THE NATIONAL COAL COUNCIL

Expedited CCS Development: Challenges & Opportunities

March 18, 2011

The National Coal Council is a Federal Advisory Committee to the U.S. Secretary of Energy. The sole purpose of The National Coal Council is to advise, inform, and make recommendations to the Secretary on any matter requested by the Secretary relating to coal or the coal industry.

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In the fall of 1984, The National Coal Council (NCC) was chartered and in April 1985, the NCC became fully operational. This action was based on the conviction that such an industry advisory council could make a vital contribution to America's energy security by providing information that could help shape policies relative to the use of coal in an environmentally sound manner and, in turn, lead to decreased dependence on other, less abundant, more costly, and less secure sources of energy. The NCC is chartered by the U.S. Secretary of Energy under the Federal Advisory Committee Act. The purpose of the NCC is solely to advise, inform, and make recommendations to the Secretary of Energy with respect to any matter relating to coal or the coal industry that he may request.

Members of the NCC are appointed by the Secretary of Energy and represent all segments of coal interests and geographical disbursement. The NCC is headed by a Chair and Vice-Chair who are elected by the NCC members. The NCC is supported entirely by voluntary contributions from its members. It receives no funds whatsoever from the Federal Government. By conducting studies at no cost, which might otherwise have to be done by the Department, it saves money for the government. The NCC does not engage in any of the usual trade association activities. It specifically does not engage in lobbying efforts. The NCC does not represent any one segment of the coal or coal-related industry nor the views or any one particular part of the country. It is instead a broad, objective advisory group with an approach that is national in scope.

Matters which the Secretary of Energy would like to have considered by the NCC are submitted as a request in the form of a letter outlining the nature and scope of the requested study. The first major studies undertaken by the NCC at the request of the Secretary of Energy were presented to the Secretary in the summer of 1986, barely one year after the start-up of the NCC.

The Secretary of Energy
Washington, DC 20585

June 1, 2010

Mr. Michael G. Mueller
Chair, National Coal Council
1730 M Street NW, Suite 907
Washington, DC 20036

Dear Mr. Mueller:

I am writing to request that the National Coal Council (Council) conduct a new study on the deployment of carbon capture and storage (CCS) technologies that build on the work you have done in the recent past by focusing on the management of emissions of carbon dioxide from both the existing and new fleet of coal-based electricity generating plants. This study will provide additional recommendations to assist the Department of Energy in managing a research, development and demonstration program that will allow the country to achieve President Obama's goal of an 83 percent reduction in CO_2 emissions by 2050.

The proposed scope of the report should tackle issues surrounding the widespread, cost-effective deployment of CCS in the post-2020 timeframe. Some of the issues to pursue include: (1) viable strategies for industry to deploy CCS technologies; (2) technical areas that merit Federal support to expedite deployment; (3) a feasible timeline for moving forward with low-carbon coal technologies; and (4) the impacts that legal and regulatory policies pose on the deployment of CCS technologies. Please offer a study completion date upon receipt of this letter.

In closing, I look forward to the Council's recommendations that directly relate to the broad deployment of economically competitive CCS technologies. As the United States is a leader in both technology development and coal reserves, I welcome this important and timely advice from the Council regarding the development of low-carbon technologies for our coal industry.

Sincerely,

Steven Chu

Executive Summary

Electricity is the lifeblood of modern society and the key to a higher quality of life around the world. In fact, the National Academy of Engineering has identified electrification as the "most significant engineering achievement of the 20th Century." Coal is the ongoing bulwark of electricity generation in the United States, providing the reliable and cost-effective power that has enabled America's dramatic socioeconomic advances since World War II. In coming decades, the continued use of coal is essential for providing an energy supply that supports sustainable economic growth in the context of climate policy goals, such as President Obama's goal for an 83 percent reduction in greenhouse gas (GHG) emissions by 2050.

Carbon capture and storage (CCS) technologies have been widely recognized as the link for realizing both the benefits of coal and the need for reducing GHG emissions. Ongoing research and development efforts are advancing the technology, but a range of issues must be addressed before CCS processes are commercially acceptable for coal-based electric generating units. It is with that context that Secretary of Energy Steven Chu requested the National Coal Council (NCC or Council) to conduct a study that "…should tackle issues surrounding the widespread, cost-effective deployment of CCS in the post-2020 timeframe."

This report examines issues related to the expedited development and deployment of CCS systems to coal-based generating units by evaluating challenges and opportunities pertaining to each aspect of the technology: capture, transportation, and geologic storage. Overall, the study determined that the current CCS demonstration program in the United States, although robust, has not progressed fast enough and is not on pace to significantly advance CCS development in the near-term due to technical and equally important non-technical obstacles. However, the study also determined that the United States, and in particular the Department of Energy (DOE), is in the best position to accelerate current efforts and overcome these development hurdles.

Challenges to CCS development and deployment can broadly be categorized into technical, financial, and regulatory areas. In terms of technical issues, key development concerns include the fact that commercial-scale CCS processes have *not yet* been demonstrated on a coal-fired generating unit. The current progress of the DOE CCS development program in bringing full-scale demonstration online is insufficient - large-scale, *operating* CCS demonstration projects representing a diversity of capture processes and geologic settings are needed in the near-term to expedite development. Another technical challenge is the need for a

greater set of reliable analytical tools for evaluating, designing, and monitoring geologic storage opportunities. As these and other technology challenges are addressed, the solution will not be as simple as one-size-fits-all, especially for retrofit projects to the existing coal fleet where unit-specific factors will require a suite of CCS process and design options.

Related to technology concerns are challenges driven by the cost of CCS projects. Federal incentives are critical for enabling first-mover CCS projects at coal-based generating units; however, such funding does not guarantee that a project will become a reality, as evidenced by the number of projects cancelled despite receiving significant funding awards. CCS projects will be inherently expensive for coal-based generation due to the size of the process, impacts to the generating unit, and associated risks, all of which are compounded by the technology being in an early stage of development. While cost considerations tend to focus on the capture process, pipeline transportation and geologic storage development costs will also be significant. Beneficial CO_2 use or conversion opportunities, such as enhanced oil recovery (EOR), can offset a portion of development costs. However, without a regulatory driver and greater certainty with respect to the management of long-term liability risks, obtaining funding or cost-recovery assurance will continue to be a significant development challenge.

Non-technical challenges related to regulatory and permitting requirements also pose a risk to expedited development, in particular with respect to the time it takes to obtain the necessary approvals and the potential cost to ratepayers. Although many of the relevant permitting programs are well established, the process of obtaining permits to *begin* construction, including obtaining required approvals from state utility commissions, can take years to complete. Consider development of even a modest CO_2 pipeline network, which would require a significant amount of baseline field evaluations to be performed to assess potential impacts to environmental (water, endangered species, wetlands, etc.) and cultural (architectural, archeological, etc.) resources. Much work is required before these evaluations can begin. For example, the scope of field evaluations is dependent on the selection of pipeline corridor options, which is dependent on the selection of potential injection well locations, which is dependent on data from an initial geologic characterization program. A significant financial and time investment is required for this entire process to be completed, which impacts the cost, schedule, and viability of a project. Other regulatory challenges relate to the scale of CCS projects, unique

environmental permitting issues, the need for public outreach programs, and uncertainties related to pore-space ownership and the management of long-term liability of the geologic storage site.

While these technical, financial, and regulatory challenges to expedited CCS development are significant, the United States has a broad foundation of tools to address them, including an extensive amount of experience in capturing, transporting, and geologically injecting CO_2 for industries not related to coal-based generation. This experience spans more than 40 years and includes a CO_2 pipeline network of over 3,600 miles, along with over 14,000 CO_2 injection wells that have been permitted primarily in support of EOR operations. To date, approximately 560 million tons of CO_2 have been used for this purpose. In addition, the DOE operates the most comprehensive and robust CCS research and development program in the world, which provides the base knowledge and ongoing data needed for targeting development where advancements are most needed. Historically, the United States, in large part through the efforts of DOE, has addressed the need for clean coal technologies with great success for other emissions - a success that can be built upon for developing the next generation of clean coal technologies using CCS.

If the policy of the United States is to balance the continued use of coal with the need to significantly reduce GHG emissions, then subsequent policies and leadership are in need of greater focus in order to take advantage of the full strength of baseline knowledge and resources that are available to accelerate CCS development. The DOE is in a unique position to provide leadership in addressing all of these development challenges. Certainly, the DOE's CCS research and development program will continue to be essential for addressing technology concerns. Equally as important is the depth and value of knowledge the DOE possesses on CCS development issues, which will continue to be very beneficial in informing the regulatory and policy development process with practical insight on the opportunities, challenges, risks, and realities of CCS technology for the coal-based generation fleet.

The report evaluates challenges to CCS development, along with opportunities for the DOE to address these challenges. The report is structured as follows:

- Chapter 1: The Context - Expedited CCS Development for Coal-Based Generation
- Chapter 2: Expediting the Deployment of Carbon Capture & Low Carbon Coal Technologies
- Chapter 3: Expediting the Deployment of CO_2 Transport, Storage & Reuse
- Chapter 4: CCS Deployment Timeline
- Chapter 5: Legal and Regulatory Policies

Overall, this report finds that the continued use of coal within the context of clean coal technologies such as higher efficiency in power plants and CCS processes provides the opportunity to significantly reduce GHG emissions. Policies and leadership should take advantage of the full strength of baseline knowledge and resources that are available to both increase average efficiency and accelerate CCS development. The DOE is in a unique position to provide leadership in addressing these technical, financial, and regulatory development challenges. Certainly, the DOE's CCS research and development program will continue to be essential for addressing technology concerns. Equally as important is the depth and value of knowledge the DOE possesses on CCS development issues, which will continue to be very beneficial in informing the regulatory and policy development process with practical insight on the opportunities, challenges, risks, and realities of CCS technology for the coal-based generation fleet. Key findings and recommendations from each chapter are summarized below.

Chapter 1: The Context - Expedited CCS Development for Coal-Based Generation

Key Findings

- Coal will continue to be the cornerstone of the energy portfolio of both the United States and the world because it is abundant, affordable, widely distributed, secure and versatile.

- Clean coal technologies, including CCS technologies, are the only way the world can achieve significant GHG emission reductions in the context of sustained economic growth.

- President Obama has set the goal of maintaining economic growth and achieving an 83% reduction in GHG emissions by 2050.

- Clean coal technologies have successfully addressed other emission challenges for coal-based generation, and through continued advancements will be able to address the development challenges for CCS and other low-carbon coal technologies.

- Ongoing and planned CCS projects for coal-based generation are advancing the development of the technology, but not at the pace necessary to support an expedited and broad-based deployment of CCS by 2050.

Recommendations

- While the Council fully supports the DOE's current research, development and demonstration programs for CCS technologies, it recommends that the DOE expand and expedite its leadership roll in developing these technologies.

- The Council recommends that the DOE aggressively expand and accelerate the near-term development (2015-2020) of integrated commercial scale CCS demonstration projects for coal-based generation.

Chapter 2: Expediting the Deployment of Carbon Capture & Low Carbon Coal Technologies

Key Findings

- Commercial-scale CCS technology has not yet been demonstrated on a coal-based electric generating unit in the United States.

- Federal government policy support is critical to advancing the development of CCS technology. Without continued government support, it is highly unlikely that a sufficient number of large-scale CCS demonstrations will occur in the near-term.

- Most large-scale CCS demonstration projects are currently in the design and engineering phase and many are awaiting review and approval through the National Environmental Policy Act (NEPA) process. In order to significantly advance development, many more operating CCS projects are needed.

- CO_2 capture from coal-based generation can be divided into three general categories: pre-combustion, post-combustion, and oxy-combustion. Development of all three is needed to achieve significant CO_2 emissions reductions across the coal generation fleet.

- Both technical and non-technical challenges must be addressed in order to expedite the development and deployment of CCS technology to coal-based generating units.

- Key technical considerations impacting the development of capture systems include those related to integration with the plant steam cycle, pre-treatment requirements of the combustion gas for other emissions, and opportunities for efficiency improvements. Retrofit considerations are generally more complicated because existing coal-based generating units were not designed with the thought of integrating CCS technology.

- Keys to evaluating the feasibility of a CCS retrofit project are whether the age of the unit and technology, efficiency, and equipment conditions warrant such a high-cost and long-life retrofit. De-rating of the existing unit (CCS auxiliary power requirements), space constraints, existing emission controls, proximity to geologic storage, and regulatory issues are also critical considerations.

- The cost to install CCS technology at an existing coal-based power plant will likely exceed the original installed cost of the entire plant. Coal-based generation with CCS, while expensive, may still be the most cost-effective option when compared to the cost of other generating technologies. CCS retrofit systems may very well be only cost-justified on the newest and most efficient generating units.

- There are many emerging CO_2 capture technologies that have provided promising results at the research phase of development. These projects are considered high risk and are not likely to progress without continued support from the Federal government.

- Some low-carbon coal technologies, such as partial capture and increased unit efficiencies, present practical and cost-effective opportunities for near-term CO_2 reductions from the existing coal-based generation fleet.

Recommendations

- In order for CCS technology to advance at the pace needed to achieve long-term emission reduction goals, the Council recommends that the DOE aggressively expand current policies and financial incentives, as well as develop new programs to support the development of a variety of capture technologies.

- The Council recommends that the DOE expand its leadership role in the development of GHG reduction policies by aggressively assessing and communicating the challenges and opportunities for CCS technology on retrofit and new coal-based generation projects to policy makers and the general public.

- The Council recommends that the DOE aggressively expand efforts to support the development of a suite of low-carbon coal technologies, including increased plant efficiency opportunities and partial CO_2 capture technologies. This includes a review of all overlapping and conflicting regulations set forth in Chapter 5.

Chapter 3: Expediting the Deployment of CO_2 Transport, Storage & Reuse

Key Findings

- For wide-spread deployment of CCS technology to occur on the United States coal-based generation fleet, which is widely dispersed across the country, an extensive pipeline network will be needed to handle the large volumes of CO_2 captured and to support facilities that lack local geologic storage capacity.

- Financing an extensive pipeline network will likely be a significant challenge as current estimates are approximately $1.5 million per mile. EOR applications can partially offset this cost. However, for CCS projects using non-EOR geologic storage, the cost for pipeline development will be a significant consideration.

- One option to complement an expansion of the CO_2 pipeline network in the United States is the hub concept that is being evaluated in Europe as part of the Rotterdam Climate Initiative (RCI). The hub concept may have a niche application to the United States, which may focus on surface pipelines, rather than the waterway systems under consideration for the RCI.

- A larger potential reservoir of EOR opportunities for CO_2 appears to exist. Currently, over 50 million tons of CO_2 per year are used for EOR. Based on estimates for the residual oil zone concept, the capacity could be several times this amount.

- To significantly move beyond EOR-related storage, it is imperative to understand the behavior of CO_2 stored in saline formations going forward since these geologic units represent the largest and best storage capacity in the near-term (to complement EOR) and for the long-term (as the primary storage reservoir).

- The DOE has implemented a systematic and logical approach to assessing geologic formations and to ensuring that adequate and diverse pore space is available for CO_2 storage. While this effort has been substantial, more information is needed for a broader portfolio of geologic settings.

- The design and evaluation of geologic storage systems is currently an empirical simulation and modeling effort that will not advance substantively until data can be collected from more operating integrated CCS projects.

- A project-specific initial geologic characterization is critical to design the geologic storage system, which determines the number of injection and monitoring wells required, the target depth for injection and the spacing between wells. Subsequently, the storage design influences the design of the pipeline network. All of these design variables, along with the need to perform the initial characterization, add complexity, cost, and time to the development process.

- Non-EOR beneficial CO_2 use/conversion technologies are currently insufficient to support the volume of CO_2 that could be captured from coal-based generation. Of these technologies,

synthetic transportation fuels production offers the potential to have a material impact on the volume of CO_2 captured from a broad-based CCS program.

Recommendations

- The Council recommends that the DOE support efforts by other agencies in the Executive Branch to address non-technical CO_2 pipeline development challenges related to financing, siting, permitting, and public outreach.

- The Council recommends that the DOE monitor the development of the European hub concept and evaluate opportunities to apply this concept in the United States.

- The Council recommends that the DOE continue and expand near-term efforts to evaluate geologic storage formations to address "information gaps" that exist by completing a diverse suite of studies to characterize storage classes and by conducting small- and large-scale field tests. Results will provide the knowledge base necessary to support future commercialization of carbon storage technologies and the proper application of monitoring, verification, and accounting (MVA) tools for various geologic storage classes.

- The Council recommends that the DOE aggressively expand programs to support the development of CCS-related MVA tools, as well as the gathering of data to allow the upgrade of both simulation and modeling programs. Both are essential to improving the design and management of geologic storage systems.

- The Council recommends that the DOE continue its current CO_2 geologic sequestration demonstration program by expanding and accelerating the number of projects in operation by 2015.

- The Council recommends that the DOE continue to evaluate the worldwide development of beneficial CO_2 use and conversion technologies, and to provide funding support for expediting the development of the most viable opportunities among these.

Chapter 4: CCS Deployment Timeline

Key Findings

- The findings and recommendations for CCS development presented in the 2009 NCC report remain applicable and have been reinforced by other studies, including the 2010 Interagency Task Force (Interagency) Report on CCS and the 2009 National Research Council report titled "America's Energy Future: Technology and Transformation."

- The three reports are unanimous in recognizing the need for large-scale integrated CCS demonstration projects as a prerequisite for commercial adoption of the technology. Both the NCC and National Research Council reports call for an initial 5-10 GW equivalent of CCS capacity to be operated for approximately five years. These projects would need to span a range of configurations to verify the performance and cost of CCS over the expected scope of commercial applications.

- Progress has been made in addressing the recommendations of the 2009 NCC report, but the pace is insufficient for the development needed to deploy CCS to coal-based generation at the rate necessary to meet President Obama's goal of an 83% reduction in GHG by 2050.

- The annual CCS capacity additions from 2020 to 2050 that would be required to meet the 2050 GHG emission reduction goal would rival the coal-based generation capacity additions of the 1970's and 1980's, which averaged approximately 11 GW per year.

- The current DOE CCS development program, although robust by world standards, has not moved fast enough and is not on pace to have the level of impact hoped for by 2020. At the current rate, CCS technologies will continue to be in an early development stage by 2020.

- The suite of ten large-scale integrated demonstration projects currently being funded by the DOE was analyzed in terms of scope, diversity, likelihood of proceeding to completion, and timing. That analysis concludes that the program has too few non-EOR projects and that, on the basis of the past experience with the DOE's large-scale demonstration programs, it is unlikely that more than two or three projects of the existing suite will initiate the injection of 1 million tonnes of CO_2 per year into geologic formations (excluding EOR) by 2020.

- If CCS technology is to be commercially available for coal-based generation by 2020, then the success rate of active projects must improve and the quantity and diversity of large-scale storage demonstration projects must be expedited and accelerated in the near time. The DOE is in the best position to lead this effort.

Recommendations

- The Council recommends that the DOE continue to evaluate and promote CO_2 storage opportunities for EOR applications, while expanding efforts to evaluate storage opportunities in saline and other geologic formations that are not associated with EOR processes.

- The Council recommends that the DOE expand and accelerate its current CCS development programs in order to implement the number of near-term demonstration projects (2015-2020)

required to facilitate the rate of CCS deployment necessary to meet the President's stated GHG emission reduction goals for 2030 and 2050.

Chapter 5: Legal and Regulatory Policies

Key Findings

- While it seems unlikely that federal GHG legislation will be enacted in the near future, the U.S. Environmental Protection Agency (EPA) has begun and intends to broaden the regulation of GHG emissions by expanding the applicability of existing Clean Air Act programs.

- The EPA's approach is multifaceted and, at a minimum, will expand consideration of CCS technologies in the development of applicable projects. For example, the EPA has expanded the applicability of the preconstruction Prevention of Significant Deterioration (PSD) and Title V permit programs to GHG. The EPA also issued draft, non-binding guidance regarding whether and how CCS should be evaluated as a Best Available Control Technology (BACT), which concludes that while CCS is a "promising technology," the EPA does not believe it will be a technically feasible BACT option in most cases. Additionally, the EPA recently announced its intent to propose New Source Performance Standards (NSPS) for GHG emissions from power plants in July, 2011.

- Some existing regulatory programs, which may currently apply to CCS projects, will add requirements and risk considerations that could affect the design, schedule, cost, and viability of CCS projects. For example, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Resource Conservation & Recovery Act (RCRA) create an unnecessary regulatory and/or liability regime for geologic injection and storage.

- A broad scope of permitting and regulatory programs apply to the development of each of the capture, transportation and geologic storage aspects of a CCS project. The process of performing baseline studies for preparing applications and working through the regulatory process to receive final approvals can range from months to years. This can result in significant cost, design, and schedule impacts, which will challenge efforts to expedite the development and deployment of CCS technology to the coal-based generation fleet.

- Since CCS is likely to play an increasingly important role in environmental regulatory decisions for the foreseeable future, regulatory and legal policy will need to be adapted to facilitate the timely and practical development and deployment of that technology.

- Led by many States and the EPA, an appropriate legal and regulatory framework for CCS is starting to take shape. The States' role in CCS regulation should not be underestimated given their historical success in safely regulating comparable injection and storage activities.

- Many States have adopted comprehensive regulations to address long-term geologic storage issues related to pore-space ownership and liability that should be sufficient to enable the permitting of early mover CCS projects.

- Given the number of pore space owners likely to be encountered when siting a CCS project, any requirement to expand the obligation to acquire pore space beyond constitutional requirements will create a significant development barrier.

- The management of long-term liability risks is a critical consideration for CCS projects. In terms of supporting the broad deployment of CCS across the coal-based generation fleet, uncertainty regarding long-term liability options remains a challenge.

- The DOE must continue to play a leading role in supporting policies that regulate CCS in a manner that protects human health and the environment, while enabling worthwhile projects to be financed, developed and operated without unnecessary legal impediments.

Recommendations

- To align and avoid an overlap of regulatory programs applicable to CCS projects and to accelerate CCS development, the Council recommends that the DOE support exempting appropriately permitted CO_2 injection and long-term storage from CERCLA and RCRA.

- The Council recommends that the DOE support policies that accelerate the permitting and regulatory approval process for deploying CCS technologies to existing and new coal-based generating plants, including policies to reduce barriers within the PSD and other programs that are inadequately designed to regulate CCS projects. This also includes streamlining the NEPA review process for CCS projects.

- The Council recommends that the DOE support policies encouraging the development of permitting programs for CCS facilities that would provide that the issuance of the permit for such a facility expressly grants the permittee the right to inject and sequester CO_2 into those portions of a geologic strata that do not contain coal, or oil and gas or other minerals in commercial quantity and do not have a current or reasonably foreseeable use.

- The Council recommends that the DOE support policies to clarify the requirements that apply to CO_2 injection and storage on Federal lands by, for example, stipulating pore space ownership and amending the Federal Land Policy and Management Act (FLPMA) and the Federal Mineral Leasing Act (FMLA) to explicitly allow long-term CO_2 storage under Federal leases.

- The Council recommends that the DOE support policies that would provide that during the construction and operational phases of a CCS project, the private sector should remain subject to both operational responsibilities and liabilities imposed by otherwise applicable law, except that such legislation should limit liability for trespass where the facility is subject to a valid permit applicable to that geologic sequestration.

- The Council recommends that the DOE support policies that would provide that during the post-closure phase of a CCS project, and after regulations have determined that the project meets applicable reporting requirements and poses no threat to human health or the environment, liability should be transferred away from the private sector. Various alternative methods for accomplishing this transfer have been offered at both the Federal and state level.