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Thank you, Mr. Chairman and members of the Subcommittee. I appreciate this opportunity to provide testimony on the U.S. Department of Energy's (DOE's) research efforts in enhanced oil recovery (EOR) using carbon dioxide (CO_2) and its relevance to carbon sequestration.

INTRODUCTION

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.

The Nation is home to a large resource of oil. Although much of the Nation's original onshore petroleum reserves have been produced, large volumes of crude oil remain stranded in place after current production operations are completed because their extraction using current technology is both technically difficult and uneconomic. As much as 70% of the oil in a given reservoir remains stranded in place after current production operations are completed due to technological and economic hurdles. The total volume of this stranded oil[1] is estimated by Advanced Resources International (ARI), of Washington, DC, to exceed 390 billion barrels, though DOE and the U.S. Geological Survey (USGS) have not yet validated the ARI estimates. Of this total, ARI estimates that roughly 200 billion barrels are relatively accessible at depths to 5,000 feet below the surface. Extraction can be aided technically and made more economic through the use of CO_2 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 resources over the past 120 years and currently have proven reserves[2] of roughly 21 billion barrels. Proven reserves are those quantities of petroleum, which, by analysis of geoscience and engineering data, can be estimated with reasonable certainty to be commercially recoverable, from a given date forward, from known reservoirs and under defined economic conditions, operating methods, and government regulations. If probabilistic methods are used, there should be at least a 90% probability that the quantities actually recovered will equal or exceed the estimate. Stranded oil is not currently included in proven reserves. Stranded oil is a resource that could add substantially to reserves when technology becomes available and economic conditions allow. It is equal to the total reserves in place, minus the proven reserves.

There is also scientific consensus that increased levels of greenhouse gases in the atmosphere, primarily CO_2, methane, nitrous oxide, and chlorofluorocarbons, are linked to climate change. Globally, about 75-80% of total greenhouse gas emissions are CO_2. In this

[1] Assessing Technical and Economic Recovery of Oil Resources in Residual Oil Zones, ARI, February 2006, www.adv-res.com/pdf/ROZ_Phase_II_Document.pdf.
[2] U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 2006 Annual Report, DOE/EIA-0216(2007), November 2007, www.eia.doe.gov/oil_gas/natural_gas/data_publications/crude_oil_natural_gas_reserves/cr.html.

connection, fossil fuel combustion, in general, and fossil-fuel power plants, in particular, have been identified as a major source of anthropogenic greenhouse gas emissions, particularly CO_2, into the atmosphere. Slowing the growth of anthropogenic greenhouse gas emissions has become an important concern.

Both of these challenges — extending the supply of domestic fuels (primarily oil) and reducing emissions of CO_2 from fossil-fueled power plants (primarily those fired with coal) — can be addressed simultaneously through the use of captured CO_2 for achieving EOR. Currently, most EOR projects rely on the availability of cheap sources of naturally occurring CO_2. If research into reducing the cost of CO_2 capture from power plants proves successful, anthropogenic sources of CO_2 may become readily available for EOR projects. The Intergovernmental Panel on Climate Change has estimated a worldwide technical capacity for CO_2 storage in EOR applications at 61 to 123 billion tonnes of CO_2. Estimates by ARI, which DOE has not yet fully evaluated, have shown that the technical limit for CO_2 storage associated with EOR is 20 billion tons. Of that quantity, ARI estimates up to 12 billion tons could be economically stored, if EOR technology continues to advance and the cost of carbon capture technology is significantly reduced. If these potentials can begin to be realized, incremental oil produced via EOR using CO_2 flooding could help offset the costs of CO_2 capture, and the prospect of relatively low-cost supplies of captured CO_2 in widespread areas of the country could, in turn, provide the impetus for a national re-evaluation of the EOR potential in many mature fields. The proximity of sources of captured CO_2 to oil reserves amenable to EOR is an important consideration, because transportation of CO_2 over long distances is expensive and can affect the economics of EOR. The use of EOR for carbon sequestration will also involve permitting issues, liability issues, monitoring and verification technologies to ensure permanent storage, and public outreach.

In summary, while conventional EOR is a commercial process, CO_2 capture from coal power systems is not yet commercial at the large scale required for deployment in power plants. 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.

TECHNOLOGY DEVELOPMENTS

The Department has recognized the importance of CO_2 EOR for more than forty years. 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 improve EOR performance in commercial projects. Technological advances 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. This DOE-funded research has helped to significantly advance industrial EOR operations, most of which currently use CO_2 from natural reservoirs, but the research focus is now on the carbon sequestration aspect of EOR, a developing application, rather than the mature oil production side of EOR.

Coupled with these advances in CO_2 EOR, the Office of Fossil Energy's Clean Coal Research & Development (R&D) Program provides for the development of new cost- and environmentally-effective approaches to coal use. The major focus of the program is developing future plant configurations that minimize CO_2 emissions by developing cost-effective approaches for efficiently capturing CO_2 from coal-fired plants, and safely and permanently sequestering the captured CO_2 in underground reservoirs. The key technology areas that make up the Clean Coal R&D Program are discussed in the following paragraphs.

Gasification is a pathway to convert coal or other carbon-containing feedstocks into synthesis gas. This 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. The Advanced Integrated Gasification Combined Cycle Program is developing advanced gasification technologies to meet the most stringent environmental regulations and facilitate the efficient capture of CO_2 for subsequent sequestration. Gasification plants are very amenable to CO_2 capture because they can be designed to produce a high-pressure stream of CO_2 that is easier to capture, compared to conventional power plant technologies. Advances in the current state-of-the-art, as well as the development of novel approaches, could provide the technical pathways enabling gasification to meet the demands of future energy markets, while minimizing greenhouse gas emissions.

The Advanced Turbine Program consists of a portfolio of laboratory and field R&D 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 large-scale turbines greater than 100-megawatt size range, and it has also worked on the development of less costly approaches for compressing 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 hold great potential to provide substantial improvements to the efficiency and emission reductions of future power plants. Fuel cell emissions per unit of electric power produced are well below current and proposed environmental limits for commercial power sources. 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, megawatt-scale fuel cell power systems that will produce affordable, efficient, and clean electric power both as stand-alone sources, or when they are incorporated into integrated coal gasification combined-cycle systems equipped with CO_2 capture and sequestration.

Carbon sequestration developments are addressing the key challenges that confront the wide-scale deployment of capture and storage technologies through research on cost-effective capture technologies; monitoring, mitigation, and verification technologies to ensure permanent storage; permitting issues; liability issues; public outreach; and infrastructure needs. For example, relative to capture costs, today's commercially available capture and storage technologies will add around 80% to the cost of electricity for a new pulverized coal plant, and around 35% to the cost of electricity for a new advanced gasification-based plant.[3] The Carbon Sequestration Program is aggressively pursuing developments to reduce these costs to less than a 10% increase in the cost of electricity for new gasification-based energy plants, and is developing a goal for pulverized-coal energy plants. Relative to EOR, the program is focusing on technologies for monitoring, mitigation, and verification that will validate permanent CO_2

[3] 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.

storage in these applications, and provide the necessary best practices protocols for using EOR as a carbon storage option.

EOR AND SEQUESTRATION POTENTIAL

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 likely the most promising technology. 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 reservoir, thereby helping to overcome the physical forces that trap the residual oil. While not all of the relatively 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 advanced CO_2-EOR technologies are developed and deployed.

A series of CO_2-EOR assessments conducted by ARI have projected that, if current high oil prices are sustained over the long-term, if low-cost captured CO_2 from power plants is available, and if there continue to be improvements in CO_2-EOR technology, 89 billion barrels of incremental oil — more than four times the current U.S. proved reserves — may be economic to produce. It was also noted in this study that widespread use of improved CO_2-EOR technologies and modified processes that emphasize using increased volumes of CO_2 in each reservoir could result in three times as much CO_2 being used, and five times more oil being recovered. These changes could result in significant recovery of this incremental oil. Since oil companies take many factors and risks into consideration when determining which investments to make, it is unlikely that all of the additional 89 billion barrels of domestic oil would be produced, due to the complexities of corporate investment decisions. DOE has not yet fully evaluated these projections and their relevance to DOE activities.

ARI estimates that 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, though DOE and USGS have not yet verified these estimates. In addition, the feasibility of converting the large unconventional in-place resource within the Bakken Shale of North Dakota into economic reserves has been examined by USGS. Their recent study estimates that nearly 4 billion barrels of (undiscovered) oil are technically recoverable from the Bakken Shale formation[4]. Additionally, a 2006 study by the North Dakota Geological Survey, which DOE and USGS have not yet verified, suggested that by using next generation CO_2-EOR technology, as much as 400 billion barrels, or more, of oil resource may be in-place[5]. If injection of CO_2 into this fractured shale could mobilize even a minor portion of this larger estimate, the Williston Basin's contribution to the Nation's oil supply would 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 United States. Estimates by ARI, which DOE is evaluating, have shown that the technical limit for CO_2 storage associated with EOR is 20 billion tonnes. Of that quantity, up to 12 billion tonnes could be economically stored if EOR technology continues to advance, and 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 anthropogenic emissions of CO_2 in the United States is around 6 billion tonnes per year, with around 2 billion tonnes per year of this CO_2 from coal-fired power plants.

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[4] USGS, Assessment of Undiscovered Oil Resources in the Devonian-Mississippian Bakken Formation, Williston Basin Province, Montana and North Dakota, April 2008.
[5] Bakken Formation Reserve Estimates, Julie LeFever and Lynn Helms, North Dakota Geological Survey, 2006.

CONCLUSION

CO_2-EOR represents an early major opportunity for helping to realize carbon capture and sequestration technologies. 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 oil/gas reservoirs, and deep saline formations. Developing the technology base needed to support a widespread expansion of CO_2-EOR could substantially increase existing United States' oil reserves and production. The Department's development efforts are providing the elements needed to help enable this expansion by advancing capture technologies to increase the supply of CO_2 and optimize EOR technologies 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.