstration projects can be on the ground and operating in the 2012 to 2014 time frame. Note that this is consistent with the DOE/EPA efforts to establish geologic storage regulations in the 2012 timeframe. We then project that we could be ready for a large scale rollout with commercial performance guarantees around the 2018 to 2019 timeframe and offer serious carbon storage beginning in perhaps in 2020. I understand that this timeline will be disappointing to some. But, the risk associated with an ill-conceived or rushed initial deployment of CCS technology could result in time lost for serious storage efforts in the future and in lower storage levels in the aggregate. We have to get the long term program right and not rush the short term learning. We believe if we proceed in a thoughtful and deliberate way, we as an industry can and will deliver the results that move our Nation towards meaningful energy security, work towards a worldwide reduction in carbon emissions, and minimizes the impact on our Nation's economy while contributing to international competitiveness.

Thank you for this opportunity to testify.

The CHAIRMAN. Thank you very much.

Mr. Perlman, go right ahead.

STATEMENT OF ANDREW PERLMAN, PRESIDENT AND CHIEF EXECUTIVE OFFICER, GREAT POINT ENERGY, CAMBRIDGE, MA

Mr. PERLMAN. My name is Andrew Perlman and I am Chief Executive Officer of Great Point Energy and one of its co-founders. Thank you for the invitation to testify here today regarding recent advances in clean coal technology and its prospect for deployment at commercial-scale in the near future.

As my testimony will explain, I believe Great Point represents a significant breakthrough in clean coal technology and we are on track to deploy our plans at commercial-scale in the next few years. So I'm here to talk about Great Point Energy and the technology that we have developed, the catalytic gasification technology that we have developed, to convert low cost coal and also petroleum coke and even biomass into pipeline quality natural gas.

We've got two major reasons for doing this. One is environmental and the other is economic. From and environmental standpoint, we can take the dirtiest of all commercial fuels and convert it to the cleanest of all commercial fuels. From an economic standpoint, we believe that we can manufacture natural gas for much less than it sells for in the industry. In fact, we were going through our economics and we actually hired Nexent, which is a division of Bectal to do a full economic and engineering analysis of our technology. All the numbers I'm going to present today come from Bectal. I was going over them with Secretary Bodman a couple months ago. One of the things that he pointed was that given the increase recently in, or over the last few years, in the cost of both L&G imports and also new natural gas exploration and production, we can actually be the lowest incremental cost of new natural gas in North America.

It is also, the other benefit, that there's virtually unlimited resources and reserves available. We can build gasification plants in places like Wyoming and Montana today, and still be building plants 100 years from now without running out of reserves and not have any of the exploration or depletion risk that's inherent with natural gas exploration today.

Unlike many of our competitors, which have focused on licensing strategies, at Great Point our strategy is to build, own, and operate gas-production facilities ourselves, in close proximity to both coal mines and oil refineries. We think this is important because, while there's been a lot of discussion about natural gas over the last few years, there haven't been a lot of shovels in the ground. So we think that it's very important, that if we want to be able to meet the aggressive timeframes that we've set out, that we make sure that we're leading the charge.

But we're not doing it alone, we are working together with some significant energy companies and over the next few months we'll be making announcements of developments that we plan with some of the largest energy companies in this country.

Well, we're a new a company, we think that we're also extremely well positioned to be able to develop the technology. We're backed by some of the leading venture capital, in fact, we think the leading venture capital firms in the country, groups like Kleiner Perkins, Draper Fisher Jurvetson, Advanced Technology Ventures, and Vinod Khosla, who you might have seen testify here in the past.

I also think we've attracted an extremely experienced management team, people like the former VP of Technology for Bectal, who built two of the four largest coal gasification plants in the United States, as well as, recently, the Chief Process Engineer for Sasol, which operates the largest coal gasification plant in the world, just joined to run our engineering group.

We have operating, successfully operating pilot plant facility in Des Plaines, Illinois and we've actually been running extremely successfully on Powder River Basin coal all summer. As I mentioned, we have economics, economic, complete economic and engineering analysis done by Nexant, a division of Bectal, and the economics are extremely compelling. We also, we haven't announced it publicly yet, but we also have a technology collaboration with one of the largest chemical companies in the world for technology development and scale-up.

Just briefly talking about the technology and how it differs from what conventional gasification is and what you might think of it today in technologies from groups like Siemens and GE and Shell and Conoco. All of these traditional gasification technologies operate at extremely high temperatures, about 1,400 degrees Celsius. At these temperatures, it's so hot that the ash in the coal actually melts and forms something called slag and the slag is constantly eating away at the reactor walls.

In fact, in order to have significant up-time and reliability, most of these manufacturers recommend that you have a second gasifier on standby so you can always be fixing one while you are running the other. They also require extremely costly equipment. In order to get to those temperatures, you need to inject pure oxygen, which means you have to freeze air down to near absolute zero to separate the oxygen from the nitrogen. Not only is that about 25 percent of the capital costs, but it's about 15 to 20 percent efficiency hit on these plants. Also, because they're at such high temperatures, you need to build them out of, a high temperature cooling equipment out of exotic materials, which raises the cost.

But most importantly, all these technologies produce, do not produce pipeline-grade natural gas. They only produce syngas, which is a low-grade, a low-BTU fuel, which is not compatible to pipeline systems and particularly economic to move over long distances. You can upgrade syngas to natural gas, but in order to do that you have to have four chemical plants, all operating at very different temperatures, from near absolute zero all the way up to 1,400 and then back down again to convert the syngas into natural gas. So, you end up with very high complexity, a very low efficiency, high capital costs, low reliability, and high price for a million BTUs of the natural gas.

So basically, the way that Great Point Energy solves this problem, is by introducing catalysts into the gasification system. So basically, coal or petroleum coke combines with steam in the presence of heat pressure and the catalyst to produce 99 percent methane or, basically, pure natural gas instead of low-quality syngas. All of the carbon dioxide, the ash, the sulfur, the trace metals, and the mercury are all safely removed as part of the gas clean-up process.

The beauty of the situation is that all of the chemical reactions perfectly heat balance. So, actually the heat of, that's produced in methanation, which is an exothermic reaction, perfectly offsets the heat required for gasification, which is an endothermic reaction, meaning that we don't need to inject any oxygen into the system and we can operate at about half the temperature of normal gasification. So, we don't have any of the maintenance or liability issues. We don't have to have high temperature cooling equipment because we're not at high temperature. But most importantly, at the end of the day, we've produced pipeline-grade natural gas.

The CHAIRMAN. Maybe you could sum up your testimony here, we're running over time.

Mr. PERLMAN. Sure, sure. The importance of that, which was discussed earlier today, is that the places where you can sequester carbon dioxide are not usually, or easily sequester carbon dioxide, are not usually the places where you want to produce electricity, which is in the population centers. So, if you can generate a pipelineable fuel, you can do that mine mouth in places like Wyoming and Montana and Texas, where you actually, where you can easily sequester the carbon dioxide or, in those places, you can actually sell the carbon dioxide today economically for enhanced oil recovery.

So, without any involvement from the Government whatsoever, you can actually, economically today, using the only proven carbon dioxide sequestration technology do that and then you can move the natural gas anywhere in the country where it needs to go.

[The prepared statement of Mr. Perlman follows:]

PREPARED STATEMENT OF ANDREW PERLMAN, PRESIDENT & CHIEF EXECUTIVE OFFICER, GREAT POINT ENERGY, CAMBRIDGE, MA

Mr. Chairman and members of the committee, my name is Andrew Perlman. I am the Chief Executive Officer of Great Point Energy, and one of its co-founders. Thank you for your invitation to testify today regarding recent advances in clean coal technology, including prospects for deploying this technology at commercial scale in the near future. Great Point is a advanced gasification technology company. Our technology allows us to convert coal directly into pipeline quality methane natural gas. As my testimony will explain, Great Point does represent a significant advance in clean coal technology, and we are on track to deploy our plants at commercial scale in the near future.

INTRODUCING GREAT POINT

Great Point does not fit the image of a start-up energy technology company. For one thing, we were able to get a running start. Our advanced gasification technology draws on—and includes many patented and significant improvements over—many years of synfuels research and development that the United States promoted and began to carry out as an urgent matter of national policy during the Energy Crisis of the 1970s. This is one key reason why Great Point's technology will soon be ready for commercial deployment, even though our company is relatively new. We stand on the shoulders of giants, and are now reaching the heights they had hoped to reach until that 1970s version of the Energy Crisis passed, oil and gas prices fell, and coal gasification technology development languished. The founders of Great Point Energy launched our company in a sincere desire to make a major contribution toward solving the current energy and global environmental crisis, which this time seems unlikely to pass away quickly.

Our company is based in Cambridge, Massachusetts. Because of our gasification technology—and, we like to think, the top management team we've attracted—we are fortunate to have gained the confidence, support, and funding of some of the greatest names in American venture capital, especially within the clean energy technologies sector: Advanced Technology Ventures, Draper Fisher Jurvetson, Kleiner Perkins, and Vinod Khosla. Our bench-scale tests, and our much larger sub-commercial demonstration test facility, have operated successfully and on a sustained basis. We have met or exceeded all our performance goals for this stage of our technology development.

We currently have thirty-five employees, nearly all of whom are highly experienced in developing, scaling, and deploying gasifiers, oil refineries, and power plants. We are ramping up rapidly now, raising significant amounts of additional funding for our large pre-commercial project, hiring additional employees and service providers, and selecting sites in the U.S. and Canada for our full-sized commercial projects, the first of which we expect will begin operating in 2011/2012.

OUR TECHNOLOGY & ITS BENEFITS

Most coal gasification efforts in North America have in common certain things: the recognition that our continent's coal reserves are vast; that coal is a key to our energy security and independence; that coal represents a relatively inexpensive source of energy; but that the traditional method of using coal—burning it—is inherently limited, dirty, and makes controlling carbon dioxide emissions extremely difficult and expensive, if not altogether impossible.

Until now, the best-known coal gasification technologies have been pursued primarily for one particular application, namely direct production of electric power in what's called "integrated gasification combined cycle" or IGCC power plants. These technologies almost all operate at extremely high temperature; about 1400 degrees Celcius. At this temperature, the ash in the coal actually melts and forms something called slag. The slag constantly eats away at the reactor walls of the gasifier and leads to high maintenance costs and low reliability. In fact, a spare gasifier is typically required in order to achieve over 90% online availability of the plant so that one gasifier can be fixed while the other one is operating.

In order to generate the heat in the system, conventional gasifiers require pure oxygen. This oxygen is generated in a plant which freezes air down to near absolute zero in order to separate the nitrogen from the oxygen. These air separation plants are extremely expensive—20% to 25% of the capital cost and result in a huge efficency hit because they utilize so much energy and operate at vastly different temperatures from the high temperature gassifier. Finally conventional gasification processes yield synthesis gas, or "syngas," which consists primarily of carbon monoxide and hydrogen gas instead of natural gas which consists entirely of methane.

Chemically as well as commercially, the syngas from conventional gassifier is very different from natural gas. For one thing, few if any pipelines exist to transport syngas, whereas a highly integrated nationwide network exists to transport natural gas. This means that conventional gasification plants must be located next to power production facilities and near major population centers. As a result solid coal must continue to be transported across the country to these facilities at high cost. The combination of conventional gasification technology with power plants designed to burn the hydrogen and carbon monoxide they produce is called IGCC or Integrated Gasification Combined Cycle. The plants are highly complex and very expensive.

The syngas from conventional gasification cannot be converted to pipeline quality natural gas without the addition of multiple complex chemical plants and processes.

Further, with conventional gasification technologies, unless additional steps are taken essentially all of the carbon that started out in the coal will end up in the atmosphere as CO_2. In order to remove CO_2 for capture and eventual storage or sequestration, conventional gasification technologies require—in addition to the capital and operating expense of the oxygen plant—the further capital and operating expense of a so-called "shift reactor." The shift reactor is a separate facility in which the proportion of carbon to hydrogen in the syngas mixture is "shifted" to a hydrogen-rich blend by injecting steam which converts some of the carbon monoxide in the syngas to carbon dioxide. The carbon dioxide is then available as a separate stream for potential capture and storage or sequestration.

Many, if not most population centers in the U.S. are located in areas where carbon dioxide cannot easily be sequestered, but these are the locations that IGCC plants need to be built to provide electricity. Therefore it is going to be very difficult to actually sequester carbon dioxide from these plants, even if they are built with technology to capture a portion of the CO_2.

Great Point's technology is different—much simpler, more efficient, lower temperature, and less costly. With the help of a catalyst, we use a single reactor vessel to carry out three different chemical reactions, as a result of which we are able to convert coal directly into pipeline quality natural gas in our gassifier instead of syngas. Roughly 50% of the carbon in the coal is removed and captured as a pure pressurized stream of CO_2. In addition to our offering a less expensive way to turn coal's energy into gas, our product—pipeline quality natural gas—is more useful than syngas. It can be transported anywhere through the existing natural gas pipeline system. Its use is not confined to the immediate vicinity of our gasifies, unlike syngas produced by conventional gasifies, which must be co-located with power generation facilities. Thus we can build our plants in locations where we can easily sequester carbon dioxide, and in areas with depleted oil wells actually get paid for doing so, and then ship our gas anywhere in the country through the nations robust pipeline system. And the gas we produce, which chemically is the same as natural gas, can be used in exactly the same manner as natural gas, and for all of the same purposes: not just power generation, but also heating, industrial uses, and chemicals production.

Our process is less costly and more efficient than conventional gasification. Ours does not require a large and expensive air separation system, a separate shift reactor, or a methanator—the costly facilities and equipment that conventional gasification technologies require as "add-ons" in order to produce syngas, or isolate CO_2 for capture, or convert syngas into SNG. The energy conversion efficiency of our process—that is, our efficiency at capturing the coal's energy in our gas—is higher than for conventional gasification, too. This higher efficiency has several benefits: (1) We don't need to integrate our gasification reaction with other major facilities and equipment, such as an ASU, shift reactor, or methanator; (2) we don't operate at the high temperatures of conventional gassifier; and (3) because we operate at lower temperatures, we also don't produce slag, which absorbs a great deal of non-recoverable energy in the form of heat (in addition to fouling equipment and adding to maintenance expense).

Our potential for cost-effective and sensible CO_2 management is much greater than for conventional gasification technologies as well. In Great Point's process, CO_2 in a separate and pure stream is simply a by-product of our producing pipeline quality SNG. Of course, the CO_2 still needs to be compressed for shipment via pipeline to locations where it can be used for enhanced oil recovery ("EOR") or otherwise stored or sequestered. That is true of any gasification technology—or, for that matter, any other technology that may allow CO_2 to be captured, including proposed oxy-combustion and other post-combustion capture technologies, if they can be made to work. The difference is that Great Point's process does not require the capital investment or operating expense of any extra facilities or equipment to produce CO_2 as a separate, capture-ready stream. That makes it different from conventional gasification technologies and hoped-for post-combustion CO_2 capture technologies alike.

Finally, of course, like other gasification technologies, Great Point's technology offers the prospect of truly clean coal in a traditional sense. We will produce almost none of the sulfur, oxides of nitrogen, or mercury emissions of power plants that burn coal. Our emissions profile for these and similar pollutants should be as good as, if not better than, the emissions of a natural gas-fired power plant in almost all respects.

Clean coal really is possible. Moreover, as I will discuss next, it is also imminent.

COMMERCIAL DEPLOYMENT

I recognize that what I've said here about Great Point's technology would be of purely academic interest to the Committee if our technology could not soon be deployed at full commercial scale. Timing, not just technology, is among your key concerns. I'm happy to be able to offer good news and encouragement on that front, too.

As I mentioned at the outset, Great Point's technology has already been demonstrated successfully both at bench scale and at the much larger scale of our test facility which we operated over the past year at the Gas Technology Institute's test facility outside Chicago.

We will next build a permanent demonstration facility which will be our final step before full commercialization. Our first commercial project operating on pet coke will be constructed in cooperation with a major Fortune 50 chemical company at a site we have already identified and which we are already designing and engineering.

We have done a great deal of work for these commercial projects already, in addition to inventing, patenting, testing, and proving the gasification technology that they will rely on. For example, we have screened literally scores of potential sites for the location of our initial commercial projects, and have narrowed down our finalists for the first such project to about six sites. In addition to a siting strategy, we have developed and are now in the process of implementing both a partnering strategy and a project design and execution strategy, so that we may rely on investment-grade industrial partners and largely standardized project designs to help us achieve and sustain an early, efficient, and rapidly expanding commercial "launch."

Our business model is focused on building, owning, and operating these commercial projects ourselves, in conjunction paid construction contractors and in partnership with our strategic industrial allies. As I mentioned at the outset, we expect our first project to begin producing revenue in the 2011/2012 time frame. By 2017—ten years from now—we plan to have at least ten revenue-producing projects in operation and sales revenues of over $3 billion as a company. Almost all will be at full commercial scale. Within a decade our goal as a company is to a material contribution of the North American natural gas requirements from coal and petroleum coke, and from biomass feedstocks as well.

GREAT POINT IN PERSPECTIVE

I hope my testimony, the information available on our website (www.greatpointenergy.com), and whatever answers or additional information that I can provide in response to questions or further inquiries from Committee will reassure you that (1) our company, for one, does have a clean coal technology that represents a significant advance, and (2) commercial deployment of this technology is relatively imminent, not some far-fetched dream for the distant future.

At the same time, I want to acknowledge three points. First, our company could not be where it is without the great technological innovations and inventions of the scientists and engineers who came before us. Those far-sighted predecessors of ours were encouraged and largely funded by far-sighted predecessors of yours, the men and women who served here in Congress and elsewhere in the U.S. government during the Energy Crisis of the 1970s. This goes to show that government can help. I know that the Chairman has drafted legislation under which the government would again contribute in a substantial way to basic research and development for climate-friendly new energy technologies that may help the global environment while also helping North America become more secure and energy independent. From what I understand of your effort, Mr. Chairman, I applaud it, and hope our company may serve as a useful example of the long-term public benefits and private sector "leverage" that government-sponsored energy sector basic research may one day yield.

Second, the advanced coal gasification sector is large, and the potential market, both domestically and globally, is huge. There is ample room for several useful and successful technologies in this field, and for many companies developing them. At GreatPoint, we simply intend to do an excellent job, and to do it as rapidly and on as large a commercial scale as may be reasonably possible.

Finally, in this spirit, there are additional things that I believe Congress and the Administration could do that would be useful to us and other companies focused on clean uses of coal that would speed the development of clean coal technologies. These include a $0.50/Gasoline Gallon Equivalent production tax credit for the generation of natural gas from North American coal, petcoke, and biomass much along the lines of the credits available for ethanol production; as well as loan guarantees and grants for coal conversion to clean natural gas. In short, we believe the conversion of coal to natural gas is at least as compelling, if not significantly more compelling, than traditional coal gasification and also as important to the nations energy independence as ethanol. We simply ask that it be treated equally with these other technologies when government support is available. In addition, we believe that setting a price floor for natural gas produced from highly efficient gasification of domestic feedstocks below which government guarantees would kick-in, would provide the assurances to enable large-scale, multi-billion dollar facilities to be rapidly deployed in the market without any substantial direct government incentives, unlike many other areas of the clean energy industry. My associates and I at Great Point would welcome the opportunity to discuss our technology and recommendations further with you and your staff.

Thank you again for this opportunity to appear before you.

The CHAIRMAN. Thank you very much.

Mr. Alix, go, is it Alix, is that the right pronunciation?

Mr. ALIX. Thank you. Yes.

The CHAIRMAN. Thank you.

STATEMENT OF FRANK ALIX, CHIEF EXECUTIVE OFFICER, POWERSPAN, PORTSMOUTH, NH

Mr. ALIX. Good morning Mr. Chairman and members of the committee. Thank you, for being invited here to speak. My name is Frank Alix and I'm CEO of Powerspan Corp. Powerspan is a clean energy technology company headquartered in New Hampshire. I'm co-founder of the company and a co-inventor on several of Powerspan's patents.

We've been in the business of developing and commercializing clean coal technology since 1994. In order to fund technology development, we've raised over $70 million from private institutional corporate investors. Our most significant clean coal technology success to date has been the development and commercialization of our ECO technology, which is an advanced multi-pollutant control technology to reduce emissions of sulfur dioxide, nitrogen oxides, mercury, and fine particles, in a single system.

First Energy Corporation of Akron, Ohio, has been a major supporter, providing the host site for ECO commercialization activities as well as substantial financial contributions. Over the past 3 years, we've successfully operated a 50-megawatt-scale, commercial ECO unit at First Energy's Burger plant in Shadyside, Ohio. This unit has demonstrated ECO has the capability of achieving emissions below best available control technology for coal plants and comparable to outlet emissions from natural gas combined cycle power plants.

ECO also produces a valuable fertilizer product, avoiding the landfill disposal of flue gas desulphurization waste. Furthermore, the ECO system minimizes water use because it requires no waste water treatment or disposal. Commercial ECO cost estimates prepared by perspective customers and their engineers indicate that ECO capital and operating costs would normally be about 20 percent less than the combined cost of separate control systems required to achieve the comparable reductions. For a 600-megawatt plant, this equates to an annual cost savings of about $5 to $10 million.

Although the utility industry has a conservative approach to new technology adoption, the environmental and economic advantages of our ECO technology has resulted in some significant commercial progress. Within the past year, First Energy announced the commitment to install an ECO system on its Burger plant, units four and five, an installation valued at approximately $168 million.

Additionally, AMP-Ohio recently announced a commitment for ECO for its proposed 1,000 megawatt plant in Meigs County, Ohio. This commitment was driven in part by the promise of a new technology Powerspan is developing for CO_2 capture, which we call ECO_2. The ECO_2 process is a post-combustion CO_2 capture process for conventional power plants. The ECO_2 technology is readily integrated with our ECO process and is suitable for retrofit to the existing coal-fire generating fleet as well as new coal-fired plants.

Since 2004, Powerspan and the Department of Energy's NETL have worked together to develop the ECO_2 process. The regenerative process uses ammonia to capture CO_2 in the flue gas. The CO_2 capture takes place after other pollutants are captured. Once the CO_2 is captured, the ammonia-base solution is regenerated to release CO_2 in a form that's ready for geological storage. Pilot scale testing of our ECO_2 technology is scheduled to begin in early 2008 at First Energy's Burger plant. The pilot unit will process a one-megawatt flue gas stream and produce about 20 tons per day of CO_2, achieving a 90 percent capture rate. We plan to provide the captured CO_2 for onsite sequestration in an 8,000 foot well.

First Energy is collaborating with the Midwest Regional Carbon Sequestration Partnership on the sequestration test project. This pilot program could be the first such project to demonstrate both CO_2 capture and sequestration at a coal-fired power plant.

The ECO_2 pilot program provides the opportunity to confirm process design and cost estimates and prepare for large-scale capture and sequestration projects. Initial estimates developed by DOE, indicate that our ammonia-based capture process could provide significant savings compared to commercially available amnion-based CO_2 capture technologies. Our own estimates, based on extensive lab testing, indicate commercially CO_2 systems should be capable to capture and compress 90 percent of CO_2 from conventional power plants at a cost of about $20 per ton.

Regarding prospects for deploying ECO_2 at commercial scale, Powerspan and its commercial partners, Siemens and Fluor, are currently evaluating opportunities to deploy commercial-scale demonstration units to process 100 megawatts of flue gas and produce approximately one million tons of CO_2 per year for use in enhanced oil recovery or geological sequestration. A project of this size would be among the largest CO_2 capture operations in the world and would serve to demonstrate the commercial readiness of ECO_2 for full-scale power plant applications.

With the anticipated success of the pilot unit, we would expect our first commercial demonstration project to begin operating in 2011 and full-scale commercial units to be operating by 2015, with commercial guarantees. Although large-scale projects, such as taking ECO_2 from a one megawatt pilot to a 100 megawatt commercial demonstration contains some risks, we believe the risk is manageable because equipment use in our process, absorbers, pumps, exchangers, and compressors, have all been used in other commercial applications. The technology in ECO_2 is innovative process chemistry. Commercial application of this unique technology holds no special challenges that we can foresee, and therefore has a high probability of commercial success.

We agree with the recent MIT study on coal that places a high priority on the commercial demonstration of CO_2 capture from several alternative coal combustion and conversion technologies, as well as CO_2 sequestration at the scale of one million tons per year. However, such an undertaking will require substantial resources. The recently proposed 30 percent investment tax credit and $10 to $20 per ton CO_2 sequestration credit is exactly the type of incentive needed and shows the Senate is prepared to provide the required leadership. It is important that such incentives apply to both pre- and post-combustion technologies and require that CO_2 capture and sequestration be accomplished at a reasonably large scale.

Additionally, in order to move large-scale CCS projects ahead as rapidly as possible, the incentives should to apply to retrofits at existing coal-fired plants, otherwise we'd need to wait for new plants to be built, which could unnecessarily delay the demonstration.

I'll wrap up now because I'm a bit over. Thank you for the opportunity and I'd be happy to answer questions later.

[The prepared statement of Mr. Alix follows:]

Prepared Statement of Frank Alix, Chief Executive Officer, Powerspan, Portsmouth, NH

Good morning Mr. Chairman and Members of the Committee. Thank you for the opportunity to share Powerspan's perspective on advances in clean coal technology. It is an honor to be invited here to speak. My name is Frank Alix and I am CEO of Powerspan Corp. Powerspan is a clean energy technology company headquartered in New Hampshire. I am a co-founder of the Company and a co-inventor on several of Powerspan's patents.

Powerspan has been in the business of developing and commercializing clean coal technology since its inception in 1994. In order to fund technology development, the company has raised over $70 million from private, institutional, and corporate investors. Our most significant clean coal technology success to date has been the development and commercialization of our ECO® technology, which is an advanced multi-pollutant control technology to reduce emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_X), mercury (Hg), and fine particles ($PM_{2.5}$) in a single system. FirstEnergy Corp. of Akron, Ohio has been a major supporter, providing the host site for ECO commercialization activities, as well as substantial financial contributions.

Over the past three years, we have successfully operated a 50-megawatt (MW) scale commercial ECO unit at FirstEnergy's R. E. Burger Plant in Shadyside, Ohio. This unit has demonstrated that ECO is capable of achieving outlet emissions below current Best Available Control Technology for coal plants, and comparable to outlet emissions from natural gas combined cycle power plants. ECO also produces a valuable fertilizer product, avoiding the landfill disposal of flue gas desulfurization waste. Furthermore, the ECO system minimizes water use because it requires no wastewater treatment or disposal.

Commercial ECO cost estimates prepared by prospective customers and their engineers indicate that ECO capital and operating costs would normally be about 20% less than the combined costs of the separate control systems required to achieve comparable reductions. For a 600 MW plant, this equates to an annual costs savings of $5-10 million.

Although the utility industry has a conservative approach to new technology adoption, the environmental and economic advantages of our ECO technology has resulted in some significant commercial progress. Within the past year, FirstEnergy announced a commitment to install an ECO system on its Burger Plant, Units 4 and 5, an installation valued at approximately $168 million. Additionally, AMP-Ohio recently announced a commitment to ECO for its proposed 1,000 MW plant in Meigs County, Ohio. This commitment was driven in part by the promise of a new technology Powerspan is developing for CO_2 capture, which we call ECO_2™. The ECO_2 process is a post-combustion CO_2 capture process for conventional power plants. The ECO_2 technology is readily integrated with our ECO process and is suitable for retrofit to the existing coal-fired generating fleet as well as for new coal-fired plants.

Since 2004, Powerspan and the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) have worked together to develop the ECO_2 process. The regenerative process uses an ammonia-based solution to capture CO_2 in flue gas. The CO_2 capture takes place after the NO_X, SO_2, mercury, and fine particulate matter are captured. Once the CO_2 is captured, the ammonia-based solution is regenerated to release CO_2 in a form that is ready for geological storage.

Pilot scale testing of our ECO_2 technology is scheduled to begin in early 2008 at FirstEnergy's Burger Plant. The ECO_2 pilot unit will process a 1–MW flue gas stream and produce 20 tons of CO_2 per day, achieving a 90% CO_2 capture rate. We plan to provide the captured CO_2 for on-site sequestration in an 8,000-foot well. FirstEnergy is collaborating with the Midwest Regional Carbon Sequestration Partnership on the sequestration test project. This pilot program could be the first such project to demonstrate both CO_2 capture and sequestration ("CCS") at a coal-fired power plant.

The ECO_2 pilot program provides the opportunity to confirm process design and cost estimates, and prepare for large scale capture and sequestration projects. Initial estimates developed by the U.S. Department of Energy indicate that our ammonia-based CO_2 capture process could provide significant savings compared to commercially available amine-based CO_2 capture technologies. Our own estimates, based on extensive lab testing, indicate that commercial ECO_2 systems should be able to capture and compress 90% of CO_2 from conventional coal-fired power plants at a cost of about $20 per ton.

Regarding prospects for deploying ECO_2 at commercial scale, Powerspan and its commercial partners—Siemens, and Fluor—are currently evaluating opportunities to deploy commercial scale demonstration units that would process a 100–MW flue gas stream and produce approximately 1,000,000 tons of CO_2 per year for use in enhanced oil recovery or geological sequestration. A project of this size would be among the largest CO_2 capture operations in the world and would serve to demonstrate the commercial readiness of ECO_2 for full-scale power plant applications. With anticipated success of the ECO_2 pilot unit, we would expect our first commercial demonstration project to begin operating in 2011, and full-scale commercial units to be operating by 2015.

Although large scale-up projects, such as taking ECO_2 from a 1–MW pilot to a 100–MW commercial demonstration, contain some risk, we believe the risk is manageable because the equipment used in the ECO_2 process—large absorbers, pumps, heat exchangers, and compressors—have all been used in other commercial applications. The "technology" in ECO_2 is innovative process chemistry. Commercial application of this unique technology holds no special challenges that we can foresee, and therefore has a high probability of commercial success.

We agree with the recent MIT study on coal that places a high priority on the commercial demonstration of CO_2 capture from several alternative coal combustion and conversion technologies, as well as CO_2 sequestration at a scale of 1 million tons per year. However, such an undertaking will require substantial resources. The recently proposed 30% investment tax credit and $10–20 per ton CO_2 sequestration credit is exactly the type of incentive needed and shows the Senate is prepared to provide the required leadership. It is important that such incentives apply to both pre-and post-combustion technologies, like ECO_2, and require that CO_2 capture and sequestration be accomplished at a reasonably large scale. Additionally, in order to move large-scale CCS projects ahead as rapidly as possible, the incentives should apply to retrofits at existing coal-fired plants. Otherwise, we would need to wait for new plants to be built with CCS, which could unnecessarily delay such demonstrations for several years.

There is growing concern that the need to address climate change combined with the expanding use of coal presents an intractable problem, one where the tradeoff is between severe environmental or economic consequences. At Powerspan, we believe the necessary clean coal technology is near at hand, and the tradeoff need not be severe. Our ECO technology, which has the capability to produce a near zero-emission coal-fired power plant, is commercially available, is being commercially deployed, and will set a new emission standard for coal-fired plants. Our ECO_2 technology, which is being developed for 90% capture of CO_2 from conventional coal-fired plants, is on a well-defined path toward commercialization using currently available commercial equipment. The cost of wide spread deployment of CO_2 capture technologies such as ECO_2 appear manageable, particularly when one considers that post-combustion approaches such as ECO_2 preserve the huge investment in existing coal-fired power plants, and avoid the need to replace a major portion of the power generating fleet.

Thank you Mr. Chairman. I would be pleased to answer any questions that you or other Committee members may have.

The CHAIRMAN. Thank you very much.

Mr. Rosborough, go right ahead.

STATEMENT OF JIM ROSBOROUGH, COMMERCIAL DIRECTOR, ALTERNATIVE FEEDSTOCKS, THE DOW CHEMICAL COMPANY, MIDLAND, MI

Mr. ROSBOROUGH. Thank you chairman, Senator Domenici, and members of the committee. My name is Jim Rosborough from the Dow Chemical Company. Thanks for the opportunity to provide our views today on clean coal technologies and the practicality of their deployment. We appreciate your efforts in the search for environmentally friendly and economically sustainable energy.

Today, I'd like to emphasize a few points on the subject. First, Dow is one of the world's largest chemical companies and is also one of the world's largest energy consumers. We convert the equivalent of one million barrels of oil every day in the chemicals, plastics, and electricity. The availability of low cost, price stable feedstocks is critical to our business and to our global competitiveness. Mr. Chairman, I can't emphasize this point enough. This is a strategic issue for the Dow Chemical Company.

Second, we are confident that coal gasification is a viable way to enhance our nation's energy security and industrial competitiveness. It can also be an important part of the solution for climate change.

Finally, to successfully implement industrial gasification at the right scale, we need a strong public-private partnership that will reduce the risk of investment and ensure the development of cost-effective carbon management techniques. The program we envision is doable now. Multiple commercial-scale industrial gasification plants that generate—sorry—that integrate the production of chemicals, plastics, fuels, and electricity can be a reality on the ground in this Nation within 10 years and they can greatly improve our energy security without breaking the carbon bank.

Senator DOMENICI. Why 10 years?

Mr. ROSBOROUGH. It takes a while to build a major-scale industrial complex, Senator. That's what we're talking about is, rather than a small demonstration facility. We're talking about major integrated sites.

Thanks for the question, and we can talk more about it in a little bit.

In 2005, our Chief Executive Officer, Andrew Liveress, appeared before this committee and said that we really want to invest in the United States, but that Dow has been discouraged from doing so recently because the United States has some of the highest and most volatile natural gas prices in the world. Since his testimony, natural gas and oil prices have remained high. In spite of Dow's improvements in energy efficiency, our feedstock costs jumped to $22 billion last year, up from $8 billion only a few years prior.

Clearly, we need a real solution to reverse this trend in the United States. Gasification can be a big part of the answer. It is versatile technology that can convert coal, biomass, wastes, or just about anything that contains carbon into virtually any product that society needs. A consortium of industrial companies, in partnership with the Government, is the best way to implement industrial gasification technology at the right scale and integrate all of the sectors that I just mentioned previously.

There are two principle barriers that stand in the way of deployment. First, is the high capital costs of initial construction. Gasification plants are more than capital intensity of their conventional alternatives. A direct loan program or something to the equivalent nature is necessary, in our minds, to offset 50 percent of the capital cost of initial projects to attract private investors such as Dow Chemical.

The second challenge is to manage the carbon footprint. Our initial analysis suggests, that by using up to 30 percent biomass and integrating the production of chemicals and plastics, along with carbon management techniques, we can cut the CO_2 footprint of a gasification complex in half. Our experience tells us that the third and fourth plants built will be progressively more efficient and cost effective than the first. As operators gain experience and technology improves, the United States policy needs to reflect this.

Mr. Chairman, we at Dow are ready and willing to participate in and even lead a gasification consortium in partnership with the Government and our industrial colleagues. We strongly believe that by working together, coal and biomass gasification can improve our Nation's energy security, revitalize our industrial competitiveness, and be an important part of the solution to climate change.

Thanks for the opportunity to speak to today, and I'll be happy to address more questions.

[The prepared statement of Mr. Rosborough follows:]

PREPARED STATEMENT OF JIM ROSBOROUGH, COMMERCIAL DIRECTOR, ALTERNATIVE FEEDSTOCKS, THE DOW CHEMICAL COMPANY, MIDLAND, MI

ABOUT DOW

Dow, founded in 1897, is America's largest chemical company. It is a diversified chemical company that harnesses the power of innovation, science and technology to constantly improve what is essential to human progress. The Company offers a broad range of products and services to customers in more than 175 countries, helping them to provide everything from fresh water, food and pharmaceuticals, to paints, packaging and personal care products. Built on its principles of sustainability, Dow has annual sales of $49 billion and employs 43,000 people worldwide, with roughly half in the U.S.

Dow has embraced a series of bold Sustainability Goals to address some of the world's most pressing economic, social and environmental concerns by 2015. One of these goals is to provide a sustainable, affordable energy supply worldwide while working to combat climate change.

Dow operates at the nexus between energy and all the manufacturing that occurs in the world today. More than 96% of all manufactured products have some level of chemistry in them. As the premier chemical producer and one of the world's largest and most efficient industrial energy users, no one has more at stake in the solution—or more of an ability to have an impact on—the overlapping issues of energy supply and climate change than we do.

Dow is uniquely positioned to continue to innovate concepts that lead to energy alternatives, less carbon-intensive raw material sources, and other products and solutions not yet imagined. This is an imperative for Dow, since our purchase of oil and natural gas accounts for nearly 50% of our costs. Last year, we paid $22 billion for the energy and feedstocks we needed, versus $8 billion in 2002. In just the second quarter of this year, these costs exceeded the prior quarter by $700 million.

Dow is working aggressively on this problem, leveraging the strength of our laboratories around the world, to achieve technological breakthroughs that will help solve the greenhouse gas and energy challenges. Most recently, on July 19 we announced a world-scale project in Brazil that will turn sugar cane ethanol into plastic. It's a first-of-a-kind facility; it's renewable; and it's energy efficient, as we will use the leftover bagasse from the sugar cane to generate electricity. The project demonstrates Dow's role as a technology integrator, as well as the opportunities we have to drive forward our strategic growth in a way that fully supports our sustainability commitments.

In addition, we:

- Pioneered the use of soybeans in the manufacture of high-quality plastic foam used in automobiles, office and home furnishings, and other products.
- Recently announced Dow will make aircraft de-icing fluid from glycerin, a by-product of biodiesel processing.

Other sustainable energy inventions are on the horizon. For example, we are developing new roofing materials that convert solar energy to electricity, a project the Department of Energy has chosen to jointly fund because of its promise.

In addition to our technology advancements, we are calling for strong government action on climate change, energy efficiency, conservation and security of supply. As a member of the U.S. Climate Action Partnership (USCAP), we are encouraging Congress to promptly enact mandatory, market-based climate legislation.

We have been recognized as leaders in energy efficiency and are believers that improved conservation offers the greatest prospect to reduce carbon dioxide (CO_2) and other greenhouse gas emissions.

We have also made real progress in this area.

In 1994, Dow made a public commitment to sustainability. We pledged then to improve our energy efficiency 20% by 2005. It was an ambitious goal—far greater than other heavy industries—and the fact that we achieved a 22% improvement is a great source of pride to our company and our employees, not only because of the reduction in our energy use, but because we did it profitably. We invested roughly $1 billion dollars and saved nearly $5 billion, which we believe is a very good return on our investment.

During this period we saved 900 trillion Btu, enough energy to power all the homes in California for a year.

Since 1990, we have improved our energy intensity by 38% and reduced our absolute greenhouse gas emissions by more than 20%, a level that exceeds Kyoto Protocol targets. We believe there is more to do, and have set a further goal to reduce our energy intensity by another 25% by 2015.

This relentless dedication to energy efficiency and our achievements is evidence that we know how to optimize the footprint of our existing assets and improve the efficiency of succeeding generations of technology.

WHY GASIFICATION?

Industrial gasification provides technologically prudent yet flexible paths to a lower carbon future and greater U.S. energy security, as it would help the country diversity with abundant, domestic energy resources while helping address the high cost we and other manufacturers pay for raw materials.

ABOUT THE TECHNOLOGY

Industrial gasification refers to the process of producing synthesis gas (syngas), a mixture of hydrogen and carbon monoxide, from a wide variety of raw materials, including coal, petroleum coke, industrial and municipal wastes, and other carbon-containing streams. Syngas is a highly efficient, highly versatile intermediate that can be converted to electricity, transportation fuels, chemicals or plastics—or a combination of any of these products, in what as known as polygeneration (Figure 1, below*).

Gasification technology can also be utilized to convert a wide range of biomass—plant matter, wood waste and crops—to energy and chemicals, replacing hydrocarbon fuels and feedstocks and reducing overall emissions of CO_2. Additionally, it can turn high-volume waste streams (e.g. plastics, municipal solid waste) into strategic fuel and feedstock sources.

By innovatively combining bio-based materials with high-energy materials such as coal, wastes streams that are otherwise "non-recyclable" (or only mechanically recyclable) can be converted into useful virgin materials, achieving a closed-loop, "cradle-to-cradle" life cycle for virtually any chemical or plastic.

CHALLENGES

Capital Costs.—Even a "small" gasifier is a complex piece of equipment. Multiple gasifiers and related unit operations (i.e. an oxygen plant) are typically required, resulting in high capital costs relative to other technologies. A coal to liquids (CTL) gasification plant requires some three to four times the capital of a comparable oil refinery.

Lack of Experience.—While gasification technologies have been around since the early 20th century, relatively few in the chemical or fuel industries have hands-on experience, contributing to the perception that gasification carries a greater-than-average technology risk. However, the operational experience to date provides evidence that a syngas platform could be a viable way to produce chemicals, plastics and fuels. Eastman Chemical in the U.S. and Sasol in South Africa are currently practicing coal-based chemistry on a commercial scale. This evidence of viability should give us confidence that larger scale deployment is achievable.

CO_2.—A globally-consistent carbon regulatory scheme is needed to create a stable long-term investment climate for gasification projects. Carbon capture and sequestration is arguably the most needed and widely acceptable technology solution for CO_2 emissions control. Financing the development of the sequestration technology and infrastructure should be a priority for government investment. Gasification plants using hydrocarbon feedstocks, with their concentrated CO_2 exhaust streams, are well suited to a national sequestration program as it develops. Economically attractive uses of CO_2, such as enhanced oil recovery, should be encouraged.

Co-gasification of biomass and wastes can help to reduce consumption of hydrocarbon feedstocks and overall CO_2 emissions. Some studies have shown that biomass can be co-gasified with coal at a rate up to 30% of total input.

With industrial gasification, a significant portion of the carbon will find its way back into the supply chain as useful product. Carbon-based products such as carpeting, water and sewer pipes, building insulation, packaging and automotive components can all be derived from either the naphtha co-product of a CTL plant, or directly from the syngas.

DOW'S PLAN

We congratulate the committee and the Senate for its recent passage of an energy bill to improve U.S. energy security. But we respectfully submit that more needs to be done, particularly on the supply side.

Our search for alternatives to the feedstocks we use currently have led us to believe that industrial gasification technology is mature and scaleable, could greatly improve America's energy security, and that building a full-scale plant of this kind in the United States can best be accomplished through a public/private partnership. We have expressed an interest in leading a consortium in the U.S. to demonstrate the technology on a commercial scale (approx. 80,000–100,000 barrels/day).

Raw material feedstocks to produce syngas are abundant, present throughout the United States, and available at low costs. However, the major hurdle for any such plant in the U.S. is the high capital cost and obtaining financing. The promise of syngas plants will matter little without the right policy and incentives. Financiers

* Figure 1 has been retained in committee files.

are hesitant to provide the capital needed for a facility of the size needed to prove its worth.

That is why we believe the federal government must dramatically increase its commitment to the development of a syngas infrastructure. Even with oil prices where they are today, the payback period deters private entities from building these plants (Chart 1*).

The government needs to jump start a public-private partnership to develop a syngas industry by providing a focused capital investment, enacting stable policies and permitting the military to enter into long-term off-take agreements. Loan guarantees and tax credits alone won't make this happen.

Based on our analysis, direct government loans covering up to 50% of the cost of a few early-mover projects seems to be what is needed to demonstrate viability (Chart 2*). We remain open to comparable alternatives.

Our view is that absent a scaleable solution like industrial gasification, which brings a range of benefits, the U.S. over time will become a bit player in the petrochemical industry. Without significant U.S. action to reduce demand, increase supply and provide alternatives, the center of gravity of the petrochemical industry, and its downstream production, will shift to the Middle East, Africa and Asia. This movement has already begun. In the last two months alone, Dow alone has announced joint ventures totaling around $30 billion in these areas. More than 10,000 direct and 60,000 indirect jobs will be created—many of which could have been created in the United States, but for the high cost of energy, particularly natural gas, a commodity that, unlike oil, is regionally, rather than globally priced.

Global competitors, integrated to low cost, often stranded feedstocks will be able to land competing products in the U.S. at a natural gas-equivalent cost of roughly half the U.S. gas price. The U.S. must continue to drive demand reduction through energy efficiency, increase domestic oil and natural gas production, and promote alternative and renewable forms of energy and feedstock. Syngas from coal, biomass or a combination of the two is a potential low-cost alternative to the high and volatile cost of natural gas, gas liquids and petroleum byproducts that are the basic building blocks of the modern chemical industry.

We expect that with the government's assistance, we—in partnership with others—would prove the worth of a U.S. syngas industry.

Syngas can be converted to chemicals and plastics as well as electricity and transportation fuels. With it, Dow can make virtually all of the products we currently manufacture. Coal is important because its abundance and established supply chain make it most capable of meeting syngas needs on a scale that will be economically meaningful.

CARBON BENEFITS

Dow fully understands that we must live in a carbon-constrained world. And we support Congress' desire to improve the carbon efficiency of coal technologies. The CO_2 must be managed. We agree with many members of this committee that in the near term, carbon capture and storage (CCS) should be developed to ease the U.S. transition from a fossil fuel-based energy economy to a low-carbon paradigm and eventually a zero-emissions future.

Industrial gasification plants will help demonstrate options for CCS. Gasification of hydrocarbon feedstocks produces relatively pure CO_2 streams, which can be used for economic purposes—enhanced oil recovery or CCS. But these are not the only ways to limit atmospheric CO_2 emissions.

Our involvement in the gasification process (a chemical process) offers another way to maximize the use of CO_2. The chemicals we make bind the carbon into useful products like plastic (Figures 2–4*).

Our initial analysis suggests that were a syngas plant to run on 30% biomass, as experts tells us is possible, and were we to make products from the plant's feedstocks, we could bring the CO_2 footprint of a CTL plant down by about half (Figure 4).

Further, we expect that through this consortium with other stakeholders, relying on experts such as those here today and our history of optimizing the chemical process will assure carbon efficiency improvements.

COAL-TO-LIQUIDS

We've heard on both sides of the Capitol from members of both parties that coal must remain a key part of the U.S. energy mix and that any ultimate climate

*Charts 1-2 have been retained in committee files.
*Figures 2-4 have been retained in committee files.

change policy must require a "Manhattan Project" for coal. The question is how to use coal in a carbon constrained world. In other words, how do you grow coal without breaking the carbon "bank"? We submit that one of the best ways is through coal gasification.

Dow believes we can participate in a coal-to-liquids plant and that doing so will improve its carbon footprint, as stated above.

Initially, these plants are likely to run mostly on coal (Figure 3). Over time, their operators will gain experience and the facilities will become more efficient, reducing their greenhouse gas emissions. Biomass will be increasingly used, further reducing greenhouse gases. And by utilizing sequestration in such a setup, there can be a net reduction in greenhouse gases compared to an oil refinery of comparable size (Figure 4).

Dow has announced its intent to form a joint venture in China to build coal-to-chemical plants, which are similar to CTL facilities. We would like to explore this opportunity here if the capital cost and carbon footprint hurdles can be overcome.

The CHAIRMAN. Thank you very much.

Mr. Fehrman, go right ahead.

STATEMENT OF BILL FEHRMAN, PRESIDENT, PACIFICORP ENERGY, SALT LAKE CITY, UT

Mr. FEHRMAN. Thank you, Mr. Chairman. My name is Bill Fehrman and I am President of PacifiCorp Energy, which provides power to PacifiCorp's customers in Utah, Oregon, Wyoming, Idaho, California, and Washington.

We are responsible for implementing the policies that will ultimately be decided through the discussions that we're having today and beyond. It's also important to note that we do not develop the technology, but we do have the requirement to justify the technology to our regulators, so that we can be seen as making prudent decisions on behalf of our customers.

We are constantly examining different ways to provide generating resources to serve our customer's fast-growing demands, while at the same time, trying to meet the strict new environmental requirements that we have today and that we expect to have in the future.

Supercritical pulverized coal technology is available today and emits, basically, the same amount of CO_2 as IGCC technology. We've used supercritical coal technology as a consideration or a bridge, if you will, while new approaches are developed to burning coal, such as IGCC with carbon sequestration and capture capabilities.

It's critical to understand that IGCC's technology and carbon capture are two completely different things and can be applied to different sorts of opportunities. For instance, as you know, IGCC gasifies the coal and then it runs through a standard combustion turbine, whereas carbon capture and sequestration essentially takes the CO_2, separates it, compresses it, and injects it deep into the earth. Both IGCC and pulverized coal technologies can be compatible with carbon capture and sequestration, they are not one against each other.

In our case, no outside body, for instance, tells Starbucks what it can charge for products or what costs it can include in its prices. That's not the case for a public utility such as PacifiCorp. Our regulators determine the rates that we can charge and most States only allow recovery on those costs that can be demonstrated to be prudent and undertaken at a very cost-effective manner.

This structure, just by itself, does not encourage utilities to become technology developers. Instead, we purchase those technologies from vendors and it's their shareholders, not our customers or our rate payers who earn the rewards of the success of bear the cost of the failure.

In evaluating any of these technologies, we ask ourselves three key questions. Is it commercially proven and reliable? Are the risks and costs comparable to other available technologies that we have in front of us? Will our State regulators allow recovery of reasonable and prudent development costs in our rates?

With respect to the IGCC technology today, our answer to each of these questions is no. The four IGCC plants operating today are not large-scale, they have not consistently achieved capacity factors comparable to supercritical plants and they do not capture and sequester CO_2. Much of the technology remains unproven and we have not received cost or performance guarantees from vendors that can give us reasonable assurance that we can meet the prudent cost recovery requirements that our regulators will demand. However, it's these unknowns that demonstrate why more research in this area is so critical and why this debate has to continue.

Most of the information on IGCC is based on the use of higher heat content bituminous coal. We believe that one of DOE's highest priorities should be IGCC R&D with sub bituminous coals and pre- and post-combustion technologies for capturing carbon from both IGCC and pulverized coal-fired plants.

Government support can clearly help direct the industry toward this higher risk investment and away from the default choice of natural gas. Support should include such things as accelerated depreciation, investment and production tax credits, R&D funding, public and private partnerships to develop and construct commercial-scale plants. In fact, in this regard, PacifiCorp was recently chosen as the Wyoming Infrastructure's partner to pursue a high altitude IGCC plant using Powder River Basin coal. I would also add that our existing Jim Bridger sits atop some of the most promising CO_2 storage locations in the United States.

Carbon capture and sequestration currently utilized it enhanced oil recovery must also fit into this picture, but it faces major challenges, as you've heard before from others. So, we're sure our Federal research, development policy dollars go. From our view, support the development of IGC plants with a focus on the most abundant coal types, i.e., there is a significant amount of coal that is available, particularly in the State of Wyoming that has a potential to solve many of our issues in the long-term, provide R&D funding for low-cost, pre- and post-combustion CO_2 capture process for both pulverized coal and IGCC, and provide funding for the advancement of technologies that result in higher availability, increased performance and cost, and eliminate the liability for sequestering CO_2, that many of us view is one of the most significant risks of this, going forward.

In order to move us toward a low-carbon future, IGC technology must be economically competitive, reliable and more broadly applicable to the lower-ranked coals and higher altitude conditions that exist in many of our locations across the United States, but particularly in the West. Remember that a combined IGCC-carbon capture and sequestration power plant does not exist anywhere in the world today, yet many talk like it's readily available.

As we debate our future energy policy, we must not lose track of these facts, and the economic impact of developing this technology.

Our customers will pay for our decisions, and when they turn on the switch, they expect the lights to come on at a reasonable price.

Thank you for the opportunity to be here, and I'd be happy to answer any of your questions.

[The prepared statement of Mr. Fehrman follows:]

PREPARED STATEMENT OF BILL FEHRMAN, PRESIDENT, PACIFICORP ENERGY, SALT LAKE CITY, UT

Thank you, Mr. Chairman for the opportunity to testify today regarding the electric utility industry perspective on the potential of integrated gasification combined cycle (IGCC) technology. My name is Bill Fehrman, and I am the president of PacifiCorp Energy, the power generation and supply division of PacifiCorp. PacifiCorp provides electric utility service in six states across the West—Utah, Oregon, Wyoming, Idaho, California and Washington. My comments today reflect my views and experiences in this industry and are not meant to represent the industry as a whole, although I believe our experiences are largely consistent with those of other companies considering investments in clean coal technologies.

BACKGROUND ON PACIFICORP

PacifiCorp's generation mix includes nearly every major resource available to our industry: coal, natural gas, hydroelectric, wind and geothermal power. Along with our sister company, Iowa-based MidAmerican Energy Company, we are the largest on-system utility owner of renewable electricity in the country through our corporate parent, MidAmerican Energy Holdings Company, and we are also looking to expand our nuclear capability.

KEY CONSIDERATIONS WITH REGARD TO GENERATION RESOURCES

PacifiCorp faces an enormous challenge to meet the demands of our customers. On one hand, we must bring new resources on line to serve the fast-growing demands of our Utah-based Rocky Mountain Power system. At the same time, we must meet strict new environmental requirements, particularly in the Pacific Northwest. It is critical that we move forward in a way that does not expose our customers to undue risk.

In determining our energy supply and resource acquisition strategies for next-generation technologies, we ask three key questions:

1) Is the technology commercially proven and capable of providing reliable power for our customers?
2) Is the cost and risk of the technology comparable to other available technologies?
3)Will our state regulators support these projects and allow recovery of reasonable and prudent costs of development to be included in rates?

UTILITIES ARE NOT ENCOURAGED TO BE TECHNOLOGY DEVELOPERS

The answers to each of these questions must be in the affirmative in order for public utilities to invest billions of dollars in new technologies. However, at the present time with respect to IGCC technology, the answer to each of these questions is no. Utilities are largely agents of the customers we serve. We assemble and integrate the various elements of electric service—power generation or acquisition, transmission, delivery, and customer service—to provide our customers with the most reliable system possible at a reasonable price, while complying with all federal and state environmental policies that may exist.

For the most part, utilities do not individually develop technologies; we purchase technologies and operate them. The reason this is true might not be immediately obvious, but it is important to understand. No outside body tells Starbucks what it can charge for its products or what costs it can include in its prices. That is not the case for public utilities. State and federal regulators determine the rates that utilities can charge, and state statutes limit the costs that can be considered for inclusion in rates. Most state statutes only allow costs to be included in rates if the utility can demonstrate that the actions that gave rise to the costs were undertaken in a cost-effective manner, which is typically defined in terms of risk-adjusted least cost.

THE ROLE OF STATE REGULATORS

Our state regulators are the consumers' watchdogs and use a premise of risk-adjusted least cost to ensure that only those costs that are prudently spent are recovered in rates. This structure does not encourage utilities to become technology developers. Those responsibilities lie with the vendor community, where the market provides greater potential rewards for successful innovation. Shareholders of these companies, not ratepayers, earn the rewards of success or bear the costs of failure.

Neither utilities nor regulators have perfect foresight regarding the development of future technologies, future market conditions, or changes in environmental laws, but we make the best projections we can in our resource development decisions. We also appreciate that the American public is increasingly concerned with environmental issues generally and global climate change specifically. A significant concern as it relates to electric utilities is carbon dioxide, the byproduct of the combustion of fossil fuels. Although the primary focus has been on coal-based generation, since it produces more carbon dioxide per unit of electric energy than other fossil fuels, natural gas-fired generation also produces carbon dioxide emissions.

For a number of years, PacifiCorp's integrated resource planning process has included an estimated cost of carbon dioxide of eight dollars per ton. This is based on the assumption that at some point in the future, Congress will establish some form of greenhouse gas emissions reduction program that will increase the cost of burning fossil fuels. However, the "cost" of carbon dioxide and the timetable for mandating carbon constraints are not known. This has led to significant uncertainty as PacifiCorp has attempted to acquire or build new resources to meet customers' growing needs. As a consequence of this uncertainty, PacifiCorp has focused on the addition of non-dispatchable renewable energy and natural gas-fired generation. Unfortunately, this does not solve our need for new baseload resources to meet growing demand for energy.

As state and federal legislative action related to mandatory greenhouse gas reduction programs move forward, we will seek to continuously update our assumptions and integrate these assumptions into our resource planning. In every case, we will seek to accomplish the same goal—providing reliable, affordable service to our customers in a manner consistent with our core "Environmental RESPECT" policy of using our resources wisely and protecting our environment for the benefit of future generations.

TODAY'S RESOURCE CHOICES

Today, electric utilities across the country are facing the same challenge. Reserve margins on the system decrease with each passing day, and it is unclear what the best fuel source is to meet the demands of tomorrow. Each energy resource option has positives and negatives:

Coal is domestically available, reliable and affordable, but it also creates carbon dioxide emissions at a higher rate than the other predominant fossil fuel of choice, natural gas. There are increasing efforts at grassroots levels to block construction of new pulverized coal-fired plants, even ones equipped with state of the art emissions control technology that meet all current environmental regulations.

Natural gas allows for plants that can be permitted and constructed relatively quickly and at relatively low capital costs compared to coal-fired plants. However, fuel prices are highly volatile and domestic resources and infrastructure is strained. Since 1990, the overwhelming majority of new electric generating capacity has used natural gas as its fuel, helping push gas prices higher for all uses. We also face increasing concerns that, for the first time ever, the United States will soon begin importing a substantial percentage of its gas supply from outside North America, furthering our dependence on foreign sources of supply.

Nuclear power is non-carbon emitting and has relatively low fuel costs, but we still do not have a long-term solution to the used fuel issue. Nuclear is an attractive option to consider in a carbon constrained universe, but to date no one in the United States has put all the pieces together to begin construction of a next-generation nuclear generating resource.

Renewables include a whole range of opportunities including wind, biomass, solar, geothermal, and small hydro. They provide emissions-free, sustainable energy sources. However, the primary renewable source is wind, which is both intermittent and non-dispatchable. In spite of rapid growth in recent years, thanks to Congress' extension of the Section 45 production tax credit, non-hydro renewables still only provide less than two percent of the country's generation mix. We are proud to be an industry leader in integrating renewables into our fuel mix. However, many of the most suitable locations are already under development, and transmission costs are likely to increase substantially. Furthermore, as renewable portfolio standards mandate ever larger percentages of energy, additional sources of backup generation will need to be installed to provide the reliability necessary due to the intermittency of wind.

Hydroelectricity is also an emissions-free renewable generation source, but we are unlikely to see new large-scale hydro facilities built in the United States due to concerns about impacts on fish, river systems, and some endangered species. Indeed, the West is experiencing significant pressure to remove existing hydroelectric dams. Nonetheless, we should explore ways to maintain the hydro resources we have in an environmentally responsible way, explore cutting-edge, low impact hydro technologies, and work to gain greater efficiency from existing facilities.

Some refer to energy efficiency as a "fifth fuel," and we agree that energy efficiency represents one of the best opportunities to both meet resource needs and near-term emissions reductions. We commend the Senate, and this Committee specifically, for passing a bipartisan package of energy efficiency requirements in this year's energy bill. However, efficiency improvements only help flatten the growth of the demand curve; they do not eliminate the need for new generation resources. Energy efficiency and renewables alone will not meet the electric energy needs of this country.

WHAT IS IGCC?

As others have testified before this Committee, IGCC technology is designed to combine a chemical gasification process with traditional combustion turbine based processes to generate electricity at comparatively high rates of efficiency and low emissions levels.

While I know that members of this Committee understand the difference, I want to emphasize for the record that IGCC technology and carbon capture and sequestration are not the same thing. IGCC describes a highly integrated two-step process: (1) coal gasification to produce a gas-based fuel that can be burned in a combustion turbine; and (2) power generation. Carbon capture and sequestration is a potential complementary add-on to this technology that would convert the carbon in the synthetic gas to carbon dioxide, separate and compress it, and ultimately inject it deep beneath the Earth's surface, resulting in permanent sequestration.

IS IGCC A PROVEN TECHNOLOGY?

Worldwide, there are four operational IGCC electricity generating plants with generation capacity of roughly 250 megawatts each. None of these plants captures or sequesters carbon dioxide. The two plants operating in the United States (in Florida and Indiana) were built with federal funding assistance as part of the Department of Energy's Clean Coal Power Initiative demonstration projects.

IGCC is not a commercially viable technology at this time. No large scale, utility-size plant has been built, and much of the technology is unproven, which is why we have not been able to obtain price and performance guarantees from any vendors. With the technology unproven, with unclear costs, and with no guarantees from vendors, we are unwilling at this time to expose our customers to these risks. Furthermore, these plants have not consistently achieved capacity factors comparable to readily available supercritical pulverized coal plants.

Moreover, most of the information on the operation of IGCC technology is based on the use of higher ranked, higher heat content bituminous coal or pet-coke. Lower ranked subbituminous and lignite coals with lower heat content and greater moisture content can be gasified, but at lower efficiency. The industry needs significantly more experience working with these coals, especially given the quantity of these types of coals in the Western United States.

The application of IGCC at higher altitudes presents unique issues that must be addressed given that a large quantity of low rank coals are found in elevations that exceed 4,000 feet. At high elevation, the air pressure—and hence the density of air—is lower. The output of all combustion turbine-based resources, not just IGCC plants, is thus reduced at higher elevations. The output of a combustion turbine is reduced approximately 3 percent with every 1,000 feet increase in altitude. For a project operating at 5,000 feet (which would apply to much of PacifiCorp's generating fleet in the Rocky Mountain region), output losses would be 15 percent. In simple terms, this increase in elevation results in a reduction in output, although the capital cost is essentially unchanged. Relocating the facility to a lower altitude and moving the electrons by wire may seem a reasonable option, but this would move the generation away from many of the most potentially suitable carbon sequestration sites in the United States and would also require moving more coal by rail. It is important to note that supercritical pulverized coal plants do not suffer the same output losses at altitude and are therefore considered to be an excellent choice for this type of application.

For IGCC to reach its full potential in the United States, the technology must be improved, with a particular emphasis on performance with lower ranked coals and especially at higher altitudes. Funding for this improvement through the Department of Energy and research institutions should be one of our country's highest energy technology priorities. Government support for IGCC development can help direct the industry toward this higher risk technology investment and away from the default choice of natural gas. This support can take the form of accelerated depreciation; investment and production tax credits; research, development and commercial demonstration funding; performance certainty guarantees; and public-private partnerships to develop, construct and operate commercial scale IGCC plants. In this regard, PacifiCorp Energy was recently chosen as the Wyoming Infrastructure Authority's partner to pursue a high altitude, IGCC plant in the state that is designed to use Powder River Basin coal, and we are together seeking this government support.

COMPARING IGCC AND SUPERCRITICAL PULVERIZED COAL

Based on our studies, vendor and engineering-constructor information, and recent bids, as well as information we have seen from other utilities at this time, a supercritical pulverized coal plant costs roughly 25–30 percent less than an IGCC plant. Moreover, supercritical pulverized coal technology is mature and reliable, whereas IGCC is still far from having acceptable performance parameters, particularly with regard to lower ranked coals and high altitude applications. It is also important to note that today IGCC and supercritical pulverized coal emit basically the same amount of carbon dioxide.

Using traditional measures of prudence and cost-effectiveness, and given our current estimates of the "cost" of carbon dioxide emissions, supercritical coal technology is the clear risk-adjusted, least-cost choice at this time. Unfortunately, in our view, a number of states have imposed emissions reductions requirements that effectively prohibit the inclusion of electricity produced by supercritical technology. Furthermore, some states are requiring that IGCC have a carbon footprint equivalent to natural gas-fired generation. This course of action essentially would require implementation of carbon capture and sequestration. Though well-intentioned, adding this requirement to IGCC will further frustrate the development of this technology. While we do not believe this is sound energy policy, we must follow the laws of the states we serve.

If regulators and policymakers eliminate pulverized coal technology from our generation mix, choices for baseload generation are effectively limited to natural gas in the near term, with IGCC and its attendant technology risks in the intermediate term and nuclear. PacifiCorp and MidAmerican Energy will also continue to add renewable energy resources such as geothermal, wind and biomass where cost effective, but these resources supplement rather than displace the need for traditional baseload resources.

In our view, the most appropriate policy would be to encourage the deployment of supercritical coal plants, while continuing to study IGCC and other clean coal technologies. At the same time, given the large number of existing pulverized coal-fired power plants in the United States, it is critical Congress and the Department of Energy increase research and development support for pre- and post-combustion technologies that would facilitate development of commercially viable carbon capture technologies for pulverized coal generation.

This policy would allow us to meet our growth needs now, provide multiple paths toward carbon sequestration, and require both power generators and state regulators to use cost-effective clean generation technologies as soon as they are available commercially.

HOW DOES CARBON CAPTURE AND SEQUESTRATION FIT IN THIS PICTURE?

Carbon sequestration has been a byproduct in the oil production industry in a process known as enhanced oil recovery in which carbon dioxide is mixed with oil under the Earth to enhance oil extraction. Carbon dioxide is captured and re-injected, and ultimately the carbon dioxide is permanently sequestered below the earth's surface. Enhanced oil recovery is a widely utilized and well established technology, although the use of carbon dioxide for enhanced oil recovery is very site specific. It is expected that the demand for additional carbon dioxide will increase as production from existing oil, using conventional means, declines and oil prices continue to remain robust. Unfortunately, the demand for carbon dioxide for enhanced oil recovery is significantly less than the amount of carbon dioxide that is expected to be permanently sequestered to meet long-term target levels.

Applying this technology to the carbon dioxide emissions streams of fossil fuel-based electric generation represents a tremendous challenge for the United States and the world. The Electric Power Research Institute's February 2007 research paper, "Electricity Technology in a Carbon-Constrained Future," demonstrates that successfully deploying carbon capture and sequestration technology provides the single largest "wedge" of carbon emissions reductions that could be achieved by the electric utility industry in meeting a goal of reducing 2030 emissions levels to 1990 levels.[1] However, broad commercial deployment of carbon capture and sequestration technology is the critical component of achieving long-term reductions in greenhouse gas emissions, both domestically and internationally.

The recent MIT study, "The Future of Coal," also endorses this course of action, stating: "We conclude that CO_2 capture and sequestration (CCS) is the critical enabling technology that would reduce CO_2 emissions significantly while also allowing coal to meet the world's pressing energy needs."[2]

The challenge of applying carbon capture and sequestration technology to electric power generation.

Applying carbon sequestration technology to the electric power sector will present at least three major challenges compared to the more limited use of the technology in enhanced oil recovery:

1) The volume of carbon dioxide that must be extracted from all power plant emissions streams is orders of magnitude greater than those captured in enhanced oil recovery processes. A single 800-megawatt coal-fired power plant will produce approximately 6.1 million tons of carbon dioxide annually, compared to the approximately 5 million tons of carbon dioxide used annually by the largest enhanced oil recovery projects.

2) An entirely new energy infrastructure will need to be built to compress and safely transport carbon dioxide to appropriate geological formations and inject it deep beneath the Earth's surface. The United States is fortunate in that we appear to have the world's greatest carbon dioxide sequestration potential. However, these formations are not evenly distributed throughout the country. Fully developing a system of permanent carbon dioxide geologic sequestration sites will require the United States to build a vast interstate pipeline system somewhat similar to the natural gas pipeline system that has been created over the last 100 years. Injection wells must be drilled several thousands of feet below the Earth's surface. This will require massive investments in commodities, industrial products and manpower.

3) Carbon dioxide injection for these purposes is designed to be complete and permanent, or nearly so. The goal of sequestration is to remove carbon dioxide from the atmosphere for centuries and in a manner that is as close to 100 percent certain to avoid leakage. In addition to the physical infrastructure that must be built to facilitate carbon capture and sequestration, the federal government and the states must develop a legal and regulatory framework to support these investments. Until a regulatory permitting legal structure is developed and the issue of liability risk is addressed, it is highly unlikely that large-scale carbon sequestration can be achieved.

RESEARCH AND DEVELOPMENT EFFORTS

More research and development is needed in a number of areas. Congress must establish regulatory and legal frameworks and remove other barriers to implementation in order to allow and encourage private sector entities to move forward with investments in these technologies and commercial-scale carbon sequestration.

We recommend the following priorities:

1. Provide additional and reliable financial support to facilitate development of IGCC plants with a focus on those locations and coal types that are the most abundant.

---

[1] Electric Power Research Institute, "Electricity Technology in a Carbon-Constrained Future," February 2007, p. 11.

[2] "The Future of Coal: Options for a Carbon-Constrained World," MIT Interdisciplinary Study, March 2007, Executive Summary, p. x.

2. Provide research and development funding for development of low-cost pre/post-combustion carbon dioxide capture processes.

3. Provide specific development goals for the advancement of IGCC technologies that focus on major components that will result in higher availability, increased performance and lower cost.

4. Provide a regulatory framework in which captured carbon dioxide is considered a commodity and not a waste/pollutant.

5. Provide financial incentives for permanent geologic carbon dioxide sequestration.

6. Develop a regulatory framework for injection wells and carbon dioxide pipelines.

7. Develop regulatory and policy certainty to eliminate all liability for sequestering carbon under scientifically-based federal standards.

8. Develop a regulatory and policy position that supports the use of supercritical pulverized coal as a bridge until new technologies are proven and can be commercially deployed.

SUMMARY

Before IGCC technology can provide a critical path toward a low-carbon future, it must be made more economically competitive, reliable, and more broadly applicable to lower rank coals and higher altitude conditions. Policy makers must understand, however, that combining a chemical process (gasification) with a mechanical process (coal-based power generation), and then capturing and sequestering the gasified carbon, is not simple and does not exist today anywhere in the world.

Policy makers must also appreciate that our first obligation as public utilities is to provide reliable electricity supplies for all our customers and that deploying new technologies to reduce carbon emissions will not come without significant increases in cost for these customers. We share the desire of Congress and the American people to proactively take actions to reduce and avoid carbon dioxide emissions as much as possible and as quickly as possible. However, technical challenges remain and emission reduction programs must be designed with these realities in mind—not based on randomly chosen timelines or politically appealing slogans.

Your committee has played a highly constructive role in holding robust examinations of these issues. We hope that all members of the Senate will take these facts into consideration in developing climate change legislation. Utilities such as PacifiCorp face growing demand for energy, and we must build some type of resource to meet this demand, as we have an obligation to serve. It is critical that as we continue to debate the future of energy supply for the United States, we don't forget our current customers, who expect to see a light come on when the switch is turned, while paying a reasonable cost to do so.

Thank you. I would be pleased to answer any questions.

The CHAIRMAN. Thank you very much.

I'm informed Senator Tester's going to have to leave in just a few minutes, let me defer to him, and he can ask my round of questions, and I'll come along later.

Senator TESTER. Mr. Chairman, I want to thank you very much for that.

I want to—we'll kind of jump around here a little bit, Frank—the technology you talked about can be retrofitted on existing coal-fired plants, correct?

Mr. ALIX. Correct.

Senator TESTER. You said that the cost is about $20 per ton of CO_2?

Mr. ALIX. Correct.

Senator TESTER. Now, I know it varies on the coal, but just how much CO_2 is produced from a ton of coal from, say Wyoming or Montana?

Mr. ALIX. We look at more, in terms of a 500-megawatt plant is going to produce about 4 million tons a year of CO_2.

Senator TESTER. Four million tons a year?

Mr. ALIX. Regardless of the coal.

Senator TESTER. Right.

Mr. ALIX. You know, to a certain extent, the coal, the carbon and the heat content are pretty closely related to CO_2 release.

Senator TESTER. OK, the size availability, it will fit on any size plant? The retrofit?

Mr. ALIX. We don't see any reason why not.

Senator TESTER. It's 90 percent efficient? On capture?

Mr. ALIX. We're at lab scale today, but our lab testing which directly correlates, we think, to our next commercial scale up shows 90 percent capture is very doable.

Senator TESTER. OK, so, and what's the cost—any idea of what it costs to retrofit a plant? Of the size you talked?

Mr. ALIX. You know, we generally look at this $20 a ton, about $10 a ton is capital cost for retrofit.

Senator TESTER. OK.

Mr. ALIX. We're in $500-plus dollars a kilowatt for the retrofit.

Senator TESTER. Five hundred a kilowatt——

Mr. ALIX. So, let me put in numbers maybe you can understand. For a base loaded plant, you know, we're maybe $200 to $300 million to put it on a 600-megawatt plant.

Senator TESTER. OK, sounds good.

Andrew, the technology you talked about that moves coal to natural gas, what's the sufficiency, BTU to BTU?

Mr. PERLMAN. It's between—depending on the type of coal and the feed sock, between 68 and 72 percent efficient.

Senator TESTER. OK.

Do you have a plant of any size?

Mr. PERLMAN. We do. In Des Plains, Illinois——

Senator TESTER. That's right.

Mr. PERLMAN [continuing]. At the Technology Institute.

Senator TESTER. What kind of production does it have?

Mr. PERLMAN. It's relatively small, it's about 3 tons per day of Power River Basin Coal.

Senator TESTER. Right. But you don't see any problem with increasing that production up?

Mr. PERLMAN. No, it's a, basically a fluid-bed reactor, it's basically a tube with no innards.

Senator TESTER. Gotcha.

Mr. PERLMAN. So, you know, the scale-up of fluid-bed reactors has been pretty well understood and modeled for——

Senator TESTER. All right.

Don, the oxy-coal process that you talked about—what is the cost per kilowatt, or megawatt or however you want to produce it, compared to a conventional plant now?

Mr. LANGLEY. I think the most relevant cost is we would say that it's between a 45 and 50 percent cost of electricity increase——

Senator TESTER. OK.

Mr. LANGLEY [continuing]. To use oxy-coal, over a plant without it.

Senator TESTER. OK. Is there additional water needs with your process?

Mr. LANGLEY. No, not particularly.

Senator TESTER. For cooling? Not, huh? OK.

Mr. LANGLEY. I don't think, I think so.

Senator TESTER. OK. Good.

Jim, first of all, I want to thank you for supporting my amendment. It's interesting what an organic farmer can combine with Dow Chemical on policy, but I really appreciate Dow's vision on that.

Mr. ROSBOROUGH. Thank you.

Senator TESTER. You talked about a public/private partnership. The amount of money that is being allocated at this point in time, is it doing any good at all? Is it heading in the right direction? If you were a person in a position that could make a decision on how the money were to be allocated to form these kinds of partnerships, how would you do it?

Mr. ROSBOROUGH. Senator, I think as you know in your amendment, there was a call for approximately $10 billion worth of direct loans, which is—to us—a fairly reasonable start for roughly three polygeneration types of complexes. It's our belief that the integration of chemicals, plastics, electricity and fuels, is necessary to maximize the carbon efficiency, and therefore get after the environmental friendliness of the feed stock issues, as well.

Senator TESTER. OK. So, $10 billion is in loans and that's how you would—that's how we'd distribute it, is through a loan program?

Mr. ROSBOROUGH. That would be a nice start, that's probably three major complexes. Our vision is, the first one would tend to be the most expensive and the least efficient, and by the time we get to the third one, we would have demonstrated improvements in both efficiency as well as technology.

Senator TESTER. Thanks.

Finally, Bill, and I'll wrap this up very quickly, you talked about the economic impact of developing the technology.

Mr. FEHRMAN. Right.

Senator TESTER. As I look at Montana that's on fire right now, we've had—I don't know what the statistics are going to come back, but probably more 100 degree days in July than maybe we've ever had before, it's been incredibly hot there, it's incredibly smoky right now, the growing season has completely shifted from when I was a kid. The question for me becomes, what are the economic impacts if we don't develop this technology?

Mr. FEHRMAN. We don't argue the fact that we have to do something, my point on this is that as we go forward with these types of technologies, we have to bring the regulators who regulate us along with us. They are bound by statute to select the least-cost alternative. Until that sort of policy has changed in one way or another, then you're placing the regulators who are assessing our willingness to do these types of things at risk. In fact, in our case, we have a public partnership, public/private partnership in place, with the Wyoming Infrastructure Authority, where we are looking to do a demonstration project with IGCC. We have talked with some of our regulators and the fact that the cost of that is so significantly higher than the next alternative that we have today, they're not clear that they would allow those costs to go through to our customers.

Senator TESTER. Gotcha. I gotcha. Point well taken, thank you.

Thank you, Mr. Chairman.

Thank you to the other members of the committee.

The CHAIRMAN. Thank you, Senator Domenici.

Senator DOMENICI. Mr. Alix, I think it's fair to say that you have an optimistic prediction for the deployment of technologies capable of capturing and sequestering carbon dioxide, especially in cases where this can be done at existing plants. Do you have a timetable in mind for the point at which your company will be able to guarantee these technologies?

Mr. ALIX. We've talked this over with our partners in building commercial designs, and estimates now, we believe that after the 100-megawatt-scale type unit, about 2012 is the timeframe we'll have that operating. We believe, in 2011, and within about a year of operation on a 100-megawatt-scale unit, we should be able to provide commercial guarantees there, consistent with all conventional pollution control equipment.

Senator DOMENICI. Twenty eleven?

Mr. ALIX. Twenty eleven for the test, 2012 for the guarantees.

Senator DOMENICI. OK. What is the response as you gather, of the companies to that kind of out-year assurance of guarantees?

Mr. ALIX. I think the initial reaction is quite a bit of skepticism, but once they get into the details of our process, and why we have confidence, and why we think the equipment's available to scale it, I think it becomes credible.

Senator DOMENICI. Jim, let me ask you—I understand that Dow is a member of the United States Climate Action Partnership?

Mr. ROSBOROUGH. That is correct, Senator.

Senator DOMENICI. Which has called for mandatory limits on CO_2 emissions in the United States. Current economic conditions have led to an increasing pattern of Dow and other manufacturers moving investment from the United States to China. In your opinion, would mandatory limits on carbon dioxide solely in the United States increase or decrease the trend in the world?

Mr. ROSBOROUGH. Senator, thanks for the question.

We look at it as an integrated problem, and therefore an integrated solution is necessary. We believe that action on emissions is necessary, and at the same time, incentives on new technology to stimulate alternative feed stock development in the United States, and its conversion to chemicals, and plastics, and fuels is the best way, overall, to go.

We are a global company, and we have investments around the world that are made for a variety of reasons—both in low-cost Feedstocks, as well as where the high-growth markets are. China is clearly a market that we're going to invest in, in the future. Really, our interest here in the United States is let's revitalize our assets here, and let's reenergize the United States to become a growth market for the Dow Chemical Company, and other industry players again.

Senator DOMENICI. One last question, and then I'll stick around.

Will Dow incorporate carbon dioxide capture and storage when, and if, they construct coal-based chemical manufacturing facilities in China?

Mr. ROSBOROUGH. Senator, another good question.

We have a corporate goal to reduce absolute carbon dioxide emissions by a significant percentage over the next 15 years. I can't, right now, give you the exact number, but it's on the record, we've stated that on our website, www.dow.com, we list that.

The project in China will adhere to the rigid environmental standards that we set globally, because as a company that wants to lead the way in environmental stewardship, we feel it's necessary to demonstrate environmental stewardship even in places like China.

Senator DOMENICI. I'm not sure we can make you do that, obviously, that's overseas, but in a sense, you would cause a great deal of disbelief in your statements with regard to corporate activities if you went one way here, and another way in China in striking out at the same problem. That would put us in a very difficult position. Say, we were for climate change control, and we pushed it here, and you were working like beavers to get it done, and we had all of these things in our law that we changed, and we see your company over there in China, doing part of it, but not the tough part. The tough part you leave off, the easy one, you say, "You don't have to do that," to your Chinese partners, "You're good without it."

You understand that'd be pretty bad, right?

Mr. ROSBOROUGH. Senator, I understand your point. The Dow Chemical Company has a global strategy, we believe that climate change is a global problem which requires a global solution.

Senator DOMENICI. Thank you very much.

That's enough for me, Mr. Chairman. Thank you.

The CHAIRMAN. All right.

Senator Corker.

STATEMENT OF HON. BOB CORKER, U.S. SENATOR FROM TENNESSEE

Senator CORKER. Well, thank you, Mr. Chairman, and I appreciate you having this hearing. I think the testimony that all of you all have given has been excellent.

You know, this September, I guess, we're going to be debating— I think, there's a possibility we're going to be debating carbon cap and trade programs, and I guess, to me, there's an opportunity for us to marry, if you will, the issue of energy security with the issue of climate change, if we do it the right way. I know that some of you have pointed out solutions. Also, I guess, there are issues of logistics and that is getting the gas piped to the right places, getting the carbon piped, or shipped, to the right places.

But I wonder if you had any comments about if something's enacted, it might be in the very near future, and my biggest concern about it is, what do we do with coal? That's the one area that seems to me to be hanging out there, if you will, and very difficult for us to deal with in the short term. I know I've only got a few minutes here, but I'd love to have a short perspective on the kinds of things—forget the incentives that you've talked about, but some of the things we ought to contemplate, if you will, in any kind of carbon cap and trade bill that might pass the Senate, as it relates to coal and timing.

I'll let all of you say that, although I want to make sure I have the opportunity to ask two more questions, so be brief.

Mr. FEHRMAN. Very quickly, my only response in this would be to ask that the level of implementation of a program generally matches the availability of the technology to meet it.

Senator CORKER. I guess, you know, of course, we had the Energy Department in several hearings ago, and they talked about commercial viability of sequestration at 2045, you all have obviously given a much shorter horizon on that, in some cases, but I think we have to look at it on a broad basis for it to make a difference, and I'm just a little concerned about how we match those two together, and again, any editorial comments, I'd love to have over the next 30 seconds.

Yes, sir, Jim.

Mr. ROSBOROUGH. Senator, in Dow's view, coal has to be in the mix for Feedstocks. It is known to have a CO_2 footprint issue associated with it, but we believe there is also technology existing already that can advance that problem to a solution. I think enhanced oil recovery has been mentioned many times today. That's a good solution because it takes the CO_2 and uses it for an economic benefit. Whenever that's possible, we should do that.

Senator CORKER. But that's, again, regional, I think. We have the same issues, in many ways, with carbon sequestration that we have with ethanol, and that is, it's produced regionally, but hard to get—I think because of the time, what I might do is ask that you all be available for some questions, because I think we have an opportunity, actually, to get it right, in many regards, if we think about it thoroughly.

Let me just ask Jim one other question, I was interested in the ranking member's questions—would Dow be interested in a carbon cap and trade program, even if all of the allowances and credits were optioned on the front end?

Mr. ROSBOROUGH. I think we'd be interested in looking at it, because we're interested in creative solutions to a very complex problem. I couldn't commit that we'd be interested in it and want to see it implemented without knowing more details about how it would work, and economic impact on the corporation. But, we're very open-minded to creative solutions.

Senator CORKER. No, just give me a judgment—a lot of the very sophisticated companies—and I would consider Dow to be one of those—certainly are crowding around all of us on cap and trade, because the sophisticated companies might get free allowances on the front-end, which is obviously very beneficial. The less-sophisticated companies, obviously will be out in the hinder lands, not doing so—how much of that is weighing in to some of the major companies coming here, and supporting—if you will—a cap and trade program, in your estimation, as an individual, not as an employee of Dow?

Mr. ROSBOROUGH. It's hard for me to separate the two, but I'll say this—any project we look at, from now on into the future, contains with it a cost estimate dealing with the carbon footprint. So, we are planning that, from now on, any plant that we produce, or any plant that we build, will have a carbon solution that goes along with it.

Senator CORKER. Let me just ask one last question—I still have 14 seconds—thank you, Mr. Chairman.

I really am interested in this, I think we have a tremendous opportunity to work together toward a good end. Some of you have talked about the initial base cost of carbon sequestration and some of you have talked about it on a per-ton basis. Our Chairman, here, has a bill that actually has a, sort of a, safety valve price of carbon per ton, and I'd be curious for all five of you just to give me an estimate, as to what the price of carbon has to be, per ton, adding in the initial fixed cost the capital base you have to put in on the front-end—what does the price per ton have to be to make sequestration—let's say in the year 2018—viable to be competitive with some of the other Feedstocks and supplies? Just, give me a number.

Mr. LANGLEY. Thirty-five dollars a ton.

Mr. PERLMAN. I think closer to $20 a ton.

I just want to briefly comment on one thing.

Senator CORKER. OK.

Mr. PERLMAN. I definitely think you should implement the programs, because we've got an amazingly innovative country that's going to come up with technologies and solutions, and there's a venture capital community here that's going to fund them. So, if you implement a program, and you give people visibility, and it's the opportunity that technology will be there.

Senator CORKER. I really am very interested, I just want to make sure that we do things right, and I appreciate you saying that. I agree, we have an opportunity, innovatively, to do some things here in our country that could make us a leader, but we've got to do it the right way.

Yes, sir.

Mr. ALIX. I'm in that $20 a ton ballpark.

Senator CORKER. Jim.

Mr. ROSBOROUGH. I suppose my colleagues have bracketed it for me, and I have to say I don't really know the answer. We've studied it a bit, but we've looked at other studies, and they're sort of doing an average of the averages right now. It requires some specific due diligence on our part before I can answer your question, Senator.

Mr. FEHRMAN. I agree with Jim.

Senator CORKER. So, the last two guys ought to run for the Senate.

[Laughter.]

Senator CORKER. I would—thank you all—I'm just kidding—thank you all very much for your testimony, and I hope that we'll be able to talk, talk to you all more in the future. Thank you very much, I appreciate it.

The CHAIRMAN. Thank you all very much.

Let me ask a question here—one of the issues that I can't quite understand, we're informed by developers of these new power plants that they cannot commit to deploying this new technology, unless they've got a performance guarantee from the vendor of the technology, or at least that's sort of what I've heard from some of them.

It seems as though, I guess, Mr. Langley, let me ask you—you mentioned that your company's involved in developing a 300–megawatt oxy-coal combustion plant with CO_2 capture. Does that mean that you have been able to issue a guarantee on this technology on that size plant? Was that not required or what?

Mr. LANGLEY. The plant had a—I'll say, a fairly unique structure. We did issue some guarantees, but they were limited in nature, so the risk of that project has been shared jointly between the providers and SaskPower Corporation.

The CHAIRMAN. I guess this question of where the risk gets placed is key in all of this—how much of it is with the technology developer, how much of it is with the plant that's being constructed, I mean, the owner of the plant, how much of it is with the Government.

Mr. Rosborough, you folks, in working, in supporting Senator Tester's bill—and I think, in your testimony today as well—call for a Government guarantee of 50 percent of the cost of the various gasification plants that you believe could be built. Why is a loan program superior to a guarantee of a loan?

Mr. ROSBOROUGH. Thank you, Senator. The issue for us is, we're thinking about mega-billion dollar chemical complexes, because that's sort of the way we do our business, we feel economies of scale are necessary to compete globally. So, you talk about an integrated site of, to $6 or $8 billion of a gasification-based technology, and compare that against a $2 or $3 billion conventional alternative investment. We look around at the investment banks available, and the kind of moneys necessary, from one single entity to make the kind of a loan, is actually getting problematic, and we think it's possible that you might develop a consortium of lenders that could do it. So, we're open minded to that. But we just think it's more feasible to consider a direct-loan program with the Government, where the money comes from the most secure entity that I can think of.

The CHAIRMAN. You also talked about a consortium of industrial companies that would work in partnership with the Government to, essentially proliferate these gasification projects. Is that consortium pretty much in existence at this time? Or is that something that would have to be created, down the road—where are we with that?

Mr. ROSBOROUGH. It is not in existence today, Senator, but it can be created down the road. I would say, given the priority that we're all putting on this subject, we'd be able to create that fairly readily.

The CHAIRMAN. Because I think about some other areas that are not particularly analogous, but I remember when the semiconductor industry came together, and essentially developed a proposal, and came to us—here in Congress, came to the Administration first, and said, "We need to establish a Semi-tack," and the Government put up half the money, and the industry will put up half the money and that will allow us to remain in the lead in the world in developing these new technology for semi-conductors.

So, you're talking about something similar in this area, as I understand it, where industry would come together and agree to fund half of the cost of a major new industrial effort. Is that a correct interpretation of what you're saying?

Mr. ROSBOROUGH. I think so, Senator, I think that's a fair assessment of a program that we've got in mind.

The CHAIRMAN. Can you do that—you know, a lot of what Dow Chemical does has nothing to do with coal-to-liquids.

Mr. ROSBOROUGH. That's correct, Senator.

The CHAIRMAN. You know, coal-to-liquids has become a bit of a difficult issue here in the Congress, and in our National debate, because of concerns about emissions.

It strikes me, though, that what you're proposing, the main thrust of what you're proposing does not get us into coal-to-liquids. It is talking about industrial gasification projects to produce all sorts of useful products that clearly we're going to need going forward. Am I correctly interpreting that?

Mr. ROSBOROUGH. Senator, that's correct. We think, I mean, our industry has been tied to fuels producers ever since it began. The by-products of fuels manufacturers are the Feedstocks for our company. A coal-to-liquids regime would, in fact, produce Feedstocks for Dow, but we don't think stopping at liquids is the most efficient way to go about it, we think that carbon maximization, carbon efficiency maximization requires you to take electricity, fuels, chemicals and plastics, and do them all together in one spot.

The CHAIRMAN. OK.

Mr. ROSBOROUGH. So we advocate a polygeneration kind of approach.

The CHAIRMAN. Senator Domenici.

Senator DOMENICI. Yes, thank you.

Senator Bingaman, let me say, this is a very good opportunity for our committee to take a look and see if we're really interested in doing something, or if we want to do some more talking. But, I'm not so sure that what we're presenting for our members to take, is well, before I finish that sentence, let me ask—would Dow be, at the offset, the most logical and perhaps most appropriate in the marketplace to do this? Or are we saying there would be more than them that could do it. It's just that they and others would have to get with it to propose this kind of efficiency.

Mr. ROSBOROUGH. Senator, thanks for the question. The Dow Chemical Company has been integrated in the manufacture of chemical, plastics and electricity ever since our inception, so we have already been a practitioner of polygeneration.

Senator DOMENICI. Right.

Mr. ROSBOROUGH. In that regard, it puts us as a logical member of a consortium.

Senator DOMENICI. Yes.

Mr. ROSBOROUGH. We're happy to take a leadership role in something, because we also know how to operate, build and manage mega-projects. But, we're not coal experts, we're not carbon sequestration experts. We're not exactly on the cusp of some this new technology, as my friend, Mr. Perlman, for example, is.

So, we believe a consortium of multiple, of multiple entities is important, and how it actually ends up getting led and managed, would be up to the members of the consortium, I think.

Senator DOMENICI. I don't think, in the end, that it's going to be quite like the entity that was put together, that both you and I were involved in, with others, where we had a Secretary of Defense who many thought was a stubborn old ox, and it turns out, you all know who he was. He turned out to be, on these kinds of things, more right than wrong. He joined in making sure that the Department of Defense was heavily involved in this mix and match, so that America would take the lead in the world. Just takes us a couple of years to get there, and a lot of resources.

Whatever the model that we would look at and say, this is what it is, it's fine with me. I think we have to start talking about how do we get there. You all have been doing some talking about how you get there, from what I see. That's good. We're not operating in a vacuum. I believe something like this must be done. It's a terrible vacuum, and it's going to be filled. We better get with it, or we won't fill it.

You all are saying, to this group—not only is that true, Senator, but we're telling you that we know somebody will fill that, because it's too natural to not happen, right? It's going to happen. It's not a hard thing, it takes a lot of hard cash, you know—there's a lot of that around, too, just given the right project, right? It doesn't matter whether it's $6 billion or twenty—they're going to get the money, they're going to have the money, if you give them the right proposal, they'll find the money.

So I want to say, Senator, I think we came together, maybe it was for a different reason, a little different. But I want to put my two cents up there that I don't know why we're going so slow on some of these. You've admitted here for awhile that if you choose the wrong vehicle, you start off with a negative receptivity. We don't want that. We want to make sure that people like you and I can both be for this, right? Not that we fight, and saying we're not bored, we've got to say that you and I and therefore, a rather large group of these people here, feel like this is really doing something for the country. It is doing something for the country. Because if we don't do this, and we let you all get away and don't do it, we're making a big mistake. If you all think you can you know, play games with us, and not be competitive, but just say, "We know we've got America here, they've got to have us, and so we're going to take them," well, that ain't gonna happen either. Because I think we do have enough smart people that it won't happen.

Mr. Chairman, thank you, it's a good meeting and I learned a lot and I appreciate it.

The CHAIRMAN. Thank you very much.

Senator Barrasso.

Senator BARRASSO. Thank you, Mr. Chairman, I know the hour is late and others need to be places, but I want to follow up on a question you asked, Mr. Chairman, and I want to agree with my distinguished ranking member of this committee, Senator Domenici, and his comments.

You know, we have 250 years of future for coal, there's so much in the United States, and Australia, and China, it's going to be used, and we need to develop the technology, and as rapidly as we can, to make sure that those energy resources are there, and we're less dependent on international and Middle East sources of energy.

My question for Mr. Fehrman, and I appreciate what you do in Wyoming, and it's not just coal, I think I read a recent story about some wind generation and renewables and a commitment of your company to all of those things. But, I'm especially impressed in your comments and in your testimony, talking about how

PacifiCorp was chosen as the Wyoming Infrastructure Authority's partner to pursue the high altitude IGCC plant in the State, and designed to use the Powder River Basin Coal. You said you needed some of the Government's support on that.

When the Energy Bill was passed—although I wasn't a member of this body, it said to me, the Government should be a player, a partner, and I don't think that the Government has come along to that degree.

I read some of your comments about some of the things you need accelerated—depreciation, investment and production tax credits—do you have a timeline on some of those things? How much you need, for how long of a period of time? To make this specific program in Wyoming possible and doable, and get started?

Mr. FEHRMAN. Thank you for the question.

The key driver on the issue with the Wyoming Infrastructure partnership that we have is really tied to the section 413 dollars that are in the Energy Policy Act, and both the WIA and ourselves are looking for Government support to go through the funding mechanism to basically bring down the cost of this project, such that when we go to our regulators, the cost of the IGCC project will be neutral, or least cost, as compared to other alternatives, as to my earlier comment on the process we have to follow.

So, we have laid out with the WIA the funding program, and essentially, the sooner we can get funds to support the project, the sooner we can begin. This is a case where we will not be able to invest significant development dollars into this program, until we have some sort of assurances that there will be the section 413 dollars coming through to help offset that difference in cost between various types of technologies.

Senator BARRASSO. Thank you, Mr. Chairman. I know the hour is late and you have other things to go to. I appreciate it.

The CHAIRMAN. Thank you very much. I think this has been very useful testimony and we appreciate you all being here and giving us the benefit of your views. We may have some follow up questions, and if we do, we'll be in touch. Thank you, again, for your patience in getting us through this delay we had to put you through.

Thank you.

[Whereupon, at 12:28 p.m., the hearing was adjourned.]

APPENDIX

Responses to Additional Questions

Responses of Frank Alix to Questions From Senator Bingaman

Question 1a. We have been told by several witnesses in the past that, absent a price on CO_2, there is no business case for capturing. What's different about your pilot project at the Burger Plant?

Answer. Powerspan has venture capital investors who believe that a cost effective system to capture CO_2 from existing coal-fired plants may be highly valued in the future. They are motivated to invest in our pilot project based on expectations of a return on their investment.

Question 1b. What's FirstEnergy's incentive to take on the additional costs?

Answer. FirstEnergy is an investor in Powerspan and also has several coal-fired plants that would benefit from a cost-effective CO_2 capture solution, should power generators face CO_2 emission limits in the future.

Question 2. Your technology is particularly attractive since it may be adaptable to the existing fleet. How extensive do you imagine such a retrofit would be at a typical PC plant?

Answer. The retrofit for our ECO_2 system would be similar in scope to a wet scrubber retrofit installed for SO_2 reductions.

Question 2b. Do most plants have sufficient space and a configuration that would accommodate retrofit?

Answer. Most plants would have sufficient space and a configuration to accommodate a CO_2 capture retrofit, however the degree of difficulty and associated cost of plant retrofits would likely show a large variation.

Responses of Frank Alix to Questions From Senator Corker

Question 3a. As the Senate prepares to debate cap-and-trade legislation this fall, please give me your perspective on how we should contemplate and deal with coal in the short-term during that debate, apart from the incentives that you laid out in your testimony.

Answer.Powerspan recognizes the need to provide for certainty regarding CO_2 emission reductions, but also the wisdom of a cap and trade approach, which incentivizes the lowest cost solutions.

Question 3b. Keeping in mind the need to rely on coal as part of our future energy mix, what do you think are appropriate emissions targets in what amount of time, such that we challenge industry without being unrealistic based on what is technologically possible?

Answer. Powerspan does not have a specific position on CO_2 emission targets or timing since once technology is available, such a decision is largely an economic tradeoff of cost against perceived climate change risk. Meaningful CO_2 emission reductions from coal plants in the short term—i.e. 5-10 years-are probably not viable because required CO_2 capture and sequestration (CCS) technology is still in the development and demonstration phase. However, the technology should be available to make reductions by the 2015 time frame. Once CCS technology is available, history has shown that the power industry can retrofit approximately 10% of the operating fleet annually without undue burden on electricity supplies.

Responses of Andrew Perlman to Questions From Senator Bingaman

Question 1. You mentioned that your process does not produce the slag that conventional gasification plant does. What is the solid-waste product of your process?

Answer. The unreacted carbon and mineral matter in the coal removed from the gasifier is treated very thoroughly to recover our catalyst leaving a clean, highly porous, and environmentally benign solid material we believe will have valuable by-product credit.

Question 2. How do you control conventional pollutants such as sulfur dioxide and mercury that are generally produced from constituents in coal?

Answer. The gasification process does not produce sulfur dioxide but rather hydrogen sulfide which is easily removed from our product gas stream and converted to saleable elemental sulfur. Any volatilized mercury is captured in an activated carbon bed and can be safely disposed.

Question 3. You envision capturing the CO_2 from the process of deriving your natural gas equivalent; do you have any similar plans to capture CO_2 from combustion of the gas for power generation?

Answer. Great Point's process produces synthetic natural gas, which has the same basic chemical composition as natural gas, or methane—CH_4. Because coal contains a higher ratio of carbon to hydrogen than natural gas, the carbon that Great Point will capture in its process is the excess carbon, above and beyond that contained in the CH_4, that would otherwise be released to the atmosphere as carbon dioxide if coal were burned in a conventional coal-fired power plant instead of being gasified.

Great Point's process, which produces CH_4 and allows capture of the excess CO_2 from coal, does not in itself involve combustion of CH_4 for power generation, nor would Great Point own or operate gas-fired power plants. Great Point is a fuel supplier.

The CO_2 that is produced when CH_4 is burned (by others) for power generation is not currently captured by any commercial technology, although post-combustion capture technology is actively being worked on by many (other) companies. However, because burning CH_4 for power generation produces so much less CO_2 than burning coal for power generation, a power plant that emits no more CO_2 per megawatt hour than a combined cycle natural gas-fired power plant is considered to have a good carbon footprint, not a bad one. The CO_2 emissions per MWh of such a plant currently represent the standard (or limit) for purposes of the new Emissions Performance Standards ("EPS") recently adopted as a progressive, climate-friendly measure by California, Washington, and other states. By making more fuel available for this comparatively climate-friendly method of power generation, Great Point will be contributing to lower power sector CO_2 emissions overall.

Responses of Andrew Perlman to Questions From Senator Sanders

In your written testimony, you are very enthusiastic about the prospects for your company's technology, which will convert coal to cleaner natural gas utilizing catalysts instead of conventional coal gasification technologies, which are much more complex. You mentioned that you have significant financial backing and suggest that your first major project will be online by 2011 or 2012. You testified that your company would be in a position to give vendor guarantees by 2012, so that the technology could be readily purchased on the commercial market. This sounds very promising especially as other witnesses did not project this kind of progress with their ideas until 2020.

Question 4a. Why then, do you suggest that it would be useful to your company to be eligible for a 50 cent per gasoline gallon equivalent production tax credit for the generation of this natural gas?

Answer. We are just as enthusiastic about our prospects for commercial success as your question suggests. The value and importance of the proposed production tax credit for the energy output of our technology, while still in its early stages—and the logic supporting such a credit—are precisely equivalent to those that support credits for other relatively new (although by now significantly older) climate-friendly energy technologies, such as wind energy and biofuels production. In summary, new technologies, even when first deployed at commercial scale, typically debut with somewhat higher costs and less perfect performance than they will attain once they have greater operating and design experience, can be optimized and "tuned," and can enter into larger-scale production of greater numbers of units and thereby reduce average costs.

There are also substantial "pioneer's penalty" risks for investors, lenders, and early adopters, as well as the company itself, during the period when the technology is still relatively new at commercial scale and relevant infrastructure is not yet fully developed.

A production tax credit is a tried-and-true method of stimulating early adoption of climate-friendly new energy technologies in the face of such initial hurdles.

Question 4b. Do your financial projections suggest that you will not be able to make a profit without this credit?

Answer. No, but the primary concern at this stage is necessarily how best (and most quickly) to attract equity investment and necessary debt from private capital markets, in order to speed the construction of production facilities. For the reasons set forth immediately above, and as demonstrated by the experience of wind energy, the production tax credit makes it far easier to attract both equity investment and lenders for large-scale commercial deployment of new energy technologies in their early years. There are more risks and initially higher costs associated with new technologies in their earlier stages than will be the case in later years, and the PTC is one method of reducing such risks and helping "level the playing field" for desirable new technologies in the stage when they naturally involve initially higher costs than established alternatives.

Question 4c. At what price do you expect to be able to sell your natural gas in 2011–12? What do you project the cost of conventional natural gas to be at that point?

Answer. Great Point expects to sell its gas at market prices from the outset, although not necessarily in the spot market or at spot market prices (the prices most frequently quoted in industry and news reports). Much of our gas may instead be sold under long-term contracts, in which the buyer gets the benefit of Great Point's coal-based production costs, relative price stability, and protection from the degree of price volatility that has characterized the market for natural gas in recent years. Some of Great Point's large industrial investors certainly hope to obtain these benefits from the technology, as well as any savings the technology may make possible vis-AE2a-vis natural gas prices.

Great Point itself does not prepare projections of natural gas prices, and instead relies on projections from the same public sources available to the Committee.

*Question 5a.*You also suggested that setting a price floor for natural gas produced from gasification of domestic feedstocks such as coal or biomass would also provide assurances that your product would be profitable, even if the price of conventional natural gas were to fall below this price floor. At what level do you think such a price floor should be set?

Answer. Ideally, the price floor would be (i) temporary, not permanent, and (ii) high enough, but no higher than necessary, to assure the profitable operation of the initial commercial facilities that employ the synthetic natural gas production technologies the Committee decides to encourage. Speaking only for Great Point, not other technology developers, in today's dollars such a price floor might reasonably be set at $[X] per MMBtu of gas produced.

Question 5b. Do you project that there will likely be conventional natural gas prices below your profitability floor anytime soon?

Answer. No, not on any sustained or nationwide basis. But natural gas prices are highly volatile and often vary sharply by season, region, and in response to fluctuations in storage levels. There will certainly be "valleys" in natural gas prices in particular localities or circumstances where the existence of a price floor for synthetic natural gas would help assure that production of synthetic natural gas proceeds and continues despite such fluctuations.

As you know, the history of new energy technologies is that both Federal and private sector efforts to develop such technologies have tended to surge when oil and natural gas prices are high, and halt when oil and natural gas prices drop—even though the drops have all proven to be temporary "retreats" on an ever-upward march. The country would be better off today if temporary drops in natural gas prices had not undermined development of new energy technologies in the past. If this cycle is to be broken, the new energy technologies should be supported consistently, and particularly in the face of inevitable temporary reductions in natural gas and crude oil prices.

Question 5c. If so, what is your estimation of the total Federal cost of such a price stabilization provision?

Answer. The appropriate total Federal cost (if any cost actually results) of such a price stabilization provision is a policy matter on which Great Point expresses no opinion. We would observe, however, that (a) there may be no federal cost at all, or very little, if as expected natural gas prices remain above the Congressionally-mandated price floor all or most of the time, and (b) Congress in any event can design the program to be something other than open-ended, or a blank check. For example, the program could have automatic phase-out or sunset provisions once synthetic natural gas production reaches a specified total annual volume, or a specified percentage of annual natural gas consumption. In any event, we would not expect the total federal cost of such a price stabilization provision even to approach the total federal cost of programs, past and present, to support the prices or reduce the costs of domestic oil and gas production.

Question 6. For some time now, the price of natural gas has been very volatile. Would you expect the price floor you mentioned to be established in such a manner that when the price of natural gas was below the price floor, the government would provide funding to your company to reach the price floor, and conversely, when the market price was above the floor, that this funding would be paid back to the government? Or would it be more advisable to establish a long-term (multi-year) calculation of the market price to determine if it would be below or above the price floor?

Answer. We would be happy to work with the Committee to help design a price floor program the Committee considers reasonable and feasible. Many variables are involved, and many possible approaches could work. For example, the price floor protections might be triggered only after natural gas prices had remained below synthetic natural gas production costs for a specified period of time. Or the protections might be made available to those who purchase the synthetic natural gas at contract prices, such as electric utilities, rather than to the producers of synthetic natural gas such as Great Point.

If the price floor provisions of such a program actually resulted in money changing hands, and if Great Point itself, as a producer, actually received any of that money, then of course Great Point would expect that the program would be designed in such a manner that money might also be paid back to the government if sales prices for synthetic natural gas exceeded some specified level. That would be appropriate and fair.

Again, Great Pont would welcome the opportunity to help the Committee design a program satisfactory to the Committee in all respects.

RESPONSE OF ANDREW PERLMAN TO QUESTION FROM SENATOR CORKER

Question 7. As the Senate prepares to debate cap-and-trade legislation this fall, please give me your perspective on how we should contemplate and deal with coal in the short-term during that debate, apart from the incentives that you laid out in your testimony.

Keeping in mind the need to rely on coal as part of our future energy mix, what do you think are appropriate emissions targets in what amount of time, such that we challenge industry without being unrealistic based on what is technologically possible?

Answer. We believe that, in general, the so-called “California” emission performance standards (“EPS”), recently adopted in California and Washington, among other states, are appropriate for power generation facilities. Basically, these particular EPS establish emissions targets per megawatt hour of power production based on the CO_2 emissions of efficiently-operated combined cycle natural-gas fired plants. Currently, this means about 1100 pounds of CO_2 per MWh in both California and Washington, although the best natural gas-fired plants are capable of CO_2 emissions of less than 900 pounds per MWh, and both California and Washington have made provision for the applicable standard to become tighter and lower as average natural gas fired power plant emissions are reduced.

Natural gas-fired power plants can meet these standards by using synthetic natural gas from Great Point Energy and other producers.

For coal gasification power projects to meet these standards, some form of carbon capture and storage (“CCS”) will be necessary. Enhanced oil recovery (“EOR”) can provide an appropriate transitional form of CCS in localities where EOR opportunities exist, provided reasonable oil field management practices for CO_2 are followed. Both CCS and EOR are currently technologically possible. (Even geological sequestration of CO_2 appears technologically possible, although currently rather costly.)

For coal combustion power plants to meet these standards, post-combustion capture technology as well as CCS would also be required. Great Point is not the best source of information for the Committee on when post-combustion capture is likely to be considered technologically possible.

RESPONSE OF BILL FEHRMAN TO QUESTION FROM SENATOR BINGAMAN

Question 1. You mentioned that for resources planning purposes PacifiCorp estimates the cost of CO_2 at eight dollars per ton. What led you to that number? Have the various bills introduced in Congress assigning prices to CO_2 caused you to revise that estimate?

Answer. Beginning in 2002, PacifiCorp looked at a variety of externally available data, including: (1) the current greenhouse gas offset market, including offset investments made by The Climate Trust established by Oregon law, (2) existing greenhouse gas markets in the United Kingdom and the European Union, and (3) U.S.

macroeconomic analyses of scenarios involving limits on greenhouse gas emissions. At the time the analysis was done, the offset market yielded estimates at the low end of the range and helped the company define a low sensitivity of $2/ton of carbon dioxide. The existing overseas markets were operating in the range of $8/ton. Public comment on the value to use has been sought as part of each subsequent Integrated Resource Plan and ultimately resulted in the use of $8/ton for our models Regarding its current adequacy, the company now believes it to be on the low side based on legislative developments.

Question 2. The MIT report, and others, have pegged $30 per ton as the price that would drive utilities to capture and sequester CO_2. Do you generally agree with this estimate?

Answer. Technology, costs and regulatory environment associated with CO_2 capture and sequestration are as yet undefined. Therefore, it is hard to conclude exactly what would happen at $30 per ton.

Question 3. We talked a bit about the order in which additional power is "called up" to meet demand, with the effect being that lower CO_2-emitting natural gas generation is used less due to high natural gas costs. Do you have an opinion regarding the potential effects on energy prices and technology deployment if some regulatory mechanism were put in place to mandate increased use of lower-emitting generation?

Answer. We can expect increased demand for gas-fired generators, increased focus on nuclear energy and deferrals/cancellations of coal-fired plants until there is much more certainty over the costs of CO_2 emissions compliance. I would expect higher gas and wholesale electricity prices as a result, in addition to increased volatility. Increased wind penetration will help dampen the upward gas and electricity price trends. Regional transmission projects will be relied upon to more efficiently utilize existing generating assets and support wind resource expansion.

Some of the key drivers behind technology deployment in the future include: (1) the structure and scope of CO_2 regulations, (2) the impact of CO_2 regulations on load growth, (3) commercial success of CO_2 removal technologies for conventional coal and IGCC, and (4) when the path to widespread CO_2 sequestration can be made from a regulatory and legal standpoint.

Responses of Bill Fehrman to Questions From Senator Domenici

Question 4. Mr. Rosborough describes gasification as "technologically proven" in his testimony, and yet you assert the opposite. Your statement maintains that, "IGCC is not a commercially viable technology at this time." Is that statement based on the fact that adding turbines to the back end of a gasification unit is significantly more complicated than the processes undertaken by Dow and other chemical manufacturers, or is it a result of significantly different levels of experience in your respective industries?

Answer. We regard "technologically proven" and "commercially viable" as two different things. For a regulated utility to adopt new technologies on a broad basis, equipment needs to be economically reasonable, available to meet specific performance guarantees, and operable as a utility dispatched asset. Current cost estimates relating to this technology show it to be significantly more expensive when compared to other generation options. IGCC refers to the integration of the gassifiers with the power block to gain efficiencies in the electrical generation process. While this integration adds efficiencies, it also adds complexity and is unproven at a commercial level.

Response of Bill Fehrman to Question From Senator Corker

Question 5. As the Senate prepares to debate cap-and-trade legislation this fall, please give me your perspective on how we should contemplate and deal with coal in the short-term during that debate, apart from the incentives that you laid out in your testimony.

Keeping in mind the need to rely on coal as part of our future energy mix, what do you think are appropriate emissions targets in what amount of time, such that we challenge industry without being unrealistic based on what is technologically possible?

Answer. On March 20, 2007, MidAmerican Energy Holdings Company chairman and chief executive Officer David Sokol testified before the House Energy and Commerce Subcommittee on Energy and Air Quality, at which he outlined the company's position on global climate change. Mr. Sokol told the Subcommittee the nation needs a phased-in technology and policy-driven approach to provide tools necessary to successfully reduce long-term global greenhouse gas emissions while minimizing the costs and risks to the economy and the impact on customers.

In the short-term, or what Mr. Sokol referred to as the first of three phases (2007-2019), the company believes climate policy should focus on technology development and market transformation activities. In the electricity sector, MidAmerican proposed the following measures:

1. Adoption of a flexible renewable energy portfolio standard.
2. More stringent energy-efficiency mandates.
3. Policies to encourage efficiency improvements at existing facilities.
4. A 10-year, multi-billion dollar public-private research and development program for emissions reduction.
5. Removal of the legal and regulatory barriers to the deployment of new technologies such as carbon sequestration and new nuclear development.
6. Tax policies to support these programs, such as a long-term extension of the renewable energy tax credit.

In the second phase (2020–2029), as technologies become widely available, a hybrid system of phased-in emissions reductions based on carbon intensity targets, together with a carbon price cap (i.e., a safety valve), should be developed. The third phase (2030+) prescribes a hard emissions cap of 25 percent reduction of U.S. greenhouse gas emissions from 2000 levels by 2030, with additional emissions of 10 percent in each succeeding five-year period through 2050.

Mr. Sokol concluded his testimony with five points he said lawmakers should thoughtfully address in any global climate change legislation.

1. The electric industry cannot change past decisions and should not be penalized for past fuel choices.
2. The feasibility and cost of clean energy technologies must be known before they are deployed, because utility companies and regulators have a responsibility to keep customers' rates as low as possible.
3. A recommitment to funding research and development in the energy sector must occur.
4. Failure to take technology development timelines into account could result in unintended consequences, such as fuel shifting from coal to natural gas, which already faces tight supply-demand constraints.
5. A cap and trade concept in itself will not reduce emissions, bring new technologies on-line or reduce prices for renewable resources. This complex issue cannot be solved that simply.

RESPONSES OF JERRY HOLLINDEN ON BEHALF OF THE NATIONAL COAL COUNCIL TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. The National Coal Council report advocates for significantly increased funding for R&D and demonstration projects. Do you envision that this will be primarily a federal government undertaking or an effort more akin to FutureGen or some other model?

Answer. In all of its reports to the Secretary of Energy, The National Coal Council has consistently advocated the need for public/private partnerships on major R&D and demonstration projects. This goes all the way back to the initial Clean Coal Technology program of the late 1980s. The combination of public support in the form of both money and policy, with that of private industry in terms of money, siting of project facilities and technology development have yielded dramatic acceleration in bringing the various technologies to the market place. The Council continues to support these types of collaborations.

The Council has also consistently supported FutureGen since its inception, and the current report continues that support. Other examples of public/private partnerships supported in the Council's report include the Carbon Sequestration Regional Partnerships, the Carbon Sequestration Leadership Forum, the Asia-Pacific Partnership Program and the Clean Coal Power Initiative. While each of these efforts has a different combination of public and private input, they, along with many other similar efforts, all are examples of this kind of partnership. The Council does not favor one over any other and in fact supports them all.

In summary, the Council believes that the best way to expedite getting technologies from the R&D phase to the market place is through a joint commitment by both public and private leadership.

Question 2. Your Report echoes the MIT report in recommending undertaking on the order of 5 large scale sequestration projects. Given the significant amounts of CO_2 required for a demonstration on this scale, where would such a project likely get the CO_2? Is it reasonably likely anyone would be capturing CO_2 at the scale necessary absent some new kind of specific incentive to do so?

Answer. While The National Coal Council does have a member who is an emeritus professor from MIT, the full Council arrived at its recommendations independent of any of the MIT work. The recommendation for 5 major projects was a best estimate by the Council. It may be necessary to conduct more projects than 5, depending on the types of capture, transportation and storage technologies developed as the R&D effort progresses. The estimate was not meant to be a goal, but was meant to recommend that the necessary number of projects be completed in an effort to bring the largest menu of options to the market place so that carbon capture and storage could be achieved at the lowest possible cost and also to reduce risk, which may be even more important.

As for the availability of sites for these projects absent a new kind of specific incentive to capture and store carbon emissions, the charge received by the Council from the Secretary of Energy was to "conduct a study of technologies to avoid, or capture and store, carbon dioxide emissions—especially those from coal based electric utilities." The Secretary did not ask the Council to investigate any incentives, new or old, for capturing CO_2, and therefore, the Council did not make this a part of the study. However, in the very first paragraph of the Recommendations Section of the Executive Summary of the report the Council did acknowledge that "the U.S. Congress will address carbon management in the near future." With the combination of the Secretary's request, the Council's strong recommendation to move forward in development of these technologies and the belief that Congress will act in the near future, the Council believes that site selection for these projects should be very manageable.

RESPONSES OF JERRY HOLLINDEN ON BEHALF OF THE NATIONAL COAL COUNCIL TO QUESTIONS FROM SENATOR DOMENICI

Question 3. Climate change is a global problem. I fear that a number of proposals to address this issue will merely result in fuel-switching, or some other undesirable path forward. It is clear that other countries, particularly developing countries, will continue to consume coal in increasing amounts.

In the absence of a binding international agreement, what clean coal technologies are developing countries likely to find desirable? Will developing countries have a preference towards efficiency improvements, oxygen-fired combustion, gasification technologies, or some other category that we can assist in the commercialization of?

Answer. The Council report spent a considerable effort discussing the international energy market place. New and major players in this market place include China, India and some of the countries in Southeast Asia. The demand for energy will continue to increase dramatically as these countries continue to grow and develop. Each will develop their own energy resources and most of them have large coal deposits.

Just looking at China as an example, they plan to increase their coal production from 1.7 to 3.2 billion tons per year by 2020. They intend to build 50 facilities to produce syngas from millions of tons of coal each year to fuel their industrial and agricultural sectors. They are planning to spend $20 billion on coal-to-liquids facilities in the next 7 years, and they are planning to build over 100 GWs of new coal-based electricity generation during that time as well. Other developing countries may not grow as dramatically, but they will grow and they will need clean coal technologies if they are to develop their coal resources.

Each country will select the technologies that best fit their needs. Therefore, development of a wide array of technologies will best allow the U.S. to participate in this technology market place. Because of this, the Council has always supported a wide variety of R&D projects including more efficient electricity generation technologies as well as emissions control technologies. Oxy-firing, gasification and liquefaction as well as carbon capture and storage technologies should all be expedited for use both here at home and in the energy market place abroad.

Question 4. I am concerned about the availability of technology, regulatory shortcomings, infrastructure sufficiency, and liability as it relates to carbon dioxide capture and storage. Do you believe we should deal with those issues before mandating carbon dioxide capture and storage, or including it as eligibility criteria for federally supported R&D projects? How do you suggest we best address those issues?

Answer. The Council's report speaks to all of these issues. The technologies to capture carbon dioxide, while still in their infancy for the size and scale needed at generation plants, are the most advanced. Progress is being made because this has been the initial area of focus for R&D. However, the industry is still many years away from having proven capture technologies that could be applied commercially.

There is currently no transportation infrastructure for moving carbon dioxide from the point of capture to the potential point of storage. This may require a whole new industry to be developed in order to be achieved. Transportation technologies are way behind the capture technologies.

Storage of CO_2 is being achieved on a small scale in regions of the country where it can be used for enhanced oil recovery. Because of this effort, storage issues are better understood. However, the scale at which these technologies will be needed for the volumes at which CO_2 will need to be stored is incompletely understood at this time. All of the candidate geological configurations must be tested, as well as have the necessary monitoring data developed to ensure no leakage occurs.

Finally, on the question of liability the Council has recommended that the Secretary work to determine the legal liabilities associated with carbon capture and storage. This includes resolving ownership issues and responsibility for stored CO_2 in the event of leakage, and the implementation of long-term monitoring at storage facilities.

The Council was not asked to address the issue of eligibility criteria for federally supported R&D projects, but it is clear that there is a need to develop technologies to address each of these issues.

Question 5. It seems to me that efficiency improvements allowing generators to get more electricity out of the same amount of coal would be in their financial interest to pursue. Can you explain the disconnect that exists in this regard, and why plants have not maximized efficiency throughout the fleet? Is it because the savings associated with an efficiency upgrade do not justify the costs of the undertaking? Are there regulatory hurdles to pursuing these tasks? If so, please identify them for us.

Answer. In May of 2001 the Council produced a report at the request of then-Secretary of Energy Bill Richardson (subsequently submitted to his successor, Secretary Spencer Abraham), that identified technologies that at the time could increase the amount of electricity from the existing fleet of coal plants by 40,000 MW. The approach set forth in those recommendations is still viable today, although several of those options may have been implemented already.

These efficiency gains can be made at various points within the plants. They include steam turbine blade upgrades, improvements in condenser systems, and in the milling systems to grind the coal. In addition, the use of coal cleaned to higher quality levels can increase plant efficiency. The full suite of recommendations can be found in the study, "Increasing Electricity Availability from Coal-Fired Generation in the Near-Term" available on the Council web page at www.nationalcoalcouncil.org.

Plant efficiency upgrades are a practical, quick and less expensive way to reduce CO_2 emissions in the near term as well. Given current clean air regulations, however, many power plant owners would not initiate helpful upgrades because of concerns that such improvements would trigger requirements for more expensive upgrades under the New Source Review program. Dialog between DOE and EPA on how best to achieve progress on this issue was recommended. Streamlining the NSR program would be highly beneficial to achieving these efficiency gains as well as avoiding CO_2 emissions.

RESPONSES OF CARL BAUER TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. The FutureGen government-industry partnership will demonstrate a number of important technologies but, as you mentioned in your testimony, there are a number of other technologies that will need similar demonstrations at commercial scale. Presuming they can't all be demonstrated through similar partnerships, can you give us some examples of alternative pathways to commercialization of advanced technologies?

Answer. In addition to the Department of Energy's (DOE's) FutureGen partnership, the most logical route to the commercial-scale technical and economic validation of developing technologies is through DOE's Clean Coal Power Initiative (CCPI). The CCPI program is unique to DOE in that it requires a minimum 50% participant cost-share, and a Repayment Plan based upon the public's sharing in any profits derived from commercialization of the technology demonstrated, with the objective of full-cost recovery of the entire amount of our project investment.

Question 2. Can you give us a sense of where you believe the state of the art to be in coal-fired generation and where you expect it to be in 10 years? Assuming a CO_2 price on the order of the MIT Future of Coal report and increased RD&D support, when do you think we may reasonably be able to deploy a variety of near-zero CO_2 emission technologies?

Answer. Today's state-of-the-art for coal-fired generation in the U.S. is supercritical pulverized coal combustion. Additionally, there are two existing commercial Integrated Gasification Combined Cycle (IGCC) plants, originally designed for coal, that are presently operating on petroleum coke and pet-coke/coal mixtures. In 10 years we expect to see coal-based ultra-supercritical pulverized coal and IGCC plants commercially deployed in the U.S.

Assuming a CO_2 price on the order of the MIT Future of Coal report[1], and a series of annual target funding levels that will encourage the continued development of enabling technologies, a process intensification effort that will permit the combination of several processes into a single step, and a near doubling of the number of demonstrations of new Carbon Capture and Storage (CCS) plants over the next 20 years, we would expect to accelerate by about 20 years (i.e., by 2030) the date by which all demand for new coal-fueled power plants in the U.S. can be economically met with CCS plants. Starting by 2020, it is expected that an increasing number of advanced CCS plants would be deployed. To ensure this result, we must begin now and continue through 2020 the demonstrations needed to drive CCS to the lowest possible cost for all U.S. coals, and to make this an attractive option for large, coal-dependent developing nations.

Examples of enabling technologies currently under development include advanced pressurized solid-feed systems, oxygen-blown transport gasifiers, ion-transport membranes, high-performance desulfurization, hydrogen turbines, solid-oxide fuel cells, and advanced CO_2 separation, capture, compression, injection, and Modeling, Monitoring, and Verification (MMV) technologies.

RESPONSES OF CARL BAUER TO QUESTIONS FROM SENATOR DOMENICI

The costs of goods and services required to build power plants have increased significantly in recent months.

Question 3a. Can you quantify these increases for us, both for next-generation plants as well as traditional designs?

Answer. New traditional plants are being adversely impacted by increases in costs, resulting from the lack of availability of materials and the lack of availability of skilled construction labor. Next-generation plants are likewise impacted by similar increases, and are further impacted by the costs of insurance associated with the requirement for performance wraps or guarantees that accompany the inherent risk of deploying new and unproven technology (current estimates for a next-generation IGCC plant performance guarantee are on the order of 35% of total plant construction cost), as well as the increased costs of construction associated with building redundancies into new plant designs to ensure defined plant performance and economic targets can be met. Furthermore, advanced coal plants, including IGCC and pulverized coal (PC) based systems with carbon capture, will require operations and maintenance personnel with significantly different skill sets, compared to those that support traditional facilities. Over the past 5 years, it is estimated that the costs of traditional pulverized coal combustion plants have gone up in the neighborhood of 75% to 100%, from approximately $1,200/kWe to approximately $2,000 to $2,500/kWe.

Over the past 5 years, it is estimated that the costs of next-generation coal-fueled plants have gone up in the neighborhood of 200% to 250%, from approximately $1,500/kWe to approximately $3,200/kWe (recent Duke Power IGCC estimate) to $3,700/kWe (recent AEP IGCC estimate).

Question 3b. Are advanced clean coal plants disproportionately impacted by this trend of increasing costs?

Answer. Yes, as a consequence of the need for both performance guarantees and risk mitigating redundancies, as explained above. Also, acquiring operations and maintenance resources with appropriate education and skill sets will result in higher personnel costs compared to traditional designs.

Question 4. Can you quantify for us the costs of construction for a plant with the best environmental technologies that are currently available at commercial scale as they compare to ultra-supercritical plants and other advanced plants that would, in fact, incorporate some form of carbon dioxide capture and storage?

Answer. NETL recently published a baseline study forecasting the "overnight" construction costs of power plant technologies that could be built and operated in

---

[1] Text drawn from MIT Future of Coal report, page XI, paragraph 3, reads "We estimate that for new plant construction, a CO_2 emission price of approximately $30/tonne (about $110/tonne C) would make CCS cost competitive with coal combustion and conversion systems without CCS."

the 2012 to 2015 timeframe.[2] The information presented here is derived from the results of this study.

Today's best estimate of the overnight construction cost for an ultra-supercritical coal-fueled plant, outfitted with those technologies necessary to meet all applicable environmental regulations, is estimated at $1,641/kWe. Today's best estimate of the overnight construction cost for an IGCC plant, outfitted with those technologies necessary to meet all applicable environmental regulations, is estimated at $1,841/kWe. For an ultra-supercritical pulverized coal plant with carbon capture and storage technology, the overnight construction cost is estimated at $2,867/kWe, and for an IGCC plant with carbon capture and storage technology the overnight construction cost is estimated at $2,496/kWe.

Estimates for the carbon capture and storage plants provided above are based on plants designed for approximately 90% carbon capture. It is also important to note that the overnight construction cost estimates presented do not include interest during construction, project-specific owner's costs (e.g., costs associated with feasibility studies, site/infrastructure improvements, permitting, legal services, and financing) or any performance guarantees. Because plants equipped with carbon capture would be "first-of-a-kind" facilities, these added costs may be substantial.

A final observation here is important. Ultra-supercritical plants, whose principal advantages are higher efficiency and lower coal fuel consumption, are more economically amenable to our European neighbors, since Europe tends to experience high coal prices, relative to the United States where coal prices tend to be both less volatile and less expensive. As a result, in markets where no incentives are present that encourage carbon mitigation, there is little, if any, economic advantage to deploying ultra-supercritical technology. Evidence of this assessment, as it applies to U.S. markets, is present in that over the past 20 years, 49 sub-critical plants (>50 MW) and 3 supercritical plants have been built. During this same 20-year period, no ultra-supercritical plants were built in the U.S., nor are we aware of any plans for their construction. Finally, as of October 2007, there are 24 sub-critical and only 4 supercritical power plants that are either under construction or in the permitting phase, and we are not aware of any plans for ultra-supercritical plants.

RESPONSES OF JEFFREY N. PHILLIPS TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. You give a hopeful picture that "learning-by-doing" in a commercial setting will lead to significantly reduced costs over time for technologies. Are there any inherent incentives for private actors to lead in deploying new technologies? Are the efficiency gains and increased certainty regarding future regulation ever enough to push for leading edge design on their own?

Answer. In short, the general answer is "yes," but in the case of carbon capture and storage (CCS), a combination of private initiative and public sector incentives is likely to be the most effective means of achieving the necessary design advances in a timely manner.

Cost reduction through "learning by doing" is real, as evidenced by the industry's history with other environmental controls, but in the case of SO_2 scrubbers, for example, regulatory requirements were clear, first through the Clean Air Act's New Source Performance Standards and later through the Acid Rain provisions of the 1990 Clean Air Act Amendments. With respect to greenhouse gas (or CO_2) emission regulations, while their prospect seems clear, their nature and timing are still big unknowns. Getting initial installations of advanced technologies in place, before regulations take effect, to start the learning-by-doing process—getting costs down before large investments are required for compliance—will take "beyond market" incentives. The Energy Policy Act of 2005 sought to address this, but even some projects that had been awarded investment tax credits have recently been shelved due to regulatory uncertainty risk for CO_2.

Other "institutional factors" and traditions have made the power industry prudent with respect to investments in not-yet-proven technologies. For example, policies in some states prohibit public utilities commissions from allowing cost recovery on investments in emission controls exceeding the requirements of current regulations. Also, coal has historically been a relatively inexpensive fuel in the United States, which has limited the amount of capital investment and risk that could be justified for unproven high-efficiency technologies. Further, the economics of power generation (and public scrutiny) always place a high premium on reliability. Because the

[2] The "overnight" construction cost includes costs for detailed engineering design, project management, construction labor, process equipment, on-site support facilities and infrastructure, and process and project contingencies.

reliability of a new technology is difficult to predict in advance of real-world application, there is an incentive to be the "second in line" when it comes to buying new technology. Thus, in EPRI's opinion, leading-edge designs such as the extremely efficient pulverized coal plants with integral CCS outlined in EPRI's UltraGen Initiative, and the new generation of integrated gasification combined cycle units suitable for (or with) CO_2 capture, will not be easy to implement without industry and government risk sharing. Programs such as the Department of Energy's Clean Coal Power Initiative can help spread risk and may "tip the scale" in favor of new technology investment. By encouraging collaborative funding of demonstration projects, EPRI also helps spread the risk of testing new technologies. Each power generator contributes a small fraction of the total cost, yet receives the knowledge gained from the tests.

Regulatory flexibility during the period of new technology introduction can also help. An example of success in this area was the incentives for early adopters of selective catalytic reduction (SCR) systems for NO_X control. "Allowance banking" and other provisions encouraged several power companies to install SCR units before the mandatory compliance date, allowing them to resolve reliability and performance issues (such as the unexpected problem of catalyst plugging by large-particle ash) while they could still legally turn off the units during normal operations.

Question 2. In your description of your proposed UltraGen Project, you include the option of capturing 25% of the CO_2 from the plant. Why only 25%? Why wouldn't you capture more CO_2 in this project?

Answer. Please allow me to clarify that we propose capturing 90% of the CO_2 from 25% of the flue gas at a new, large (800 MW_e net) clean and eficient pulverized coal plant. Capture of 90% of the CO_2 from the inlet flue gas is the goal of the Department of Energy and many technology developers. Treating 25% of the gas flow from a very eficient plant (equivalent to 200 MW_e) corresponds to a volumetric flow rate equal to the expected rating of an early commercial post-combustion CO_2 capture module. Thus, choosing to treat 50% of the gas flow would mean testing two of the same modules rather a single larger "more commercial" module. As a result, the research value would be only marginally improved while the cost of the CO_2 capture demonstration element would nearly double. Were adequate funding for two test modules available, a better research strategy would be to put them on two different plants using different coals (and UltraGen is open to this possibility).

Further, the scale-up to a 200 MW_e CO_2 absorber module represents an ambitious challenge in its own right. The largest post-combustion unit in current operation captures 500 tons of CO_2 per day (from a steam reformer used in the production of urea fertilizer). About 200 MW_e worth of flue gas from our proposed UltraGen I unit corresponds to more than 4000 tons of CO_2 per day, an eightfold increase. We will use an advanced amine solvent to reduce energy penalties, and demonstrate thermal integration of the solvent reboiler (the step that releases CO_2 from the solvent for subsequent clean-up and compression) with other plant processes to further reduce energy penalties, and hence operating costs. The follow-on UltraGen II project will treat at least 50% of the flue gas with a 90% CO_2 removal process (potentially using a further improved solvent that allows for a larger single absorber module). The ultimate commercial plant, embodied in UltraGen III, will treat all of the flue gas with a 90%+ CO_2 removal process (or could possibly demonstrate oxy-combustion CO_2 capture).

Question 3. In your analysis of the technical potential for emissions reductions from CO_2 capture and storage, did you include retrofits of existing plants for CO_2 capture and storage? If not, why not, and what would be the impact if we did?

Answer. The economics of CO_2 capture are best on plants that operate at high capacity factors (i.e., baseload). As new coal plants come on-line, they are dispatched in baseload mode while some existing plants are moved to load-following service. Thus, EPRI's "Prism" analysis assumed all new coal plants coming on-line after 2020 would be the first to be built with CCS. Given differences in the generation mix serving regional grids and the likely variations in the compliance strategies ultimately adopted by U.S. power generators in response to CO_2 regulations, we expect that some existing units may be retrofitted with CCS. But because costs for retrofits are higher and energy penalties greater, to be conservative in the Prism analysis, we assumed that existing plants underwent efficiency upgrades but not conversion to CCS.

Research by EPRI and others suggests that retrofitting CO_2 capture equipment to existing coal plants not originally designed for such systems would be very costly, ranging from "considerably more expensive" than the incremental cost of incorporating CO_2 capture equipment in new plants up to situations where it would be prohibitively expensive (virtually impossible) due to lack of available space in the plant. With respect to the latter, up to 6 acres at the back end of the plant is needed for a 500 MW unit. In addition, the energy impacts (in terms of output and efficiency reduction) are greater for retrofits than for new plants. EPRI has not conducted a plant-by-plant analysis to ascertain the number of existing units that could, in theory, be converted to CCS, and thus cannot estimate the CO_2 emissions reduction potential (or cost and capacity reduction) of such retrofits. Instead, EPRI's analysis of the potential CO_2 emissions reductions from CCS focused on the incorporation of CO_2 capture into the sizeable new fleet of advanced coal plants (as projected by the Energy Information Administration) built to the growth in electricity demand.

Question 4. We talked a bit about the order in which additional power is "called up" to meet demand, with the effect being that lower CO_2-emitting natural gas generation is used less due to high natural gas costs. Have you done any analysis to determine the potential effects on energy prices and technology deployment if some regulatory mechanism were put in place to mandate increased use of lower-emitting generation?

EPRI hasn't conducted such an analysis for today's generation mix, but as part of the background pap er for the EPRI 2007 Summer Seminar, "The Power to Reduce CO_2 Emissions: The Full Portfolio" (see http://epri-reports. org/ DiscussionPaper2007.pdf), EPRI ran scenarios for 2050 in MERGE, a general equilibrium economic model used for analyzing the cost of CO_2 emissions mitigation. Although this isn't a dispatch model, it can be used to estimate the composition of the generation mix and wholesale price of electricity when various potential solutions for reducing CO_2 emissions are allowed or not allowed. The most dramatic difference in wholesale price occurred when the "full portfolio" scenario was compared with one in which new coal plants with CCS and new nuclear plants were not allowed. In the latter scenario, natural gas became the dominant fuel for generation and thus the comparison with the full scenario (which is rich in coal with CCS and nuclear) is somewhat of a surrogate for the question you pose. Our results showed that the 2050 wholesale price of electricity was more than double in the gas-dominated scenario versus the full portfolio scenario. We also found this price increase would have a considerable adverse effect on the U.S. economy.

Question 5. The MIT Future of Coal report pegged \$30/ton of CO_2 as the point at which we may expect widespread deployment of developed capture and sequestration technologies. This assumes the technologies are demonstrated and ready for mass deployment. Throughout this hearing we have heard of the great potential technologies but that significant hurdles remain, especially in getting large-scale initial deployment. Has EPRI done any analysis of what type of price level for CO_2 would be needed to make early adoption and initial demonstration of these technologies an economical proposition for generators?

Answer. Sadly, "50" is the new "30." The \$30/ton-CO_2 figure generally predates the recent run-up in costs for capital projects due to record high commodity prices and tighter U.S. markets for craft labor given post-Katrina rebuilding. Illustrative of this point, the Chemical Engineering Plant Cost Index increased by about 35% from June 2003 to June 2007, after five years of virtually no change. In a recent paper prepared for the California Energy Commission, MIT estimated the avoided cost of CO_2 for new baseload-duty coal-based plants in California at about \$50 per metric ton when a modest contingency for first-of-a-kind technology was included. On this same basis, the avoided cost of CO_2 in the traditionally lower-cost Gulf Coast area was about \$40 per metric ton. Analyses by EPRI's "CoalFleet for Tomorrow" program suggest that the price of CO_2 needed to make a new coal plant with CCS competitive (on a levelized cost-of-electricity basis) with an existing clean coal plant buying emission allowances or paying a carbon tax is now almost \$70 per metric ton.

RESPONSES OF JEFFERY N. PHILLIPS TO QUESTIONS FROM SENATOR SANDERS

Question 6. In your testimony, you predicted that the efficiency of coal-fired electric power plants will increase over the next two decades from the current 33% efficiency to as high as 44–49% efficient by 2025, as more high-technology systems are employed, such as ultra-supercritical pulverized coal. You also mentioned that this assumes no carbon dioxide capture, but with CO_2 capture, these efficiencies would be lowered to 39–46%, a penalty for the extra energy needed for capture of 3–5%. These efficiency losses reflect a 90% capture of CO_2, but not the compression or transportation of the CO_2. If one were to incorporate the compression, transportation, and sequestration values, how much more of a loss of efficiency would result? Is it fair to say that this better technology will allow us to still see increased efficiencies, over the current 33% efficiency, while at the same time completely taking care of carbon emissions with carbon capture and storage?

Answer. Please allow me to clarify that the "with capture" eficiency values reflect the energy penalties for both CO_2 capture and compression, but as you correctly point out, not the losses associated with transportation and injection. Please also allow me to clarify that the 33% eficiency value is an overall average for the current fleet of coal plants, some of which are 50 years old or more and some of which are operated in a less efficient (but grid support critical) load-following mode. With those qualifiers in mind, the answer to your question is "yes." We foresee new base-load advanced coal plants with CCS (including the efects of a modest transportation distance and injection) having eficiencies exceeding those of the current fleet average. Of course, this won't happen automatically. A sustained, accelerated RD&D program involving private and public sector stakeholders will be required to bring the promise of ultra-eficient clean coal plants with CCS to commercial fruition in a timely manner. Existing research programs and roadmaps by DOE, EPRI, equipment suppliers, industry groups such as the Coal Utilization Research Council, and others provide the foundation for the necessary collaborative and proprietary efforts.

In calculating the efficiency penalty for CO_2 compression, EPRI assumes the use of an interstage-cooled compressor with a final delivery pressure of 2200 pounds per square inch (psi). This impact is typically reported in combination with the efficiency penalty for capture because both take place within the plant boundary. The efficiency impact of transportation depends on the distance the CO_2 must be shipped and the diameter of the pipeline. Unless unusually long distances or undersized pipelines are involved, the impact is typically small relative to the energy penalty for capture and compression. Similarly, the additional energy requirements for injection are small given that pipeline delivery pressure is already at 2000+ psi.

Question 7. You testified that you predict only a 10% increase in the cost of electricity by 2025 if carbon is captured and stored. Does this estimate include just the capture of CO_2 or the full capture, compression, transportation, and storage?

Please allow me to clarify that EPRI's goal for post-combustion CO_2 capture is an energy penalty of no more than 10% and a levelized cost-of-electricity increase of no more than 20%. This reflects the cost of CO_2 capture and compression, but not the cost of transportation and storage because these can be highly variable depending on how far a power plant is from a storage site and the permeability of the target formation. Transportation and storage could add another $5/MWh or more to the levelized cost-of-electricity.

Question 8. You also mentioned that if liquefied carbon dioxide is not cleaned of sulfur or other contaminants before it is stored underground, it may clog up the pores in the underground rock, so that, instead of a 30-year storage capacity, you may only get a five-year storage capacity. Can you explain at what levels of contamination this is likely to occur? Does it depend on the kind of rock or saline substrata that the CO_2 is being sequestered in?

Answer. Although there is currently some uncertainty over the impact of CO_2 impurities on subsurface rocks during injection and over the course of long-term storage, and further research is warranted, the scenario of plugging to the point that injection was no longer possible, as posed in the question, is not considered likely by researchers at Lawrence Berkeley National Laboratory.

The most likely sulfurous impurities in a CO_2 stream captured at a coal-fired power plant, hydrogen sulfide (H_2S) and sulfur dioxide (SO_2), will form acids upon interaction with subsurface moisture, and those acids can dissolve soluble materials such as calcium minerals (which actually increases porosity). Although reaction products can subsequently re-precipitate out of solution, any associated deposition is likely to be small relative to the aggregate pore cross-sectional area of the injection zone.

Traces of H_2S have been shown to have a beneficial effect when the CO_2 is injected into a depleting oil field for enhanced oil recovery.

RESPONSES OF JEFFREY N. PHILLIPS TO QUESTIONS FROM SENATOR DOMENICI

Question 9a. The timeline in your testimony indicates a belief that the most substantial reductions in CO_2 emissions from coal consumption will not occur until post-2020. What steps should we be taking in the interim, however?

Answer. As noted in my response to Question 10, technologies to improve the efficiency of existing coal-fired units are available today and their application offers an option (barring New Source Review issues) to begin curbing CO_2 emissions. The substantial CO_2 reductions from ultra-eficient coal plants and CCS shown taking place after 2020 will only be possible if we accelerate and augment current RD&D programs in a comprehensive, well-coordinated manner with sustained funding commitments from the private and public sectors between now and then.

To enable commercial deployment of CCS by 2020, about a half dozen large-scale CO_2 storage demonstrations must be conducted in various geologic settings; CO_2 capture technologies need to be scaled up and demonstrated in pre-combustion, post-combustion, and oxy-combustion configurations; and CO_2 pipeline networks will need to be constructed. Each of these activities represents a substantial set of capital projects, costing hundreds of millions to billions of dollars, and taking five or more years with some projects needing to be coordinated or sequenced with others. Similarly, RD&D to improve the cost, performance, and reliability of advanced power block technologies for IGCC and USC PC units using various coal types (bituminous, subbituminous, lignite) needs to be conducted expeditiously over this same timeframe. EPRI believes that integrated CCS demonstrations provide the dual benefit of proving CO_2 capture and storage technologies to be safe and effective while addressing real-world multi-agency permitting and monitoring/verification issues. For long-term CO_2 storage, important legal and regulatory uncertainties need to be resolved before widespread commercial deployment can take place.

Question 9b. In the context of energy security, and our nation's desire for reliable and affordable energy, do you believe it is wise to oppose the construction of new coal plants even if they employ the best, commercially available, environmental technologies?

EPRI believes that even with aggressive investment in conservation and end-use energy eficiency improvement (which we support), a substantial number of new power generating units will be needed to meet demand growth and to replace retiring units. We believe that in the economic interest of ratepayers and in the interests of national security, a full and diverse portfolio of generating resources—including new state-of-the-art coal plants—is our best strategy.

Domestic resources including nuclear, renewables, and fossil fuels (particularly natural gas and coal) as well as imported resources like liquefied natural gas and oil will play different roles in different parts of the country. Coal is our largest domestic fuel resource, it provides over half our electricity today, and we project that it will be needed to provide affordable power in the future. Today's new coal plants are more efficient and much cleaner than older units and produce less CO_2/MWh. EPRI studies have shown that without both new coal with CCS and nuclear power in the portfolio of solutions to the challenge of CO_2 reductions, wholesale power prices will more than double and the U.S. economy will shrink (relative to its size with the full portfolio of CO_2-reducing technologies) by $1 trillion.

Question 10. As we look at the existing fleet of coal-fired electrical generation, and ways to reduce the carbon dioxide emissions from it, what do you believe are the costs and benefits of the choice between efficiency improvements versus seeking to retrofit these plants with carbon dioxide capture technologies?

Efficiency improvements and CCS retrofits are compatible approaches, not alternatives. Investments in efficiency improvement today help reduce (albeit modestly) the cost of future retrofit of CO_2 capture systems.

Technologies for efficiency improvement are available today and can be applied in the near-term. Some are relatively low cost and easy to implement, providing modest improvements, whereas additional options providing greater improvement entail more significant equipment modifications at greater cost. Such upgrades typically provide economic benefits unless they are burdened with costly pollution control add-ons as a result of New Source Review (NSR) requirements. The resulting reduction in CO_2 emissions is significant but limited—approximately a 2% reduction in CO_2 emissions for every 1 percentage point improvement in plant efficiency. A policy approach that enabled plant modifications for efficiency improvement without incurring the costs of NSR emission control additions/upgrades could encourage investments yielding CO_2 reductions of 5–10%.

Because CO_2 capture equipment is sized on the basis of the volume of flue gas to be treated, efficiency improvements reduce its cost by reducing the volume of flue gas produced per MWh generated. Overall, however, CCS retrofits will remain major capital projects requiring substantial investments and equipment additions—indeed, some plants may not even have room for it. Where feasible, CCS retrofits have the potential for major CO_2 emission reductions, in theory up to about 90%. Plant output and/or efficiency are reduced in the process, and retrofits will not generally offer the same possibilities as new plants for optimized "heat integration" to reduce these impacts.

Because it will take time to build commercial-scale CO_2 capture systems for demonstration, inject significant volumes of CO_2 and monitor/verify its subsurface behavior to assure safe and effective storage, it will take considerably longer to apply CCS than to apply efficiency upgrade measures. Accordingly, efficiency improvements can have an impact on electricity sector emissions sooner than can CCS.

Question 11a. Do you believe a resistance on the part of state utility commissions and other regulatory bodies to allowing cost recovery for more expensive clean coal technologies has impeded technological progress?

Answer. We believe the charter of public utility commissions in a number of states requires consideration of the least-cost strategy that satisfies new generating capacity needs in the interest of the ratepayers. This may limit allowance of higher-cost strategies that serve other objectives, such as control of currently unregulated CO_2 emissions.

Question 11b. Is this an issue that the Institute has looked into in any detail?

Answer. No, EPRI has not examined this potential obstacle in particular.

RESPONSES OF JIM ROSBOROUGH TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. You envision both carbon capture and gasification of biomass with coal to reduce the carbon footprint of a plant. How do you estimate the lifecycle greenhouse gas (GHG) emissions of such a plant would compare to a plant using conventional feedstocks?

Answer. Mr. Chairman, we believe that the reduction of GHG emissions requires a multi-faceted approach. We can briefly describe our evolving position on this subject as follows:

Choice of feedstock is an important component of the solution, and biomass utilization provides GHG reduction benefits at two points: (1) during feedstock conversion, where "plant emissions" occur, and (2) during downstream use of product.

> (1) During feedstock conversion, CO_2 is generated as a natural by-product of hydrocarbon processing. We pursue an efficiency campaign to minimize the CO_2 generated in our processes ("maximizing carbon efficiency"). For the remaining CO_2 produced, the percentage of biomass as feedstock directly ofsets or "neutralizes" a corresponding percentage of CO_2. This is consistent with the view that CO_2 generated from renewable feedstocks is GHG neutral.
>
> (2) The percentage of biomass in the feed will also translate into a corresponding percentage of "renewable carbon" in the product. If the last fate of such product were to be combustion, the percentage of renewable carbon in the product would generate a corresponding percentage of "GHG neutral" CO_2.

A specific example is required to calculate exactly what the expected benefits would be, but the above logic indicates you get a "double benefit" from biomass utilization on a life cycle basis.

We believe that maximizing carbon efficiency (minimizing CO_2) requires industry to integrate processes, continue to improve in operational disciplines and practices, and make advances in the practical utilization of alternative feedstocks such as biomass.

Question 2. You mentioned biomass as a potential feedstock along with coal. We've heard of gasifiers operating with some percentage of municipal solid waste and other materials; are these likely to be suitable for your process as well?

We believe so. Gasification enables virtually any hydrocarbon containing material to be utilized as a feedstock. The list includes municipal solid waste (MSW), post-consumer plastic waste, industrial wastes, municipal sewage sludge, as well as various kinds of biomass. We are evaluating a whole slate of technologies that can contribute to the utilization of these materials, and feel confident that with our engineering capabilities, we can make this work technically.

The primary hurdles are centered on logistics and economics. The question we ask is, "What do the economics of these technologies look like, and are they practical for improving our competitiveness in a global context?" To answer this question, we believe that partnership with government to assist in the acceleration of development and mitigation of initial risk is imperative to making the concept into a reality.

Question 3. You generally seem to assume co-production of liquid fuels at an industrial gasification plant. Is this a necessity either because of physical design or economically? Assuming integration of heat recovery and cogeneration of power in each case, can you compare economics of a plant producing chemicals and plastics only to a plant that would produce a mix of products and liquid fuels?

Answer. Maximizing carbon eficiency is our goal. The more one integrates complementary industrial processes, the better. Fuels are not necessarily a critical part of the process, depending on the plan, consumer needs, market realities, etc. Our industry benefits from fuels production because those processes also produce chemical feedstocks as a by-product. Whether or not one chooses to make fuels in a polygeneration setting, the economics depend on capital cost, operating and logistics costs, and market conditions.

RESPONSES OF JIM ROSBOROUGH TO QUESTIONS FROM SENATOR DOMENICI

In many ways, the chemical industry is more familiar with CO_2 capture than the electric utilities.

Question 4a. What opportunities do you believe exist for the two industries to collaborate in a carbon-constrained world?

Answer. Dow has engaged in the polygeneration of chemicals, plastics, and electricity for the better part of our 110 years as a company. There is considerable opportunity for collaboration with electric utilities, and in fact we have a history of such activity. A key point we observe as we look forward to solve GHG emissions challenges is this: if you make only electricity, 100 percent of the carbon is converted to CO_2. If you make chemicals together with electricity, less than half of the carbon is converted to CO_2.

Question 4b. Do you believe it is appropriate, or you might say "' 'fair', to require or ask the utility industry, which has significantly less experience with these technologies and processes, to abide by the same timeline that your industry is likely to be capable of?

Gasification is essentially a chemical process, and we are expert in operating chemical processes for maximum efficiency and effectiveness. We don't see ourselves as having expertise in commercial power generation and distribution, but we believe we can be helpful in bringing our process knowledge into these projects, in a way that shouldn't disrupt the timeline.

Collaboration with electric utilities is not unlike the joint venture model that we commonly practice, with each participant bringing diferent skills to the party. One of the important issues to recognize is that the world's power plants aren 't yet capture ready. The world needs a solution for legacy plants, and chemistry can be a part of that solution.

RESPONSES OF JIM ROSBOROUGH TO QUESTIONS FROM SENATOR CORKER

Question 5a. As the Senate prepares to debate cap-and-trade legislation this fall, please give me your perspective on how we should contemplate and deal with coal in the short-term during that debate, apart from the incentives that you laid out in your testimony.

Answer. As the most abundant and lowest cost energy and chemical feedstock in the United States, we believe that coal must have a place in our alternative feedstocks portfolio moving forward. Dow is committed to working with industry to determine and implement the cleanest, most effective and eficient technologies for utilizing coal, both in the short term and the long term.

We also point out that the United States must avoid a renewed "rush" to natural gas. We are already observing the highest natural gas prices and volatility in history. Further exacerbating the already tight supply/demand balance of natural gas in the US would be detrimental to the economy and further strain the already threatened competitiveness of US industry.

We believe that a "phase in" approach for standards is the best way to enable affordable progress. Progress should then trigger stricter standards, and the process can be repeated. Multiple problems require our attention, not the least of which are the need for retrofit solutions for carbon capture at conventional natural gas and coal-fired power plants. The carbon constraints on our energy mix must acknowledge this development curve as we move forward, for any and all feedstock choices.

Question 5b. Keeping in mind the need to rely on coal as part of our future energy mix, what do you think are appropriate emissions targets in what amount of time, such that we challenge industry without being unrealistic based on what is technologically possible?

Answer. We're still evaluating details. We know that successive generations will demonstrate improvements, i.e., the third plant will perform better than the second, which will perform better than the first. We believe that a CO_2 emissions standard at 75% of a conventional oil refinery's life cycle footprint is feasible. We might need to establish a lower hurdle at first, and apply a graduated standard with a lookback provision so the learnings from the most efficient plants are applied to the early movers. What is critical to consider now is, how will the government and industry partner together to accelerate the necessary experience we need to determine the best approach.

RESPONSES OF DON LANGLEY TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. Developers of new power plants tell us they cannot commit to deploying a new technology without a commercial performance guarantee from the vendor. You mention that your company is involved in developing a 300 megawatt oxy-coal combustion plant with CO_2 capture. Does that mean you are able to issue a guarantee on this technology at that size, or is the developer willing to go without the guarantee?

Answer. This situation could best be characterized as "semi-commercial." The SaskPower project is a leading edge endeavor to achieve positive climate change while using local natural resources in a socially responsible manner. The OxyCoalCombustion (OCC) process utilizes industry-proven enhanced technologies based on years of successful implementation into the commercial market. As such, major items such as the steam generator, turbine and air separation unit can all be offered with commercial guarantees and warrantees. Integrating of these technologies into the OCC process and delivering CO_2 to a permanent storage site have first-of-a-kind (FOAK) risks associated with the process, and they are being borne mostly by the owner. Additionally, the presence of FOAK risk naturally leads to contingent designs (multiple solutions or pre-planned modifications to be implemented based upon first experiences) that also add costs to a project. These are also being borne by the owner. In the US, these two added risks are areas where the Federal government could step in and provide financial support that would lead to faster development and deployment, and put the US into a world-wide lead in carbon management.

Question 2. It seems a bit like a commercial performance guarantee requires demonstration of the technology at scale but no commercial developer is willing to risk implementing the technology at scale without a performance guarantee. This sounds a bit like a catch-22. Is there an effective way past this problem? Are you aware of how other countries are addressing this issue?

Answer. There will never be a substitute for the learning-by-doing final phase of technology development. The electric utility industry is the most capital intensive industry in the US and, therefore, at-scale demonstrations are a required precursor for both the technology provider and the technology adopter. Enabling large demonstration projects (in this case, projects that capture between 500,000 and 1,000,000 tons per year of CO_2) is the first step in breaking through the implied conundrum. Following a demonstration, the technology then is validated at commercial scale by an early adopter who has some incentive or special risk mitigation structure to take this scaleup risk. With validation of the technology, performance assurances would become available enabling market forces to sort out the winners in a true commercial context. Cost reductions and capital efficiency come after the initial deployment and with continued use of the technology and processes.

Like the DOE, many other governments (EU, Japan and Australia) provide funding for fundamental research and pilot testing of new technologies. The final phase of first commercial use stills tends to fall to the first owner (Utility) to take the risk. Many of those Utilities may still receive government support that is unseen (Japan), or simply be large multi-national companies that can be exposed to the risk (RWE and Vattenfall). The risk associated with the first deployment of full carbon capture and storage power plants is one of the largest undertakings ever planned for the electricity generation infrastructure. It is, therefore, essential that the Federal government provide the leadership and support for that final step for US first adopters and pioneers.

RESPONSES OF DON LANGLEY TO QUESTIONS FROM SENATOR DOMENICI

Question 3a. Your testimony clearly predicts that commercial-scale carbon capture and storage will not be viable until the year 2020. What do you believe we should be doing in the interim, in addition to research and development, to reduce carbon dioxide emissions from coal-fired electricity?

Answer. The Coal Utilization Research Council (CURC) has put together a near-term program to address CO_2 emissions from coal-fired plants. First, improving the efficiency of the existing fleet would have an immediate payback in reduced emissions. There are many plants that could make improvements and upgrades that would lead to less coal consumed for the power output. One such upgrade could be the new coal drying technology developed recently with them support of the DOE in North Dakota. Secondly, enact an investment credit or production credit for those who add up to 10% biomass co-firing to their existing plants. With biomass considered a carbon neutral fuel, there would be an immediate reduction of CO_2 emissions. The addition of this amount of biomass requires a separate fuel handling and delivery system, which is a capital investment. Finally, ultrasupercritical (USC) power plants are ready to deploy today, and they can be designed with future carbon capture in mind. These plants would reduce CO_2 emissions 15–17% below the current fleet-wide average, and coupled with normal retirements of older, less efficient plants, can have an immediate impact in the near term.

Question 3b. Do you predict availability of ultra-supercritical plant designs in the year 2020 also, or is commercial application of this technology more imminent?

Answer. New ultrasupercritical power plants are available today, as seen in the state-of-the-art plant that AEP is planning to build in Arkansas, which will be the first USC coal unit ever built in the US. This technology will reduce CO_2 emissions by 15–17% over the fleet-wide average. The plant will operate with a steam temperature of 1115 F (600 C). The technology development path that we are on, with support from the DOE, is to build power plants at 1400 F (760 C), similar to the path Japan and the EU are on. This advanced ultrasupercritical plant design would have 28–30% less CO_2 emissions than the current fleet. To meet a date of 2020, more work has to be done, and additional Federal government support is needed to push this technology into full deployment and market acceptance, starting with the completion with the material development program, followed by the first demonstration plant.

RESPONSES OF DON LANGLEY TO QUESTIONS FROM SENATOR CORKER

Question 4a. As the Senate prepares to debate cap-and-trade legislation this fall, please give me your perspective on how we should contemplate and deal with coal in the short-term during that debate, apart from the incentives that you laid out in your testimony.

Answer. New plants should be capture-ready following a rigorous guideline similar to that proposed by the IEA–GHG Programme. This will ensure that there is no carbon-lock in, and that efficient use of our natural resources is enabled, thus maintaining our world leading economy and manufacturing base. Ultrasupercritical power plants should be deployed to realize the benefits of the higher efficiency operation and continued reduction in all emissions. Existing plants should evaluate the benefits of efficiency improvements and co-firing of biomass. Along with all these, the continued deployment of coal fired power plants is critical to our economy and energy security. We cannot take a hiatus or implement a moratorium on new coal and push our reliance into the volatile natural gas market (which competes with our manufacturing base and home heating), or the dangerous and uncertain world of imported LNG.

Question 4b. Keeping in mind the need to rely on coal as part of our future energy mix, what do you think are appropriate emissions targets in what amount of time, such that we challenge industry without being unrealistic based on what is technologically possible?

Answer. The Coal Utilization Research Council (CURC) has a twenty year roadmap with emissions targets for intermediary time periods. We feel that this is a challenging and realistic set of goals with the support of all parties, government and private industry.

○