Testimony of
Larry S. Monroe, Ph.D.
Senior Research Consultant and
Manager, Engineering Science and Technology
Southern Company
Birmingham, Alabama

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**Summary**

Southern Company is active in developing and demonstrating advanced coal technologies. As a charter member of the Southeast Regional Carbon Sequestration Partnership (SECARB), Southern has co-funded SECARB's activities, as well as serving as a host site for a Phase II sequestration project injecting 3,000 tons into a saline reservoir at one of our power plants in southeast Mississippi. With SECARB, we have a goal to scale up to a sequestration project of 100,000 to 150,000 tons $CO_2$ per year into similar geology at another of our Gulf Coast power plants. This project would feature a 25 MWe scale $CO_2$ capture plant built by Southern Company and research partners to supply the $CO_2$ for the sequestration project.

Southern Company has a further goal of developing a larger scale up of this sequestration project that would feature 1 million tonnes $CO_2$ per year for at least 5 years into the saline reservoirs of the Gulf Coast region. Building on the results of the smaller demonstration, this project would include a 170 MWe $CO_2$ capture plant to supply the $CO_2$ for the sequestration project. This proposed project was submitted by Southern Company in response to both the Restructured FutureGen solicitation as well as the CCPI Round 3 solicitation. Southern Company will likely resubmit this project to CCPI 3 when it is reopened later this year.

Southern Company's Mississippi Power affiliate has asked the Mississippi Public Service Commission for approval to build a 600 MWe (net) IGCC power plant using native lignite and designed for 50% $CO_2$ capture from startup. The captured $CO_2$ would be sequestered in EOR operations in Mississippi oil fields. This new power plant is partially funded with DOE funds from CCPI Round 2 and with investment tax credits authorized by the Energy Policy Act of 2005.

In partnership with the DOE, Southern Company operates a research station in Wilsonville, Alabama, that has focused on advanced power generating technologies, including fundamental R&D for coal gasification, and is now moving its focus towards

fundamental R&D and scale up for technologies to capture $CO_2$ from both conventional combustion coal plants and IGCC plants.

The barriers to widespread commercial deployment for CCS are mostly cost and timing. Both the pilot and industrial scale trials of $CO_2$ capture systems are much more expensive to build and operate than the technologies that have been tested and developed for control of other emissions like NOx, $SO_2$, or mercury. The same high cost penalties apply to current $CO_2$ capture and sequestration approaches for full scale power plants. Therefore, both a robust program of technology development and a program of fundamental R&D are needed. Many of the nation's scientists are only just now turning their attention to this field and breakthroughs are possible. New science, teamed with scale up and demonstration programs will help bring forward affordable and effective CCS technologies.

A parallel barrier to widespread deployment of CCS is the need to demonstrate to various stakeholders the effectiveness and safety of geological sequestration. To get to that point, it is necessary for the nation to have multiple concurrent large scale sequestration demonstrations of over 1 million tonnes $CO_2$ per year for at least 5 years in duration. In order to have these results in adequate time, these demonstrations need to be started as soon as possible.

Working in partnership with the U.S. DOE, vendors, and other utilities, Southern Company looks forward to the challenge of developing, demonstrating, and improving technologies to capture $CO_2$ from coal-based power plants and towards demonstrating the effectiveness of geological sequestration of $CO_2$.

## Introduction

Chairman Baird, Ranking Member Inglis, and members of the Subcommittee, thank you for the opportunity to speak with you today about Southern Company's activities and plans for developing and demonstrating advanced coal technologies.

Southern Company is a super regional energy company serving customers in Alabama, Florida, Georgia, and Mississippi. Southern Company is the one of the largest generators of electricity in the United States with 42,000 megawatts of generating capacity and over 21,000 megawatts of it is coal-fired. I hold a Ph.D. in Chemical Engineering from MIT, and have been involved in research on pollution control for coal-based power plants for over 25 years in university, not-for-profit research institute, and corporate settings. At Southern Company, I have two roles: I support our technology research organization as a senior research consultant and I also support our gasification and carbon capture research station as the manager of Engineering Science and Technology. With these efforts, I am deeply involved with the development and demonstration of advanced ways of using coal to generate electricity.

Southern Company has a long history of cooperative work with the U.S. Department of Energy in development of technologies for the utility industry, including work on low NOx burners and selective catalytic reduction (SCR) systems for NOx emissions reductions, flue gas desulfurization (FGD) systems for sulfur oxides reductions, mercury control technologies to reduce mercury emissions, and various others.

As we face a future with possible legislation and/or regulations that would limit emissions of greenhouse gases, including carbon dioxide ($CO_2$), we believe that coal must continue to play a role in the energy future of the country. It currently represents 50% of the electricity generated in the nation today and it's ample and relatively low cost domestic supply means it must continue to power our homes, businesses, and industries in the future. We believe however that coal can and must play a role in a future with constraints on carbon emissions. Technologies are currently being developed and adapted from other industries to capture and store emissions of $CO_2$ from coal power plants to achieve this goal. However, the technologies are not yet ready for the utility sector to use in a commercial way – they are not yet proven in utility service and as of today, they are too costly in both capital and operating expenses. This is the issue going forward, how can these technologies (or new ones not yet invented) be proven and the costs reduced to make them commercially viable in the future for which they will be needed?

## 1.0 Development of Technology for the Utility Industry for Carbon Capture and Storage (CCS)

The lack of large scale storage of electricity means that technologies for generating electricity must be proven and robust in order to maintain the reliability and stability of the electric grid. Generation must meet demand and the industry cannot test new technologies at full scale without assurance that it will not threaten operations and reliability. For this reason, the utility industry has learned that new technologies and processes must be developed and proven in a series of tests that start at small sizes and move to progressively larger sizes before they can be relied upon at a full scale generating plant. It is typical for new utility technologies to take 4 or 5 demonstration steps and between 7 to 15 years of development time to prove that they are adequate, robust, affordable, and reliable.

The development path of technologies to capture and store carbon dioxide ($CO_2$) emissions from coal-based power plants will follow a similar path. Given that regulatory or legislative efforts to limit $CO_2$ emissions from power plants are active, there is a pressing need to develop technologies that can be used in coal-based electricity generation and simultaneously achieve the environmental, economic, and operational requirements. Carbon capture and sequestration (CCS) for coal-based power plants is really a series of four steps: (1) capturing the $CO_2$ from the power plant, (2) compressing the $CO_2$ to the pressure required for pipeline transport, (3) transporting the $CO_2$ through a pipeline to the sequestration field, and (4) injecting the $CO_2$ deep underground into stable geological structures (sequestration).

$CO_2$ capture is a technology and cost challenge; processes in the chemical and petroleum industries have been developed to capture $CO_2$ from similar streams, although not with some of the particular difficulties nor the scale facing large central station power plants. Additionally, the costs of these capture processes at the scale of utility power plants is very high. Current capture technologies can add 30 to 85% to the cost of electricity from the plant. The main issue is the amount of heat required to operate the capture plant which can mean a loss of 20 to 25% of the electrical output from a plant where this technology is added. Integrated Gasification Combined Cycle (IGCC) plants, where coal is gasified and burned in a combustion turbine – steam turbine combination, offer some promise that the $CO_2$ can be captured from the synthetic gas (syngas) before combustion. This presents advantages because the $CO_2$ is at higher concentrations in the syngas and it is already at pressure and therefore may require less of the compression energy described next. However, the vast majority of existing plants are conventional coal combustion units, with only 2 operational IGCC plants in the entire U. S.

Compression of the $CO_2$ can be accomplished with available technologies, although the compression costs can amount to 10% of the power plant electrical output. (For the steam requirements for capture and the energy for compression of the $CO_2$, this could total some 30-35% of the energy output of the plant to operate with 90% $CO_2$ capture.) For new conventional coal plants with CCS, it is possible to integrate the compression into the steam cycle of the plant and some efficiency improvements can be made.

Pipeline transport of $CO_2$ to sequestration sites is a conventional technology available today – the U. S. has over 3,600 miles of $CO_2$ pipelines to move the gas from natural and industrial sources to oil fields for enhanced oil recovery (EOR). $CO_2$ is used to pressurize oil fields and the $CO_2$ dissolves into the crude oil making it easier to flow out of the underground reservoir. Pipeline issues for large scale CCS are mainly associated with the expected difficulty in siting and acquiring property for pipeline routes. It has been estimated that a pipeline network equal to one-third of the size of the existing natural gas pipeline network would be needed to capture $CO_2$ from the existing coal fired fleet in the U.S. (MIT's "The Future of Coal" states that if all of the coal power plant carbon emissions are captured and transported by pipeline, the $CO_2$ moved would be equal to three times the weight of the annual natural gas delivered by the U. S. pipeline system, but only one-third of its volume.)

The most challenging aspect of developing CCS for the utility industry is sequestration. The technology for injecting $CO_2$ underground for EOR is well-developed and the history of EOR operations indicates that sequestration can be accomplished in a safe and secure manner. However, the scale and potential widespread location of sequestration sites for utility capture of $CO_2$ will require that sequestration tests be made at sufficient scale for multi-year periods to demonstrate to stakeholders including the general public, regulators, utilities, insurance companies, and financial entities, that it is safe and effective. MIT, in their "The Future of Coal" report, states that "we believe high priority should be given to a program that will demonstrate $CO_2$ sequestration at a scale of 1 million tonnes $CO_2$ per year in several geologies." They further recommend "a minimum of three projects … of the order of 1 million tons $CO_2$/year for a minimum of 5 years." Unfortunately, it is not

possible to accelerate the timescales for sequestration tests, so it is necessary to start these projects as soon as possible. Because we need to study the movement of $CO_2$ in the underground structure, there are no good technical ways to make it move faster without disrupting the test. In other words, the spread of the $CO_2$ will be predicted with models at the beginning of injection, and the goal of these sequestration tests is to see if the spread of injected $CO_2$ matches the model predictions in both distance and time to get there.

## 2.0 Accelerated Technology Development for Utility CCS

As described above, the normal technology path for new technology development in the utility industry is to proceed from an invention or development in the laboratory, to a small pilot-scale test, to a larger pilot-scale test for a longer time period, to industrial scale (normally 5 to 10% of large full-scale utility plants), and finally to the first operational utility plant. Each of these steps would normally take on the order of one to three years, with the whole process, assuming success at every step, taking a total time of anywhere from 7 to 15 years. It is also typical that several different technology approaches proceed through these steps simultaneously as competitive solutions to a given problem. For Southern Company, the time from our initial pilot-scale work on SCR in a DOE Clean Coal project to our first commercial unit was over 6 years, and it took 11 years before our first large scale power plant SCR retrofit was operational. A similar timeline for Southern Company's FGD installations, and is holding true for mercury control technology. Our first test of an activated carbon injection into a baghouse for mercury control occurred around 1998 at a pilot scale unit of 1 MW, followed by a DOE sponsored test at 135 MW starting in 2001, and finally to our first full scale project (880 MW) which started at the end of 2008, a period of 10 years.

We believe that the timeline for the development and demonstration of technologies for the capture of $CO_2$ and the demonstration of sequestration must be compressed to the maximum extent practicable. A combination of parallel development steps (as compared to the normal sequential steps described above) for $CO_2$ capture will have to be undertaken to accelerate the technology development. Larger demonstrations will need to be initiated before the smaller scale tests have been completed.

It is also necessary to start large scale sequestration injection tests as soon as possible to be able to demonstrate the ability of this approach to sequester large amounts of $CO_2$ in a safe, effective, and cost effective manner. Ironically, a current complication of attempting to perform large sequestration projects is the relative scarcity of $CO_2$ for these tests. There are currently no large scale capture plants in the utility industry to supply the needed $CO_2$, and most natural and industrial sources are already in use for the food industry and EOR. Therefore, it becomes necessary to build $CO_2$ capture plants in order to obtain the gas to start these sequestration tests.

## 3.0 Southern Company's Activities on CCS Technology

Southern Company is active in all of these areas of technology development for CCS advancement. We are a charter member of the Department of Energy's regional

partnership for our service territory, the Southeast Regional Carbon Sequestration Partnership (SECARB). The SECARB partnership covers an eleven-state region including the states of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia. Southern Company has been a funding member of SECARB, and has participated as a host site for a Phase II injection project, and a potential host site for a Phase III injection project. (The seven Regional Partnerships for carbon sequestration were established with funding by DOE to help develop and demonstrate the technology, equipment, and regulations to implement large-scale $CO_2$ sequestration in various regions and geologies across the U. S.)

Through SECARB, Southern Company's Plant Daniel in southern Mississippi served as the site for injection of 3,000 tons of $CO_2$ into a saline formation at a depth of about 8,500 feet below ground level. The purpose of this project was simply to test the deep saline reservoirs located near the large coal power plants along the Gulf Coast for geological sequestration of $CO_2$. This very successful test has led to SECARB being awarded DOE funding for a larger Phase III project to inject 100,000 to 150,000 tonnes $CO_2$ per year into similar geological formations at a Southern Company plant located elsewhere on the Gulf Coast. As mentioned above, a real difficulty in performing these sequestration tests is the availability (and cost) of $CO_2$ for the injection. For the smaller injection of 3,000 tons, the $CO_2$ was contributed by Denbury Resources who use naturally occurring $CO_2$ for EOR activities. However, for the larger SECARB Phase III injection program, that amount of $CO_2$ is not available.

To advance this larger scale sequestration project and to obtain the needed $CO_2$, Southern Company has established a goal to design, construct, and operate an industrial scale $CO_2$ capture process at the generating plant site integrated with a sequestration test. (Southern Company has not determined the actual plant site for such a test, but it would be on the Gulf Coast). Through partnerships with EPRI and other utilities, Southern Company's goal is to work towards retrofitting this capture plant for partial capture with one of the leading technologies for $CO_2$ capture from conventional coal plants. The costs of this capture plant would be borne by these private entities. As indicated above, the estimated costs of $CO_2$ capture for projected full-scale installations are high in capital and operating costs, and therefore, it is not surprising that pilot and industrial scale test plants are expensive as well. The total project costs for the 25 MWe capture plant to supply the $CO_2$ for the Phase III sequestration project of 100,000 to 150,000 tonnes $CO_2$ per year are estimated to be $140M. In the current economic downturn, it has become a difficult challenge to raise the capital for such a large scale demonstration project, and its prospects are currently being evaluated. We are hopeful that these types of large scale advancement projects can proceed, but economic challenges stand to threaten our ability to pay for such capture demonstrations – which would of course limit our ability to test larger scale sequestration such as the SECARB Phase III project.

If this 25 MW demonstration plant can be constructed, then we have a further goal to expand upon this capture and sequestration demonstration with a larger version, designed to reach the MIT goal of 1 million tonnes $CO_2$ per year for at least 5 years. This proposal would involve building a $CO_2$ capture plant of about 170 MWe size to capture the needed

one million tonnes per year. Southern Company has applied for federal assistance on this combined project in response to both the Restructured FutureGen solicitation and the Clean Coal Power Initiative Round 3 (CCPI 3). DOE has recently announced the intent to reopen CCPI 3 with additional funding and Southern Company will likely resubmit an updated proposal in response. The total estimated cost of this 170 MW program would be $750M.

Southern Company has also been actively involved in the development of Integrated Gasification Combined Cycle (IGCC) technology. Southern's subsidiary, Mississippi Power is developing a full-scale IGCC power plant of about 600MWe (net) on native lignite in east central Mississippi, located in Kemper County. Mississippi Power has submitted an application to the Mississippi Public Service Commission for approval and is in the environmental permitting process. This project has received funding from DOE as an award from CCPI Round 2, as well as having qualified for investment tax credits from Section 48A of the Energy Policy Act of 2005. This new IGCC will also feature 50% $CO_2$ capture from the startup of the plant, with the captured $CO_2$ being supplied to the oil fields of Mississippi for EOR. (In addition to EOR recovering more oil from the field, EOR is also a sequestration technology as the $CO_2$ replaces the oil in the pores of the sandstone, with about half of the $CO_2$ flood of the oil field remaining underground and therefore being sequestered. The $CO_2$ remainder is captured and sent underground again for further EOR operations.) The Kemper County project has a projected capital cost estimate of approximately $2.2 billion. The project is expected to utilize DOE CCPI 2 funding of about $270M and investment tax credits up to $133M. Pending approval by the Mississippi Public Service Commission, it is scheduled to come online in late 2013.

Finally, Southern Company has been working in partnership with the U.S. DOE at the Power Systems Development Facility in Wilsonville, Alabama. Originally dedicated to improving technology to advance the efficiency of particulate removal from high pressure, high temperature gases, the facility has been instrumental in developing and proving the IGCC technology that will be used at Kemper County, one that is well-suited to low rank coals which are economically important to the U.S. economy. Continuing this partnership with DOE, the facility will be exploring fundamental technologies that will improve or completely replace the current technologies for capturing $CO_2$ from both conventional combustion coal power plants as well as IGCC plants. The particular role for the PSDF in carbon capture will be to assist in transitioning promising technologies from their research laboratory size to the power plant size and environment. Southern Company believes strongly that a robust fundamental research and development program and the associated means to scale up promising technologies is vital to success in commercial CCS development and commercial deployment – and the ability to use the U.S. coal reserves as an energy source for the future.

## 4.0 Challenges Going Forward for CCS

The challenges for CCS going forward are basically cost and timeframes. The costs of pilot and larger scale research programs for $CO_2$ capture are much higher than the similar research programs for control of other emissions such as nitrogen oxides (NOx), sulfur

oxides ($SO_2$ and $SO_3$), and mercury – in fact they appear to be over 10 times the capital and operating costs of these previous efforts. Given current economic conditions, the utility industry has limited ability to self-fund these projects and advance these technologies to get them ready for commercial use.

Commercial $CO_2$ capture systems using today's technology are very costly, so much so that the future of coal as a base energy source in the utility sector is threatened. The capital costs of a new conventional coal plant with CCS may be as much as 50% to 100% higher than the same coal power plant without CCS. Operating costs for the energy required for the capture process and $CO_2$ compression make the plant much less efficient than today's coal plants. For a $CO_2$ capture plant added to an existing coal power plant, somewhere between 30 and 35% of the plant's electrical output would be lost to operate a 90% $CO_2$ capture system. In other words, a large 900 MWe power plant when equipped with a CCS system would become a 650 MWe plant. Other generation – from coal, natural gas, or some other source – would have to be built to make up for this lost generation.

The timeframe issue is mostly centered on sequestration and the need to perform large scale sequestration projects for multiple years to demonstrate the methods, measurements, stability, and safety of this approach. In order to gain acceptance from multiple stakeholders that geological sequestration is commercially viable, it is essential that these large scale sequestration projects be started as soon as possible. Assuming MIT's recommendation of a minimum of 5 years of testing, a start today would mean it would be mid-2013 at the earliest before long term decisions on sequestration could be made.

## 5.0 Next Steps for CCS Technology Development

The steps needed to advance CCS technology and improve its cost and performance are straightforward: (1) a continuation of the historically successful public-private partnerships between the U.S. Department of Energy and the utility industry in demonstrating and improving CCS; (2) a strong focus on performing large scale capture and sequestration projects as soon as possible; and (3) continued focus and funding for fundamental research and development based on cutting-edge science to develop new technologies and improve the costs and performances of existing CCS technologies.

Southern Company looks forward to working with the Department of Energy, vendors, and the domestic and international utility industry to improve and advance CCS.