EMD Coal Committee

EMD Coal Committee Annual Report - 2011

William A. Ambrose, Chair

March 23, 2011

Vice-Chairs:

Dr. John S. Mead (Vice-Chair: University), Southern Illinois University, Carbondale, Ill.

Susan J. Tewalt (Vice-Chair: Government), U.S. Geological Survey, Reston, Va.

Committee Activities

In the 2010-2011 business year, the Coal Committee appointed two Vice-Chairs, (1) Dr. John S. Mead (jmead@siu.edu), Director of the Coal Research Center at Southern Illinois University, as the University Vice Chair, and (2) Susan J. Tewalt (stewalt@usgs.gov), geologist and NCRDS State Coops Technical Officer at USGS, who is serving as the Government Vice Chair. The Industry Vice Chair will be appointed later this year.

The Coal Committee is following up its last-year's sponsorship of the poster session "Coal: Versatile Fuel Source for the Future" at the 2010 Annual AAPG Conference in New Orleans, with the oral session "Clean Coal and Coalbed Methane" at the 2011 Annual AAPG Conference in Houston (Tuesday, April 12 at 2:00 PM). The following oral presentations are slated for the session:

- Duncan, I. J., and Ambrose, W. A., "An overview of clean coal technologies and carbon capture and storage (CCS)".

- Gulen, G., and Foss, M., "Economic and regulatory considerations for clean coal".

- Pashin, J., "Clean coal technology developments and its impact on the energy industry in the southeastern United States".

- Arminian, K., "Predicting CBM well production performance".

- Ayers, W. B., Jr., McVay, D. A., Barrufet, M. A., Hernandez, G., Bello, R., and He, T.,, "Potential for enhanced methane production from coal, with concomitant CO2 sequestration—examples from a high-rank coal (Pottsville Formation) and a low-rank coal (Wilcox Group), Texas Gulf Coast Basin)".

The list of references for the Coal Committee has been updated and posted on the committee website. Also, the list of coal-related conferences and events for the 2011 calendar has been updated. Many thanks to Brian Cardott for updating these references and to Janet Brister for posting these items, which can be accessed via:

http://emd.aapg.org/members_only/coal/index.cfm
http://emd.aapg.org/members_only/coal/calendar.cfm

Discussions are currently underway with DEG President Mary K. Harris and President-Elect Doug Peters to jointly coordinate efforts with DEG's CO_2 Sequestration Committee, including a possible jointly sponsored technical session at the 2012 Annual AAPG Conference in Long Beach, California.

Coal Commodity Report

This coal commodity report is an expanded version of the report submitted as part of the EMD commodity review article, edited by past EMD President Peter Warwick, for the journal *Natural Resources Research* (NRR).

World Coal Production and Consumption

Coal is a significant component of the world's energy production and consumption, accounting for 27% of total energy use (Energy Information Administration, 2010). Recent developments in clean coal, underground gasification, and coal-to-liquids technology promise to expand coal's role in power generation and fuel consumption. Research institutions and governmental agencies, including the U.S. Department of Energy (DOE), the International Energy Agency (IEA), and the National Energy Technology Laboratory (NETL) are conducting new research in clean-coal, coal gasification, FutureGen-type power-generating facilities, as well as sequestration and industrial application of gasification by-products.

Estimated worldwide coal production in 2010 was >7 billion short tons, or 130.4 quadrillion BTU. Non-OECD (Organisation for Economic Cooperation and Development) Asia led the world in coal production (72.8 quadrillion BTU) in 2007, of which China produced 55.3 quadrillion BTU. In contrast, 2007 coal production in OECD North America represented only 25.3 quadrillion BTU, of which coal production in the United States was 23.5 quadrillion BTU. World coal production is estimated to rise to ~207 quadrillion BTU by 2035 to meet expected increasing demand (Energy Information Administration, 2010). Approximately 64% of international coal consumption in 2008-2009 was used for generation of electricity, whereas 33% was sold for industrial use (primarily steel manufacture). The remainder was primarily for consumers in residential and commercial sectors. Although most steel-producing countries reduced their steel production >10% from 2008 to 2009, China, India, and Iran saw increases.

U.S. Coal Production and Consumption

Coal has traditionally provided ~50% of U.S. electricity generation, although this has recently declined to 47%, owing to a variety of factors that include increased use of cheaper natural gas for power generation, decrease in demand owing to the recent recession, as well as delays in commissioning new proposed coal-fired power plants. In contrast, electric-generation capacity from natural gas has increased from 18 to 21% and DOE estimates that 90% of new power plants built in the next 20 years will be fired with natural gas. Approximately 300 gigawatts (GW) or 281,557 billion BTU of electrical capacity in the U.S. was provided by coal from ~1,500 generating facilities in 2009 (Energy Information Administration, 2011). The National Coal Council estimates that 375 million short tons (mst) yr^{-1} for 100 GW of new electric power from coal must be installed by 2025 to meet projected demands in the U.S. (Beck, 2006) although few new coal-fired power plants are currently being commissioned for reasons given above.

U.S. coal production fell from 1,171.8 to 1,074.9 mst between 2008 and 2009, the largest one-year decline since 1949 (Energy Information Administration, 2009). Likewise, coal consumption in the electric sector declined by 10.3%, whereas coking coal consumption decreased by 30.6%. These declines resulted in record high coal stocks of 233.0 mst at the end of 2009 (Energy Information Administration, 2009).

The western coal region, which includes Alaska, Arizona, Colorado, Montana, New Mexico, North Dakota, Utah, and Wyoming, continues to lead the U.S. in coal production, accounting for ~585 mst in 2009 (Table 1). Wyoming was the greatest coal-mining state, although coal production in Wyoming decreased for the first time in 17 years. West Virginia in the Appalachian Basin experienced the greatest tonnage decline in the region in 2009, dropping by 20.7 mst to 137.1 mst (Table 1). Most states experienced declines, with the exception of Ohio, Illinois, Western Kentucky, Alaska, and North Dakota.

Coal-Producing Region and State	**2008 Production (mst)**	**2009 Production (mst)**
Appalachian Total	**390.2**	**341.4**
Alabama	20.6	18.8
Kentucky, Eastern	90.3	74.7
Maryland	2.9	2.3
Ohio	26.3	27.5
Pennsylvania	65.4	58.0
Tennessee	2.3	2.0
Virginia	24.7	21.0
West Virginia	157.8	137.1
Interior Total	**146.6**	**145.8**
Arkansas	0.1	0.0
Illinois	32.9	33.7
Indiana	35.9	35.7
Kansas	0.2	0.2

Kentucky, Western	30.1	32.6
Louisiana	3.8	3.7
Mississippi	2.8	3.4
Missouri	0.2	0.5
Oklahoma	1.5	1.0
Texas	39.0	35.1
Western Total	**633.6**	**585.0**
Alaska	1.5	1.9
Arizona	8.0	7.5
Colorado	32.0	28.3
Montana	44.8	39.5
New Mexico	25.6	25.1
North Dakota	29.6	29.9
Utah	24.4	21.7
Wyoming	467.6	431.1
Refuse Recovery	**1.4**	**2.7**
U.S. Total	**1,171.8**	**1,075.0**

Table 1. U.S. Coal production by region and state, 2008-2009. Modified from Energy Information Administration, 2009.

Clean Coal

Clean coal is coal that is stripped of minerals and other impurities and then gasified and burned in high-oxygen mixtures with capture of CO_2 and hydrogen. The U.S. federal government has recently been favoring initiatives to develop clean-coal technology for power plants that involve carbon capture and storage (CCS). In June, 2008 DOE issued a Funding Opportunity Announcement (FOA) to invest in Integrated Gasification Combined Cycle (IGCC) or other clean-coal power plants with CCS technology. DOE has generated >30 reports summarizing recent and ongoing clean coal demonstrations, as well as DOE post-project assessment (NETL, 2010). The program performance goal of DOE in coal gasification is to complete research and development for advanced power systems capable of achieving 45 to 50% electrical efficiency at a capital cost of $1000 per kilowatt (in constant 2003 dollars) or less for a coal-based plant. DOE also has a goal for the year 2015 to have ready an operating zero-emission, high-efficiency, co-production power plant that will produce hydrogen from coal. Partial oxidation of coal is a promising technology for co-production of hydrogen and electric power and hydrogen using

IGCC technology. However, currently there are no commercial demonstrations of these joint power and hydrogen plants. (U.S. Department of Energy, 2010). The World Resources Institute (WRI) is also involved in research in CCS, especially in regard to coal. WRI has compiled an extensive set of CCS guidelines, many of which are directly applicable to clean coal technology (WRI, 2009).

Factors that impact costs and the selection of optimal areas for new clean-coal sites include (1) proximity of sites to mine mouths, (2) distance of CO_2 transport via pipelines to carbon sinks, and (3) transmission losses between new power-generating facilities and user load (Mohan and others, 2008; Cohen and others, 2009; Dooley and others, 2009; Hamilton and others, 2009). Newcomer and Apt (2008) conclude that optimal sites for new clean-coal facilities should be near user electric load, owing to transmission losses exceeding costs of installing new CO_2 pipelines and fuel transport. However, economic incentives that support new clean-coal facilities should also be considered, including EOR (enhanced oil recovery) with generated CO_2 (Holtz and others, 2005; Advanced Resources International, 2006a, b; Ambrose and others, 2010). Other incentives include ECBM (enhanced coalbed methane recovery) (Reeves, 2003: McVay and others, 2009), and underground coal gasification with CCS (Roddy and Younger, 2010).

Several U.S. states, including Texas, have a wide variety of geologically defined areas that could be potentially targeted for new clean-coal facilities. Areas in Texas with favorably co-located geologic CO_2 source-sink factors related to coal and lignite trends include the Gulf Coast, the Eastern Shelf of the Permian Basin, and the Fort Worth Basin. However, areas outside coal and lignite basins, particularly the Permian Basin where a new clean-coal facility is being planned, also have clean-coal potential because of existing CO_2 pipelines and proximity to EOR fields that can economically sustain new clean-coal facilities (Ambrose and others, 2010).

Clean-coal activity in North America is led by the Dakota Gasification Company, where ~95 million cubic feet per day of CO_2, generated by gasification of North Dakota lignite, is transported via a 205-mile (328-km) pipeline to Weyburn oil field in Saskatchewan for EOR (Chandel and Williams, 2009). Weyburn field has become the largest land-based CO_2 storage project in the world, having sequestered >12 million metric tons (Mt) (Preston and others, 2009).

In March 2010 DOE announced that it reached a cooperative agreement with Summit Texas

Clean Energy LLC to design, build and demonstrate a coal-gasification plant near Odessa, Texas (Fairley, 2010). The plant is designed to provide electricity for >165,000 homes. Approximately 90% of the CO_2 (3 Mt yr^{-1}) produced from the plant will be captured and transported with existing CO_2 pipelines for EOR in nearby oil reservoirs. CO_2 sales to oil and gas operators are projected to increase plant revenues by 50%. Revenues from EOR could cover the price premium for carbon capture at the Odessa clean-coal facility, assuming an oil price of $75 per barrel (Al-Juaied and Whitmore, 2009). Funding will be provided by DOE and NETL. The estimated total cost for the project is $1.73 billion and DOE's share will be $350 million.

DOE has awarded AEP (American Electric Power) funding for 50% of the cost, up to $334 million, of building a commercial-scale CCS installation at the Mountaineer plant in West Virginia. The project, to be operational by 2015, will capture and store ~1.5 million metric tons of CO_2 per year. Its goal is to remove up to 90% of the CO_2 from a 235 MWe portion of the power plant's flue gas (American Electric Power, 2009).

Underground Coal Gasification

Underground Coal Gasification (UCG) is conversion of unmined subsurface coal into a gas that can be used for power generation, manufacture of hydrogen for fuel cells, synthetic natural gas, liquid fuels, and fertilizers. UCG involves drilling wells into coal seams, with injection wells containing oxidants and other wells producing syngas created from coal combustion. An advantage of UCG technology is low plant costs, owing to no surface gasifiers and coal-transport expenditures. UCG is also associated with fewer surface emissions and could be employed in conjunction with CO_2 storage after gasification.

UCG activity is worldwide, with projects planned or beginning operation in China, India, Australia, South Africa, Europe, and North America. China is currently operating ~30 projects in various stages of development, whereas India plans to develop UCG in ~350 billion tonnes (Gt) of coal resources (World Coal Association, 2011). South Africa has identified 160 Gt of coal resources with UCG potential (ESI-Africa, 2010).

Current UCG proposed projects in the U.S. include an underground coal gasification plant in

Alaska and sites in Colorado. In Alaska, Cook Inlet Region Inc. (CIRI) is pursuing permits with Laurus Energy to construct an underground coal gasification facility to support a 100-MW power plant. The operation will convert coal into a synthetic gas at a depth of ≥1,800 ft (≥550 m). An estimated ≤3 acres yr^{-1} of underground coal will be required to support the power facility, with ~90 acres to supply the plant for its expected lifetime. Commercial power production is projected to begin in 2014 (Greentechmedia, 2010). The Colorado Geological Survey estimates that total coal resources in Colorado exceed 434 billion short tons (394 Gt) to a depth of 6,000 ft (1,830 m). It is estimated that almost 12 billion short tons (10.9 Gt) of bituminous and sub-bituminous coal resources in Colorado have UGC potential (Carroll, 2010).

Coal-to-Liquids (CTL)

CTL technology consists of breaking coal down into a solvent at high temperatures and pressures, followed by treatment with hydrogen gas and a catalyst. It also involves indirect liquefaction, with an initial stage of gasifying coal into an artificial syngas, and then manufacturing zero-sulfur synthetic fuels from the syngas. CTL fuels have benefits compared to many conventional liquid fuels. For example, many countries have direct access to domestic coal resources, and there is a strong international coal market. Access to these domestic potential fuels decreases reliance on oil imports and improves energy security. Coal liquids are versatile and can be used for a variety of activities and products, including transport, cooking, power generation, and manufacture of chemicals. In addition, coal-derived fuels are sulphur-free, and low in nitrogen oxides, and are low in particulate content. However, several economic, technical, and environmental obstacles, including high refinery and potential CO_2-sequestration costs, must be overcome for future CTL production to contribute significantly to world's energy base. For examples, CTL fuel can be expensive, owing to high front-end expenditures. For example, a 10,000 barrel-a-day (bbl d^{-1}) plant can cost $600-700 million to construct. Moreover, the refinement process is three to four times more expensive than refining an equivalent amount of oil. This estimate does not include costs of sequestrating captured CO_2, projected to increase CTL fuel prices to $5 per barrel. Introduction of carbon caps would also raise these costs, resulting in CTL production plus carbon storage at costs ranging from $1.40 to $2.20 per gallon or more by 2025.

China is currently active in CTL development, where new coal-liquefaction plants could provide an annual production capacity of 440 million barrels of liquid fuel. South Africa, through its SASOL, has produced >700 million barrels of synthetic fuels from coal since the early 1980s (Mining Weekly, 2010). Approximately 85% of the coal consumed in South Africa is used as synfuels feedstock or to produce electricity. Efforts in CTL production in South Africa are underway, although there are CO_2-storage issues to overcome. For example, SASOL recently reported slowdowns in the Mafutha Project, a proposed 80,000 bbl d^{-1} CTL project in Limpopo province. SASOL representatives have stated that the project will not progress within the originally envisaged timeline, pending clarity on a commercially viable CCS solution. China is planning a $6 billion investment in new liquefaction plants for a projected total annual production capacity of 440 million barrels of liquid fuel. A CTL facility planned for Mongolia in 2007, based primarily on U.S.-developed technology, is producing 50,000 bbl $d^{-1}$of clean-burning gasoline and diesel fuel.

The U.S. coal industry should be able to process a modest CTL industry, using 60 to 70 mst (54 to 64 Mt) of coal yr^{-1}, without premature depletion of the country's coal reserves (Milici, 2009). Plans for CTL production in the U.S. are underway at various sites. Accelergy, a company in Houston, Texas, has developed a process for converting coal into jet fuel. The company plans to sell jet fuel to the U.S. Air Force and has already received inquiries from commercial aircraft and engine manufacturers (Sourcewatch, 2010). A proposed CTL plant in Belwood, Mississippi would produce synthetic diesel and other fuels from coal and petroleum coke. The project is funded by $2.75 billion state-issued bonds. Several large airline companies have signed a memorandum of understanding to purchase 500,000 barrels per month of jet fuel from the proposed plant. Plans for a CTL plant have been made for McCracken County, Kentucky. The plant, proposed by Clean Coal Power Operations of Louisville, Kentucky, would produce 40,000 barrels of synfuels per day from coal and a maximum of 300 MW of electricity (Sourcewatch, 2010). A significant asset of the site is a 2-mile-deep brine-bearing formation for CO_2 sequestration. However, Carlisle County Kentucky is now receiving attention for the site of the CTL plant, owing to a more favorable tax environment.

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