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Before the

Subcommittee on Energy and Environment
Committee on Science, Space and Technology
U.S. House of Representatives

Coal Research and Development

October 13, 2011

Thank you Chairman Harris and members of the Subcommittee; I appreciate the opportunity to discuss the Department of Energy's (DOE) coal research & development activities.

Interagency Task Force on Carbon Capture and Storage

Before I discuss the Department's Clean Coal Research Program, I will briefly review the conclusions from the Interagency Task Force on Carbon Capture & Storage (CCS). In August 2010, the final report from the Task Force was issued summarizing the Administration's efforts to develop and deploy CCS technologies, and proposed a plan to overcome the barriers to the widespread, cost-effective deployment of CCS within ten years, with a goal of bringing five to ten commercial demonstration projects online by 2016. This report is the collective work of 14 executive departments and Federal agencies, which were tasked with developing a comprehensive and coordinated Federal strategy to speed the commercial development and deployment of clean coal technologies. The task force concluded that while there are no insurmountable technological, legal, institutional, regulatory or other barriers that prevent CCS from playing a role in reducing GHG emissions, early CCS projects face economic challenges related to climate policy uncertainty, first-of-a-kind technology risks, and the current high cost of CCS relative to other technologies.

Clean Coal Research Program

DOE continues to play a leadership role in the development of clean coal technologies with a focus on CCS. The Clean Coal Research Program – administered by DOE's Office of Fossil Energy and implemented by the National Energy Technology Laboratory – is designed to enhance our energy security and reduce environmental concerns over the future use of coal by developing a portfolio of revolutionary clean coal technologies. The Program is well positioned to help overcome the technical challenges associated with the development of clean coal technologies.

The Clean Coal Program, in partnership with the private sector, is focused on maximizing efficiency and environmental performance, while minimizing the costs of these new technologies. In recent years, the Program has been restructured to focus on clean coal technologies with CCS. The Program pursues the following two major strategies:

1) capturing and storing greenhouse gases; and
2) improving the efficiency of fossil energy systems.

The first strategy aims to eliminate concerns over emissions of greenhouse gases from fossil fueled energy systems. The second strategy seeks to improve the fuel-to-energy efficiencies of these systems, thus reducing pollutant emissions, water usage, and carbon emissions on a per unit of energy basis. Collectively, these two strategies comprise the Clean Coal Program's approach to ensure that current and future fossil energy plants will have options to meet all emerging requirements for a safe and secure energy future.

Core Research and Development Activities

The Clean Coal Program is addressing the key technical challenges that confront the development and deployment of clean coal technologies through research on cost-effective capture technologies; monitoring, verification, and accounting technologies to ensure permanent storage; permitting issues; and development of advanced energy systems. As an example, today's commercially available CCS technologies would increase the cost of electricity by 80 percent for a new pulverized coal plant (equivalent to about $45 per ton CO_2 captured), and increase the cost of electricity by 35 percent for a new integrated gasification combined cycle plant (equivalent to about $32 per ton CO_2 captured).[1] The Program is aggressively pursuing developments to reduce these costs to less than a 35 percent increase in the cost of electricity for pulverized coal energy plants (about $20 per ton CO_2 captured) and less than a 10 percent increase in the cost of electricity for new gasification-based energy plants (about $10 per ton CO_2 captured).

Research is focused on developing technology options that dramatically lower the cost of capturing carbon dioxide (CO_2) from fossil fueled energy plants. This research can be categorized into three technical pathways: post-combustion, pre-combustion, and oxy-combustion. Post-combustion refers to capturing CO_2 from the stack gas after a fuel has been

[1] 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.

combusted in air. Pre-combustion refers to a process where a hydrocarbon fuel is gasified to form a mixture of hydrogen and carbon dioxide, and CO_2 is captured from the synthesis gas before it is combusted. Oxy-combustion is an approach where a hydrocarbon fuel is combusted in pure or nearly pure oxygen rather than air, which produces a mixture of CO_2 and water that can easily be separated to produce pure CO_2. Collectively, research in each of these technical pathways is exploring a wide range of approaches such as membranes; oxy-combustion concepts; solid sorbents; advanced gas/liquid scrubbing technologies; and advanced hybrid concepts such as liquid membrane contactors. These efforts cover not only improvements to state-of-the-art technologies but also development of several revolutionary concepts, such as metal organic frameworks, ionic liquids, and enzyme-based systems. Coupling these developments with other advances in efficiency improvements and cost reduction from developments in gasification, turbines, and fuel cells, will help provide a technology base for commercial deployment of fossil energy systems integrated with CCS.

The Department is the primary supporter of the National Carbon Capture Center (NCCC), which is a joint partnership between DOE and industry. The NCCC is a one of a kind, world class facility which offers an opportunity to validate capture technologies on actual gas from a coal-fired power plant or gasification facility. Because of the ability to operate under a wide range of process conditions, research at the NCCC can effectively evaluate technologies at various levels of maturity for many different applications.

Regional Carbon Sequestration Partnerships

The Regional Carbon Sequestration Partnerships were created by the DOE in 2003 through a competitive solicitation. The Partnerships were designed to address a range of issues associated with geologic storage of CO_2. The Clean Coal Program has been performing CCS field tests focused on injection, monitoring, verification, accounting and other aspects of geologic storage for many years, and the seven Regional Carbon Sequestration Partnerships are critical to this effort. These Partnerships are comprised of state agencies, universities, and private companies. They represent more than 400 unique organizations in 43 States, and four Canadian Provinces. Geographic differences in fossil fuel use and potential storage sites across the United States dictate the use of regional approaches in addressing CCS, so each Partnership is focused on a specific region of the United States and Canada that holds similar characteristics relating to CCS opportunities.

Together, the Partnerships form a network of capability, knowledge, and infrastructure that will help enable geologic storage technology to play a role in the clean energy economy. They represent regions encompassing 97 percent of coal-fired CO_2 emissions, 97 percent of industrial CO_2 emissions, 96 percent of the total land mass, and essentially all the geologic storage sites that can potentially be available for geologic carbon storage.

Regional Partnerships are drilling wells and injecting small quantities of CO_2 to validate the potential of key storage locations throughout the country. To date, the Regional Partnerships have injected over 1 million tons of CO_2 at 18 small scale injection projects throughout the United States and Canada. These tests have helped to validate storage at a small scale to understand the fate of CO_2 in different depositional systems containing saline water, oil, and natural gas. Several large scale projects are also underway that will inject several million tons of CO_2 over the life of the projects. One of these projects has safely and securely injected over 3 million metric tons of CO_2. Several more large-scale field tests will begin later this year.

Over the course of these initiatives, DOE and the Partnerships are addressing key infrastructure issues related to permitting, pore space ownership, site access, liability, public outreach, and education. We are also jointly developing Best Practice Manuals on topics such as site characterization, site construction, operations, monitoring, mitigation, closure, and long-term stewardship. These manuals will serve as guidelines for a future geologic sequestration industry in their regions, and help transfer the lessons learned from DOE's Program to all regional stakeholders. The first editions of the Best Practice Manuals are available on DOE's reference shelf[2] and the Manuals will be periodically updated as lessons learned from the large scale field tests are realized. Finally, DOE and the Partnerships continue to work closely with the Environmental Protection Agency (EPA) and other Federal and state agencies in developing CCS regulatory strategies, which will provide additional certainty for future CCS deployments.

Demonstrations at Commercial-Scale

The success of the Clean Coal Program will ultimately be judged by the extent to which emerging technologies get deployed in domestic and international marketplaces. Both technical and financial challenges associated with the deployment of new "high risk" coal technologies must be overcome in order to be capable of achieving success in the marketplace. Commercial-scale demonstrations help the industry understand and overcome start-up issues, address

[2] http://www.netl.doe.gov/technologies/carbon_seq/refshelf/refshelf.html

component integration issues, and gain the early learning commercial experience necessary to reduce risk and secure private financing and investment for future plants.

The Department is implementing large-scale projects through the Regional Partnerships, the Clean Coal Power Initiative (CCPI), and FutureGen. Phase III of the Partnerships is focused on large-scale field tests of geologic carbon sequestration on the order of 1 million metric tons of CO_2 per year, and are addressing the liability, regulatory, permitting, and infrastructure needs of these projects. As described previously in this statement, the Partnerships have brought an enormous amount of capability and experience together to work on the challenges of these large projects.

The CCPI is a cost-shared partnership between the Government and industry to develop and demonstrate advanced coal-based power generation technologies at the commercial scale. CCPI demonstrations address the reliability and affordability of the Nation's electricity supply from coal-based generation. By enabling advanced technologies to overcome technical risks involved with scale-up and bringing them to the point of commercial readiness, CCPI accelerates the development of both advanced coal generation technologies and the integration of CCS with both new and existing generation technologies. The CCPI also facilitates the movement of technologies into the market place that are emerging from the core research and development activities.

The CCPI program received an additional $800 million from the 2009 American Recovery and Reinvestment Act (Recovery Act) which, in combination with base funding, was used to fund four CCPI Round III projects, two pre-combustion and two post-combustion capture projects. In addition, a CCPI Round II project, with Southern Company Services, has been modified to demonstrate CCS at a new integrated gasification combined cycle power plant. Having completed all design and National Environmental Protection Act (NEPA) activities, this project began construction in 2010 and is scheduled to be operational in 2014.

We are working closely with the project developers to comply with NEPA, air and water regulatory requirements, and complete initial Front End Engineering & Design (FEED) studies for each of the CCPI projects. The CCPI project with Summit Texas Clean Energy, LLC, completed FEED in June 2011 for the new IGCC power plant, and the NEPA Record of Decision was issued in September 2011, clearing the way for the project to meet financial agreements with its investors. Construction is expected to begin in early 2012 with operations expected to start in 2014. The Hydrogen Energy California (HECA) CCPI project with Hydrogen Energy International was restructured in September 2011 to acknowledge sale of the project by BP and Rio Tinto to SCS Energy, LLC. Also, as a result of the ownership change, the project was modified to augment the IGCC-CCS concept to include poly-generation of electric power, carbon dioxide for enhanced oil recovery, and urea and urea ammonium nitrate fertilizers. The project began FEED for the poly-generation facility in September 2011 and is expected to begin operations in 2017. American Electric Power (AEP) announced in July 2011 that they were placing their CCPI Round III post-combustion capture project on hold until economic and policy conditions create a viable path forward. Consequently, AEP requested a termination of their DOE award, concluding all project activities after the completion of FEED in September 2011. Following the results of FEED for their CCPI post-combustion capture project, NRG

Energy determined that a scale increase was desired to improve project economics and make the project more financially sound. As a result, FEED is currently underway for the larger scale project and is expected to be complete, along with the NEPA Record of Decision, in early 2013 and operational in 2015.

The FutureGen Project intends to conduct novel large-scale testing to accelerate the deployment of a set of advanced oxy-combustion power production technologies integrated with CCS. This project will be the first advanced repowering oxy-combustion project to store CO_2 in a deep saline geologic formation. On August 5, 2010, Secretary of Energy Steven Chu announced an award totaling $1 billion in Recovery Act funding to the FutureGen Alliance; and Ameren Energy Resources along with their partners: Babcock & Wilcox, and Air Liquide Process and Construction, Inc., to repower an existing plant with advanced oxy-combustion technologies. Together, these two awards comprise the FutureGen 2.0 project for clean coal repowering with CCS. On February 28, 2011, the FutureGen Alliance selected Morgan County, Illinois, as the preferred location for the FutureGen 2.0 CO_2 storage site, visitor center, and research and training facilities. In addition to the CCPI and FutureGen 2.0 projects, the Recovery Act has also helped fund more than 80 additional projects, which includes three large scale Industrial CCS demonstrations, 10 geologic site characterizations, 43 university research training projects, seven CCS research training centers, six Industrial CCS projects focused on CO_2 reuse, and 14 projects focused on accelerated component development in the core research program.[3]

[3] Details about all of the Fossil Energy projects funded by the Recovery Act can be found here: http://www.fossil.energy.gov/recovery/index.html.

CO_2 Utilization Technologies

The coal research and development program has supported research on CO_2 utilization technologies for more than a decade. When the Carbon Storage Program (formerly named the Sequestration Program) was initiated in the mid-1990s, it was recognized that technologies such as mineralization, chemical conversion to useful products, algae production, enhanced oil recovery (EOR) and enhanced coalbed methane recovery could play an important role in mitigating CO_2emissions. Other than EOR, the CO_2 emissions reduction potential of these approaches is limited, due to factors such as cost and market saturation of salable byproducts. Even so, these approaches are logical "first-market entry" candidates for greenhouse gas mitigation, due to their ability to produce revenue from use of the CO_2 that could be used to offset the costs for these "early adopters." Hence, these options provide a technology bridge and smoother transition to the deployment of the large-scale, stand-alone geologic sequestration operations that will ultimately be needed to achieve the much larger reductions that would be required to approach stabilizing greenhouse gas concentrations in the atmosphere.

EOR represents the most near term and most commercially attractive utilization option for CO_2 storage that could produce substantial quantities of oil while permanently storing the CO_2 in geologic formations. The Department has recognized the importance of CO_2 EOR for more than 40 years, though the focus has shifted from increased incremental oil production to monitoring, verification, and accounting of geologically stored CO_2 as part of a climate change mitigation strategy. As early as the 1970s, DOE-funded projects were developing concepts to improve the effectiveness and applicability of CO_2 EOR. Currently, most EOR projects have been strategically located near cheap sources of naturally occurring CO_2 or along pipelines from such sources. 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 tons of CO_2.[4] Estimates by Advanced Resources International (ARI) have shown that the technology limit for CO_2 storage associated with EOR in the United States is 20 billion tons. Of that quantity, ARI estimates over 10 billion tons could be economically stored with existing EOR technology and the cost of carbon capture technology is significantly reduced.[5] 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. Most important to the Clean Coal Research Program, the use of EOR for carbon sequestration will involve permitting issues, liability issues, monitoring and verification technologies to ensure permanent storage, and public outreach. 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

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[4] 2005 IPCC Special Report on Carbon Dioxide Capture and Storage; http://www.ipcc-wg3.de/publications/special-reports/.files-images/SRCCS-Chapter5.pdf. The storage capacity values from the IPCC report represent the potential storage global capacity as assessed by the IPCC for existing oil fields using business as usual practices. The IPCC recognized that storage capacity in oil and gas reservoirs could be and order of magnitude higher if 2nd generation enhanced recovery practices were utilized and undiscovered assets were included in future assessments.

[5] "Improving Domestic Energy Security and Lowering CO_2 Emissions with "Next Generation" CO_2-Enhanced Oil Recovery(CO_2-EOR)," DOE/NETL-2011/1504, July 2011 http://www.netl.doe.gov/energyanalyses/refshelf/PubDetails.aspx?Action=View&PubId=391. Estimates and work performed by Advanced Resources International (ARI) for the report.

could help realize this synergy between the coal/power industry and the oil industry. Utilization of the CO_2 in EOR will impart knowledge that will be instrumental in the Department's continued R&D in other geologic storage formations such as saline that has a larger storage potential for CO_2.

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 DOE's advanced coal technology program. These efforts helped accelerate production of cost-effective compliance options to address legacy environmental issues associated with coal use. CCS and related clean coal technologies can play a critical role in mitigating CO_2 emissions under many potential future carbon stabilization scenarios. CO_2 utilization technologies with salable byproducts are logical "first market entry" candidates for greenhouse gas mitigation due to their ability to produce revenue from the use of CO_2. EOR will be the dominant utilization opportunity in the near term and will impart additional experience that will be useful in the Department's continued longer-term R&D in other promising storage formations. Nevertheless, challenges remain to achieving cost-effective commercial deployment of CCS. The Department's research programs are a vital step to advancing the readiness of these emerging clean coal technologies.

I applaud the efforts of this Committee and its Members for taking a leadership role in addressing these timely and significant issues.