Harnessing Coal's Carbon Content to Advance the Economy, Environment, and Energy Security

National Coal Council

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Executive Summary

"The implementation of clean, state-of-the-art coal-based technologies will help insure America's energy security," ***The Blueprint for a Secure Energy Future,*** The White House, March 2012

The purpose of this report is to respond to a request to the National Coal Council from the Secretary of the United States Department of Energy (DOE) to conduct a new study focused on the capture of carbon dioxide (CO_2) emissions from the combustion of fossil fuels for power generation and from using coal to make alternative fuels, chemical and other products, or synthetic natural gas. The Secretary also requested that the study address the storage of CO_2 and its use for enhanced oil recovery (EOR) or the production of other products. Our study shows that advanced coal technology, coupled with capturing carbon emissions for use in EOR, could lead to annual revenues of $200 billion in industry sales and $60 billion in federal, state, and local taxes, and to the creation of over one million jobs. Further, we could reduce our imports of petroleum by over six million barrels per day, thereby increasing our energy independence, and reduce carbon emissions equivalent to almost 100 gigawatts of coal-based electric power.

Introduction

Vision

More than any other nation, America can control its own energy destiny. Coal is the foundation of that control. Almost 30% of the world's coal reserves are in the United States. Our nation stands at the threshold of a unique opportunity to deploy clean coal technologies to more fully use domestic coal resources in order to accomplish a full range of socioeconomic and environmental goals. Our leadership in deploying these technologies would benefit the global community as well. In a future world of 8.5 billion people in 2035, the EIA's projected 50% increase in energy consumption will require President Obama's "all of the above" energy resources – oil, gas, renewables, nuclear – but coal will continue to be the cornerstone, providing more incremental energy over the next 25 years than any other single fuel. As MIT Professor Ruben Juanes recently stated, "We should do many different things, but one thing that's not going away is coal."

The National Coal Council (NCC) has identified its vision for coal in earlier reports. First, coal's abundance and widespread distribution present powerful means to produce electricity reliably and affordably. Second, coal's versatility allows conversion to liquid transportation fuels, substitute natural gas, and chemicals. Third, improving coal's environmental performance through advanced coal technologies coupled with CO_2

capture and EOR will not only make it possible to meet climate policy goals but also open the door to the beneficial use CO_2. Finally, the dynamic activity associated with deploying advanced coal, carbon capture, and EOR technologies will stimulate the economy, provide jobs, revive established industries, and create new ones. But, without a facilitating regulatory regime in place to assure proper integration of these three elements, attaining these benefits will remain elusive as all nations struggle to meet the rising tide of energy demand amid higher prices, uncertainty, international tension, and the need to improve our global environment.

Coal-Based CO_2 and Petroleum Independence

Clean coal technologies work. The National Energy Technology Laboratory (NETL) concludes that "Technologies… have helped to dramatically reduce potentially harmful emissions, even as coal use for electricity generation has risen substantially." Now, the creative gaze of the scientific and engineering communities turns to carbon capture, utilization, and storage (CCUS). Private sector companies have already demonstrated that underground storage of CO_2 is more than a waste disposal business as shown by the success of EOR technology. The emergence of CO_2 as a commodity enables society to fully unlock the value of advanced, low emission coal technologies.

The use of CO_2 for EOR is the CCUS approach providing the greatest potential for economic and environmental pay offs over the next several decades. DOE-sponsored research found that "next-generation" CCUS and EOR technologies would enable the economic recovery of 67 billion barrels of "stranded oil" which could be produced assuming an $85 per barrel oil price. In addition, there is emerging recognition that the Residual Oil Zone (ROZ) resources are enormous, and could yield yet another 33 billion barrels for a total of at least **100 billion barrels** of oil that would otherwise remain unavailable.

But, the *sine qua non* of such recovery is the availability of adequate amounts of CO_2. New EOR projects are being delayed due to a lack of CO_2. Advanced Resources International (ARI) estimates that as much as 20 billion metric tons of CO_2 will be needed to produce this recoverable resource, and, if potential ROZ production is included, the required CO_2 exceeds 33 billion metric tons. However, only about 2 billion metric tons of CO_2 will be available from natural sources and natural gas processing. Coal-based CCUS technologies can help meet this 31 billion metric ton shortfall to enable our nation to produce our own petroleum resources and avoid reliance on imported oil that severely impacts our trade balance of payments and national security.

Aspirational Case for Increased Petroleum Production from Coal

Regardless of the scenario, large-scale development of CO_2 EOR will require massive amounts of CO_2, economically derived from large concentrated stationary sources, e.g., coal generation along the Ohio River, one of the regions hit hardest by the national decline in manufacturing. These large supplies of CO_2 are available at such coal-based

power plants and also at potential coal conversion facilities like coal-to-liquids (CTL) plants. Many of the 320 gigawatts (GW) of existing coal-based generation units can serve as the foundation for the vast amounts of CO_2 required, pending development of adequate pipelines and infrastructure. And, since coal generation will continue to be the leading source of electric power, it will provide a steady, affordable, and reliable source of CO_2.

In order to develop a point of reference, an Aspirational Case for enhanced petroleum production using CCUS EOR technologies is presented in this report that draws from sources such as previous work by the NCC as well as work by the National Academy of Sciences and ARI/NETL. In essence, such an Aspirational scenario through 2035 posits:

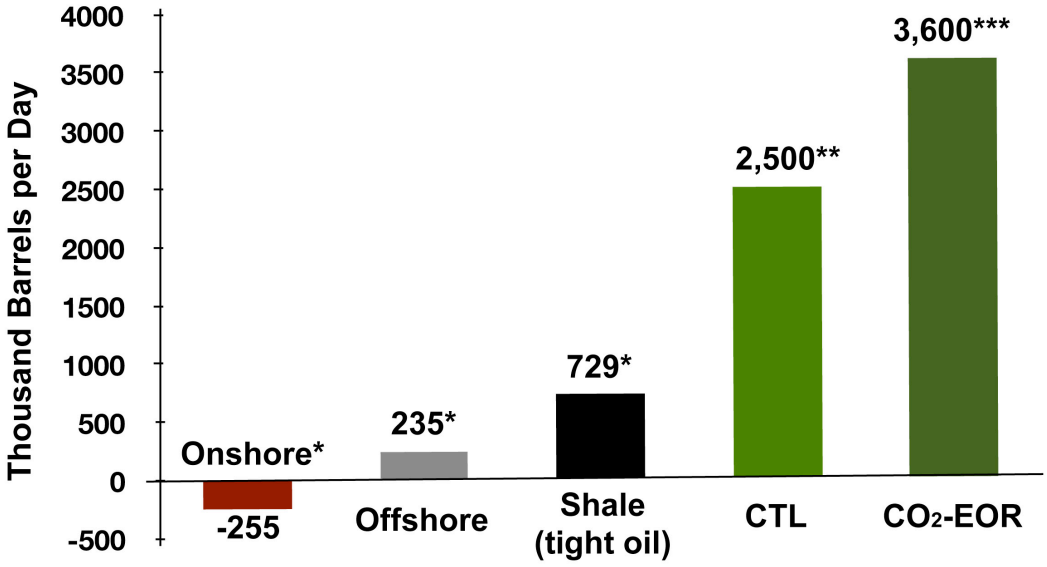
- Continued reliance on America's extensive fleet of coal power plants,
- Continued national consumption of petroleum for transportation fuels and chemicals of at least 15 million barrels per day (bbl/d),
- Development of 100 GW of coal-based generating capacity with capability to capture CO_2 over the next two decades, about half retrofits and half new builds,
- CTL facilities with carbon capture capability to produce 2.5 bbl/d of liquid transportation fuels, and,
- Utilization of over 500 million metric tons of coal-based CO_2/y to produce 4 million bbl/d of domestic petroleum through CO_2 EOR for over 40 years.

Kuuskraa (ARI) estimates using captured CO_2 for EOR petroleum production would offset the emissions of approximately 100 GW of coal based power plants that would consume at least 300 million tons of coal per year. Since CO_2 used in EOR operations is effectively retained in the oil reservoir, minimal CO_2 would be emitted from the 100 GW of coal- based units. Approximately 475 million tons of coal per year would be needed to produce 2.5 million bbl/d of synthetic fuels or chemicals through CTL technologies. Therefore, a total coal supply of almost 800 million tons per year – perhaps 600 million of which would be new demand – would be needed for the Aspirational Case. Our national coal consumption would rise to over 1,700 billion tons per year based on EIA projections.

Benefits from Coal-Based CO_2 Use

The reward from implementing the Aspirational Case would be great. Our nation would benefit from domestic production of more than an additional 6 million bbl/d of oil that would not need to be imported -- more than twice the production of Venezuela. Additional jobs would be created through the EOR deployments and the increased coal production. The figure below illustrates coal's potential role in meeting our needs for crude oil compared to others sources. There is little doubt that the potential production of oil from CO_2 EOR could far surpass other projected domestic sources of oil supply. Thus, by 2035, the powerful tandem of CO_2 EOR and CTL could provide almost 30% of our projected liquid fuel consumption and enhance America's energy security for decades.

Projected Incremental Crude Oil Production Relative to CO_2-EOR and CTL Potential by 2035



*EIA projection **National Coal Council estimate ***NETL/ARI estimate

Outlook for Production of Substitute Natural Gas from Coal

The Council has studied the production of substitute natural gas (SNG) from coal in earlier reports (2006, 2008, 2009) and found this technology to be viable under favorable market conditions. In the current gas markets in the United States, the interest in SNG has waned because of the belief that shale gas has permanently institutionalized the expectation of increased natural gas supply at low prices. But the unknowns relating to shale gas abound. Regarding supply, long term questions on environmental impacts, deliverability, cost and price stability remain unanswered. Paralleling these unknowns, factors increasing the demand for gas further cloud the future – LNG export facilities are being built, the chemical industry is rejuvenating, gas vehicles are entering the market and gas-based generation capacity is growing.

In short, the gas market of today is not the gas market of tomorrow and predictions of the future supply and price of gas have a high level of uncertainty. Longer term, the probability is that liquefied natural gas (LNG) at the global level will be tied to the price of oil, similar to the current situation in Asia where LNG prices have exceeded $17 per mmbtu during the first half of 2012. As the U.S. enters this global market, LNG prices will gain increasing significance in policy decisions relating to cost and energy security. To counteract these escalating costs of LNG, China is already converting hundreds of millions of tons of coal to SNG and related products. China also plans to use such new technologies as hydromethanation to continue to convert coal to SNG at scale.

The Council's previous studies have shown that over 4,000 billion cubic feet of pipeline quality SNG can be produced utilizing 325 million tons of coal. SNG with CCUS has significantly lower GHG emissions than LNG production. SNG facilities would create thousands of jobs in the mining and gas production sectors and enhance national security.

Findings

Advanced coal technologies coupled with carbon capture and EOR are key to achieving deep reductions in greenhouse gas (GHG) emissions for electric power generation and for producing transportation fuels and chemicals. These achievements can be realized at affordable cost. A wide range of other benefits, opportunities, and issues have been identified in our report and are summarized below:

- **Significant benefits result from implementing coal-based CCUS-EOR technologies:** Implementing the Aspirational Case will create new industries, revitalize a large number of U.S. industry sectors, manufacturing, and technology, and create numerous professional technical and skilled jobs. Over the next two decades, the Aspirational Case will annually generate nearly $200 billion in industry sales, over 1 million jobs, and $60 billion in federal and state and local government tax revenues. If "Advanced Coal/CCS/EOR" were a company, it would rank fifth on the Fortune 500.

- **CCUS can expand domestic oil production:** Recent pioneering EOR projects are dramatically expanding the view of commercial oil reservoir targets, including the Residual Oil Zone. With what we now know, a U. S. contribution to global carbon storage could be occurring at a much faster pace. This process would not only be a major stride toward achieving climate change goals, but also provide insurance against economic and energy security crises. CO_2 EOR can almost immediately assist with the two challenges of: 1) providing revenue for plants which capture carbon and 2) identifying candidate regions where CO_2 can be permanently stored.

- **Integrated deployment of CCUS-EOR can bring widespread economic development:** Essentially undeveloped, the source potential in the Midwest for petroleum recovery is equal to the Gulf Coast and Texas combined. It is important for those states involved to proactively help to remove barriers and align surface and subsurface resources. Multi-plant pipeline systems connecting multiple sources to multiple fields offer significant flexibility and provide a better overall strategy to linking sources and EOR sinks than close coupled systems.

- **CCUS-EOR deployment would reduce emissions of CO_2:** Because of the size of the U.S. coal-based generation fleet, retrofitting operating units for capture of CO_2 from the flue gas represents a major opportunity for reducing CO_2 emissions and for providing CO_2 for EOR. The findings indicate that CO_2 captured at many existing U.S. coal power plants could provide large volumes of CO_2 for pipeline transportation to EOR fields.

- **New electricity and CTL coal plants should be strategically sited:** Coproduction plants would be a viable route for providing synfuels in regions where new electricity supplies are needed and would provide a strong basis for economic revitalization of regions such as the Ohio River Valley, an area where many coal power plant retirements have been announced. New coal-fired power plants will be more efficient, and the CO_2 capture process would be integrated into the plant steam cycle. These new plants should be strategically located near existing or new CO_2 pipelines.

- **A national network of CO_2 pipelines is needed:** The Permian Basin is the region where CO_2 EOR could be expanded most quickly, but the Ohio River Valley region offers the greatest near-term potential for providing CO_2 for EOR – underscoring the national need for establishing long trunk East-West CO_2 pipelines complementing those already built or being planned (e.g., Rockport-Tinsley).

- **CTL synfuel plants offer benefits of co-production, inexpensive carbon capture, and high quality fuels:** Stand-alone synfuel plants and coproduction synfuel plants (e.g., plants producing fuels and electricity) offer the lowest capture cost of all the technologies considered, coal or natural gas. These technologies are commercially ready and economically attractive at current world oil prices. Coal/biomass coprocessing plants will significantly expand the use of domestic coal. Synfuel and coproduction plants that capture CO_2 for EOR markets and coprocess modest quantities of biomass with coal would provide liquid transportation fuels with near-zero levels of sulfur and other contaminants.

- **Coal-based CCUS power plants are more economical than natural gas power plants:** Per climate policy goals, carbon capture must be implemented at natural gas power plants as well. For a design capacity factor of 85%, the capture cost for Natural Gas Combined Cycle (NGCC) power plant with carbon capture is relatively high at $57/t. If, as a result of dispatch competition, a typical capacity factor of this plant plants turns out to be 40%, the capture cost would increase to $100/t. Overall, these plants: (a) are likely to fare poorly in economic dispatch competition and (b) would offer very low Internal Rate of Return on Equity (IRRE) values and (c) would have high levelized cost of electricity (LCOE) rates at all examined CO_2 selling prices.

- **CCUS-EOR should be recognized as a valid carbon emissions control technology:** Emissions of CO_2 from new and modified coal-fired power plants and other major stationary sources of GHGs are regulated under a variety of federal Clean Air Act permitting and emission control programs. Those facilities will only be able to sell their CO_2 for EOR if the U.S. Environmental Protection Agency (EPA) recognizes that activity as a form of emissions control under the federal Clean Air Act.

- **CCUS EOR should be treated as a Class II injection process:** Similarly, CO_2 EOR operators will only be willing to purchase CO_2 from facilities whose emissions are regulated under the federal Clean Air Act if they are not penalized. More specifically, CO_2 EOR operators need to be able to quantify the permanent storage of such CO_2 while continuing to operate their wells under Class II of the federal Safe Drinking Water Act's Underground Injection Control (UIC) program when they purchase coal-derived CO_2.

- **Substitute natural gas from coal is a viable option:** As demonstrated in a number of previous Council reports, the production of SNG from coal can be an important economically viable option for future gas supplies not only in the United States but also globally.

Recommendations to the Secretary of Energy

The National Coal Council offers the following recommendations to the Secretary of Energy as an outcome of the study:

- **Regulatory Certainty**: Regulatory certainty is necessary for the development of a robust CCUS/EOR industry. The Council recommends that the appropriate federal, state, and local regulatory agencies, with coordination and cooperation from industry, work with the Secretary of Energy to develop a stable and consistent regulatory framework to promote CCUS/EOR technology applications. When this regulatory environment is established, industry will work to develop the necessary implementation technologies for CCUS/EOR.

- **Demonstration Projects**: The U.S. Department of Energy has proven its leadership capabilities on regional CO_2 storage projects. Based on these past successes, the NCC recommends that the Energy Secretary meet and work with a wide range of stakeholders (including, but not limited to, coal, electricity generation, petroleum production, chemical manufacturers, and other stakeholders) to find new and innovative ways to develop financial support to create demonstration/early mover projects. Lessons learned from developing Nth-of-a-kind (NOAK) plants will reduce the CO_2 capture costs and promote growth in CCUS/EOR application. Accelerating the widespread deployment of CCUS/EOR technologies will allow the economic benefits to the nation presented in this report to be realized more rapidly.

- **Future Workforce**: Education and training programs are needed to develop the necessary work force with the appropriate skills for implementation of a robust CCUS/EOR industry. While it is incumbent upon industry and the appropriate educational entities to work together to develop and implement such programs, support and encouragement from the Energy Secretary on this educational need is recommended.

- **State Development and Regulatory Practices**: Regulations on the state level will be required to support the concurrent use of CO_2 for EOR and storage of CO_2. Such regulations must be based both on commercial viability and environmental protection. Rules adopted by the state of Texas can be used as a template for other states new to deploying EOR technologies. The Interstate Oil and Gas Compact Commission (IOGCC) has considerable experience in this forum. The Energy Secretary should work with the IOGCC group and similar resources to develop regulatory recommendations for concurrent EOR and CO_2 storage. Under his leadership, a national work group of states and industry representatives could be established to provide expert advice regarding regulations pertinent to the industries involved.

- **Long Distance CO_2 Pipelines**: In order to develop a long distance pipeline network for transport of captured CO_2, regional, large-scale coal-based capture projects must be developed. Industry and the Energy Secretary should collaborate to develop pipeline network scenarios that will incentivize the development of these long distance pipelines.

- **Promotion of EOR Deployment**: The DOE, through the Regional Carbon Sequestration Partnerships, along with private industry, environmental groups, and other appropriate stakeholders, should work together to promote CO_2 emissions capture technologies, CO_2 pipeline construction, and wide-scale deployment of EOR technologies. The DOE is uniquely situated to coordinate this effort that would expedite the implementation of CCUS/EOR in candidate areas of the country thereby speeding and enhancing economic development in these areas.

- **Coproduction Technologies for Liquids from Coal and Biomass**: The advantages of CCUS/EOR technologies will help increase the economic viability of CTL industries in the U. S. The technologies involved in CTL production are mature, thereby presenting reduced technology risks, but would benefit from opportunities that reduce the financial cost of such plants, thereby reducing the financial risk. The Energy Secretary should work with interested parties in the private sector, to develop pathways whereby commercial-scale coproduction plants would be built and demonstrated. Coproduction technologies could include the inclusion of biomass as part of the feedstock.

- **Continued Support for Developing Advanced Coal Technologies**: Industry will continue to conduct research on, and development of, advanced coal technologies as well as work to reduce the cost of capturing CO_2 emissions from coal-based electricity generating plants. The Secretary should assist in coordinating the private sector R&D effort, including recommending congressional support for federal cost sharing and conducting information exchange workshops and meetings with stakeholders, so that advanced coal technologies can be deployed more rapidly in commercial scale operations.

- **Deployment of EOR Technologies**: The Energy Secretary should take advantage of the numerous opportunities he has available to promote the deployment of CCUS/EOR in both domestic and international venues. With this support, and with that of private industry, CCUS/EOR technologies will be a commercial success.

Concluding Comments

Coal is the cornerstone of electricity production in the United States, but that is only the beginning of the story. Carbon Capture Utilization and Storage presents a powerful opportunity for the U.S. to take even greater advantage of the Nation's vast coal resources to affordably meet energy needs, reach climate policy goals, create new businesses, revive established operations, create jobs, and enhance national energy security. The recognition that CO_2 is a valuable commodity that can be utilized to create wealth for the American people is a sea change in the way we will view coal and other fossil fuels going forward. Adding the "U" to CCS is the crucial step toward the business model that will unlock the full value of coal for future generations.