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**BEFORE THE**

**SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,**

**SCIENCE, TECHNOLOGY, AND INNOVATION SUBCOMMITTEE**

**HEARING ON "COAL GASIFICATION TECHNOLOGIES AND THE**

**NEED FOR LARGE-SCALE PROJECTS"**

**APRIL 9, 2008**

Thank you Mr. Chairman and Members of the Committee. I appreciate this opportunity to provide testimony on the Department of Energy's (DOE's) Coal Gasification Research and Development (R&D) Program.

The economic prosperity of the United States over the past century has largely been built upon an abundance of fossil fuels in North America. The United States' fossil fuel resources represent a tremendous national asset. Making full use of this domestic asset in a responsible manner enables the country to fulfill its energy requirements, minimize detrimental environmental impacts, positively contribute to national security, and provide for the economic welfare of its citizens.

Coal gasification, when done in conjunction with carbon capture and storage (CCS), is one technology option that offers our Nation an attractive approach to utilize our indigenous fossil energy resources in a more efficient and environmentally sound manner for producing

clean, affordable power from coal with dramatically reduced carbon emissions. Coal gasification with CCS can also reduce the carbon impact of using coal to produce ultra-clean fuels for the transportation sector, substitute natural gas (SNG) to heat our homes and fuel our industrial sector, fertilizers to ensure an abundant food supply, and chemicals that play an integral part in our every day lives.

Another coal gasification concept that could further reduce carbon dioxide ($CO_2$) emissions is co-feeding coal and biomass into gasifiers to produce electricity or conventional transportation fuels. The transportation fuels application is referred to as the coal-biomass-to-liquids (CBTL) process. When combined with CCS, CBTL can reduce the greenhouse gas footprint of the fuel by 20% (compared to petroleum) with the addition of roughly 10-18% by weight biomass to the coal while remaining cost competitive at today's world oil prices Similar benefits in reduction of carbon emissions can be achieved by co-feeding coal and biomass for electricity generation in advanced gasification-based systems.

Gasification-based processes are an efficient and environmentally friendly way to produce low-cost electricity, compared with other conventional coal-conversion processes. For power generation applications, gasification technology utilizes 30-50% less water and produces about one-half the amount of solid wastes as conventional power plants. By the very nature of the process, sulfur oxides, nitrogen oxides, mercury, particulates, and other emissions can be reduced to near-zero levels and gasification is often the least expensive approach for the capture of $CO_2$.

The gasification of coal dates back as far as the end of the eighteenth century, and by the middle of the nineteenth century the basic underlying principles of gasification were fairly well understood. The use of gasification was very prominent in the latter part of the nineteenth

century and the first half of the twentieth century for the production of town gas for residential and industrial use. Although this application has nearly vanished, due to its displacement by inexpensive natural gas and petroleum, new applications evolved in the industrial and manufacturing sectors.

Gasification is at the heart of many processes that offer industry low-cost, reliable, and highly-efficient options for meeting a host of market applications. Gasification-based systems are capable of utilizing all carbon-based feedstocks, either separately or in combination with one another, including coal, petroleum coke, biomass, municipal and hazardous wastes. In the gasification process, carbon-based feedstocks are converted in the gasifier in the presence of steam and oxygen at high temperatures and moderate pressure to synthesis gas, a mixture of carbon monoxide and hydrogen. The synthesis gas is cleaned of particulates, sulfur, ammonia, chlorides, mercury, and other trace contaminants to predetermined levels consistent with further downstream processing applications. At this point, various options exist for the utilization of the synthesis gas. In one option, Integrated Gasification Combined Cycle (IGCC) for the production of electricity, the cleaned synthesis gas is combusted in a high-efficiency gas turbine/generator, and the heat from the turbine exhaust gas is extracted to produce steam to drive a steam turbine/generator. Furthermore, IGCC can be readily adapted for concentrating, capturing, and sequestering $CO_2$.

In addition to being used for power generation, a portion or all of the synthesis gas can be chemically shifted (by reaction with steam) to a mixture of hydrogen ($H_2$) and $CO_2$. Here the $H_2$ and $CO_2$ can be separated, with the hydrogen being used in the gas turbine or highly efficient fuel cells for the production of electricity in a carbon-constrained world, while the $CO_2$ can be captured and sequestered. The shifted synthesis gas can also be processed in chemical reactors

to produce high-quality transportation fuels, SNG, and chemicals. Gasification-based systems are the only advanced processes within the Department's research portfolio that are capable of co-producing both power as well as a wide variety of commodity and premium products to meet future market requirements.

Today, there are nineteen gasification plants operating in the United States. Nine of these plants use natural gas to produce carbon monoxide and hydrogen for synthesis of chemicals and petroleum refining, four use petroleum-based liquids for chemicals production, and six operate using solid feedstocks, i.e., coal and/or petroleum coke. Of the six solid-feed gasification plants, two produce chemicals, three operate as IGCC power plants, and one produces SNG. The following are examples of gasification plants in operation in the United States today.

The largest operating coal gasification plant in the United States is the Dakota Gasification Company's Great Plains Synfuels Plant in Beulah, North Dakota. This plant was constructed with a loan guarantee from the Department of Energy and began operation in 1984. The plant has a capacity for producing up to 170 million cubic feet per day of SNG from nearly 18,500 tons per day of North Dakota lignite from an adjacent mine. The SNG is injected into an existing natural gas distribution pipeline to the Midwest. It should be noted that while the plant was a technical success, it was not a financial success: in 1985 the project sponsors defaulted on the loan, due in part to falling natural gas prices at the time, and the US Treasury paid $1.550 billion to cover the guarantee.

Eastman Chemical Company operates two coal gasifiers at its Kingsport, Tennessee, chemical complex. Approximately 1,200 tons per day of eastern bituminous coal is converted to synthesis gas that is used as the building blocks for nearly 75% of the chemical products produced at the plant. Many of the products from this plant find their way into every day

household products such as scotch tape, screw driver handles, Kodak 35-mm film, and flat screen TV panels. In addition, products such as Tylenol® and NutraSweet® also have their origins in coal from this facility.

The Coffeyville Resources Nitrogen Fertilizer plant located in Coffeyville, Kansas, is the only other solid-feed gasification plant focusing on chemicals production, namely ammonia and urea fertilizer. This plant began operation in 2000 and today is the lowest cost manufacturer of nitrogen-based fertilizer products in North America.

Three IGCC power plants using solid feedstocks are in operation today in the United States – Tampa Electric's Polk Power Station in Tampa, Florida (250 MWe); SG Solutions Wabash River plant in West Terre Haute, Indiana (262 MWe); and Valero's Delaware Clean Energy Cogeneration project in Delaware City, Delaware (160 MWe). The Florida and Indiana projects both received federal cost-share through DOE's Clean Coal Technology Program. These two projects successfully demonstrated coal-fueled IGCC and have been instrumental in giving the utility industry confidence in IGCC technology and in generating commercial interest in IGCC deployment.

The Department's Office of Fossil Energy (FE), which manages research efforts within the Gasification Program that are implemented by the National Energy Technology Laboratory, recognizes the complex energy and environmental challenges facing America today. To address these needs, FE has a core coal R&D program that provides for the development of affordable and environmentally effective technologies to use coal. This core coal R&D program includes not only the Coal Gasification Program but also the Advanced Research (advanced materials, sensors and controls, and computational modeling), Advanced Turbines, Carbon Sequestration, Fuel Cells, Hydrogen and Fuels, and Innovations for Existing Plants Programs.

DOE is developing advanced gasification technologies to meet the most stringent environmental regulations in any state, and to facilitate the efficient capture of $CO_2$ for subsequent sequestration – a pathway to "near-zero atmospheric emission" coal-based energy. Gasification plants are complex systems that rely on a large number of interconnected processes and technologies. Advancements in the state-of-the-art, as well as development of novel approaches, could expand technical pathways and enable gasification to meet the demands of future markets while contributing to energy security.

***Technical Issues/Hurdles –*** A technical report prepared by the Gasification Program in July 2002, "Gasification Markets and Technologies – Present and Future: An Industry Perspective," specifically outlines key technology issues affecting the commercial acceptance and deployment of gasification-based processes. Our coal research efforts in gasification are aimed at addressing these key issues, and good progress continues to be made towards their resolution. Foremost at that time was the need to improve process reliability and reduce capital cost. More recently, our research has expanded to address the cost and integration of gasification, particularly IGCC, with CCS.

Areas identified as significantly impacting process reliability included refractory wear, feed-injector life, and high-temperature measurement instrumentation. Areas targeted for capital cost reduction efforts included improved feeding systems capable of handling multiple feedstocks, lower cost air-separation technologies, and high-temperature gas cleaning capable of deep removal of all contaminants. Some of the significant research programs addressing these issues are described below.

***Ion Transport Membranes –*** Conventional cryogenic air-separation technologies used in today's gasification plants are both capital and energy intensive. Typically, the cryogenic air

separation constitutes 12-15% of the cost of an IGCC plant and can consume upwards of 10% of its gross power output. A promising technology being developed today that offers significant potential for cost and parasitic power reductions are known as Ion Transport Membranes (ITM). This technology has been under development by the Department, in partnership with Air Products and Chemicals, Inc. (APCI), for nearly ten years. During this time, ITM technology has progressed from fundamental materials development to the operation of full-scale membranes and half-size modules in a 5 ton-per-day unit operating at APCI's Sparrows Point industrial gas facility near Baltimore, Maryland. Engineering analyses have consistently shown nearly a 35% reduction in the capital cost of the air-separation unit for an IGCC plant and nearly a one-point gain in thermal efficiency. To achieve maximum benefit, the ITM must be integrated with a gas turbine. The program is in its third phase of development that will culminate in the integrated testing of a 150 ton-per-day process module with a gas turbine that will be located at an existing coal gasification site in 2010. Upon successful completion of this phase, plans are being discussed for further scale-up to a 1,500 to 2,000 ton-per-day prototype unit.

***High-Temperature Gas Cleanup –*** Removing sulfur and other impurities from coal-derived gas in an IGCC plant generally accounts for 10-12% of the capital investment of the plant to meet recent emissions standards. It is recognized that deep-cleaning technologies are required to meet future near-zero emission standards from coal-fired power plants, as well as achieve the desired synthesis gas purity for the production of transportation fuels and chemicals. Technologies for such deep cleaning are available, but are very costly and inefficient due to their low temperature of operation. Development of innovative deep-cleaning technologies that operate at process temperatures consistent with downstream processing applications, i.e., 400 to

900 degrees Fahrenheit, would provide significant benefits. Although several approaches are being investigated, the most advanced employs a high-temperature, zinc-based sorbent in a transport reactor. Over 3,000 hours of operation with this particular sorbent have recently been completed using coal-derived synthesis gas at Eastman Chemical Company. Planning is in progress for slipstream testing of a 50-MWe size unit at a commercial gasification site.

***Coal-Feed Pumps –*** The development of coal-feed pumps will reduce the cost and improve the efficiency of all gasification-based processes. They will also improve the economics of utilization of vast low-rank coal reserves. With DOE support, Stamet Incorporated successfully developed a single-stage rotary feed pump that has the capability of injecting high-moisture coal into the high-pressure gasifier – up to 1000 psig. In 2007, General Electric purchased Stamet for use with their gasifier technology to make their technology suitable for low-rank coal gasification. Concurrently, DOE was engaged with Pratt & Whitney Rocketdyne to also develop a coal-feed pump. Detailed design of a 400 ton-per-day pump is in progress and testing is scheduled to begin in late Fiscal Year 2009.

***$H_2$ and $CO_2$ Separation Membranes –*** Today's technologies for $CO_2$ removal impose significant impacts on the thermal efficiency and capital cost of IGCC plants. It is believed that this impact can be greatly reduced through the use of advanced technologies such as membranes for separation. Furthermore, cost-effective and efficient gas separation technologies are vital in any chemical process operation and will impact the overall cost of the system. For the production of hydrogen from coal, gas separation is required for the separation of the shifted synthesis gas stream into pure $H_2$ and $CO_2$ streams. Separation of hydrogen from shifted synthesis gas is a key unit operation of any gasification-based hydrogen production system. The Gasification Program and its partner, Eltron Research and Development Company, are pursuing

the development of a dense metallic-based membrane to reduce the cost and increase the performance of hydrogen separation. This membrane has achieved nearly all of DOE's 2015 performance goals for membrane-based systems. The Fuels program is also working on hydrogen separation technologies.

***Coal/Biomass Gasification –*** The process for turning gasified coal and/or biomass into liquid transportation fuels is mature and commercially available, with technology improvements driven by the marketplace. However, the technology for co-feeding and gasifying coal-biomass mixtures is not commercially available. DOE's program includes development of technology for co-feeding and gasifying coal/biomass for electricity generation application. As with much of DOE's gasification program, DOE's FY 2009 coal/biomass research targets electricity generation applications, but could also be used by the private sector for other applications, such as production of transportation fuels. Co-feeding of coal and biomass up to about 20% by weight is well within the range of operability for large-scale plants. Operators of the NUON IGCC plant in Buggenum, The Netherlands, successfully fed a mixture of coal and 30% (by weight) demolition wood into a high-pressure, entrained-flow gasifier.

***Gasification and Carbon Sequestration*** – DOE is taking a leadership role in the development of CCS technologies. The Carbon Sequestration Program is addressing the key challenges that confront the wide-scale deployment of capture and storage technologies through research on cost-effective capture technologies; monitoring, mitigation, and verification technologies to ensure permanent storage; permitting issues; liability issues; public outreach; and infrastructure needs. Gasification technology holds substantial promise as the best coal conversion technology option to utilize carbon capture technologies. The Gasification Program is aggressively pursuing developments to reduce the cost of carbon capture so that the cost of

electricity to the public will result in an increase of less than 10% for new gasification-based energy plants.

***FutureGen*** – The Department's FutureGen program offers a key opportunity to validate gasification technology coupled with CCS in commercial settings. In light of recent proposals for over 30 gasification-based commercial coal plants throughout the United States, and the potential siting issues that may require these plants to have carbon capture capability, the restructured FutureGen focuses on multiple gasification technology demonstrations with CCS in commercial plant settings. With this new strategy, the Department will help fund the CCS portion of the demonstration unit of the overall plant, thereby limiting the Department's, and taxpayer's, cost exposure. This restructured approach allows DOE to maximize the role of private sector innovation, provide a ceiling on federal contributions, and accelerate the Administration's goal of increasing the use of clean energy technologies to help meet the steadily growing demand for energy while also mitigating greenhouse gas emissions.

In today's business environment, markets and market drivers are changing at a rapid pace. Environmental performance is a much greater factor now than in previous years as emission standards tighten. In addition, the reduction of $CO_2$ emissions is one of the major challenges facing industry in response to global climate change. To help meet these challenges, there is a need for more environmentally sound, flexible, efficient, and reliable systems that still meet the ever-present demand for higher profitability. Gasification is a technology that is poised to meet these requirements.

Mr. Chairman, Members of the Committee, this completes my statement. I would be happy to take any questions you may have.