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CLEAN COAL TODAY

A Newsletter About Innovative Technologies for Coal Utilization

News Bytes

Secretary of Energy Samuel Bodman spoke at the groundbreaking September 10, 2007, of the Southern Company Services, Inc. (SCS) *Demonstration of a 285-MWe Coal-Based Transport Gasifier* project at the Stanton Energy Center in Orlando, Florida. Bodman lauded the project — a first-of-a-kind advanced clean coal electric generating facility — as a major milestone in the Clean Coal Power Initiative. The Kellogg Brown and Root (KBR) Transport Integrated Gasification (TRIG™) technology was developed by SCS at the Power Systems Development Facility in Wilsonville, Alabama, in partnership with DOE and KBR. ◆

On November 9, 2007, the U.S. Department of Energy announced completion of its Final Environmental Impact Statement for the FutureGen Project. A Record of Decision will follow no sooner than 30 days after an Environmental Protection

See "News Bytes" on page 3...

Inside This Issue

Air Quality VI Details Environmental Progress

The International Conference on Air Quality VI, organized and sponsored by North Dakota's Energy and Environmental Research Center (EERC) convened in Arlington, Virginia, over September 24–27, 2007, to discuss key topics related to mercury, trace elements, sulfur trioxide (SO_3), particulate matter and greenhouse gases. Nearly 450 representatives from government, industry, and the research and academic communities attended the conference. In all, 41 states, 13 countries, and 239 organizations were represented. The importance and timeliness of conference topics were underscored by participation of such key officials as the new U.S. Department of Energy (DOE) Under Secretary C.H. "Bud" Albright, Jr., DOE's National Energy Technology Laboratory (NETL) Director Carl O. Bauer, North Dakota Senators Kent Conrad and Byron L. Dorgan, and North Dakota Congressman Earl Pomeroy. The Air Quality conference, which meets every two years, is co-sponsored by the DOE, NETL, the U.S. Environmental Protection Agency (EPA) Center for Air Toxic Metals (CATM), and the Electric Power Research Institute (EPRI).

NETL Director Carl O. Bauer provides keynote remarks.

Over the years, the conference has kept pace with evolving issues. This year a separate track was added for greenhouse gas reduction, with panels on greenhouse gas policy and markets, CO_2 capture and sequestration, and monitoring, mitigation, and verification. As part of the more traditional agenda, panels met every day to address the issue of mercury emissions, regulations and technology development, and coal utilization by-products. A number of presentations addressed mercury measuring/monitoring technologies. Uncertainty exists over the best methods to meet the January 2009 requirement under the Clean Air Mercury Rule (CAMR) for installation and certification of mercury monitoring systems. Particulate matter (PM) was also discussed in various sessions dealing with PM transport, atmospheric chemistry and modeling, health effects, and regional haze concerns. The National Ambient Air Quality Standards (NAAQS) cycle for fine particulates ($PM_{2.5}$) is just

See "Air Quality VI" on page 2...

... "Air Quality VI" continued

beginning and, according to EPA speaker Lydia Wegman, will be the first under a new process which calls for more concise documentation, e.g., a Scientific Assessment instead of an encyclopedic Criteria Document. Processes for SO_3 removal were also discussed in a half-day panel.

In keynote remarks, NETL Director Carl Bauer noted that emissions have gone down since 1970 even though coal consumption has increased. Energy solutions, he said, are complex because strategic components have competing needs. Economic sustainability calls for reduced energy consumption, focusing on efficient and effective use of limited resources. But two other strategic components — energy supply security and environmental mitigation — may require greater energy use. More energy will be needed to serve a growing population, and to power environmental control technologies such as carbon capture and storage. Technical innovation, Bauer suggested, can help to find solutions that can simultaneously meet otherwise competing strategic goals.

Conference discussions showed that government and industry are well placed with technology to address environmental challenges. Mercury removal at the 90 percent level is, according to several speakers, close to being commercial. DOE began its field test program 10 years ago. Fruits of this work, especially in Activated Carbon Injection (ACI) technology, coincide with EPA's mercury regulatory timetable. Phase 1 caps under the CAMR go into effect in 2010. According to the Institute of Clean Air Companies, about 30 GW of coal-fired capacity have procured ACI.

EPA's Robert Wayland discussed the interim findings of EPA's Advanced Coal Technology Working Group, which indicate that carbon capture technology is demonstrated and likely feasible, but integration costs are still uncertain. Technical experts noted progress in pre-combustion processes such as membranes, and oxycombustion is showing promise in pilot tests. Plants such as FutureGen would involve both CO_2 capture and sequestration, while producing electricity and hydrogen. Sequestration via enhanced oil recovery is considered the most near-term storage technology, evidenced by successful large projects such as the Weyburn project in Canada. In the United States and Canada, the seven DOE-sponsored Regional Carbon Sequestration Partnerships have characterized the sequestration resources (some 3,500 billion tons in candidate storage capacity) and published results in the *Carbon Sequestration Atlas of the United States and Canada.* Deep saline reservoirs and unmineable coal seams are considered to have the greatest capacity. Regional partners are undertaking field tests and three projects for large-scale demonstration were just selected. No regulations apply specifically to CO_2 intended for permanent storage underground, but attendees largely insisted that CO_2 is a resource and not a waste. Liability and property rights issues remain, and an important part of the Regional Partnership efforts involve outreach and education to gain public acceptance.

While technological headway is being made, Larry Monroe of Southern Company Generation, and George Offen of EPRI spoke of regulatory uncertainties that obstruct utility decision making and R&D planning. Monroe emphasized that decisions on coal need at least five years lead time, which is difficult in the face of uncertainties over CO_2 regulation and a value for CO_2 credits. Even for known regulations, Offen pointed out that, for each new permit, conditions are becoming increasingly strict. The "big three" of concern, he said, are the Clean Air Interstate Rule issued in 2005 capping SO_2 and NO_X in eastern states; the 2005 CAMR; and the Clean Air Visibility Rule and associated Best Available Retrofit Technology standards. Also important are ozone NAAQS due out early next year, and renewable portfolio standards imposed by some states. Michael Rossler of Edison Electric Institute spoke of the "patchwork quilt" adoption by states of mercury regulations. If too many states opt out of a trading program, some conference participants feared there would not be enough mercury allowances for a Federal trading program to function effectively.

Trading of CO_2 was the topic of an overview given by Annika Colston of Blue Source, LLC, a private equity firm with a portfolio of carbon offsets. Colston described programs for international "compliance" trading, as well as voluntary programs in the United States. Environmental stewardship and preparation for a possible mandatory system may be a motivator in the voluntary market. Colston noted that in order for credits to be monetized, reductions must be beyond business-as-usual. Projects must represent a permanent CO_2 reduction, be unique, and verifiable by a third party.

In terms of $PM_{2.5}$, the NAAQS issued in 2006 retains regulation based on the mass, not type, of PM. Panelists noted interest in "speciated" standards based on specific types of PM based both on source (such as vehicles) and associated health risk. EPA has identified this as one area needing more research.

In all, Air Quality VI provided an excellent overview of the state-of-the-science regarding key pollutants and CO_2, the corresponding regulatory environment, and the technology readiness of mitigation techniques. ■

A Snapshot of the Carbon Market

European Union Emissions Trading Scheme (EU ETS): Launched in 2005, with a cap on GHG emissions from installations representing 40% of total EU emissions. The installations were awarded allowances that permitted them to emit to a certain level. To avoid emitting above the allowance and incurring a penalty, the installation could reduce internal emissions, buy allowances, or buy a small amount of emissions reductions from projects registered under the Kyoto Protocol.

Kyoto Protocol: Ratified in 2004 by 175 countries, with 36 countries required to reduce GHG emissions by an average of 5% below 1990 levels during the commitment period of 2008–2012. The emissions reduction can be achieved at lowest cost using three flexibility mechanisms: 1) Emissions Trading whereby emissions can be created and sold between countries required to reduce emissions; 2) Clean Development Mechanism (CDM) whereby emissions reduction projects are undertaken in the developing world and sold for compliance; and 3) Joint Implementation (JI) whereby a party with a reduction target may implement an emission-reducing project in the territory of another party (in Economies in Transition) and count the resulting emission reduction units (ERUs) towards meeting its own Kyoto target.

U.S. State Schemes: The Regional Greenhouse Gas Initiative (RGGI) is made up of nine Northeastern and Mid-Atlantic States committed to implementing a regional cap and trade program within the power sector. RGGI begins in 2009, and has set an emissions cap at 188 million tonnes CO_2 equivalent. Although other states have announced plans for reducing emissions, including California, none have determined the exact role of carbon offsets or cap and trade.

Chicago Climate Exchange (CCX): CCX members have made a voluntary, but legally binding, commitment to reduce their GHG emissions to 6% below their baseline by 2010. Members can buy and sell Carbon Finance Instruments (measured as tonnes of CO_2 equivalent) on the exchange.

Voluntary Carbon Market: In the absence of regulation, projects that reduce GHG emissions beyond the business-as-usual scenario are being developed and sold on a voluntary basis to buyers, to improve corporate social responsibility, environmental stewardship, or to speculate and learn about a potential future compliance market. A retail sub-sector (a small % of total volume) sells carbon credits directly to end users to offset airline trips, car emissions, home energy use, etc. The majority of carbon credits are sold to large corporations, electric utilities or industry, and financial institutions. The voluntary market is rapidly developing with a number of new project standards emerging.

(Adapted from a presentation by Annika Colston, Blue Source, LLC, September 26, 2007)

... "News Bytes" continued

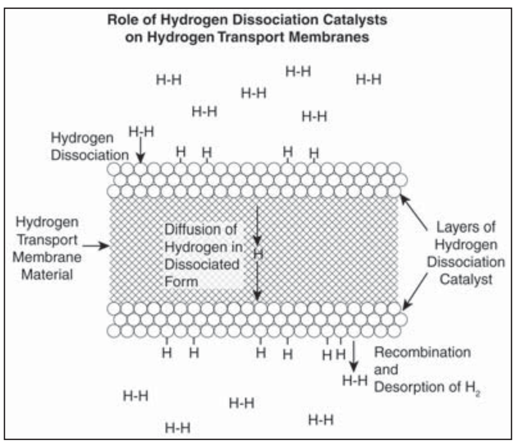
Agency's Notice of Availability is published in the Federal Register. For the EIS, or instructions on ordering a CD or paper copy, see www.netl.doe.gov/technologies/coalpower/futuregen/EIS/. In other FutureGen news, Australia has become the latest international partner to join the Alliance. Participation was announced as part of a Joint Statement on Climate Change and Energy issued on September 5, 2007, by the Prime Minister of Australia John Howard, and U.S. President George W. Bush. ◆

Round III of the Clean Coal Power Initiative is under way, with release October 4, 2007, of the draft Funding Opportunity Announcement, Model Cooperative Agreement, and Model Repayment Agreement. A well-attended public meeting took place November 1, 2007, in Pittsburgh. A final Funding Opportunity Announcement is expected in January 2008. Round III focuses on carbon capture and sequestration technologies. ■

MEMBRANE SEPARATION ADVANCES IN FE HYDROGEN PROGRAM

Since its inception in Fiscal Year 2003 as part of the President's $1.2 billion Hydrogen Fuel Initiative, the Office of Fossil Energy (FE) Hydrogen from Coal Program has sponsored more than 60 projects and made advances in the science of separating out pure hydrogen from syngas produced through coal gasification. For hydrogen applications, recovery of as much hydrogen as possible from the syngas stream is important, as is the removal of contaminants. These contaminants can have deleterious effects on hydrogen utilization technologies — such as fuel cells — that require a highly pure product.

The current process to separate hydrogen from syngas involves several gas clean-up steps, followed by the water gas shift (WGS) reaction to convert carbon monoxide and water to hydrogen and carbon dioxide, and subsequently the separation of hydrogen from the mixed gas stream by pressure swing adsorption (PSA). The PSA process has the disadvantage of parasitic power loss, and up to a 10 percent increase in capital costs. Consequently, the Program is focusing on advanced hydrogen separation technologies, which include membranes, and combining the WGS reaction and hydrogen separation in a single operation known as "process intensification."



Schematic showing the mechanism of hydrogen transport membranes.

TECHNOLOGIES

The separation of hydrogen from syngas using a membrane is a function of several variables, including the flux (rate of flow of hydrogen per square inch of membrane), the pressure differential between each side of the membrane, and the temperature of operation. The flux in turn is affected by a variety of other factors. For example, membrane thickness inversely affects hydrogen flux, so membranes tend to be made as thin as possible. Thin membranes require a membrane support to assure sufficient rigidity during operation. Catalysts, which speed up the hydrogen separation process, may be coated on the membrane's surface or incorporated within the membrane. However, most catalysts are susceptible to poisoning by sulfur and other contaminants in the syngas stream, and eventually become ineffective. Contaminants also affect stability and durability of the membrane in the hot syngas environment. Varying materials and blends of materials within a membrane can make it more stable and durable. Theoretically, an infinite number of candidate membranes may be produced by varying membrane thickness, construction materials and material blends, catalysts, and membrane supports. To minimize the testing necessary to evaluate the performance of each candidate membrane, the program has utilized computational chemistry and thermodynamic modeling of membrane processes. This process has determined optimum materials and material combinations, support materials, and other design parameters.

Program research is investigating several different membrane types: microporous, metallic, and ceramic/metal composites. Microporous membranes act like microfilters to separate hydrogen gas from contaminants. Metallic membranes consist of a thin palladium metal or metal-alloy film layered on a strong support. The metallic film only allows hydrogen atoms to pass through it, thereby blocking out all other contaminants and producing very pure hydrogen. Ceramic membranes can be either pure ceramics or ceramic metal composites (cermets). Pure ceramics separate hydrogen by allowing hydrogen ions and electrons to diffuse through a ceramic matrix and recombine at the other side to form hydrogen molecules. Cermets, depending upon the type of materials used, can separate hydrogen either through the pure ceramic or metallic transport mechanism.

KEY FE MEMBRANE PROJECTS

Most of the projects supported by FE involve separating 99.999 percent pure hydrogen from syngas, which is essential for fuel cell applications. Following are highlights of some of the many noteworthy projects. A major step in the development of a hydrogen separation membrane was recently reported by Eltron Research, Inc. Eltron's proprietary membrane was scaled up and demonstrated in continuous tests conducted for over 11 months on an artificial (or simulated) syngas. Laboratory tests showed a membrane flux of approximately 300 ft3/hr/ft2 at 100 psi ΔP at 300–400 °C, which achieves the

2015 Program flux target but needs to be verified at increasingly larger scale. Eltron plans to scale up from a 1.3 lb/day hydrogen separation unit to a 220 lb/day prototype facility, and eventually to a 4 ton/day unit for engineering-scale demonstration.

The use of vacuum deposition methods for the fabrication of free-standing palladium-alloy membranes is being investigated by the Southwest Research Institute (SwRI), Texas. Free standing membranes do not require supports and seals, thereby reducing overall costs. Using vacuum deposition, membranes are deposited onto flexible supports that can be chemically removed or separated using a water-soluble release agent and recycled after use. To date, SwRI has produced several membranes that are less than 3 µm thick with areas of 110 in^2. The highest hydrogen flux obtained was 242 $ft^3/hr/ft^2$ at 20 psi at 400 °C, with a feed pressure of 20 psig. This exceeds the program's 2010 target for hydrogen flux. Further work involves screening an initial set (six) of ternary alloys using pure gases (hydrogen and nitrogen), fabrication of a minimum of 20 membrane specimens with different copper concentrations for the 2–3 most promising ternary alloys, and production of a minimum of 5 sq. ft. of optimized membrane material for an independent third-party evaluation.

The Gas Technology Institute has developed a single membrane configuration using a new class of dual-phase, microporous and proton conducting membranes. So far, a novel reactor using such membranes has been built as a high-temperature, high-pressure unit.

Another project of interest is that of the Aspen Products Group, which has developed a robust WGS membrane reactor using a contaminant-tolerant WGS catalyst and a palladium-copper (Pd-Cu)-coated tantalum membrane. The system has shown itself to be active and stable in the 300–500 ºC range.

Aspen is also preparing and testing finely dispersed, unsupported and alumina-supported Mo_2C and metal sulfide catalysts, along with the commercial Fe_2O_3-Cr_2O_3 catalysts to identify the most active and stable candidates for the reactor. It will use an electroless plating method to fabricate Pd/Cu-coated Ta membrane tubes with different wall thicknesses and test them for hydrogen separation. Based on the results, Aspen will design, construct and test a small bench-scale WGS membrane reactor that processes one liter of hydrogen/hour to demonstrate their proposed technology. The final stage of the project is a cost analysis to estimate the cost of a membrane reactor and identify potential issues relating to its manufacturing and scale-up.

COMPUTATIONAL CHEMISTRY

Computational chemistry, as well as thermodynamic modeling, is being used to identify promising metal alloys, supports, and catalyst combinations that may be constructed and tested as hydrogen separation membranes. United Technologies Research Corp. utilized atomistic and thermodynamic modeling studies to identify a stable, Pd-Cu trimetallic alloy membrane that should provide commercially viable hydrogen permeation rates in the presence of trace amounts of carbon monoxide and sulfur. The modeling effort extends to the development of a robust WGS catalyst by identifying target catalyst structures and synthesis methods, and determining micro reactor kinetics.

NETL has employed both computational chemistry and laboratory testing to evaluate various sulfur-resistant Pd alloys. These membranes have the potential to meet or exceed the program's 2015 target for sulfur tolerance (>100 ppmv). Preliminary results show that above 635 °C, all Pd-Cu alloys tested exhibited no detectable permeability loss on exposure to 1,000 ppm H_2S. Other WGS gases showed little effect on the hydrogen flux of an 80 wt%/20 wt% Pd-Cu membrane, but certain gas combinations and temperatures affected the membrane surface. A study of 5-day exposures to 1,000 ppm H_2S on different Pd-Cu alloys (100, 80, 60, 53 wt% Pd) showed that a 60 wt%/40 wt% Pd-Cu alloy exhibited the highest permeability at temperatures below 500 °C, but with little sulfur tolerance. The tests also showed that an 80 wt%/20 wt% Pd-Cu alloy exhibited the highest permeability at temperatures above 500 °C with high sulfur tolerance.

Developments in membrane technology can make a key contribution to production of hydrogen from coal in large plants such as FutureGen by recovering increasing amounts of hydrogen from the syngas stream, and by producing high-purity hydrogen for fuel cell applications and a highly concentrated stream of carbon dioxide for sequestration. Membranes show potential to reduce the cost of hydrogen separation, increase process efficiency, and, through process intensification, can simplify the hydrogen-from-coal production process. Further details on FE's hydrogen program are available at http://www.fossil.energy.gov/programs/fuels/index.html. ■

FE Encourages Small Business Research

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) are U.S. Government programs in which federal agencies set aside a specified percentage of their research and development (R&D) funding for competitions among small businesses only. Award recipients keep the rights to any technology developed, and are encouraged to commercialize the technology. For purposes of this program, a small business is one with no more than 500 employees at the time of award. More criteria are provided by the Small Business Administration's Small Business Size Regulations (13 CFR Section 121). Each year, the 11 federal agencies that participate in SBIR and/or STTR set aside 2.5 and 0.3 percent, respectively, of their extramural R&D budgets. Each agency has similar but unique programs tailored to their specific needs. For the Department of Energy (DOE) in Fiscal Year 2007, these set-asides corresponded to $112.7 million and $13.5 million for SBIR and STTR, respectively. The DOE Office of Fossil Energy (FE) share of this was $11.7 million. In addition, DOE's Office of Basic Energy Science funds several FE projects.

DOE issues the SBIR/STTR solicitation annually, and since 2000, these two programs have been part of one solicitation. Proposals are invited in energy production (fossil, nuclear, renewable, and fusion); energy use in buildings, vehicles, and industry; fundamental energy sciences (materials, life, environmental, and computational sciences, and nuclear and high energy physics); environmental management; and nuclear non-proliferation. Proposals are subject to external peer review. During the past six years, small business has shown growing interest in the SBIR/STTR programs, leading to a rise in the number of high-quality proposals.

SBIR and STTR projects begin with Phase I, which explores the feasibility of the innovative concepts with awards up to $100,000 for studies up to nine months in duration. Only Phase I award winners may compete for Phase II, the principal R&D effort, with awards up to $750,000 over a 2-year period. There are over 70 fossil energy-related Phase I and II projects. In Phase III, federal agencies may award non-SBIR/STTR-funded, follow-on grants or contracts, or the companies may proceed with commercialization on their own. Proposal-to-award ratios are about 5-to-1 for Phase I, and 2-to-1 for Phase II.

Precision Combustion, Inc.'s RCL™ catalytic combustor.

Over the 24 years the DOE SBIR/STTR Program has been in operation, 4,413 Phase I projects and 1,816 Phase II projects have been funded. Since 1993, Phase II grant applications have been required to submit commercialization plans. Commercialization assistance and market training also are provided to awardees. Other program enhancements include increased outreach, and data collection on the Small Business Administration Historically Underutilized Business Zones (HUB Zones). Phase II awardees can participate in the annual Commercialization Opportunity Forum, which assists small businesses in developing a business plan and introduces them to potential investors.

Successes

The SBIR/STTR program has provided seed money for a number of fossil energy technologies that are now commercial. One such project is Precision Combustion, Inc.'s breakthrough catalytic combustor, which has demonstrated below 3ppm NO_x emissions when utilized in advanced, natural gas-fueled gas turbine engines. Successful Phase III performance led to full engine trials in 2003/2004. The developed technology is applicable to large utility, industrial, and microturbine gas turbines, and can be utilized in the pilot embodiment or as a full RCL™ catalytic combustor. The full RCL™ catalytic combustor enables lower emission operations of gas turbines without the use of expensive after-treatment systems such as selective catalytic reduction. PCI has been selected as one of Connecticut's fastest growing technology companies by Deloitte and Touche, and has been identified as a Connecticut "Fast Fifty" award winner. PCI also was honored with the Tibbetts Award from the Small Business Administration.

A Phase II award made in 1998 has allowed NexTech Materials, Ltd. to develop key technology for nanomaterials in solid oxide fuel cells. A new coating methodology was developed and applied to the Siemens Westinghouse tubular fuel cell. NexTech is offering a partnership program for supply of materials, components, services, and intellectual property to major DOE contractors involved in the Solid State Energy Conversion Alliance (SECA) program.

SELECTED PHASE II SBIR/STTR PROJECTS	
Project Title	**Firm Name**
Field-Deployable Gas Analyzer for MMV Applications (to determine sequestered CO_2 leakage)	Los Gatos Research
A Low-Energy, Low-Cost Process for Stripping Carbon Dioxide from Absorbents	AIL Research, Inc.
Early Remote Risk Assessment Survey Technology	Physical Optics Corporation
Efficient Treatment of Toxic Metal-Contaminated Wet Scrubber Wastewater from Coal-Fired Power Plants	Lynntech, Inc.
Intelligent Control (boiler-related) of Advanced Power Generation Systems Using Model-Free Adaptive Control Technology	CyboSoft, General Cybernation Group, Inc.
Hybrid Ceramic/Metallic Recuperator for SOFC Generators	Acumentrics Corporation
Novel Supports and Materials for Oxygen Separation and Supply	Eltron Research, Inc.
Novel Surface Modification Method for Ultrasupercritical Coal-Fired Boilers	Inframat Corporation
H_2 Separation Membranes	TDA Research, Inc.
Robust, Low-Cost Membranes for Hydrogen Production from Coal-Derived Syngas	Aspen Products Group, Inc.
Proton Conducting Solid Oxide Fuel Cells	Ceramatec, Inc.
Sorbents for Air Separation	TDA Research, Inc.
Advanced Coal Gasification Systems (chemical looping)	Eltron Research, Inc.
Water-Conserving Steam Ammonia Power Cycle	Energy Concepts Company
High Volume Utilization of Fly Ash Containing Mercury-Impregnated Activated Carbon	Ceramatec, Inc.
Adaptable Sensor Packaging for High Temperature Fossil Fuel Energy Systems	Sporian Microsystems, Inc.
Utilize Cementitious High Carbon Fly Ash (CHCFA) to Stabilize Cold In-Place Recycled (CIR) Asphalt Pavement as Base Course	Bloom Consultants, LLC
Foil Gas Bearing Supported High Speed Centrifugal Blower	R&D Dynamics Corporation
Low-Cost Hot Anode Recycle Blower	Phoenix Analysis and Design Technologies
Development of Electrically Mediated Electrophoretic Deposition for Thermal Barrier Coating System	Faraday Technology, Inc.
Nanostructured Coatings by Pulsed Plasma Processing for Alloys Used in Coal-Fired Environments	Karta Technologies, Inc.
An Economic Process for Coal Liquefaction to Liquid Fuels	Specialties Group, Inc.
Accelerated Biomethanation of Sequestered Carbon Dioxide and Paraffin in Coal Beds	Altuda Energy Corporation
Multicontaminant Warm Gas Cleanup	TDA Research, Inc.
Optimization of Metal Alloys for High Pressure Hydrogen Separation Membranes	Eltron Research, Inc.
Membrane-Based Hybrid Process to Capture CO_2 from Warm Flue Gas	Chembrane Research and Engineering, Inc.
Rigorous Screening Technology for Identifying Suitable CO_2 Storage Sites	Advanced Resources International, Inc.
Multiple-Input Data Acquisition System (MIDAS) for Measuring the Carbon Content in Soil Using Inelastic Neutron Scattering	XIA, LLC

In other important work, Alchem Field Services, Inc. was awarded a Phase II grant in 2005, and has developed a technology for capturing methane emissions from landfills and converting nearly 100 percent of these emissions into a high-quality synthetic diesel fuel, using a commercially viable gas-to-liquids (GTL) process. This proprietary GTL technology, now being used in oil and natural gas fields, will be adapted for use with municipal solid waste landfills. As a result, Alchem won the Tibbetts Award for 2006 in recognition of significant achievements involving technological innovation related to the federal SBIR program.

Still another success is Carbozyme Inc.'s novel gas separation membrane — awarded a Phase II grant in 2003 and a Phase III grant in 2006 — which features high permeance (flux), selectivity, and efficiency, as well as potentially low energy costs for removing CO_2 from flue gas. The ability to enrich CO_2 streams up to 90 percent was demonstrated in the laboratory. The membrane scrubber should provide a safe, environmentally friendly, economical, and efficient method for capturing CO_2, the key greenhouse gas, thereby reducing global warming.

For additional information, including upcoming conferences, refer to the following websites: http://sbir.er.doe.gov/sbir/ and http://www.sbirworld.com/ ■

RECS Student Sequestration Program

The 2007 Research Experiment in Carbon Sequestration (RECS) met at the Montana State University (MSU) and a variety of field sites over the 10-day period of July 29 – August 10. This year's group consisted of 17 students from graduate and doctoral programs in the United States and Canada, as well as early career professionals in fields related to carbon mitigation. Appropriately, because greenhouse gas reduction and storage is a global problem, the group included seven international students — from France, Iran, Paraguay, Turkey, Russia, and India. RECS is a first-of-a-kind classroom instruction and field program in carbon sequestration, and is a collaborative effort between MSU's Big Sky Carbon Sequestration Partnership, MSU's Zero Emissions Research and Technology Center (ZERT), Los Alamos National Laboratory (LANL), and EnTechStrategies, LLC. EnTech's managing partner, Pamela Tomski, founded the program in 2004 and serves as RECS program director. RECS was sponsored in 2007 by the U.S. Department of Energy's Office of Fossil Energy, with support from PPL Montana, the State's leading electric utility. Previous RECS programs were held in Santa Fe, New Mexico in 2004 and 2005. To date, the RECS program has graduated over 60 students from 15 different countries, and is starting an active alumni networking group.

Somayez Goodarzi displays a poster on her doctoral research in geomechanical effects of CO_2 sequestration. Jason Deardorff (left) is also researching CO_2 sequestration in geological media.

Classroom talks featured experts from academia, government, national laboratories, and the private sector, who discussed carbon capture and storage technologies and related policy issues. Then, students traveled to Colstrip, Montana to visit PPL Montana's coal-fired power plant and view the local geology along the Montana/Wyoming border. Finally, students spent several days in hands-on work at ZERT, using carbon dioxide (CO_2) detection and monitoring equipment.

The several-day geology field trip allowed students to understand how various geologic features in surface outcrops were formed, and their potential impact on the integrity of subsurface CO_2 storage. The group visited the Elk Basin Oil Field and Clarks Fork Canyon on the Wyoming-Montana border. The well-exposed and accessible Elk Basin Oil Field gave participants an opportunity to learn about the geologic structure of a typical Rocky Mountain oil-producing anticline, and gain an understanding of its structural geometry through the distribution of outcrops surrounding the field. Fracture patterns in surface outcrops were described in the context of how they may affect the integrity of a geologic carbon storage site. Following this, the group traveled to the mouth of the Clarks Fork Canyon along the southeast front of the Beartooth Mountains. This spectacular locality helped participants understand the regional distribution of oil and gas fields in the central Rocky Mountains, which are potential carbon storage sites.

Another visit included the west flank of Sheep Mountain anticline in the eastern Bighorn Basin. This deeply eroded structure is breached to the level of Paleozoic reservoir rocks that will likely be the host rocks for carbon sequestration in more deeply buried structures in the region. This locality provided an unparalleled, close-up view of the primary sequestration reservoir rocks (fracture patterns, lithology, porosity, permeability).

Returning to the MSU campus at Bozeman, students prepared for hands-on field work at ZERT. The ZERT is funded by DOE and headed by Dr. Lee Spangler, who also heads the Big Sky Regional Partnership and serves as RECS technical co-Director (along with Julianna Fessenden of LANL). ZERT began operating last December, and is the only educational test facility of its type in the country. The students learned how to measure carbon movement in the near-surface environment, and used various techniques to track the carbon plume and examine water chemistry, CO_2 concentration and flux (concentration over time), plant response using hyperspectral analyses and microbial population changes.

Students used two devices to measure CO_2 flux, or concentrations over time. In one, a tunable diode laser and a detector are contained in a housing placed two inches above ground, directly above the underground pipe. Light is bounced off mirrors 30 feet away. Interference with the light beam will indicate CO_2 leakage to the atmosphere. RECS students also tested an infrared gas analyzer.

See "RECS" on page 13...

CASE STUDIES ON RECENT FOSSIL-FIRED PLANTS

The Clean Coal Centre (CCC), established in 1975 under the auspices of the International Energy Agency (IEA), is a collaborative project funded by member countries and industrial sponsors that provides impartial information and assessment services on coal technologies. Products include topical reports on all aspects of coal use, and on-line databases of coal information as well as facilitation of R&D. The U.S. Department of Energy is a major contributor to the program.

The Plan of Action on Climate Change, from the Gleneagles G8 Summit of World leaders in July 2005, mandated the IEA, among other actions, to:

"… carry out a global study of recently constructed plants, building on the work of its Clean Coal Centre, to assess which are the most cost effective and have the highest efficiencies and lowest emissions, and to disseminate this information widely …."

Behind the request was the recognition that an effective, economic way to minimize growth in emissions of CO_2 from fossil-fired power generation is to ensure that new plants, being built to meet demand growth and replace old capacity, be as efficient as possible. High efficiency design will be equally as important in carbon capture plants. The work was carried out by the IEA Clean Coal Centre. Findings are being disseminated at conferences and workshops and through a report, to be issued shortly.

Recent coal-fired power plants of high efficiency use pulverized coal combustion (PCC) with supercritical (S/C) or ultra-supercritical (USC) steam turbine cycles, so most of the case study units were of this type. Examples were chosen from four continents, because local factors (such as ambient conditions, cooling water availability and temperature, coal type) influence attainable efficiency. To cover such effects, it was necessary to include two subcritical units. There was no recently built example of a coal-fueled integrated gasification combined-cycle (IGCC) plant using a modern syngas combustion turbine. So, to ensure inclusion of this potentially important technology, a review of IGCC developments was included instead of a specific case study. There also was a case study of a natural gas-fired combined-cycle plant to facilitate comparisons.

Most of the plant data and descriptions were collected by questionnaire and site visits. Some information was obtained from published sources. Information gathering was carried out during 2006, and was followed by analysis and report preparation. The report underwent several stages of peer review.

CASE STUDY PLANTS

The plants in Europe were a cold sea water-cooled plant fired on internationally traded bituminous coals (Nordjylland 3, Denmark), and an inland, lignite-fired unit in Germany (Niederaussem K). Both are leading examples of USC systems. The case study plant in Canada (Genesee 3) is the first sliding pressure supercritical unit in North America, and fires sub-bituminous coal.

In Asia, three plants were included. In Japan, Isogo New Unit 1 has near-zero conventional emissions and the highest steam conditions in the world among operating sliding pressure USC units. The first two S/C units at Younghung Thermal Power Plant in the Republic of Korea illustrate the progression in steam conditions there, and the first two units at Wangqu in China mark a development in firing low-volatile coals in S/C systems. The subcritical plants in India, at Suratgarh, and South Africa, at Majuba, cover high-ash coal burning in difficult locations, with Majuba illustrating the use of dry cooling. The gas-fired plant at Enfield in the UK has an advanced reheat combustion turbine. Table 1 summarizes information on the plants. Following are a few highlights.

MOST EFFICIENT PLANTS

The most efficient plant is the Nordjylland 3 unit in Denmark. This is a USC system with double reheat and cold sea-water cooling. Double reheat was selected for its ability to keep the steam wetness in the low-pressure turbine sufficiently low to prevent erosion while enhancing efficiency. Nordjylland 3 also exports heat, but the 44.9 percent HHV efficiency is for power-only mode. The world's most efficient lignite-fired plant is Niederaussem K in Germany. The 37 percent HHV efficiency has been achieved through a combination of USC steam conditions with novel heat recovery arrangements. It was notable that the operating efficiencies of the base-loaded plants generally lay close to design values.

CURRENT PRACTICE

PCC projects now use S/C or USC conditions as a matter of routine to

See "CCC" on page 10...

... "CCC" continued

Table 1. Case study plants with some summary data

Plant (commissioning date), capacity, technology	Suppliers: boiler; turbine	Coal	Capital cost, US$/kW (net)	Achieved emissions at 6% O_2, dry	Steam conditions MPa/°C/°C(/°C)	Annual operating efficiency, net, %, HHV basis	Factors affecting efficiency and other comments
Europe – Denmark: Nordjylland 3 (1998) 384-MWe USC	FLS miljo/BWE, Aalborg Industries, Volund Energy Systems; GEC Alsthom (now Alstom)	International bituminous	No data. 1,500 (2006) for new 800-MWe excluding owners costs or IDC	NO_x 146 mg/m^3 SO_2 13 mg/m^3 Dust 18 mg/m^3	29/582/580/ 580	44.9 (not annual)	High steam parameters Cold sea water cooling Double reheat Low auxiliary power Extremely low emissions No solid waste for disposal
Europe – Germany: Niederaussem K (2002) 965-MWe USC	EVT (now Alstom), Babcock and Steinmüller (today HPE); Siemens	Lignite	1,175 (2002) Total project cost	NO_x 130 mg/m^3 SO_2 <200 mg/m^3 Dust <50 mg/m^3	27/580/600	37 (base load)	Lignite fuel, 50–60% moisture content High steam parameters Large cooling tower for low condenser pressure Innovative heat recovery Low auxiliary power Lignite drying demonstration
North America – Canada: Genesee 3 (2005) 450-MWe S/C	Babcock-Hitachi	Sub-bituminous	1,100 (2005) Overnight cost	NO_x 170 mg/m^3 SO_2 295 mg/m^3 Dust 19 mg/m^3	25/570/570	39.6 (base load)	Moderately high steam parameters Low auxiliary power First N American sliding pressure supercritical Sub-bituminous coal
Asia – Japan: Isogo New Unit 1 (2002) 568-MWe USC	IHI; Fuji Electric (Siemens)	International bituminous	1,800 (2006) Total project cost	NO_x 20 mg/m^3 SO_2 6 mg/m^3 Dust 1 mg/m^3	25/600/610	40.6 (base load)	Extremely low emissions High steam parameters Moderately warm sea water cooling Low auxiliary power No solid waste for disposal
Asia – Korea: Younghung (2004) 2 x 774-MWe S/C	Doosan Heavy Industries & Construction Co.	International bituminous	993 (2003) Basis uncertain	NOx 83 mg/m^3 SO_2 80 mg/m^3 Dust 10 mg/m^3	25/566/566	39.7 (capacity factor not known)	Moderately high steam parameters Very low emissions Low auxiliary power
Asia – China: Wangqu 1, 2 (2006) 2 x 600-MWe S/C	Doosan Babcock; Hitachi	Chinese lean	580 (2006) Overnight cost	NO_x 650 mg/m^3 SO_2 70 mg/m^3(des) Dust 50 mg/m^3	24/566/566	40 design	Moderately high steam parameters Low auxiliary power Advanced low-NO_x lean coal combustion system
Asia – India: Suratgarh 1-5 (1998–2002) 5 x 227-MWe Sub-crit (drum)	BHEL	~30% ash	822 (2002) Basis uncertain	SO_2 unabated Dust 50 mg/m^3 (unit 5)	15/540/540	32.1 (base load)	Subcritical cycle High ash coal
Africa – South Africa: Majuba 1–6 (1996–2001) 3 x 612-MWe (dry) 3 x 669-MWe (wet) all sub-crit (once-through)	Steinmüller; Alstom	~30% ash	410 (2001) Total project cost	SO_2 unabated Dust 50 mg/m^3	17/540/540	32.8 (two-shifting)	Subcritical cycle High ash coal Dry cooling from water supply constraints
Europe – United Kingdom: Natural gas: Enfield (2002) 373-MWe Advanced GTCC	Alstom	Natural gas	950 (1999) Total project cost	NO_x 128 mg/m^3 SO_2 negligible Dust zero	Reheat GT 3 pressure R/H ST	47 (40% capacity factor)	Combined-cycle with reheat gas turbine Low auxiliary power Zero solid waste
IGCC general review 300-MWe/module			PCC+20%	NO_x 50-75 mg/m^3 SO_2 ~20 mg/m^3 Dust <1 mg/m^3	IGCC	38–41	Combined-cycle Syngas-fired gas turbine Inert solid waste

USC: ultra-supercritical (steam temperatures of 580 °C and above); S/C: supercritical; sub-crit: subcritical achieve high efficiency. Materials developments have resulted in steels that have given high availabilities, for example over 96 percent at Isogo. The extent of confidence of utilities in using high steam conditions is illustrated by the fact that many are building sister units using higher parameters. These systems can be purchased for a wide range of coal types. Wangqu showed that even low-volatile coals can be successfully wall-fired in S/C systems. In Canada, Genesee 3 fires an Albertan sub-bituminous coal in a modern sliding pressure S/C plant, and the USC Niederaussem K fires a lignite of 50–60 percent moisture content.

Flexibility and Innovation

All modern plants need flexibility. Although new units are generally operated at high capacity factors, this cannot be depended on in the deregulated environments in which most generators have to compete. Sliding pressure S/C and USC systems have good efficiency at reduced output.

Improved thermodynamic cycles have evolved as a result of innovation by utilities and manufacturers. Examples are the double reheat cycle at Nordjylland 3, and the heat extraction and utilization systems on Niederaussem K. In the latter, one new feature is heat extraction downstream of the air heater in a flue gas cooler utilizing non-metallic components to avoid corrosion. Another innovation is a lignite drying demonstration on 25 percent of the fuel flow, using low-grade heat from the plant, and returning much of this for low-pressure feedwater heating. When applied to the full flow of a plant, a four percentage points efficiency improvement would be realizable.

Near-Zero Emissions

It is well known that IGCC can achieve very low levels of dust and SO_2. What is less well recognized is that emissions from PCCs can also be taken to very low levels. The following performance was achieved among some of the PCC case study plants using conventional systems: **Particulates**: emissions down to ~10 mg/m^3 (~0.008 lb/MMBtu) even with ESPs; **SO_2**: Limestone/gypsum FGD capable of getting SO_2 below 20 mg/m^3 (~0.02 lb/MMBtu); **NO_X**: Combustion measures (LNBs and OFA) plus SCR capable of NO_X of 50–100 mg/m^3 (~0.04–0.08 lb/MMBtu).

The most impressive environmental performance was at Isogo, where the dry regenerable flue gas desulfurization system (known as ReACT) also removed further dust and NO_X emerging from the conventional systems, resulting in extremely low emissions: **NO_X**: 20 mg/m^3 (~0.02 lb/MMBtu); **SO_X**: 6 mg/m^3 (~0.005 lb/MMBtu); **Particulates**: 1 mg/m^3 (~0.001 lb/MMBtu).

ReACT is now being marketed abroad for multi-pollutant control, including mercury.

Costs

Although the capital costs of power projects have been rising sharply since these units were built, some trends remain relevant. PCC-specific capital costs, after bringing to a common basis, were observed broadly to correlate with steam parameters and with efficiency, reinforcing the subjective view that one "gets broadly what one pays for." Construction times varied from three to five years, depending on site constraints.

Technology Comparisons

IGCC could play a major role if recent commercial offerings succeed. However, the technology still has hurdles to overcome, including higher capital cost, lower availability, and lack of recent orders. Both PCC and IGCC system suppliers are likely to be able to offer systems approaching 50 percent efficiency in about 10 years, and both can be supplied now to be CO_2 capture-ready. Natural gas-fired combined-cycle plants are more efficient, less expensive, and quicker to construct than systems based on coal, but coal-fired generation is likely to remain more economic because of relative fuel costs.

High coal costs, tightening environmental standards, and the need for operational flexibility have led to continuing advances in PCC with adoption of new steels and innovative water/steam cycles. This process is continuing, with efficiencies and emissions improving all the time. At a time when IGCC is receiving much attention, it is important to ensure that clean combustion technologies also remain available as one of the platforms for future carbon capture plants.

Further information on IEA CCC reports and its other products can be viewed on the Centre's website at: http://www.iea-coal.org.uk

The full report on the G8 case studies prepared by the Clean Coal Centre will be published shortly by the IEA: http://www.iea.org

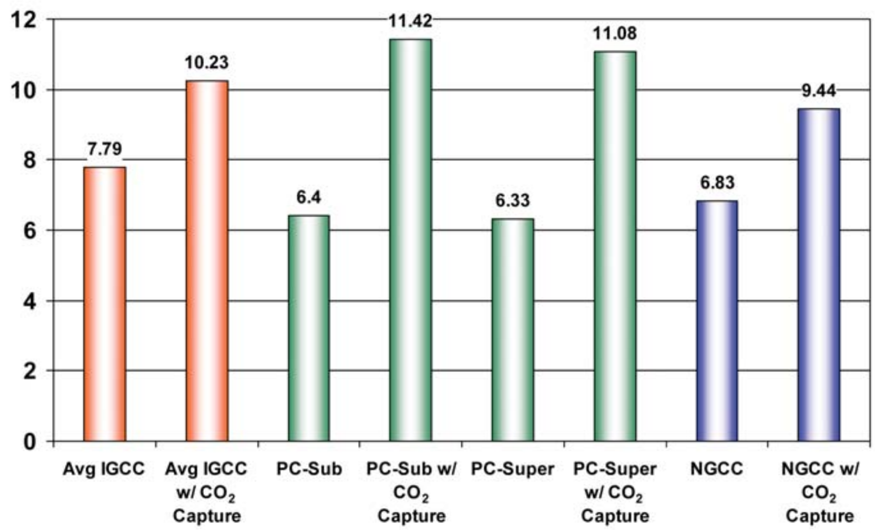
Colin Henderson, who wrote this article, is a senior author and consultant to the IEA CCC. He led the G8 case studies work. ■

SYSTEM STUDIES GUIDING FOSSIL ENERGY RD&D

The U.S. Department of Energy Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL) performs system studies to provide guidance to managers of FE's research, development and demonstration programs (RD&D). Examples of recently completed studies are described below, all of which may be accessed on NETL's website: http://www.netl.doe.gov/energy-analyses/ref-shelf.html.

Cost and Performance Baseline for Fossil Energy Power Plants–Volume 1: Bituminous Coal and Natural Gas to Electricity (May 2007): This study established the baseline cost and performance for state-of-the-art power generation plants that are fueled with bituminous coal or natural gas. Each type of plant was modeled with and without the capture of carbon dioxide (CO_2). This baseline data is essential for guiding the FE RD&D Program because it establishes the key environmental and economic benchmarks that new technologies must surpass in order to justify the investment required for their development. Comparing projected or measured performance against the baseline data allows research managers to efficiently screen out less promising concepts while quantifying the benefits of technology breakthroughs. The baseline data also is critical for informing energy policy decisions that relate to the cost and performance of the current generation of new power plants. NETL plans to complete two additional volumes that will focus on: i) the conversion of coal to substitute natural gas, and ii) the conversion of low-rank coals (sub-bituminous and lignite) to electricity.

Increasing Security and Reducing Carbon Emissions of the U.S. Transportation Sector: A Transformational Role for Coal with Biomass (August 2007): NETL is investigating how the synergistic benefits of co-gasifying coal and biomass, along with the use of carbon capture and storage (CC&S), can enable the nation to utilize secure, domestic energy resources while reducing greenhouse gas emissions. This study, conducted jointly with the U.S. Air Force, estimated the cost and performance of a facility that converts coal, together with biomass, into liquid transportation fuels while capturing and sequestering carbon dioxide. The study concluded that utilizing a modest amount of biomass (7–11% by energy or 10–18% by weight) in a coal-and-biomass-to-liquids (CBTL) facility with CC&S could meet the Air Force goal of limiting life-cycle greenhouse gas emissions to a level 20 percent less than that of the conventional petroleum production pathway. Furthermore, the analysis found that such a facility would be competitive when crude oil prices are at or above about $60 per barrel. Although this study did not assign a value to the captured CO_2, the economics would be improved if revenues were obtained from enhanced oil recovery.

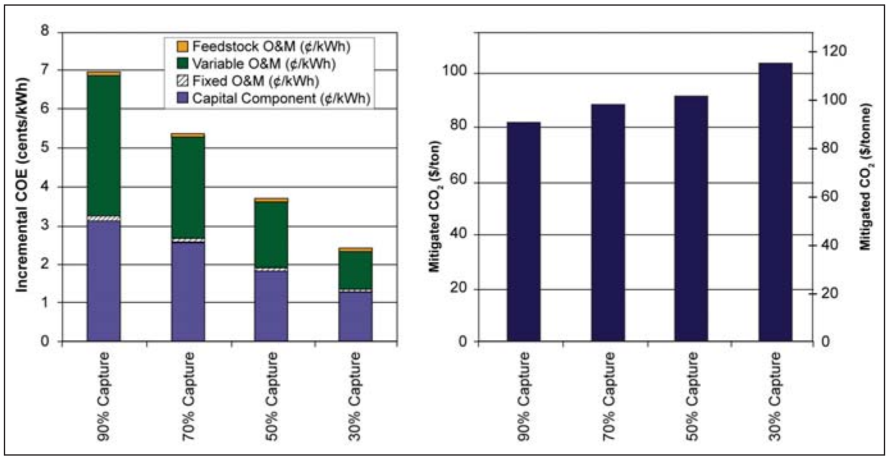


Cost of Electricity Comparison (May 2007 baseline study)
January 2007 dollars, Coal cost $1.80/10^{6}Btu. Gas cost $6.75/10^{6}Btu

Industrial Size Gasification for Syngas, Substitute Natural Gas, and Power Production (April 2007): Fluctuating natural gas prices can significantly impact energy-intensive industrial gas processes. Industrial-scale coal gasification offers the opportunity to provide such processes with synthesis gas or synthetic natural gas (SNG) that is derived from plentiful, and price stable, domestic coal resources. This study evaluated the technical and economic viability of using industrial-scale gasification to refuel energy-intensive U.S. industries that have been challenged by the volatility and magnitude of domestic natural gas prices.

Conceptual plant designs were assessed for different refueling scenarios based on the BGL 1000 (British Gas Lurgi) gasifier — a dry feed, fixed bed, slagging gasifier that can gasify essentially all of the coal types mined in the United States. Judging from the energy and environmental profiles the study developed for potential U.S. industrial customers, there are a large number of industrial plants (100–200) whose natural gas energy consumption rate is greater than the syngas or SNG output of a single BGL 1000 gasifier. Some of these plants may be in areas where site constraints may inhibit installation of coal gasification facilities on-site; however, it is likely that a large number will be acceptable candidates, or can be served by remote location of the gasification plant.

Carbon Dioxide Capture from Existing Coal-Fired Power Plants (December 2006): This study evaluated the technical and economic impacts of removing CO_2 from an existing pulverized coal (PC) power plant using an amine-based, post-combustion CO_2 capture system. The power plant analyzed in the study, American Electric Power's Conesville Unit 5, is a 30 year-old, subcritical PC plant with a nominal 450 MWnet output, and is considered a good representation of the current fleet of coal-fueled power plants. The addition of CO_2 scrubbing impacts the power plant performance in two ways. First, steam that could be used to generate power must be used for CO_2 solvent regeneration. Second, significant auxiliary power is required by the CO_2 capture and compression systems. The study investigated the performance and economic impacts of retrofitting an existing plant for various levels of CO_2 capture (30, 50, 70, and 90 percent), establishing greenhouse gas reduction benchmarks to help guide related Fossil Energy RD&D programs.



Impacts of Retrofitting Existing Plants with CO_2 Capture

As shown in the above figure, retrofitting for 90 percent CO_2 capture is projected to add about seven cents per kilowatt-hour to the cost of producing electricity. Furthermore, the incremental costs of carbon capture and CO_2 mitigation were found to have an almost linear relationship with the CO_2 capture level. Because significant improvements are expected in amine solvent regeneration, sensitivity to this variable was analyzed. The results of this study also will serve as a foundation for follow-on studies that explore the impact of widespread CO_2 capture across the entire U.S. fleet of coal-fueled power plants. ■

... "RECS" continued

A closed chamber, which looks like an inverted bucket, is placed over the ground to trap air that then is pumped into the analyzer. Within the closed chamber, CO_2 absorbs the light coming from the laser. Researchers take measurements every 10 meters as the closed chamber is moved over the terrain. To study plant response, students used hyperspectral analysis. Sunlight reflects off the plants to a camera, and the amount of reflected light indicates degree of plant stress from CO_2. Microbial DNA analysis was another part of plant study. Some microbes are known to thrive in the presence of CO_2, so the discovery of such microbes indicates a leak.

On the final day, students had the opportunity to make presentations on their own areas of academic research or professional activity. RECS plans to hold another program next summer and is inviting corporate sponsors and interested students and faculty. See the RECS website at: http://www.recsco2.org.

The 2007 RECS students: *Ben Bryant,* Pardee RAND; *Benjamin Court,* Princeton University; *Jason Deardorff,* Colorado School of Mines; *Andrea Feldspauch,* Texas A&M; *Brookie Gallagher,* Georgia State; *Somayeh Goodarzi,* University of Calgary; *Tim Grant,* DOE's National Energy Technology Laboratory; *Craig Griffith,* Carnegie Mellon and NETL; *Jonathan Levine; David Mann,* National Hydrogen Association/Technology Transition Corp.; *David McCollum,* University of California-Davis; *Juan Nogues,* Princeton University; *Egemen Ogretim, Cesar Silva*, West Virginia University; *Artur Usanov,* Pardee Rand; and *Preeti Verman*, World Resources Institute Climate Change and Energy Program. ■

ACTIVE CCT DEMONSTRATION, PPII, AND CCPI PROJECT STATUS

CCT DEMONSTRATION STATUS

Kentucky Pioneer Energy (KPE), LLC – *Kentucky Pioneer Energy Project*. The Cooperative Agreement has expired. The Draft Final Report is in progress. (Trapp, KY and West Terre Haute, IN)

TIAX, LLC (formerly Arthur D. Little, Inc.) – *Clean Coal Diesel Project.* The Post Project Assessment is in review. The project is in close-out. (Fairbanks, AK and Beloit, WI)

PPII STATUS

Universal Aggregates, LLC – *Commercial Demonstration of the Manufactured Aggregate Processing Technology Utilizing Spray Dryer Ash.* The Cooperative Agreement for this project expired on December 31, 2006. Universal Aggregates continues to make equipment modifications to improve throughput capacity and to extend the continuous run time of the plant. The Universal Aggregates project team submitted the Final Report in September 2007. The plant is producing and selling lightweight aggregate to the concrete block industry. (King George, VA)

CONSOL Energy Inc. – *Greenidge Multi-Pollutant Control Project.* Testing of the emissions control systems installed in Unit 4 of the AES Greenidge plant in Dresden, NY, has verified that the plant meets the guaranteed performance parameters warranted by the technology suppliers. Plant operators are currently establishing operating settings and injection rates for optimum performance across a range of operating conditions, including output capacity. A series of performance tests are scheduled to be conducted over the next 12 months to measure the longer-term effectiveness of the emissions control systems. (Dresden, NY)

CCPI STATUS

MEP-I LLC (Excelsior Energy Inc.) – *Mesaba Energy Project.* Excelsior's application for pre-construction site environmental permits continues through the Minnesota Public Utilities Commission (MPUC) approval process. The application included requests for a large electric power generating plant site permit and routing permits for a high voltage transmission line and natural gas pipeline. Also included was Excelsior's request for air and water-related permits. The Draft Environmental Impact Statement, prepared jointly with the Minnesota Department of Commerce, has been released and public hearings are scheduled for November 28–29, 2007. The MPUC is also considering Excelsior's petition for approval of a Power Purchase Agreement (PPA) with Northern States Power (i.e., Xcel Energy), per the Minnesota Innovative Energy Project and Clean Energy Technology statutes. The MPUC has not issued a ruling but has directed Excelsior and Xcel to enter into a dialogue with other Minnesota utilities to determine their interest in participating in the PPA. The Project Definition and Development phase runs through April 2008. (Itasca & St. Louis Counties, MN)

NeuCo, Inc. – *Integrated Optimization Software.* Integrated Optimization Software. The project at Dynegy's Baldwin Energy Complex has completed the planned efforts in Budget Period 1 within budget and on schedule. The Combustion Optimization module achieved the NO_x reduction goal of 5 percent along with improvements in cyclone stability. NeuCo has shown that its SCR Optimization module reduces ammonia consumption by 18 percent. NeuCo has installed the Sootblowing Optimization module on two separate units, with and without an intelligent sootblowing control system. This dual approach allows NeuCo to address a wide range of sootblowing issues. The latest release of CombustionOpt, SCR-Opt, and PerformanceOpt provide a variety of enhancements that were designed to make each of the Optimizers less of a "black box." All three optimizers now support advanced functionality for real-time analytics. (Baldwin, IL)

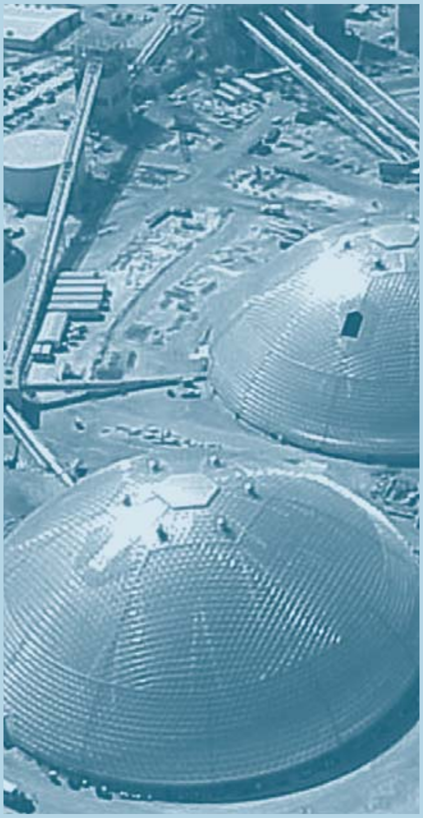
We Energies – *TOXECON™ Retrofit for Mercury and Multi-Pollutant Control.* Testing has been completed of Trona (hydrated sodium bicarbonate carbonate), as a potential SO_2 and NO_x sorbent. Trona injection resulted in a reduction in SO_2, no effect on NO_x, virtually no effect on opacity, but a net decrease in mercury capture at a constant PAC injection rate. Increase in the PAC injection rate allowed for 90% mercury capture while maintaining 70% SO_2 reduction. Without Trona injection, 90% mercury removal requires only 1.5 lb/MMacf PAC injection rate. A permit has been issued by Michigan Dept. of Environmental Quality (MDEQ) to allow WE Energies Presque Isle Power Plant to perform an ESP detuning test. ADA-ES has developed a portable mercury CEM system for use as an Instrumental Reference Method (IRM) in response to industry needs. A real time IRM instrument has now been demonstrated for compliance testing at mercury concentrations which are below the Ontario Hydro measurement limit (<1.0 µg/m3) and which could save significant time and money for coal-based power plants that required mercury instrument compliance measurement. (Marquette, MI)

Western Greenbrier Co-Generation, LLC – *Western Greenbrier Co-Production (WGC) Demonstration Project.* The preliminary process design is completed. WGC continues to finalize key project areas including the plant engineering/procurement/construction, and operations and maintenance contracts. Arrangements are in progress for sale of power to support a public tax-exempt bond sale. A National Environmental Policy Act (NEPA) Record of Decision (ROD) is expected later this year, following release of the final EIS. (Rainelle, WV)

Great River Energy (GRE) – *Lignite Fuel Enhancement.* On September 1, 2007, GRE proceeded to Budget Period 3 to build two more full-scale dryers. A four-dryer integrated system, to be completed next year, would meet the fuel needs of the 546-MW unit #2. In Budget Period 2, two dryers have been fabricated and site preparation activities for the construction of the dryer system have been initiated. Detailed specifications for auxiliary equipment have also been developed. (Underwood, ND)

Pegasus Technologies – *Mercury Specie and Multi-Pollutant Control.* Baseline testing was completed in November 2007. All installed instrumentation systems functioned smoothly. Mercury data were compiled from the probes at the electrostatic precipitators as well as across the flue gas desulfurization system. Validation of mercury data is obtained using EPA method 30B (Sorbent Trap). Coal and ash samples were also obtained for off-site analysis, data validation and mercury balance. In the period prior to operation, additional software installation and development will continue and baseline testing will be performed. NeuCo acquired Pegasus Technologies Inc. in May 2006. The Pegasus NeuCo technology provides plant operators the ability to assess detailed plant operating parameters which affect mercury capture efficiency as well as overall heat rate, and ESP particulate removal and flue gas desulfurization efficiencies. The technology, once demonstrated, should have broad application to existing coal fired boilers and provide positive impact on the quality of saleable by-products such as fly ash. (Jewett, TX)

Southern Company Services, Inc. – *Demonstration of a 285-MW Coal-Based Transport Gasifier.* Detailed engineering of the gasifier island is underway. The groundbreaking ceremony was held on September 10, 2007, at the Stanton Energy Center in Orlando, FL. Secretary Bodman, David Ratcliffe, Southern Company's Chairman, President, and Chief Executive Officer; Lonnie Bell, OUC Board President; and William P. Utt, KBR's Chairman, President, and CEO all spoke at the ceremony. The 285 MWe plant will demonstrate an air-blown Transport Integrated Gasification (TRIG™) combined cycle. The Transport Gasifier is an advanced circulating fluidized-bed system designed to operate at higher circulation rates, velocities, and riser densities when compared to a conventional circulating bed unit. The high circulation rates result in higher throughput, better mixing, and higher mass and heat transfer rates. (Orlando, FL) ■



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