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Thank you Mr. Chairman. I appreciate this opportunity to provide testimony on the Department of Energy’s (DOE’s) advanced clean coal technologies. I fully support the President’s 20 in 10 goal for alternative liquid fuels, including cellulosic ethanol, ethanol, biodiesel, and coal-derived liquids.

The economic prosperity of the United States over the past century has benefited by the abundance of fossil fuels found in North America. The United States’ fossil fuel resources represent a national asset that is important to our energy security and global economic competitiveness. However, concerns over climate change and air pollution challenge our ability to take full advantage of our fossil fuels resources.

The sometimes competing priorities of improving energy security by reducing fuel imports, while simultaneously mitigating energy-related GHG and air pollution emissions, can inject uncertainty into the business decisions that can inhibit energy project development. The present legal and regulatory uncertainties surrounding the mitigation of GHG and the significant increase over the last several years in world oil and gas demand are other factors that contribute to this uncertainty within the business community. The development and introduction of advanced and cost-effective technologies that employ domestic fossil fuel resources and improve GHG and air pollutant emissions could help reconcile these goals.

One potential technology that could support these strategic energy objectives is coal-biomass-to-liquids (CBTL). This approach represents a process that uses both coal and biomass gasification combined with technology to produce liquid transportation fuel products, while incorporating technology to mitigate CO_2 emissions via carbon capture and storage. CBTL provides an opportunity to apply the Nation's abundant coal reserves and biomass potential to the creation of alternative liquid transportation fuels, contributing to strengthening our Nation's energy security. This process can potentially improve GHG emissions, compared to traditional refining, while meeting the mitigation requirements for all other pollutants.

If CBTL were to become a viable economic technology option, it would depend on technologies including coal and biomass gasification, syngas-to-liquids, carbon capture and storage, and enhanced oil recovery.

Gasification and Coal-to-Liquids (CTL)

To date, CTL has only been used by countries without access to world petroleum markets, and has been uneconomic compared to petroleum. China is currently developing CTL plants, but while potentially economic in China the environmental criteria imposed by China are not as stringent as in the U.S. The designs China is considering may almost double the GHG emissions compared with petroleum transportation fuels.

Efforts in conversion of CTL in the U.S. accelerated after the Second World War. The Bureau of Mines began pilot-scale testing aimed at extending German synthetic fuels technology. This was followed by the construction and dedication on May 21, 1948, of coal to synthetic gas and liquid fuels laboratories and pilot plants (both direct and indirect liquefaction technologies), including coal gasification experimental work.

Work in the 1970s on integrated gasification combined cycle (IGCC), which is for electricity generation, resulted in two clean coal technology demonstration projects – Tampa Electric and Wabash River. The only large-scale coal and biomass gasification experience in the U.S. has been performed in the Tampa IGCC plant. Over the past fifteen years, DOE has invested significantly towards R&D required for the advancements in gasification systems. As a result of this investment, a third IGCC demonstration project, based upon the transport gasifier developed by DOE in partnership with Southern Company, is under development in Orlando, Florida. Additionally, advanced air-separation technologies and high-temperature gas-cleaning technologies are progressing to large-scale testing at commercial coal gasification plants, making these technologies ready for demonstration in FutureGen. (FutureGen is a Government-industry initiative to design, build, and operate an advanced coal gasification-based, near-zero atmospheric emission, coal-fired electricity and hydrogen production plant.) The commercial U.S. operating IGCC plants and the advanced process technologies have been realized through cost-sharing partnerships with industry.

DOE's work on gasification has evolved from its early days of laboratory, bench, proof-of-concept demonstration scale research to its current state-of-the-art computer-based computation, modeling, visualization, and simulation approach validated by experiment. Unique capabilities exist to model the dense, reacting multiphase flows that are encountered in coal and coal-biomass gasifiers. In addition, modeling at the atomic scale of the Fischer-Tropsch (F-T) catalytic reaction of carbon monoxide and hydrogen to produce clean liquid fuels has been under investigation since 2000, but has been discontinued because F-T is a mature technology subject to evolutionary advancements for which industry has adequate incentive to develop without government assistance.

The F-T process for production of liquid fuels from coal starts with gasification. Coal is fed to a gasification system that produces a gas mixture consisting mostly of carbon monoxide, hydrogen, and carbon dioxide. This gas mixture is further processed to remove carbon dioxide and trace contaminants, such as sulfur compounds and mercury. This clean gas mixture is sent to a chemical reactor where the gas mixture is catalytically converted to liquid products. After a moderate amount of on-site petrochemical fuel processing, a commercial CTL plant would produce a near-zero sulfur, high-performance diesel fuel for automotive applications and a near-zero sulfur jet fuel for commercial or military applications. Between one-third to one-half of the product of commercial CTL plants would be a mixture of liquids (primarily naphtha) that can be used to manufacture motor gasoline, either at the CTL plant site or at a petroleum refinery.

Since the end of World War II, the only commercial experience in CTL production has occurred in South Africa under government subsidy. In particular, a South African synthetic fuels capacity constructed from the 1950s through the 1980s currently produces fuels and chemicals that are the energy equivalent of about 150,000 barrels per day of oil.

According to the Energy Information Administration (EIA) the U.S. demand for petroleum in 2005 was 20.8 million barrels per day. Of that amount, 12.5 million barrels per day, or 60 percent, was from net imports. Domestic production of transportation fuels such as CTL, CBTL, cellulosic ethanol, ethanol, and biodiesel, would have positive national security benefits by reducing our foreign oil dependence.

Carbon Capture and Storage (CCS)

The technology option represented by CCS could be used in conjunction with the CBTL technology concept, as the CO_2 produced and stored from the biomass component of the feedstock can derive negative GHG emission balances due to the photosynthetic carbon being drawn from the air and stored underground. The benefits claimed for GHG reduction for biomass co-feeding scenarios account for photosynthetic carbon uptake. This represents an option for substantially mitigating the otherwise undesirable GHG emissions performance of a CTL plant, compared to traditional petroleum refining.

Over a decade of effort has been underway in DOE's Sequestration Program relating to CCS technologies, which was formally defined as a program in 1997, with an initial budget of $1 million. Funding for CCS has steadily increased over the past ten years to a level of around $100 million in Fiscal Year 2007. Cumulative funding over the past decade is on the order of $360 million. Research has focused primarily on capture and storage of CO_2 for electricity generation applications, though many of the technologies could be used for other applications. As part of this effort, the program has organized Regional Partnerships to address infrastructure issues for carbon storage. NETL, in conjunction with the Regional Partnerships, have performed and published a capacity assessment for geologic storage showing adequate storage potential for hundreds of years. DOE is moving into Phase 3 (Deployment Phase) whereby large volumes of CO_2 will be injected for storage, which will help to significantly advance geologic sequestration as a viable carbon mitigation option.

CTL and CBTL systems are easily amenable to carbon sequestration because a large degree of CO_2 separation is inherent to the process.

Enhanced Oil Recovery (EOR)

Although much of the Nation's recoverable onshore petroleum resource has been produced, large volumes of crude oil remain in place after current production methods are exhausted through technology referred to as EOR. These remaining oil resources are held in place by physical forces or left behind due to geologic complexity being both economically and technologically challenged. The total volume of this stranded oil is estimated by Advanced Resources International of Washington, DC, to exceed 390 billion barrels, of which roughly 200 billion barrels are estimated to be relatively accessible at depths of up to 5,000 feet but do not have CO_2 available for EOR. To put these numbers in context, according to EIA, we have produced about 195 billion barrels of our petroleum resource over the past nearly 150 years and currently have proven reserves of roughly 22 billion barrels (Source: EIA online database, as of December 2005; crude oil, does not include natural gas liquids).

Incremental oil produced from EOR applications could help offset the costs of CO_2 capture in CBTL opportunities, while the prospect of low-cost supplies of captured CO_2 in widespread areas of the country could provide the impetus for a national re-evaluation of the EOR potential in many mature fields. Long-term GHG benefits would only be realized if the EOR would be implemented in a manner that ensured the permanent storage of the $CO_{2.}$ While EOR is a technology that has been in commercial use for decades, CO_2 capture from processes such as CBTL is not yet commercial. Continued evolution of EOR and transformational advances in development and deployment of CO_2 capture from CBTL could help realize this synergy between the new alternative fuel industry and the traditional oil industry.

While the challenges are significant, the U.S. has experience in the relevant technologies. The oil industry has been using CO_2 for EOR in commercial applications for decades. As early as the 1970s, DOE-funded projects were assessing the fluid properties of CO_2 to establish its applicability in EOR. A special focus was given to developing correlations that helped the oil industry utilize these properties to optimize commercial EOR projects. During 1993-2003, DOE funded nearly half of the $100 million spent on the Class Program CO_2-EOR Field Demonstration Projects. Approaches included the use of horizontal wells for improved reservoir contact, four-dimensional seismic to monitor the behavior of CO_2 floods, automated field-monitoring systems for detecting problems, and the injection of increasingly larger volumes of CO_2 to increase recovery rates. This DOE-funded research has helped advance industrial EOR operations, but the focus is now on the carbon sequestration side of EOR, which is focused on developing technology to maximize CO_2 storage in producing oil fields. DOE-funded research continues to include research on carbon sequestration in the context of EOR.

CBTL and Environmental Benefits

While a large CTL industry could have positive national security benefits there are economic challenges and environmental costs that need to be considered. If no provisions are in place to manage CO_2 emissions, then the use of CTL fuels to displace petroleum fuels for transportation will roughly double GHG emissions. Theoretically, GHG emissions from CBTL systems can be well below those associated with the use of conventional petroleum fuels, depending upon the specific design of the CBTL system and the proportion of coal and biomass feed to the system.

Co-feeding at these levels is well within the range of large-scale plants (12 percent by energy and 20 percent by weight) amounts of biomass. At the NUON plant in the Netherlands they successfully fed a mixture of coal and 30 percent (by weight) demolition wood into a high-pressure, entrained-flow gasifier. The amount of biomass available and able to be utilized at a

CBTL plant with CO_2 capture and storage may or may not be sufficient to provide the GHG benefit versus petroleum-based fuels.

A more advanced case from Professor Robert Williams, of Princeton University, illustrates how a CBTL system with 38 percent (on an energy basis) switchgrass feed will result in a life-cycle GHG emission rate of zero. Due to the high amount of biomass in the feed and the high percentage of carbon sequestration (approximately 90 percent), this system does not increase the amount of CO_2 in the atmosphere, even considering the fuel emissions at the tailpipe of vehicles using the product fuel. Thus, this system represents an opportunity to not only mitigate the impact of carbon fuels at stationary sources, such as the CBTL production facility, but also to mitigate the impact of mobile sources such as automobiles that burn the product fuel.

The context of the total fuel life-cycle evaluation is well-to-wheels or coal-mine-to-wheels. A "well-to-wheels" analysis considers the GHG emissions from all parts of the production supply chain. For petroleum liquid fuels, the steps include crude oil extraction, crude oil treatment, crude oil shipment to a refinery, refinery processing, delivery of finished product to a dispensing station, and end-use combustion emissions.

Another aspect of CBTL systems is the tradeoff between biomass and coal as a feedstock. Increased coal greatly reduces the amount of biomass needed to produce a given amount of liquid fuel, but it increases the carbon emissions. Conversely, increased biomass greatly increases the amount of biomass needed to produce a given amount of liquid fuel, but it decreases carbon emissions. Another important consideration is the economic impact of replacing coal with biomass.

Analysis performed by Professor Williams indicates that the biomass energy input needed to produce liquid fuels via CBTL is 50 percent or less than the amount of biomass energy needed for a corresponding amount of corn-based ethanol. This more efficient use of biomass has two benefits. First, lowering the amount of biomass needed to produce a set amount of liquid fuels lowers pressure on the agriculture industry to find suitable land to grow the biomass needed for liquid fuel production. Second, there is an economic trade-off between the amount of biomass that can be delivered to a central processing facility and the distance needed to deliver the biomass. By including coal in the feedstock, the central CBTL facility can be larger than the corresponding 100 percent biomass facility, and can take advantage of economies of scale in construction and total output of liquid fuel.

Non-food crop biomass resources suitable as feedstocks for CBTL production plants include switchgrass, corn stover, short rotation woody crops (poplar), forest residues, mixed prairie grasses, and crops that would be grown on dedicated energy plantations. Because CBTL can use non-food biomass as a feedstock, this will reduce pressure on supply of food-based biomass production. In addition, CBTL facilities would provide a stimulus to the agriculture industry to develop the infrastructure and biomass resources needed to provide cellulosic biomass for the production of liquid transportation fuels, which can also support future opportunities for cellulosic ethanol production.

Under one scenario for the coal-biomass feedstock mix, a CBTL facility would produce about 0.8 short tons of CO_2 along with each barrel of liquid fuel. For CBTL plants located near oil fields with recoverable crude, this CO_2 can be used to drive additional oil recovery. Based on studies sponsored by DOE, opportunities for EOR provide carbon management options for at least a half million barrels per day of CBTL production capacity. As a consequence of using EOR for carbon management, this half million barrels per day of CBTL liquids will promote an additional one million barrels per day of domestic petroleum production. Although capacity for

CO_2 sequestration through EOR in the U.S. is much smaller than total U.S. CO_2 production over time, EOR activity will provide important early opportunities for advantageous economics for utilization of CO_2.

The economic viability of CBTL is dependent upon several assumptions, including exact configuration of the facility, proportion of biomass in the feed, the value (if any) assigned to the disposition of captured CO_2, and the value of any power sold to the electricity grid.

The conversion of clean synthesis gas to liquids, as practiced by SASOL in South Africa, is commercial. However, the introduction of biomass to the front-end of the process (i.e., CBTL), when combined with sequestering the CO_2 produced in feedstock conversion, presents unique challenges and offers the opportunity to produce fuels, electric power, and hydrogen with a much reduced, and even net negative, life-cycle carbon footprint. To our knowledge, a CBTL technology that is capable of producing clean liquids, hydrogen, and electric power, on a carbon neutral, or net negative, life-cycle basis is not commercially available anywhere in the world today, nor is it economic.

Conclusion

The prospect for the development of a CBTL industry in the United States has resulted from decades of development of enabling predecessor technologies that can be combined with the President's 20 in 10 goals for cellulosic ethanol, ethanol, and biodiesel to provide a solution to both energy security and reducing GHG emissions for the Nation. If economic, A CBTL industry could become a domestic source of liquid transportation fuels production, helping enhance domestic energy security. The carbon capture and storage associated with CBTL could help mitigate the adverse GHG affects associated with a standard CTL process, and could improve upon normal refining plant emissions. With varying proportions of biomass, CBTL could achieve levels evaluated as GHG neutral. Such zero GHG emissions for the process would not only apply to the stationary fuel production plant emissions but also the tailpipe emissions of vehicles using the product fuel from the plant, providing an avenue for GHG mitigation within the transportation industry.

Early CBTL opportunities with access to parallel EOR opportunities can offer avenues to offset the added costs of CO_2 mitigation. They can also support increased domestic fuel production by roughly two barrels of EOR production per barrel of CBTL production.

Combining coal and biomass in a CBTL production facility allows for the production of significantly larger volumes of environmentally acceptable domestic transportation fuels, per unit of biomass, a factor that will become increasingly important as our potential biomass resources are increasingly brought into the Nation's energy mix.

The primary barriers to commercial introduction of CTL technology, and by extension to CBTL technology, have been the: uncertainty of world oil prices; high cost of production coupled with high initial capital cost ($70 to $90 thousand dollars per barrel of daily capacity for the first U.S. plant, for a total cost of $3 billion or more for a full-scale plant) and the long decision-to-production lead times (which could be in the seven-year range).