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Thank you Mr. Chairman. I appreciate this opportunity to provide testimony on the Department of Energy's advanced clean coal technologies and the program for carbon capture and storage.

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.

The Nation is also home to a large resource of oil. Although much of the Nation's onshore petroleum resource has been produced, large volumes of crude oil remain in place after current production methods are exhausted. These resources are being held in place by physical forces or left behind due to geologic complexity being both economically and technologically challenged. The total volume of this stranded oil is estimated by Advanced Resources International (ARI) of Washington, DC, to exceed 390 billion barrels, of which roughly 200 billion barrels are estimated to be relatively accessible at depths of up to 5,000 feet but do not have CO_2 available for EOR. To put these numbers in context, according to the Energy Information Administration (EIA), we have produced about 195 billion barrels of our petroleum resource over the past 120 years and currently have proven reserves of roughly 22 billion barrels (source: EIA online database, as of December 2005, crude oil, does not include natural gas liquids).

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, in general, and coal-fired power plants, in particular, have 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.

Both of these challenges—developing domestic sources of fossil fuels and reducing emissions of carbon dioxide (CO_2) from coal-fired power plants—can be addressed simultaneously through the use of captured CO_2 for enhanced oil recovery (EOR). While not the complete solution to either of these challenges, incremental oil produced from such applications could help offset the costs of CO_2 capture, while the prospect of low-cost supplies of captured

CO_2 in widespread areas of the country could provide the impetus for a national re-evaluation of the EOR potential in many mature fields. While EOR is a mature technology that has been in commercial use for decades, CO_2 capture from coal power is not yet commercial. Continued evolution of EOR and transformational advances in development and deployment of CO_2 capture from coal power could help realize this synergy between the coal/power industry and the oil industry.

How is DOE Responding to these Issues?

While the challenges are significant, the United States is well positioned to capitalize on these synergies. The oil industry has been using CO_2 for EOR in commercial applications for decades. As early as the 1970s, DOE-funded projects were assessing the fluid properties of CO_2 to establish its applicability in EOR. A special focus was given to developing correlations that helped the oil industry utilize these properties to optimize commercial EOR projects. During 1993-2003, DOE funded nearly half of the $100 million spent on the Class Program CO_2-EOR Field Demonstration Projects in six states. Approaches included the use of horizontal wells for improved reservoir contact, four-dimensional seismic to monitor the behavior of CO_2 floods, automated field-monitoring systems for detecting problems, and the injection of increasingly larger volumes of CO_2 to increase recovery rates. In summary, this DOE-funded research has helped advance industrial EOR operations, but the focus is now on the carbon sequestration side of EOR, which is a developing technology, rather than the oil production side of EOR, which is a mature technology. DOE-funded research continues to include some research on EOR.

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. It includes technologies that will either facilitate the efficient capture of CO_2 from coal-fired plants for subsequent sequestration or directly address solutions for safely and permanently sequestering it in underground reservoirs. These programs include gasification, advanced turbines, fuel cells, FutureGen, and carbon sequestration, and are described in more detail below.

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 is developing 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.

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.

Fuel Cells

Fuel cells could help support the efficiency and emission targets of future power plants, such as FutureGen. 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. 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 that capture at least 90% of the CO_2 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.

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. 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.

Opportunities for Synergy Between Coal and Oil Industries

Many EOR processes incorporating thermal, chemical, microbial, and a variety of miscible gas-injection methods have been employed in the United States. Among these, CO_2-

EOR is most promising and has in fact produced one billion barrels of oil to date. Because CO_2 is miscible with crude oil under certain conditions, it can be injected into previously drained oil reservoirs and used to sweep a portion of the remaining oil from the rock, helping to overcome the physical forces that trap the residual oil. While not all of the easily accessible stranded oil is susceptible for recovery by CO_2-EOR, a large proportion could be recovered if a source of low-cost CO_2 and improved CO_2-EOR technologies are developed and applied to the problem.

A series of CO_2-EOR assessments conducted for DOE's Office of Fossil Energy by ARI concluded that, if current high oil prices are sustained over the long-term, low-cost captured CO_2 from power plants is available (at a cost of between $27 and $34 per ton of CO2 delivered to the oil field), and improved CO_2-EOR technology is applied which maximizes oil recovery while minimizing the CO2 needed, 47 billion barrels of incremental oil—more than twice the current U.S. reserve—would be economic to produce. Of course, only a few companies currently have access to the state of the art technology and oil companies take many factors into consideration when determining which investments to make. Therefore, even if these technological advances are made, it is possible that not all of the additional 47 billion barrels of domestic oil would be produced.

Within just the large fields in North Dakota's portion of the Williston Basin, as much as 390 million barrels of incremental oil could have a cost of production less than the current price of oil under this scenario. In addition, the feasibility of converting the large unconventional in-place resource within the Bakken Shale of North Dakota into economic reserves using next generation CO_2-EOR technology has not been examined (studies have suggested that 100 to 150 billion barrels, or more, of resource may be in-place). However, if injection of CO_2 into this fractured shale could mobilize a portion of this resource, the Williston Basin's contribution to the Nation's oil supply could be significantly expanded.

In addition, while the main focus of CO_2-EOR is on maximizing the amount of oil produced rather than the amount of CO_2 injected, its sequestration potential is still significant, though much less than the sequestration potential of saline formations in the U.S. Estimates by Vello Kuuuskraa at ARI are that the technical limit for CO_2 storage associated with EOR is 20 gigatons and that between 8-12 gigatons can be economically stored if next generation EOR technology is developed and applied, assuming that the cost of CO_2 is less than \$30 - \$38/ton delivered, which would require significant advances in carbon capture technology. To put this into context, total man-made U.S. greenhouse gas emissions (carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons) in 2004 were the equivalent of about 7.8 gigatons of CO_2 equivalent. This total includes approximately 6 gigatons of actual CO_2. About 2.2 gigatons of this CO_2 comes from coal-fired power plants, and the balance (approximately 3.8 gigatons) stems from oil and gas use.

According to the Energy Information Administration's Annual Energy Outlook 2007, coal-fired generation produced 84% of the CO_2 associated with electrical power generation in 2006, and 33% of total U.S. emission of CO_2. This forecast also suggests that CO_2 from coal-fired power generation is expected to represent 88% of all CO_2 related to electric power generation by 2030, and 37% of total U.S. emission of CO_2.

CO_2-EOR projects represent an early major opportunity for helping to realize carbon capture technology. This opportunity has unique potential to overcome economic, social, and risk obstacles associated with the commercialization of technology. In addition, the use of CO_2-EOR projects could help power generation companies to take advantage of the oil industry's expertise with CO_2 handling and injection, and help accelerate the implementation of other underground CO_2 sequestration options in coalbeds, depleted gas reservoirs, and deep saline formations.

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. Evidence of this progress includes:

- 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.
- Carbon dioxide capture technology is being developed for solvent, sorbent, membrane, and oxy-combustion systems that, if successfully developed, would be capable of capturing greater than 90% of the flue gas carbon dioxide 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 CO_2 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.
- 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.

Developing the technologies needed to support a widespread expansion of CO_2-EOR could substantially increase existing U.S. reserves and production. The DOE efforts listed above are providing the elements needed to enable this expansion by advancing capture technologies to ensure a reliable low-cost supply of CO_2 and improved EOR technologies to optimize for carbon sequestration co-benefits.

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