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HEARING ON "FUTURE OF COAL: CARBON CAPTURE AND STORAGE"

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Thank you Mr. Chairman and Members of the Committee. I appreciate this opportunity to provide testimony on the Department of Energy's (DOE's) development of Carbon Sequestration technologies to mitigate climate change.

The economic prosperity of the United States over the past century has benefited by the abundance of fossil fuels found in North America. The United States' fossil fuel resources represent a national asset that is important to our energy security and global economic competitiveness. However, concerns over climate change and air pollution challenge our ability to take full advantage of our fossil fuels resources.

In 2004, global anthropogenic CO_2 emissions amounted to 27 billion metric tons, of which United States' emissions represented 22 percent. The projected growth of total global annual CO_2 emissions by 2030 is forecasted to be 16 billion metric tons, resulting in total global CO_2 emissions of 43 billion metric tons. The United States' share of this growth is expected to be 12.7 percent, with the portion allocated to U.S. coal-fired power generation being 6.4 percent. The parallel share of global growth in CO_2 emissions for the same period from China, India, and

other non-OECD (Organization for Economic Cooperation and Development) Asian nations is expected to be 57.2 percent.[1]

Recently, countries like China have seen dramatic growth in the use of coal as they grow their economy at a very rapid rate. China already uses more coal than the United States and its use will likely continue on a very steep curve well into the future. In fact, China is building approximately one major coal fired power plant every other week. It is also likely that economic growth in the countries of Eastern Europe will be fueled in part by coal. The advancement of carbon capture and storage technologies will not only have domestic benefits in energy security and addressing CO_2 emissions, but its advancement and deployment is an essential technology if we are to address long-term CO_2 emissions around the world.

Of the 43 billion metric tons of CO_2 emissions projected for 2030, the United States' share is expected to be 18.5 percent and U.S. coal-fired generation would represent 6.8 percent.[2]

Carbon capture and storage (CCS) technologies offer a great opportunity to reduce these potential emissions. Fortunately, the United States and Canada are blessed with an abundance of potential geologic storage capacity. At the current rate of energy production and use, we could potentially store all of the associated CO_2 emissions in North America for a period of 175 to 575 years, according to the range of geologic storage capacity estimates recently made by DOE's Regional Carbon Sequestration Partnerships (Partnerships). These results were recently published in the "*Carbon Sequestration Atlas of the United States and Canada"* that is available on our website at http://www.netl.doe.gov/publications/carbon_seq/refshelf.html.

[1] EIA's International Energy Outlook 2007
[2] EIA's Annual Energy Outlook 2007 and International Energy Outlook 2007

Geologic Storage Potential

In the *Carbon Sequestration Atlas of the United States and Canada*, DOE identified hundreds of years of storage potential in deep saline, depleted oil and gas, and unmineable coal seams. The over 3,500 billion metric tons of CO_2 storage capacity that exists throughout these regions represents a significant resource, capable of storing centuries of projected coal-fueled power plant carbon emissions. This assessment was performed by DOE and the Partnerships to summarize the completed Characterization Phase of the Regional Partnerships. The geological sequestration experts from the Partnerships, the National Carbon Sequestration Database and Geographical Information System (NATCARB), and the National Energy Technology Laboratory (NETL) created a uniform and consistent set of methodologies to determine the capacity for CO_2 storage in the United States and Canada and an Atlas from data generated by the Partnerships and other databases, including the United States Geological Survey (USGS). Carbon storage estimates will be updated in the future.

One scenario that DOE has looked at in terms of accelerating the commercial application of carbon capture technology is to couple CO_2 capture from power plants with an enhanced oil recovery (EOR) operation. This may help provide financial incentive for a power company to assume the economic and technical risk of investing in the utilization of carbon capture technology currently under development at an existing plant.

It is estimated that at a world oil price of $50 a barrel, with CO_2 priced at $40 a ton for the domestic EOR industry (the current price of CO_2 for EOR is significantly lower, around $20 a ton), there would be 5.0 gigatonnes of CO_2 capacity available for EOR to the lower-48-state market. This 5.0 gigatonnes would satisfy the sequestration needs of 30 gigawatts of coal-fired

power demand for 30 years at an 80 percent capacity factor.[3] (At the current price of $20 a ton of CO_2, the sequestration capacity for EOR would be 47 gigawatts.) The capacity of the domestic EOR market to economically serve the demonstration needs of early large-scale sequestration projects can be seen to be more than adequate, and represents a unique U.S. advantage. It is estimated that advanced EOR technology, with CCS and other approaches applied, can increase U.S. reserves by 26 billion barrels over 20 years or more, from the current estimate of 22 billion barrels.

Market Barriers

In today's world of global commerce, there is no significant incentive to deploy carbon capture technology. The most prominent consequence of carbon capture in a world lacking a global regulatory framework is placing goods and services produced in one nation at a competitive disadvantage relative to others.

The United States can speed the deployment of CCS technologies here at home and set an example of leadership for the world. That leadership could bring us economic rewards in the new business opportunities it creates here and abroad, and it will provide important leverage to help speed engagement by critical countries like China and India.

In order for the marketplace to more aggressively address our Nation's need for effective, safe, permanent, and economic carbon mitigation options we must move toward:

- An established regulatory framework for industry and its financial partners in order that risk may be properly assessed in advance of investment.
- The development of accurate methods to calculate the allocation of risk and potential financial consequence associated with long-term liability issues, and to assess

[3] Various reports relating to regional U.S. enhanced oil recovery potential performed for DOE's Office of Fossil Energy by Advanced Resources International (ARI) of Washington, DC, 2005-2006

responsibility for those risks to contributing technology developers, performers, and investors.

- International agreement on needed patent and intellectual property protections to allow our Nation's best and brightest minds to examine CCS technologies, and to allow our domestic industries to protect and recover the costs of R&D needed to develop and take advanced technologies to commercialization. Particularly as these risks present themselves in unique ways in the developing nations and potential commercial markets of China and India.
- The development of the advanced technologies needed to deliver an economic option.

Perspective on U. S. Power Generation

Based on the Energy Information Administration's (EIA's) 2007 new capacity forecast, 145 gigawatts of new coal-based capacity will be added in the United States by 2030, while still maintaining most of the 300 gigawatts of generating capacity in the existing coal fleet. We have a fast-approaching opportunity to introduce a "new breed" of power plant – one that is highly efficient compared to existing coal plants, capable of producing multiple products, and has very low emissions rates. If we wanted to dramatically reduce our carbon emissions from coal power, there would also be demand for new technology that would permit efficient, cost-effective capture of CO_2 emissions from the existing fleet. DOE's R&D program is aimed primarily at providing the scientific and technological foundation for carbon capture and storage for both new coal-fueled power plants, but some of that technology is applicable to existing plants.

Today, proposed new coal-fired power plants, in permitting or under construction, represent 46 gigawatts. For perspective, over the past five years the U.S. has put into operation 3 gigawatts.[4]

The economics of CCS using today's available commercial technologies are an overwhelming disincentive to their widespread application. Yet, the large presently installed coal-fired fleet, which provides 50 percent of our Nation's power, is expected to account for approximately 77 percent of the cumulative power plant CO_2 emissions produced by the power sector through 2030. All coal plants, including those newly installed, will be responsible for 84 percent of cumulative power plant CO_2 emissions through 2030.[5] The impact on the Nation's cost of electricity depends significantly on whether goals for carbon reduction include carbon capture for not only the new builds but also the existing fleet of coal-fired plants. Significant reductions in carbon emissions can be achieved by including carbon capture in new installed coal power. However, since a majority of coal-based electricity generation in 2030 will still come from the currently existing assets, CO_2 control from those assets, if required, would be a substantial economic challenge.

A new opportunity has recently presented itself using coal with biomass and sequestration. NETL's system's engineers have modeled this technology on a limited life-cycle basis, and believe it may lead to carbon-neutral or even net-negative carbon balance electric power. By co-feeding 11 percent biomass by energy (15 percent biomass by weight) with coal through an Integrated Gasification Combined Cycle (IGCC) plant employing 90 percent capture and sequestration, a process referred to as Coal/Biomass-IGCC (CB-IGCC), NETL estimates that net-GHG emissions would be zero. By example, a nominal 500-megawatt net plant,

[4] Estimate made using Energy Velocity database, August 29, 2007
[5] EIA's Annual Energy Outlook 2007

consuming 900-tons per day (TPD) of switchgrass, 5,000-TPD of coal, and capturing 12,000-TPD of CO_2, if one takes credit for the switchgrass, would yield a net-zero life-cycle carbon footprint that includes not only the power island but also the upstream coal and biomass preparation and transport.[6]

At the NUON 250-megawatt IGCC plant in the Netherlands, they have successfully fed a mixture of coal and 30 percent (by weight) demolition wood into a high-pressure, entrained-flow gasifier. The 900-TPD of biomass is well within a reasonable economic limit of 5,000-TPD, as recently published in the NETL-United States Air Force report on coal-biomass to liquids. This technical option reflects the potential of CCS to enhance the carbon reduction benefits, intended by those States that have chosen to enact renewable portfolio standards on their electric suppliers, by allowing for negative (rather than neutral) CO_2 credits to be applied to biomass CO_2, to which CCS is applied.

Carbon Sequestration Technology Roadmap

DOE's coal RD&D program is focused on addressing the technical uncertainties and reducing the costs and risks associated with CCS from coal-based systems. Today's commercially available technology will add from 81 to 86 percent to the cost of electricity for a new pulverized coal plant, and from 32 to 40 percent to the cost of electricity for a new advanced gasification-based plant.[7]

By cost-effectively capturing CO_2 before it is emitted into the atmosphere and then permanently storing or sequestering it, fossil fuels could be used in a carbon-constrained world with reduced impact to economic growth. DOE is taking a leadership role in the development of

[6] Estimate performed by NETL's Office of Systems, Analyses and Planning
[7] Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity , U.S. Department of Energy/National Energy Technology Laboratory, DOE/NETL-2007/1281, Final Report, May 2007

CCS technologies by addressing cost-effective capture, geographical diversity, permanence, monitoring, mitigation and verification (MMV), permitting and liability, public acceptance, and infrastructure.

The Carbon Sequestration Program is addressing these challenges through applied research, proof-of-concept technology evaluation, pilot-scale testing, large-scale demonstrations, stakeholder involvement, and public outreach.

We have accelerated the scheduled dates for commercial readiness of CCS technologies by several years by expediting the large-scale field tests. The programs current technology roadmap and program plan is set to achieve the following goals on the timeline indicated:

- 2007: Initiate deployment of Regional Carbon Sequestration Partnerships.
- 2008: Establish MMV protocols; enable 95 percent of CO_2 stored to be credited.
- 2009: Inject 0.5 million metric tons CO_2 total at 1 or more large-volume field test sites.
- 2012: Complete pilot-scale operations from a combination of CO_2 capture, MMV and storage system component projects such that, when integrated into a systems analysis framework, will collectively meet the goals of 90 percent capture, 99 percent permanence, at no greater than 10 percent added cost of electricity.
- 2013: Equipment specifications and designs available to industry.
- 2020: Optimized sequestration technology ready for commercial deployment.

Reflecting on a historic precedent represented by the 1970 Clean Air Act, it required approximately 10 years to establish the key technologies that industry would employ to meet the requirements of the regulation, then an additional 10 years to approach the widespread deployment of applicable technologies. This timeframe is reflected in the goals of the accelerated roadmap presented above, even though the costs and magnitude of CCS have been

only subjectively drawn, and may be much greater than those associated with Clean Air Act compliance.

Carbon Sequestration Program

DOE's Carbon Sequestration Program leverages basic and applied research with field verification to assess the technical and economic viability of CCS as a greenhouse gas mitigation option. The Program encompasses two main elements: Core R&D and Validation and Deployment. The Core R&D element focuses on technology solutions, including low-cost, low-energy intensive capture technologies, which can be validated and deployed in the field. Lessons learned from field tests are fed back to the Core R&D element to guide future R&D.

The key challenges the program is addressing are to demonstrate the ability to store CO_2 in underground geologic formations with long-term stability (permanence), to develop the ability to monitor and verify the fate of CO_2, and to gain public and regulatory acceptance. DOE's seven Regional Carbon Sequestration Partnerships are engaged in an effort to develop and validate CCS technology in different geologies across the Nation.

Collectively, the seven Partnerships represent regions encompassing 97 percent of coal-fired CO_2 emissions, 97 percent of industrial CO_2 emissions, and 97 percent of the total land mass, and essentially all of the geologic storage sites in the United States potentially available for sequestration. The Partnerships are evaluating numerous CCS approaches to assess which approaches are best suited for specific geologies, and are developing the framework needed to validate and potentially deploy the most promising technologies.

The Regional Partnership initiative is using a three-phased approach.

Characterization, the first phase, was initiated in 2003 and focused on characterizing regional opportunities for CCS, and identifying regional CO_2 sources and storage formations. The Characterization Phase was completed in 2005 and led to the current Validation Phase.

Validation, the second phase, focuses on field tests to validate the efficacy of CCS technologies in a variety of geologic storage sites throughout the United States. Using the extensive data and information gathered during the Characterization Phase, the seven Partnerships identified the most promising opportunities for storage in their regions and are performing widespread, multiple geologic field tests. In addition, the Partnerships are verifying regional CO_2 storage capacities, satisfying project permitting requirements, and conducting public outreach and education activities.

Deployment, the third phase, involves large-volume injection tests. This phase was initiated this fiscal year and will demonstrate CO_2 injection and storage at a scale necessary to demonstrate potential future commercial deployment. The geologic structures to be tested during these large-volume storage tests will serve as potential candidate sites for the future deployment of technologies demonstrated in the FutureGen Project as well as the Clean Coal Power Initiative (CCPI). The Department expects to issue a CCPI solicitation for carbon capture technologies at commercial scale in calendar year 2007.

DOE also recognizes the importance of the existing fleet of coal-fired power plants in meeting energy demand and possible future carbon constraints. Research is being pursued to develop technologies that dramatically lower the cost of capturing CO_2 from power plant stack emissions. This research, supported by the Office of Fossil Energy, is exploring a wide range of approaches that includes membranes, ionic liquids, metal organic frameworks, improved CO_2 sorbents, advanced combustor concepts, advanced scrubbing, and oxy-combustion.

Additionally, advanced research is being pursued on high-temperature materials, advanced sensors & controls, and advanced visualization software. These developments could provide significant efficiency improvements and cost reductions for both existing and future power plants, based on pulverized coal combustion.

Closing Remarks

Carbon sequestration can play an important role in mitigating CO_2 emissions under potential future stabilization scenarios. The United States is underlain by a large capacity of geologic formations amenable to CO_2 storage. DOE's Carbon Sequestration Program will continue to move sequestration technology towards commercial deployment when it is needed.

Mr. Chairman, members of the Committee, this completes my statement. I would be happy to answer any questions you may have.