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CLEAN COAL TODAY

A NEWSLETTER ABOUT INNOVATIVE TECHNOLOGIES FOR COAL UTILIZATION

NEWS BYTES

The U.S. Department of Energy has named **Mark Maddox as Acting Assistant Secretary for Fossil Energy**, replacing Carl Michael Smith who recently resigned after two years of service. Since September 2003, Maddox served as Principal Deputy Assistant Secretary under Smith. Prior to that, he was a senior policy adviser to Secretary of Energy Spencer Abraham and specialized in fossil energy, environmental management, and communications issues. Under the administration of President George H.W. Bush, Maddox was a DOE deputy director of public affairs. In the private sector, Maddox was vice president of a mid-size lobbying firm, and later moved to

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ZERO EMISSIONS TECHNOLOGIES: A NEW INITIATIVE

A new generation of fossil energy technologies may enable Asia Pacific countries to meet all of their energy needs, while at the same time, offer promise of environmental sustainability. These technologies, known as Zero Emissions Technologies (ZETs), are being developed in the United States and throughout the world, and eventually will be deployed in the Asia Pacific region. The International Energy Agency (IEA), through its Working Party on Fossil Fuels (WPFF), has started a major new initiative to facilitate international collaboration on the development and deployment of ZETs both in the Asia Pacific region and elsewhere.

As one example, China's Energy Research Institute expects that China alone will need to build 20 gigawatts (GW) per year of new power generating capacity between now and 2020, with possible acceleration thereafter. The 2002 World Energy Outlook, published by IEA, estimates that global reliance on fossil fuels will remain at around 85 percent of total energy supply during the first two decades of this century, and the world's fossil fuel consumption will likely double during the 2000–2030 period.

To this end, the WPFF and the U.S. Department of Energy (DOE) hosted the IEA ZET Conference February 17–19, 2004, on Australia's Gold Coast to provide a platform for active dialog among stakeholders. The 242 participants from 21 countries (predominantly from the Asia Pacific region) included government and community leaders, industry, academia, and non-governmental organizations.

Carl Michael Smith, DOE's departing Assistant Secretary for Fossil Energy

During the conference, over 45 presentations were given. Speakers in the Opening Plenary on Global Perspectives included DOE's former Assistant Secretary for Fossil Energy, Carl Michael Smith; Ian Macfarlane, MP, Minister for Australia's Industry, Tourism and Resources (ITR); Georg-Wilhelm Adamowitsch, Vice Minister of Germany's Federal Ministry of Economics and Labour; and Dr. Antonio Pfluger, Head, Energy Technology

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Collaboration Division, IEA. Barbara McKee, Director of the DOE Office of Fossil Energy, Coal and Power Import and Export, and the IEA WPFF Chair, co-chaired the conference with Andy Lloyd, Mining Executive, Rio Tinto Ltd. of Australia. McKee described the task ahead for ZETs as a "walk-about" journey that has just begun, with goals that are highly ambitious and difficulties that should not be underestimated. However, she expressed the belief that ZETs are feasible and can be developed and deployed over the coming decades, provided they receive adequate RD&D resources and effective international cooperation.

The keynote speaker for the host country, Australian ITR Minister Macfarlane, reviewed his country's leadership role in a number of ZET-related activities. He focused on COAL 21, the national clean coal strategy, which is a voluntary government/industry partnership to advance clean coal and zero emissions technologies. Current technologies being investigated include ultra-clean coal, integrated gasification combined-cycle (IGCC), Oxy-Fuel, drying of brown coal, coal bed methane, and geological sequestration. Australia has identified some 60 areas ideal for sequestration and has three projects in progress, including annual re-injection of up to 5 million metric tons of CO_2 in the Gorgon liquefied natural gas project. Minister Macfarlane also announced that Australia will host the Second Ministerial Meeting of the Carbon Sequestration Leadership Forum to be held in Melbourne in September 2004. He noted that Australia has established Climate Action Partnerships with the United States, China, Japan, Europe, and New Zealand. He also took the opportunity to launch the Australian Technology Roadmap activity, a government inter-departmental initiative to produce a "street directory" for meeting a clean fuel goal. It will map out five years of R&D followed by a 10–15 year plan for deployment followed by a 30-year evolution of a hydrogen economy.

The Honorable Ian Macfarlane MP, Minister for Industry, Tourism and Resources, Australia

Dr. Antonio Pfluger, Head, IEA's Energy Technology Collaboration Division

A day-long ZET Technical Workshop and the APEC workshop on "Near-Term Options to Reduce CO_2 from Existing Power Plants," preceded the formal conference. Conference participants arrived at a number of conclusions that will serve as signposts for the ZETs R&D journey. They noted that no single technology would suit all needs; ZET applications would be region-specific and a robust portfolio of technologies would be needed. Attempts to stabilize CO_2 concentrations would require deep cuts in emissions beyond the capabilities of current technologies. Competing emission reduction technologies should be developed in parallel, and international cooperation will be needed to match needs, resources, and priorities. Improving the technology and economics of CO_2 capture and storage is essential, as is better standardization of cost estimates. Resolution of risk assessment, liability, and monitoring issues could increase public acceptance. Financial and policy/regulatory incentives will be necessary, at least in the short term. Participants applauded the U.S.-proposed FutureGen project as an example of appropriate government fostering of new technology.

Conference participants noted that implementation of R&D efforts — from current technology to what is expected of the technology in the future — must be logically sequenced. The role of near-term technologies in this sequence was explored at the APEC workshop. This workshop was sponsored by the APEC Experts Group on Clean Fossil Energy, chaired by the DOE Office of Fossil Energy's Scott Smouse. Two APEC studies titled *Options to Reduce CO_2 Emissions from Electricity Generation in the APEC Region (Phases I and II)* are available on the Internet at (http://apec-egcfe.fossil.energy.gov/), and provided a springboard for discussions at the workshop. These studies outline a number of proven technology options to reduce CO_2 from existing plants, such as supercritical and ultrasupercritical coal boilers, IGCC (without sequestration), coal/

biomass co-firing, and advanced gas turbines. Phase I analyzes 19 technology options, while Phase II presents actual case studies of emissions reductions. Often, case studies showed a CO_2 abatement benefit. In the majority of cases, the improvements were economically viable in their own right. Repowering initiatives were most successful, giving large increases in generating capacity for the same fuel consumption, and corresponding large reductions in greenhouse gases. At the workshop, over 30 speakers provided a substantial body of new information on efficiency improvements in existing plants, near- and medium-term options for new generation, emissions strategies (including voluntary trading), and fuel and power plant strategies.

In all, the conference and workshops provided an important starting point for the international cooperation necessary to bring ZETs to the marketplace over the coming decades.

DOE MERCURY CONTROL PROGRESSING

Coal-fired electric power generating facilities are being considered as a major source of atmospheric mercury. In view of the potential health and environmental impacts of mercury emissions, the U.S. Environmental Protection Agency (EPA) has determined that regulation of mercury emissions from coal-fired utilities is necessary (see box on page 5). To help ensure that the existing fleet of coal-fired power plants can meet future regulatory requirements, the U.S. Department of Energy (DOE) Office of Fossil Energy's Innovations for Existing Plants (IEP) program has been carrying out an R&D program at DOE's National Energy Technology Laboratory (NETL) to control mercury emissions from coal-based power systems. Working collaboratively since 1990 with power plant operators, the Electric Power Research Institute (EPRI), academia, state and local agencies, and EPA, the program has greatly advanced the understanding of formation, distribution, and capture of mercury from electric utility boilers.

To date, research shows that no single technology can cost-effectively provide add-on mercury control for all power plant configurations or all fuel types. For example, activated carbon injection (ACI) has shown promise as a near-term mercury control technology, but the process applied to coal-fired boilers is still in its early stages and its effectiveness under varied conditions (e.g., fuel properties, flue gas temperatures, and trace-gas constituents) is still being investigated.

The current NETL R&D goal is to develop mercury control technologies that achieve 50–70 percent mercury capture at less than three-quarters of the baseline cost estimate of $50,000–70,000 per pound of mercury removal for ACI technology. The aim is to have these technologies available for commercial demonstration by 2005 for bituminous coal plants, and by 2007 for lignite and subbituminous plants. The longer-term goal is to achieve 90 percent or greater capture at one-half to three-quarters of the cost of ACI technology, and be available for commercial demonstration by 2010. In addition to the stakeholder R&D, in-house NETL researchers are developing several promising new technologies — such as the use of unburned carbon from the host furnace as a mercury sorbent, and the use of ultraviolet light to enhance mercury oxidation. The NETL program also includes assessing the effect of mercury control technologies on reuse and disposal of coal-fired power plant solid by-products (e.g., fly ash), and characterization and modeling of atmospheric reactions of mercury en route from power plant stacks to ambient receptors.

PROBLEMS AND UNCERTAINTIES

Unique configurations of power plants — the variety of coal types and pollution control technologies — require a range of solutions. For example, the combination of selective catalytic reduction (SCR) (which can enhance mercury oxidation) and wet flue gas desulfurization (FGD) (which removes the oxidized mercury) has resulted in very effective mercury removal at some plants that burn high-sulfur bituminous coals. However, the same positive

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"Mercury" continued...

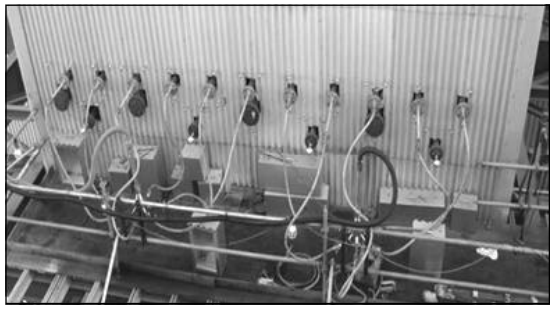
effects do not occur at all coal plants with SCR and FGD, especially those burning subbituminous or lignite coals. Similarly, unburned carbon in fly ash can be beneficial in adsorbing mercury in some cases. Unfortunately, the presence of unburned carbon in fly ash often negates the ability to sell the fly ash for use as a concrete admixture — an important source of revenue for many plants. Removal of mercury from low-rank coals such as lignite is very difficult because of the tendency for mercury in these flue gases to occur in the elemental (Hg^0) versus the oxidized (Hg^{2+}) form; oxidized mercury has been found to be easier to remove from flue gases via ACI or wet FGD technologies.

FIELD TESTING

In September 2000, NETL awarded projects for full-scale field testing of two approaches to mercury control (ACI and wet FGD enhancement) that could meet the program's short-term goals. Results of the field experiments conducted under these projects were presented in the Fall/Winter 2002 edition of *Clean Coal Today*. While the short-term mercury removal achieved in these field tests was encouraging (removals ranged from 51 percent to almost 90 percent), the testing periods were too short to fully assess the long-term balance-of-plant issues (baghouse life, electrostatic precipitator (ESP) performance, effect on by-products). NETL began to address these issues by conducting a one-year performance evaluation of the impact of ACI on the compact hybrid particulate collection system at Alabama Power's E.C. Gaston Plant. However, many long-term questions related to balance-of-plant issues at other facilities still remain.

Building on this, NETL initiated a second phase of field-testing in September 2003 to provide data from a 1–6 month test period. A broader range of coal types and pollution control device configurations such as a smaller ESP, with a particular focus on low-rank coals were used. The goal of eight newly awarded projects is to provide cost and performance data to facilitate the design and operation of commercial demonstration projects.

Five of the new projects deal with the long-term use of dry sorbents to achieve mercury removal. In one of these projects, full scale ACI will be tested at four power plant configurations that are representative of 78 percent of existing coal-fired generation facilities. Two of these projects will evaluate alternatives to ACI at full scale: one will evaluate sorbent performance at plants equipped with ESPs with small size collection areas, and the other will focus on enhancing the effectiveness of activated carbon in capturing mercury in plants burning low-rank lignite coals.



Injection lances deliver activated carbon into flue gas for mercury control

Two additional projects selected in September 2003 are attempting to enhance mercury oxidation upstream of wet FGD systems. A final project will provide long-term testing of a novel "polishing" device (a regenerable, fixed-structure sorbent) designed to remove elemental mercury downstream of wet or dry FGD systems.

Currently, DOE is soliciting proposals that are focused on long-term testing of mercury control technologies for plants burning Powder River Basin, Texas lignite, or coal blends. Proposals are due by April 30, 2004.

NOVEL CONCEPTS: PILOT-SCALE TESTING

Beginning in 2001, pilot-scale tests have been conducted on a wide variety of low-cost novel sorbents using a flue gas slipstream in a small-scale pilot system. The results indicated that mercury capture performance varied, ranging from 5 percent to greater than 90 percent mercury capture, with iodine-impregnated carbon performing the best at low injection rates (e.g., <1 lb/10^6 actual cubic feet (MMacf)). Slipstream tests also have been conducted to evaluate mercury control performance of ACI in conjunction with the advanced hybrid particulate collector (AHPC), a combination ESP and fabric filter (FF) system designed to optimize fine particulate collection. Somewhat unexpectedly, co-combustion of tire-derived fuel (TDF) in the boiler was found to enhance mercury removal; at an ACI rate of 1.5 lb/10^6acf, mercury removal ranged from approximately 65 percent without TDF co-firing to approximately 90 percent with TDF co-firing.

Pilot-scale field-tests also are being conducted to optimize the mercury control performance of two

"multipollutant" control technologies. In one project, an alkaline sorbent will be used in conjunction with flue gas cooling and humidification to take advantage of the fact that mercury can be adsorbed on particles and removed in ESPs much more easily when flue gas temperatures are reduced. The other project is evaluating the electro-catalytic oxidation (ECO) process — a nonthermal, plasma-based reactor designed for the simultaneous removal of SO_2, NO_x, and fine particulate emissions. The ECO reactor can convert elemental mercury to oxidized mercury. Preliminary tests indicate an average mercury removal efficiency of 88 percent across the pilot plant.

Coal Utilization By-Products

To address concerns that mercury captured in coal utilization by-products (CUB) could be reemitted into the environment during disposal or utilization, NETL is sponsoring a number of projects to evaluate potential leaching and volatilization of mercury and other trace metals from CUBs and products manufactured from CUBs such as cement, gypsum wallboard, and manufactured aggregates. Preliminary results indicate that a minimal amount of mercury is leached from CUBs, with less than 1 ppb of mercury detected in all of the leachate samples collected from 14 different coal-fired plants.

Emission Transport and Fate

NETL also is sponsoring research to evaluate the transport and fate of mercury emissions from coal-fired plants. Some of the projects characterize the speciation and reactions of mercury in the plumes of coal-fired plants. Other projects collect field information to determine the extent of local mercury deposition in the vicinity of coal-fired power plants. A particular effort has been under way to model the emission, transport, and deposition of mercury from coal-fired plants in the Ohio River Valley region. If the research indicates that local deposition "hot spots" are unlikely, proposed mercury emissions trading programs could offer additional compliance options for units that may otherwise require costly retrofit technologies.

Storage silo for activated carbon

Potential Program Benefits

In response to regulatory and/or legislative mandates, there appeared to be no question that mercury control technologies will be implemented at many coal-fired power plants over the next 5 to 7 years. The estimated market for mercury control technologies is 320,000 megawatts under President Bush's proposed Clear Skies Initiative. If DOE can help produce lower cost and more effective mercury control technologies, U.S. ratepayers could save $550–800 million per year by 2010.

Regulatory Approaches to Mercury Control

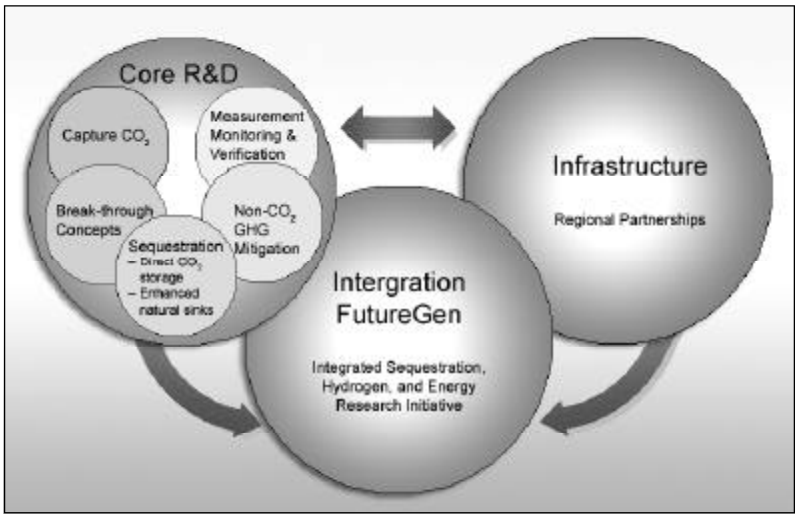
In January 2004, EPA proposed and asked for public comment on two different strategies for implementing mercury emission controls on coal-fired power plants. The first approach would require each major mercury-emitting facility to install the maximum achievable control technology (MACT). The levels of control required under MACT would be determined by the mercury removal efficiencies achieved at the best-performing facilities currently in existence. The second option would be a "cap-and-trade" approach in which the total mercury emissions from electric power plants in the U.S. would be capped at a predefined level that is below the current overall emissions level (now estimated to be 48 tons per year). Individual facilities would either reduce their own mercury emissions or purchase "allowances" from other facilities that already have reduced their emissions. The cap and trade approach has proved to be cost-effective for controlling emissions of SO_2 and NO_x, and is embodied in the Clear Skies Act of 2003 (S. 1844).

Information on the two proposed EPA regulations can be found on the Internet at: http://www.epa.gov/mercury/actions.htm. Information on the Clear Skies Act of 2003 can be found on the Internet at: http://www.epa.gov/clearskies/.

CARBON SEQUESTRATION PROGRAM EXPLORES OPTIONS

Recognizing the importance of carbon sequestration in greenhouse gas mitigation, the U.S. Department of Energy (DOE) established the Carbon Sequestration Program in 1997. The program, administered within the DOE Office of Fossil Energy and the National Energy Technology Laboratory (NETL), has more than quadrupled over the last several years. It directly supports the Global Climate Change Initiative set forth by the Administration, which calls for an 18 percent reduction in the carbon intensity (ratio of greenhouse gas emissions to economic output) of the U.S. economy by 2012.

Technologies are being developed to sequester (or store) greenhouse gases in underground reservoirs, convert them to rock-like, benign solid materials, or enhance absorption by trees, grasses, soils, or algae. The vision of the Carbon Sequestration Program is to develop the scientific understanding of carbon sequestration and provide cost-effective, environmentally sound technologies that ultimately lead both to a reduction in greenhouse gas intensity *and* stabilization of overall atmospheric concentrations of CO_2. Core R&D is undertaken in key areas, with the seven recently established Regional Partnerships (see Fall/Winter 2003 *Clean Coal Today*) providing the infrastructure that will be needed to deploy the various sequestration options where they are appropriate. Core R&D and Regional Partnerships feed directly into the projects to be undertaken under the FutureGen initiative. FutureGen is focused on bringing carbon sequestration technologies to large, commercial scale testing through development of a coal gasification-based IGCC facility incorporating advanced fuel cell, turbine, and membrane technologies in emission-free operation.



The overarching goals of the program are set forth in the roadmap issued in March 2003. Among these goals, the program expects instrumentation and measurement protocols by 2006, at a cost no greater than 10 percent of sequestration system costs; advanced indirect sequestration technology by 2008; a large-scale demonstration of geological storage by 2009; a portfolio of commercial direct capture and sequestration technologies that increase cost of energy services <10 percent by 2012; and finally, direct capture, sequestration systems, and conversion processes for commercial deployment with virtually no net cost increase for energy services by 2018.

Much of the core R&D is performed through competitively awarded, cost-shared contracts with industry and academia. One vital area, *CO_2 capture* technology, is designed to lower capital costs of extracting CO_2 from fuel streams. It includes such techniques as chemical and physical sorbents, membranes, and electrochemical pumps. Strong synergies exist between improved efficiency in fossil fuel conversion and carbon capture. Under the program, capture research is taking place at laboratory and pilot plant scales.

In one important activity, Research Triangle Institute and Church & Dwight Inc. have developed a CO_2 separation technology, which is about to begin pilot-scale testing. The technology captures CO_2 from power plant flue gas. Thermodynamic analysis and preliminary laboratory tests indicate that the technology is viable. Process data has been collected to assess the technical and economic feasibility of various process configurations. Of note, the process also is applicable to removing CO_2 from high-temperature gasification streams.

Once CO_2 is captured, the goal is to somehow store it permanently. *Sequestration* in geologic formations is an area of primary emphasis due to an abundance of potential storage sites (depleting oil reservoirs, unmineable coal seams, and saline formations). American Electric Power and Battelle Memorial Institute are conducting a site assessment to de-

termine the capacity for carbon storage in a deep sandstone saline formation overlain by caprock in the Ohio River Valley. Baseline information is being developed to evaluate the potential for long-term sequestration, including integrity of the overlying rock, and to determine which formations show promise for future injection of CO_2. Benefits also are being pursued in enterprises that combine sequestration with other, more profitable activities. At an unmineable coal seam in Marshall County, West Virginia, Consol and other partners are studying sequestration coupled with coal bed methane production. At the Weyburn project in Canada, sequestered CO_2 is enhancing oil recovery.

In another important activity, the University of Texas at Austin is leading a team to develop criteria for characterizing saline formations for long-term CO_2 sequestration. Current efforts in this project are directed at performing a field test in which a small amount of CO_2 is injected into a deep saline reservoir. The interaction of the plume with the reservoir, and the dispersion of the CO_2 over time, are monitored. An injection of 3,000 tons of CO_2 over a 3-month period is scheduled for later this year.

Terrestrial sequestration projects focus on the integration of energy production, conversion, and land reclamation. In one project, managed by the Virginia Polytechnic Institute and State University, forests are being restored on mined lands in Virginia, West Virginia, and Ohio. The study is exploring the tradeoffs occurring among such factors as maximizing CO_2 uptake, harvesting wood for wood products and biomass energy, and ecosystem benefits — increased biodiversity and recreational value, along with improved water quality. Also in this area of research, the University of Kentucky is demonstrating low compaction surface mine reclamation techniques and carbon sequestration through the growth of high-value trees. Researchers are studying the effects of species, soil type, and handling as a function of CO_2 uptake.

Improvements in *measuring, monitoring and verification (MMV)* techniques are important to accurately establish a baseline for the system, and to study environmental impacts for terrestrial and geologic sequestration. Accurate MMV is requisite to regulatory approvals at the local and state level, and to greater public trust. Each geologic field test includes an MMV component. For example, Strata Production Company and project partners are conducting a comprehensive modeling and site monitoring field test in the West Pearl Queen Field in New Mexico. This project is using a comprehensive suite of computer simulations, laboratory tests, and field measurements to monitor the geochemical and hydrogeologic processes to better understand, predict, and monitor CO_2 sequestration in a depleted sandstone oil reservoir. Approximately 2,100 metric tons of CO_2 — the equivalent of one day's emissions from an average coal-fired power plant — were injected into the formation. Monitoring is taking place following a 6-month soaking period. An important international activity that emphasizes MMV is Statoil's Sleipner offshore project in Norway. For that effort, DOE is working to develop tools for monitoring the CO_2 injected into a saline aquifer.

Revolutionary breakthrough concepts are being pursued for their potential to provide low cost, permanent, globally available sequestration options. The emphasis is on methods that mimic or harness natural processes that convert CO_2 to other carbonaceous substances. NETL and the National Academies of Science (NAS) are working together to expand the research portfolio in this area. In March 2004, eight innovative projects were selected that proposed such projects as advanced separation techniques to capture CO_2 and hydrogen from fossil-fired plants, advanced subsurface technologies and geochemical methods, and CO_2 recycling into value-added products.

Techniques and processes for control of *non-CO_2 greenhouse gases*, such as methane and nitrous oxide (N_2O), also are being pursued. The objective is to integrate the capture of these low net-cost gases with energy production, conversion, and use via such projects as controlled landfills. In one project, ongoing since 1994, the Department of Public Works of Yolo County has been testing an advanced control approach to landfill bioreactors at its Yolo County Central Landfill site near Davis, California. Model data have projected results with attractive implications for new approaches to landfill management. Over seven years, methane recoveries have averaged fivefold over the typical values for comparable landfill waste. In terms of greenhouse benefits, fractional volatile organic compound and methane energy recovery are estimated to exceed 90 percent.

INTERNATIONAL INITIATIVES

CSLF MEETS IN ROME

Nearly 150 members and observers from 14 member countries and the European Commission and five non-member countries gathered in Rome, Italy, from January 20–24, 2004, for the second meeting of the Policy and Technical Groups of the Carbon Sequestration Leadership Forum (CSLF). The CSLF was established in February 2003 by the U.S. Departments of Energy and State for the purpose of international collaboration in carbon capture and storage technologies through data gathering, R&D, and joint projects. The initial meeting of the CSLF and signing of the Charter was held at Tysons Corner, Virginia in June 2003. Under the CSLF charter, the Technical Group reports to the Policy Group, which governs the overall CSLF direction and activities. The Policy Group is chaired by the United States and co-chaired by Australia and Italy. The Technical Group is chaired by the United States, with Canada and Norway as co-chairs.

The Policy Group approved the Terms of Reference and Procedures, outlining the roles and responsibilities of member nations performing under the CSLF Charter. The Policy Group also continued the important process of refining the roadmap, a draft of which was prepared by the Office of Fossil Energy's Import/Export Activities, which acts as Secretariat to the CSLF. The United Kingdom (UK) will develop a framework for the roadmap document, which will be drafted through the joint efforts of the United States and the UK, with the goal of final approval at the next CSLF ministerial meeting in Melbourne, Australia in September 2004. Additionally, 13 carbon sequestration projects were proposed by the Technical Group at the Rome meeting for endorsement by the CSLF. These projects will be evaluated over the coming months, with findings to be presented to the Policy Group at Melbourne.

At the meetings, member countries gave presentations on their expected sequestration needs. These needs vary by country, depending on such factors as geography and energy resources, as well as the economic, legal, and regulatory climates. The Rome meeting resulted in approval of guidelines for projects that could be endorsed by the CSLF, allowing the projects increased international visibility. It was decided that project sponsors must be willing to share non-proprietary project information with other CSLF members. Information from the projects could improve future applications of the technologies by providing data on technical performance, cost, and benefits.

The Secretariat presented an action plan for framing the discussion of issues that the CSLF should explore in the areas of regulatory/legal, financial, stakeholder involvement, public awareness and outreach, and project endorsements. While reinforcing a commitment to geological sequestration, the CSLF did not exclude consideration of any other type of sequestration. Groups at the Rome meeting recommended that further studies be performed of public outreach, project financing, carbon trading, economic modeling, and sequestration in development countries. Case studies in the legal/regulatory area, and a gap analysis of legal issues will be presented at the Melbourne meeting. Italy took charge of a working group to explore stakeholder issues.

For more information on the CSLF, see http://www.cslforum.org/.

U.S.-CHINA COORDINATION CONTINUES

Under the Protocol for Cooperation in the Field of Fossil Energy Technology Development and Utilization between the U.S. Department of Energy (DOE) and China's Ministry of Science and Technology (MOST), the first U.S.-China Low-NO_x Combustion and SO_2 Control Workshops were held in Shenyang, China in November 2003. The 4-day workshops attracted over 150 participants including 41 U.S. representatives from major DOE stakeholders who sell low-NO_x combustion and SO_2 control technologies. Over 100 Chinese from

various government, power utility, and university organizations attended along with representatives from the Chinese State Environmental Protection Administration, and provincial and local environmental organizations. The workshop was organized under the Protocol's Annex IV on Energy and Environmental Control Technologies, and was co-chaired by DOE's National Energy Technology Laboratory (NETL) and China's National Power Plant Combustion Engineering Research Center (NPCC).

In addition to the technical presentations, the attendees toured NPCC's combustion R&D facilities, and a number of U.S. and Chinese companies met to discuss possible commercial cooperation such as joint ventures and licensing issues. A follow-on study tour to the United States will be organized in the spring 2004 so that interested Chinese organizations can tour U.S. power plants where the latest environmental equipment has been installed, and meet with U.S. technology suppliers to discuss business opportunities.

NPCC officials expressed interest in establishing a U.S.-China CO_2 Research Facility at NPCC to strengthen cooperation with the United States on the ongoing joint research on carbon capture and sequestration. NETL presently is cooperating with NPCC on R&D to use aqueous ammonia to capture CO_2 in flue gas from coal combustion (see *Clean Coal Today*, Summer 2003). NETL's lead researcher has visited NPCC and a reciprocal visit by NPCC to NETL is being planned to discuss further cooperation.

Following these activities, a training workshop on coal bed methane (CBM) was organized under Annex III (Oil and Gas) of the Protocol. This event was sponsored by MOST and the China Petroleum and Chemical Industry Association, and organized by the U.S.-China Energy and Environmental Technology Center (EETC) and Chem International. The training, with some 100 Chinese participants, shared the extensive U.S. experience and capabilities in developing and bringing CBM resources to market.

FE CHAIRS APEC EXPERT'S GROUP MEETING IN KOREA

The Asia Pacific Economic Cooperation (APEC) Experts Group on Clean Fossil Energy, chaired by U.S. Department of Energy (DOE), National Energy Technology Laboratory representative Scott Smouse, held a technical and policy seminar, *Technology: Coal's Way Forward*, in Seoul, Korea, December 9–12, 2003. Workshop co-sponsors included the Korea Institute for Energy Research (KIER), which served as the local host, the Korea Ministry of Commerce, Industry, and Energy, the Korea Energy Management Organization, Japan's New Energy and Industrial Technology Development Organization, and the Japanese Committee for Pacific Coal Flow.

Informative Korea workshop focuses on coal power generation

The seminar focused on important commercial and developing fossil energy technologies for power generation (e.g., integrated gasification combined-cycle, and supercritical pulverized coal), carbon capture and sequestration, gasification, and emissions control. A total of 29 presentations were made during the two-and-a-half day event along with opening remarks from high-level government officials from Korea and Japan. After the workshop, a tour of KIER's R&D facilities for CO_2 capture and fuel cells was provided for foreign participants. DOE representatives also met with senior officials at KIER to discuss potential cooperation under a new bilateral agreement, with the initial focus on collaborative CO_2 capture R&D. This agreement, which is being developed, follows a visit to Korea last year by DOE Under Secretary Robert Card, who discussed R&D cooperation on energy technologies important to both countries.

NRC REPORT CITES PRIME HYDROGEN ROLE FOR COAL

Coal offers a key energy security advantage to the U.S. energy mix as a major component of an emerging hydrogen economy, according to a new National Research Council (NRC) report. At the request of the U.S. Department of Energy (DOE), the NRC, part of the National Academy of Science, has released a report, *The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs*. While a complete version of the report is available on-line through the National Academies Press (http://www.nap.edu), following are some of the highlights that relate to coal as a long-term, reliable source of hydrogen for a hydrogen economy.

A massive effort to produce hydrogen could use abundant domestic supplies of U.S. coal resources, and not have to rely on imports. Advanced coal plants of the future could co-produce electricity and hydrogen (i.e., a FutureGen facility), achieving high efficiencies using advanced turbines and fuel cells, while sequestering the by-product CO_2. Overall, the committee's recommendations for coal designate it as a significant component of any domestic R&D program aimed at producing large amounts of hydrogen. DOE was urged to continue its R&D in these areas, while striving to better link its programs of hydrogen, CO_2 capture, and storage. According to the NRC, the hydrogen-from-coal and integrated gasification combined-cycle technology development should be pursued in tandem. Gasification systems, while commercial, need further development with respect to hydrogen production. There also is a need to accelerate the development and evaluation of carbon capture and sequestration technologies. The report gives a strong endorsement of FutureGen as a means to integrate and provide a large-scale test bed for advanced technologies for the production of hydrogen, with CO_2 capture and storage. The importance of public acceptance of all of these efforts is emphasized throughout the report narrative.

Natural gas/distributed generation are expected to dominate markets during a 25-year transition period, the report indicates, with coal then used to produce greater amounts of hydrogen from central stations. Coal plants would need to be large to achieve economies of scale, and demand would have to be sufficient to support large-scale investment. By 2050, coal-to-hydrogen could amount to 13–15 quadrillion Btu/year. Were that the case, by 2050 the United States would need to have sequestered a total of some 20 billion metric tons of CO_2. The NRC notes that carbon sequestration is a critical component of a coal-based hydrogen production activity. However, there appears to be sufficient capacity in geological formations to store this CO_2. NRC saw no insurmountable barriers to development of the needed capture and sequestration technologies.

It is anticipated that, from a cost perspective, technology advances will decrease the costs of hydrogen from coal by some 25 percent. System analyses have indicated that CO_2 capture would add some 10 percent to the cost of producing hydrogen from coal without sequestration. As a result of studies performed by the NRC, the report cites $1.03/kg as the current cost of producing hydrogen from a large central power station. This figure could be brought down to $.90/kg if R&D could lead to such advances as capital cost reduction, standardization of design, reliability improvements, process integration, and oxygen plant optimization, among others. Co-production of electricity and hydrogen would lower costs as would co-capture of CO_2 and sulfur, or other criteria pollutants. Hydrogen from a central power station plant (natural gas or coal) used in fuel cell vehicles can be roughly cost equivalent to gasoline in a hybrid vehicle on a "gasoline-efficiency-adjusted" basis.

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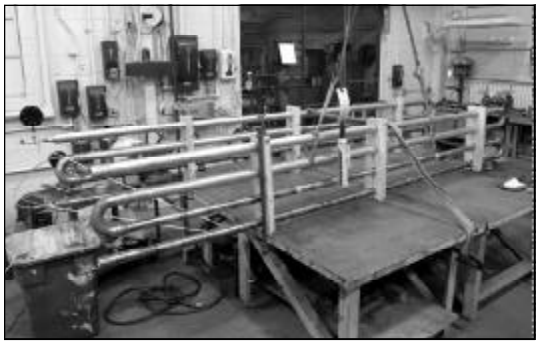
CONSORTIUM MAKES PROGRESS ON MATERIALS DEVELOPMENT

A consortium, which includes Energy Industries of Ohio, the Electric Power Research Institute, Inc., Oak Ridge National Laboratory, and four major U.S. boiler manufacturers (Babcock & Wilcox Company, Riley Power, Foster Wheeler, and Alstom Power), is conducting a five-year materials development program to advance materials technology used in coal-fired power generation. The objective of this program, partially funded by the U.S. Department of Energy and the Ohio Coal Development Office, is to allow boiler operation at much higher temperatures and pressures than are presently used in conventional power plants. These higher operating conditions will enable the use of advanced, more efficient ultra-supercritical (USC) steam cycles in coal-fired power generation, which offers the added advantage of reducing carbon dioxide emissions. As part of this development effort, new high-temperature, corrosion resistant alloys must be evaluated and tested in a hot corrosive coal-fired environment that can produce steam up to 1,400 ºF and 5,000 psi.



Completed USC test loops (shown above) prior to being delivered to the Niles plant for installation

To evaluate the high-temperature fireside corrosion resistance of candidate materials for USC power generation, two super-heater test loops comprised of seven different advanced alloys have been designed and fabricated by the Babcock and Wilcox Company (B&W) in Barberton, Ohio. Both test loops were constructed at the B&W Research Center by welding together 6-inch long tube sections arranged in repeating sequences of six different alloys, including alloy 230, alloy 740, CCA 617, HR6W, Super 304H, and RA333. During construction of the loops, all welds were successfully produced using alloy 625 filler metal, and some of the tube sections were clad with protective weld overlays of alloy 52, alloy 72 or alloy 622.

After fabrication, the two USC test loops were installed during a scheduled outage at the Reliant Energy power plant in Niles, Ohio, which burns high-sulfur Ohio coal. The control system for the loops was specially designed by B&W to ensure that this development activity would not interfere with the normal operation of the power plant. Testing began in December 2003. Throughout the planned 18-month test, steam flow will be controlled to simulate USC boiler design operating conditions with metal temperatures up to 1,400 ºF. Operating parameters during the test will be continuously monitored by B&W engineers using an on-line remote access computer system. During normal outages at the plant, the test loops will be physically inspected within the boiler, photographed, and measured for evidence of wastage. At the end of the 18-month test, the loops will be removed for metallurgical examination by B&W.

Gauge measures water pressure and possible leaks in loop system prior to installation in boiler

For those plants affected by fireside corrosion, test results from this program are expected to enable ranking of materials and selection of optimized alloys for retrofit in the boiler. Test results also should allow estimation of the remaining life of super-heater/reheater tubing, thereby providing the operator guidance on outage planning. It is anticipated that correlation of the corrosion rates with respect to time and temperature will provide further data on optimized operating conditions. By comparing the results of steam loop testing in plants while burning coals with varying sulfur content, a plant operator could select coals to minimize erosion, or at least be able to identify the penalty for using non-optimal coal.

COMPUTER CODE CAN HELP BUILD BETTER FLUIDIZED BEDS

A computer program known as MFIX (Multiphase Flow with Interphase eXchanges), developed at the U.S. Department of Energy's National Energy Technology Laboratory (NETL), helps scientists, engineers, and utility and industrial plant designers to better understand the workings of fluidized-bed combustion systems by describing the hydrodynamics, heat transfer, and chemical reactions inherent in these systems. Historically, scaling of solids flow has been the single most difficult challenge, which equates to risk, in moving solids-based processing technologies to commercial scale. The underlying issues in trying to scale solids flow relate to complex interactions between the solids, entrainment gas, and physical boundaries. Developers have had to resort to full-scale cold flow testing to reduce risk, which is quite expensive.

MFIX expresses detailed mathematical equations in a computer code that can generate their numerical solutions. These equations must then be interpreted. One method of interpretation is to create graphics from the equations, allowing scientists to visualize the inner workings of fluidized beds — the fluid dynamics of the heavily loaded flue gases.

This type of visualization eventually will allow scientists to operate fossil-fueled systems under a wider range of conditions, and will ease the task of moving fluidized-bed technologies from pilot-plant size to large, commercial plants. Fluidized beds can be difficult to scale up, and MFIX equations, if they can be solved accurately, adequately account for scaleup if the appropriate physics have been captured by model equations.

A major problem with progressing from pilot-plant simulations to those of larger-size units is mesh resolution. Accurate simulations on even small-scale systems involve very small computational cells. When scientists understand a tiny cell and the activities within it and the cells around it, they have also captured the local behavior of a large vessel (a fluidized bed). But more and more of these cells are needed to fit the bed's size. The difficulty is keeping the resolution or refinement the same as the vessel gets larger, at which point the computational cost becomes very large.

MFIX programs are large and time-consuming to run, but have a variety of applications that make the code extremely useful. In fossil-fuel processing, MFIX is being used to simulate black-liquor and coal gasifiers by accounting for the type of fuel that is used, tracking air/particle flow, chemical reactions, and process temperature. It also can be used to understand those advanced carbon dioxide sequestration processes that involve fluidized beds. When the flue gas stream is passed through a fluidized bed of absorbent particles, the bed selectively absorbs CO_2, allowing nitrogen and water to escape.

One of MFIX's more recent uses involves NETL and Oak Ridge National Laboratory working together to simulate the preparation of fuel pellets for advance (air-cooled) nuclear reactors. When a reactor burns uranium dioxide (UO_2) fuel, fission products like ash in conventional burning are produced. To ensure reactor safety, the UO_2 must be carefully coated with material to capture the fission product while slowing the speed of the neutrons that are released as the uranium decays. This chemical vapor deposition process is done in a fluidized bed, the behavior of which must be completely understood.

The computer code also has many chemical- and mineral-processing applications, including petroleum cracking. The tallest unit seen at any oil refinery is a "cat cracker," where tons of hot particles are carried upward by the very rapid flow of petroleum. When the petroleum comes into brief contact with the hot particles, the oil "cracks" into smaller molecules that can be separated to make useful products including gasoline, diesel oil, and fuel oil, among others.

Another current application for MFIX is the refinement of silicon. A Washington state company is using the MFIX code to design a plant capable of creating solar-grade silicon.

One of MFIX's more intriguing uses involves predicting the trajectory of rocks that are thrown from an erupting volcano. That is, scientists are attempting to use MFIX to estimate how far magma will be thrown and in what direction, once size and weight are factored in. Its multiple uses have led to more than 250 worldwide applications of MFIX in the last two years alone. Along with documentation and example cases of its use, it is available as open source software from www.mfix.org/.

"News Bytes" continued...

Lockheed Martin, Inc., where he served as a director of communications and public affairs. In Fossil Energy (FE), he will oversee some 1,000 scientists, engineers, technical, and administrative staff at headquarters and field offices across the country, and oversee several high-priority Presidential initiatives.

DOE submitted the ***FutureGen Program Plan*** to Congress in March 2004, detailing the strategy for demonstrating the world's first coal-fired, zero emissions electricity and hydrogen production plant, which also will incorporate CO_2 sequestration. The report was required by the conference report accompanying the fiscal year 2004 appropriations law under which the activity is funded. A full text of the plan can be found at the FE home page at http://www.fe.doe. gov/.

Two of four planned demonstration test burns have been completed at the 300-MW **JEA Large-Scale Circulating Fluidized-Bed (CFB) Combustion Project**. This CCT project hosts the largest CFB combustion unit to operate on a commercial scale anywhere in the world, and is located at JEA's Northside Station, Unit 2 in Jacksonville, Florida. The first test burn, on 100 percent coal (Pittsburgh #8) began January 5, 2004, and was completed January 16, 2004, at 100, 80, 60, and 40 percent of full load. The second test burn on 50 percent coal (Pittsburgh #8) and 50 percent petroleum coke began January 26, 2004, and was completed January 31, 2004, at 100, 80, 60, and 40 percent of full load. Emissions were monitored at each load level during both tests and were well below permitted values.

DOE just made an award to **NeuCo, Inc., the first Round 1 award of the Clean Coal Power Initiative**. In the $19-million project, NeuCo will design and demonstrate an integrated online optimization system at Dynegy Midwest Generation's Baldwin Energy Complex in Baldwin, Illinois. NeuCo will use its Process Link™ technology platform of neural networks, advanced algorithms, and "fuzzy" logic to maximize performance from the power plant's combustor, soot removal system, and emission controls. This would be the first time that all of these modules have been integrated into a computerized process network. Watch for further details on this and other CCPI projects in future issues of *Clean Coal Today*.

On February 17, 2004, DOE announced the release of the second solicitation under the **Clean Coal Power Initiative (CCPI)**. DOE plans to provide approximately $280 million in Federal matching funds for these important projects in support of the President's Clear Skies and Climate Change Initiatives. The CCPI projects also provide the technical foundation for Future Gen. Proposals are due June 15, 2004. The solicitation and explanatory material can be found on the Internet (http://www.netl.doe.gov/coalpower/ccpi/index.html).

UPCOMING EVENTS

April 18–22, 2004
The 29th International Technical Conference on Coal Utilization & Fuel Systems
Sponsors: Coal Technology Association working closely with ASME, DOE, and NETL
Location: Clearwater, Florida
Contact: Barbara Sakkestad
(301) 294-6080
BarbaraSak@aol.com

May 2–6, 2004
Third Annual Conference on Carbon Capture and Sequestration
Sponsors: U.S. DOE, NETL, Monitor Exchange Publications and Forums, U.S. Climate Change Science Program, USDA, and U.S. EPA
Location: Alexandria, Virginia

May 11–6, 2004
SECA Annual Workshop and Core Technology Program Peer Review Workshop
Sponsor: NETL
Location: Boston, Massachusetts

May 18, 2004
Conference on Reburning for NO_x Control
Sponsor: NETL
Location: Morgantown, West Virginia

For information on the May events, contact:
Kimberly Yavorsky
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STATUS OF ACTIVE CCT DEMONSTRATION AND PPII PROJECTS

ENVIRONMENTAL CONTROL DEVICES

Southern Company, Inc. – *Demonstration of Advanced Combustion Techniques for a Wall-Fired Boiler*. The purpose of the project was to evaluate the use of GNOCIS and other computerized process control software to further optimize operation of Plant Hammond Unit 4. The project ended on April 30, 2003. A Final Report and Post Project Assessment has been prepared. (Coosa, GA)

ADVANCED ELECTRIC POWER GENERATION

JEA – *ACFB Demonstration Project.* The second demonstration test burn of 50% coal (Pitt #8)/50% petcoke was completed in the 300-MW JEA large-scale circulating fluidized-bed (CFB) combustion project. The 300-MW project is the largest CFB combustor operating at commercial scale anywhere in the world and is located at JEA's Northside Station, Unit 2 in Jacksonville, FL. The first test burn began January 5, 2004, and was completed 11 days later. The second test burn ran from January 16–31, 2004. Both tests were conducted at 100%, 80%, 60%, and 40% of full load. Emissions were monitored at each load level and were well below permitted values. Four coal blends are being tested as part of the demonstration project. (Jacksonville, FL)

Kentucky Pioneer Energy (KPE), L.L.C. – *Kentucky Pioneer Energy Project.* FuelCell Energy (FCE) has requested a no-cost-to-DOE time extension in order to complete installation and demonstration testing of the fuel cell at the Wabash River site. The FCE Cooperative Agreement (CA) expires May 13, 2004. FCE proposed test program revisions include an increase in the amount of coal gasified during the six month demonstration period to 100% Kentucky coal. KPE will request a no-cost-to-DOE time extension in order to develop additional project information permits and zoning timelines. The KPE CA expires on April 30, 2004. (Trapp, KY and West Terre Haute, IN)

Tampa Electric Co. – *Tampa Electric Integrated Gasification Combined-Cycle Project.* Tampa's Polk Power Station completed demonstration operations at the end of October 2001 with over four-and-one-half years of successful commercial operation. A Final Report has been issued, and the Post Project Assessment is in review. (Polk County, FL)

TIAX (formerly Arthur D. Little, Inc.) – *Clean Coal Diesel Project.* The Usibelli coal-water-fuel (CWF) was successfully tested on the injector bench test stand in December. The bituminous CWF from CQ Inc. was tested on the injector bench test stand during January and February and was found to become a pasty substance during injection. TIAX has been investigating the cause of the problem. Bench scale testing on the rheology of the mixture has shown that a softer base coal and a smaller particle size distribution may be the culprit. TIAX is currently preparing for a test on a two-cylinder engine at Fairbanks Morse in Beloit, Wisconsin. (Beloit, WI)

COAL PROCESSING FOR CLEAN FUELS

Western SynCoal LLC (formerly Rosebud SynCoal® Partnership) – *Advanced Coal Conversion Process (ACCP) Demonstration Project.* In January 2003, Westmoreland Power, Inc. transferred ownership of Western SynCoal LLC to ENPRO, of Butte, Montana. DOE received the draft in March 2004, and is finalizing the report. (Butte, MT)

INDUSTRIAL APPLICATIONS

CPICOR Management Company, L.L.C. – *Clean Power From Integrated Coal/Ore Reduction (CPICOR).* The CPICOR Cooperative Agreement expired on August 30, 2003. Geneva Steel has been notified of the DOE's intent to deobligate the remaining project funds. (Vineyard, UT)

PPII STATUS

Tampa Electric Company, Big Bend Power Station Tampa – *Neural Network Sootblower Optimization Project.* The Pegasus neural network intelligent soot blowing system has been installed and is operating in closed loop mode (without operator supervision) at Tampa Electric's Big Bend Station. Preliminary reduction in NO_x levels in the range of 10–20% and boiler efficiency improvements in the range of 0.5–1% have been observed. Further opportunities for additional improvements have been identified by adjusting soot-blowing sequencing, duty cycles, and finer soot-blower subgroupings. These refinements are being implemented in the model (offline) and will be tested Spring/Summer 2004. (Apollo Beach, FL)

Universal Aggregates, LLC – *Commercial Demonstration of the Manufactured Aggregate Processing Technology Utilizing Spray Dryer Ash.* The Universal Aggregate PPII project, Commercial Demonstration of Manufactured Aggregate Processing Technology Utilizing Spray Dryer Ash, moved into Phase 3 operations on February 1, 2004, and is now in shakedown. A three-month shakedown period is planned with full production starting May 1, 2004. The project is scheduled to end in May 2005. (King George, VA)

Sunflower Electric Power Corp. – *Demonstration of a 360-MWe Integrated Combustion Optimization System*. The combustion optimization sensors package consisting of the Burner Profiler, loss-on-ignition/furnace exit gas temperature (LOI/FEGT) sensors, and carbon dioxide (CO) sensors is operational. Data are being archived on the MKE computer and by EtaPRO, which also collects plant performance data. The low-NO_x burner modifications and coal-balancing dampers have been installed. The coal-balancing dampers on Mill C are operating in automatic mode. System performance is being monitored and data are being archived in EtaPRO. The automated coal flow balancing system on Mill C is operational following resolution of a cable problem. An evaluation of the available data is currently being made to determine the impacts of overfire air on furnace exit gas temperature. (Garden City, KS)

Otter Tail Power Company – *Demonstration of a Full-Scale Retrofit of the Advanced Hybrid Particulate Collector (AHPC) Technology.* The project came on line in October 2002. Operations have shown very good particulate removal efficiency, but at the cost of higher system pressure drop. Performance testing has shown that the average collection efficiency of the AHPC is 99.997 percent. The outlet dust loading is almost two orders of magnitude lower than the guarantee limit of 0.002 gr/acf. However, AHPC system pressure drop also has exceeded guarantee limits and has resulted in premature bag replacement, excessive bag pulsing and premature bag failure. In July and August of 2003, the Big Stone plant exceeded all historic power production levels for those months. The particulate collector remains on-line treating the full flow from the 450-megawatt power plant. The current demonstration period runs through October 2004. (Big Stone City, SD)

NeuCo, Inc. – *Integrated Optimization Software.* This is the first project awarded under Round I of the Clean Coal Power Initiative (CCPI). NeuCo, Inc. of Boston, Massachusetts, a leading provider of optimization software for electric power producers, will design and demonstrate integrated on-line optimization systems at Dynegy Midwest Generation's Baldwin Energy Complex located in Baldwin, Illinois. The optimization modules to be developed will address combustion, sootblowing, selective catalytic reduction (SCR) operations, overall unit thermal performance, and plant-wide profit optimization at all three of the 600-MW coal-fired generating units. Two of these units are cyclone boilers with SCRs, while the third is a tangentially fired boiler. The benefits of this project will include reduced NO_x emissions, increased fuel efficiency, and improved reliability. The increases in the fuel efficiency (heat rate reduction) will also provide commensurate reductions in greenhouse gases, mercury, and particulates. (Baldwin, IL)

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