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# CLEAN COAL TODAY

A Newsletter About Innovative Technologies for Coal Utilization

## News Bytes

In January 2006, **We Energies** began commercial operation of the TOXECON™ Mercury and Multi-Pollutant Control System at its Presque Isle power plant in Marquette, Michigan. The project, co-funded by DOE's Clean Coal Power Initiative (CCPI), began in April 2004. Results thus far are promising — an 80–95 percent reduction in mercury through injection of activated carbon in the flue gas has been achieved.

Several other CCPI projects have recently begun. A cooperative agreement with **Pegasus Technologies, Inc.** was signed in April 2006. The host site is Texas Genco's Limestone Station in Jewett, Texas. The

*See "News Bytes" on page 5...*

## Inside This Issue



## Sequestration Conference Explores Technology Progress

Some 400 government and industry representatives, as well as attendees from academia, the research community, and 10 foreign countries, gathered May 8–11, 2006, in Alexandria, Virginia, for the Fifth Annual Conference on Carbon Capture and Sequestration. The conference is co-sponsored by the U.S. Department of Energy (DOE), DOE's National Energy Technology Laboratory, and Exchange Monitor Publications & Forums, along with several coordinating partners.

The capacity attendance underscored the growing importance of carbon capture and sequestration (CCS) in allowing for energy as well as economic growth in what may become a carbon-constrained world, and the need for a leveraged public-private effort irrespective of any carbon regulation system. CCS can potentially contribute as much as 55 percent of reductions necessary to achieve stabilization of greenhouse gas concentrations, according to a recent report on carbon dioxide ($CO_2$) capture and storage authored by the Intergovernmental Panel on Climate Change (IPCC).

The conference focused on carbon capture, geological and terrestrial sequestration of $CO_2$ including regulatory and economic aspects, and international cooperation. Geological sequestration — introducing $CO_2$ into oil and gas reservoirs, unmineable coal seams, and saline formations — is thought to have the greatest potential in terms of the amount of $CO_2$ stored. The IPCC estimates geological storage capacity of at least 2,000 gigatons of $CO_2$. In areas not favored by such geology, terrestrial sequestration has possibilities, and the conference explored such methods as reforestation, creation of wetlands, and reclaiming mined sites. Conference talks highlighted a variety of promising pilot projects as well as the industrial-scale sequestration projects — Weyburn Enhanced Oil Recovery in Canada, Sleipner in the North Sea off Norway, and In-Salah in Algeria. Technical sessions featured such topics as risk assessment; monitoring, mitigation, and verification (MM&V);

*ASFE Jeffrey Jarrett and Energy Secretary Samuel Bodman at opening session of Carbon Capture and Sequestration Conference*

*See "Sequestration" on page 2...*

*..."Sequestration" continued*

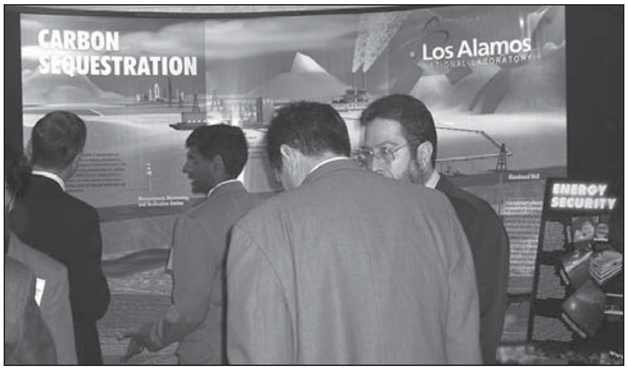
pre- and post-combustion capture; oxycombustion; $CO_2$ conversion to solids; well integrity; and regulatory and economic issues.

Energy Secretary Samuel Bodman, in keynote remarks at the opening plenary, outlined the Administration's multi-faceted approach toward ensuring clean and reliable sources of energy as put forth in the Advanced Energy Initiative announced by President George W. Bush in his January 2006 State of the Union address. The Initiative supports transformational technologies that would include carbon sequestration and a variety of clean coal technologies, as well as such efforts as the Global Nuclear Energy Partnership, Solar America, and the Hydrogen Fuel Initiative. Secretary Bodman noted that coal is the nation's most affordable and abundant energy resource, and is described in the Advanced Energy Initiative literature as the "workhouse of the electric power industry." The Secretary applauded successful sequestration projects, such as Weyburn, as indicative of momentum that is carrying CCS projects toward commercialization. The Regional Carbon Sequestration Partnerships, another success story, address the heterogeneous nature of sequestration possibilities.


The variety of CCS R&D activities is closely linked to the FutureGen project — a 275-MW plant that will integrate power and hydrogen production with geologic sequestration, and provide a test facility for advanced technology. As part of his remarks, Secretary Bodman took the opportunity to announce that the FutureGen Industrial Alliance had received 12 proposals for siting the plant (see box on page 3).

Elaborating on international collaborative CCS efforts, DOE Assistant Secretary for Fossil Energy, Jeffrey Jarrett, spoke of accomplishments of the Carbon Sequestration Leadership Forum (CSLF), where he serves as Chair of the Policy Group. Twenty-one nations and the European Union comprise the CSLF. Member nations emit 75 percent of the world's $CO_2$, and also represent more than 75 percent of the world's economy. The CLSF has been exploring issues such as capacity building, MM&V, and the regulatory aspects of sequestration in order to promote a uniform system around the globe. Increasingly, CSLF is focusing on the involvement of developing countries and the role of stakeholders. Various speakers noted the importance of U.S. leadership in order for CCS technologies to take hold internationally. Only several countries are major $CO_2$ emitters, which some participants believe makes containment more possible.

Jeff Sterba, CEO of PNM Resources and Chair of EPRI, was one of the first speakers and discussed investing and deploying $CO_2$ emission reduction technologies. Greenhouse gas reduction, he said, is the most important environmental issue faced by the power sector, and there is growing pressure to act on $CO_2$ control. Industry faces mounting cost pressures — rising fuel costs; $50 billion in pollution-control investment that would be required under Clear Skies Initiative; and uncertainties such as capacity needs, transmission expansion, and renewable portfolio issues. Mandatory targets and timetables, Sterba said, are not sufficient without policies to support increased investment in low-emitting technologies. From the customer viewpoint,




while some technologies are ready, they must be integrated and packaged into a saleable product.

Conference participants agreed that reducing greenhouse gases and overcoming challenges to CCS deployment turns on technology. Sterba believes it vital to reduce the cost of retrofitting $CO_2$ capture to pulverized coal plants, since replacing all new capacity with integrated gasification combined-cycle (IGCC) technology would be cost prohibitive. James J. Dooley, the principal author of a just-released analysis by Battelle's Joint Global Change Research Institute, emphasized the roles of IGCC and CCS in supplying the hundreds of gigawatts of decarbonized baseload capacity that could be needed in the United States by 2050 under various greenhouse gas control regimes. Dooley as well as other speakers emphasized a critical window of opportunity for research and field experimentation over the next 5–10 years before large-scale commercial adoption of CCS can take place. A number of speakers noted that the large-scale deployment of CCS within the electric power sector will not likely start until carbon prices begin to reach $25/ton $CO_2$, a cost comparable to (and in some cases less than) other large-scale emissions reduction and abatement options.

Several speakers discussed the public acceptance aspects of CCS deployment. NUMBY (Not Under My Back Yard) plays a part, as well as concerns over potential $CO_2$ leakage, migration, or contamination of groundwater. Established regulatory standards would facilitate public acceptance. However, technical experts such as Howard Herzog, lead author of the recent study by the IPCC CCS study, did not see leakage as a significant risk as long as the proper reservoirs are chosen at the outset.

A conference panel on regulation provided useful information on current U.S. Environmental Protection Agency (EPA) categorization of sequestration as Class V experimental wells, as designated by the Underground Injection Control (UIC) program under the Safe Water Drinking Act. An EPA working group is attempting to ease application procedures, and is studying how $CO_2$ should be regulated once sufficient projects render the technology no longer experimental. An EPA speaker pointed out that regulation under the UIC program does not mean that $CO_2$ is categorized as a waste.

The conference provided an important forum for CCS stakeholders to exchange views, and promote CCS deployment worldwide. It also provided an opportunity to discuss progress in carbon capture and storage technology, as well as challenges to commercial applications.

## FUTUREGEN UPDATE

On May 4, 2006, the FutureGen Alliance received 12 applications in response to its Request for Proposals for a FutureGen Host Site, issued on March 7, 2006.

Projects are proposed in or near the following locations:

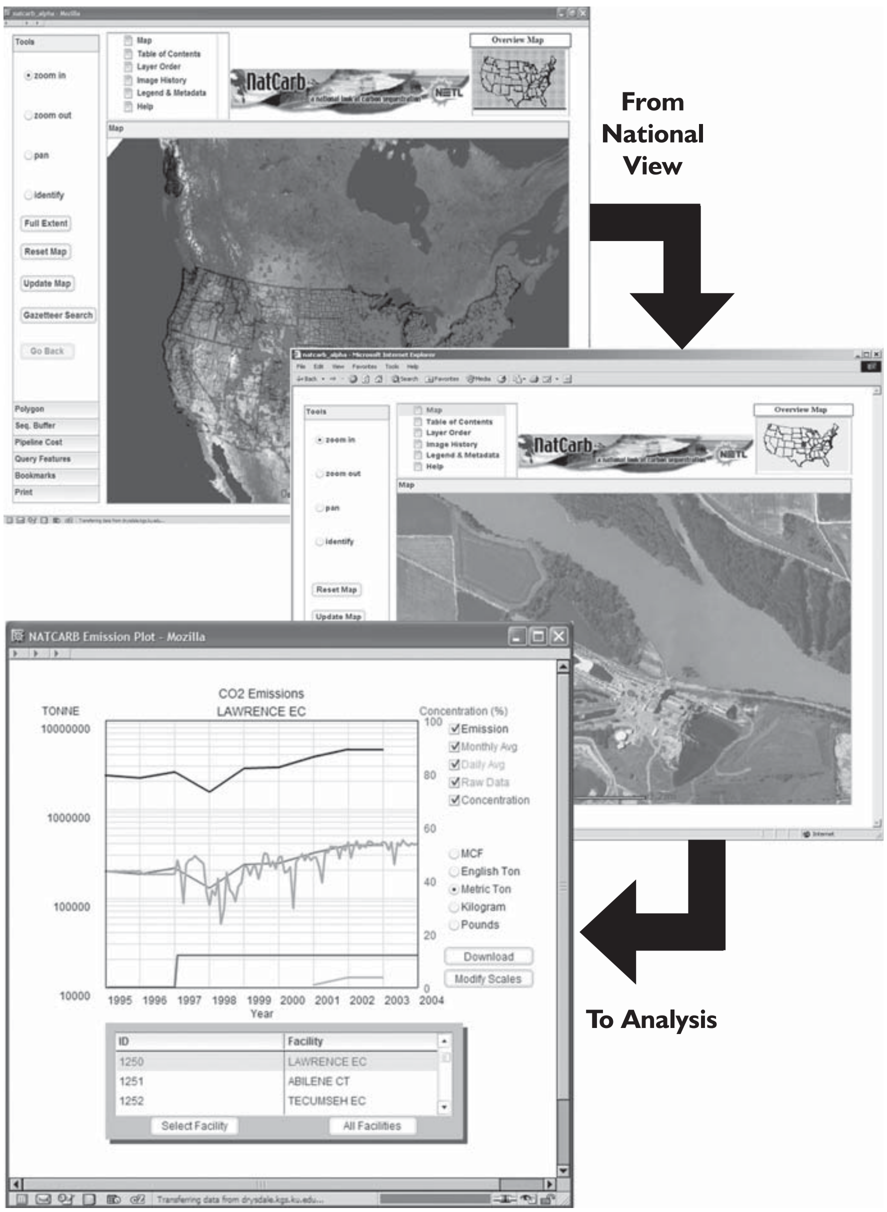
- Effingham, IL
- Marshall, IL
- Mattoon, IL
- Tuscola, IL
- Henderson County, KY
- Bowman County, ND
- Meigs County, OH
- Tuscarawas County, OH
- Odessa, TX
- Jewett, TX
- Point Pleasant, WV
- Gillette, WY

The government-industry consortium will build and operate a $1 billion 275-MW prototype plant that will use coal to generate both electricity and hydrogen, with near-zero emissions, and at the same time sequester $CO_2$ underground. The plant is expected to be on line in 2012. For further information see www.futuregenalliance.org/.

*India Joins FutureGen* – India's Ministry of Power Secretary R.V. Shahi and Fossil Energy Assistant Secretary Jeffrey Jarrett signed a "Framework Protocol" on April 3, 2006, for cooperation on FutureGen. India is the first Carbon Sequestration Leadership Forum member to accept Energy Secretary Bodman's invitation to join the Alliance, and has agreed to contribute $10 million. The Framework follows President Bush's visit to India in March, where he and Indian Prime Minister Singh announced a joint agreement on FutureGen.

# NATCARB EVALUATING CARBON SEQUESTRATION POTENTIAL

As part of the Department of Energy-led Regional Carbon Sequestration Partnerships started in 2003, an important data tool — the National Carbon Sequestration Database and Geographical Information System (NatCarb) — is allowing display and analysis of potential carbon sequestration sites nationwide. NatCarb is funded under a cooperative agreement between the Office of Fossil Energy's National Energy Technology Laboratory (NETL) and the University of Kansas Center for Research. NETL is providing 20 percent of project costs. The database started in 2000 as MIDCARB — a partnership of Illinois, Indiana, Kansas, Kentucky, and Ohio. Geological Survey organizations from these states continue as partners in the expanded, national effort, and are joined by the U.S. Geological Survey (USGS), the seven Regional Partnerships, and the Massachusetts Institute of Technology. Sequestering $CO_2$ in geological formations is a favored method of storing carbon for long periods. This method requires efficient access, as well as analysis of large quantities of data in order to investigate geological feasibility, environmental safety, and economic impact.




*Top view of large stationary sources across North America; the search is refined to identify $CO_2$ emissions from a single source (shown at bottom)*

The NatCarb system uses information collected from Phase I of the Regional Partnerships (which ended last summer) to develop a national portal to access $CO_2$ source and sink data, as well as transportation infrastructure information, for North America. NatCarb organizes and enhances critical information relevant to $CO_2$ sources and potential sequestration opportunities. Using web-based technology, NatCarb can access, query, model, analyze, and display natural resource data related to carbon management. Real-time on-line access is provided to data stored by the Partnerships and numerous national data warehouses.

The data is used to assess the carbon sequestration potential in North America. A database management system with spatial query capabilities evaluates the geographic distribution, physical characteristics, and economic parameters of potential geologic and terrestrial sequestration sites. Large stationary $CO_2$ emission sources and volumes are identified, accurately located, and characterized.

The Regional Partnerships are characterizing potential $CO_2$ sequestration sites, including producing and depleted oil and gas fields, unconventional oil and gas reservoirs, uneconomic coal seams, abandoned subsurface mines, saline reservoirs, and terrestrial sequestration opportunities to determine reservoir quality, size, and geologic integrity. NatCarb users can simultaneously access multiple servers in various locations across North America. NatCarb is one of the first demonstrations of a large-scale distributed database of natural resources and geological information.

## DISTRIBUTED RESOURCES — DISTRIBUTED EXPERTISE

Rather than housing data on a centralized server, the NatCarb portal implements web technologies (similar to Google Earth) to incorporate data on-the-fly from a variety of disparate sources. To facilitate the integration of map services into NatCarb, each Partnership can register map services and databases with the portal. NatCarb is an integrated Geographic Information System (GIS) effort, and a functional demonstration of cyberinfrastructure, joining both distributed resources (data and facilities) and distributed multidisciplinary expertise (Regional Partnerships). GIS layers accessible through NatCarb provide access to millions of records at multiple scales (*e.g.*, from individual well bore or $CO_2$ source, to coal basins stretching across regions and states). Such a distributed environment can meet the complex challenge of creating a nationwide network to determine the most suitable technologies, regulations, and infrastructure requirements for safe and efficient carbon capture and sequestration.

## ACCOMPLISHMENTS

The NatCarb map server is active and currently running on the internet, and can be accessed at http://www.natcarb.org. Reliable communication among the various servers has been established, and tools have been developed to query, display, and analyze $CO_2$ source, sink, and transportation data. The tools allow the user to query and plot emissions or production through time for a single source or a combination of sources across a region. Other layers, such as high-resolution earth images, can be overlayed.

To provide national coverage, data are retrieved in real time from public servers, including the USGS Earth Resources Observation Systems (EROS) center, and from the Geography Network. Data on major $CO_2$ sources are obtained from U.S. Environmental Protection Agency databases, and data on major coal basins and coalbed methane wells are obtained from the U.S. Energy Information Administration.

By linking sources, sinks, and transportation facilities within a spatial database, NatCarb provides decisionmakers consistent access to common sets of high quality data. Check http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html for more information on the Regional Carbon Sequestration Partnerships program.

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The *Index* is updated through Winter 2005, and is available at:

http://www.netl.doe.gov/technologies/coalpower/cctc/newsletter/newsletter.html

...*"News Bytes" continued*

project will demonstrate advanced multi-pollution controls, including mercury reduction, at an existing 890-MW utility boiler. A second CCPI cooperative agreement was signed in January 2006 with **Southern Company** to build an IGCC plant (see article page 14).

A third CCPI cooperative agreement (for the **Mesaba Energy Project**) was signed in May 2006, with MEP-I LLC (a project company of Excelsior Energy, Inc.). The Minnesota Congressional delegation participated in the signing ceremony. This project is located in Hoyt Lakes, Minnesota, and will demonstrate advanced IGCC, perfecting the technology developed at the Wabash River Clean Coal Project. Also in May, a cooperative agreement was signed with **CONSOL Energy for the Greenidge Multi-Pollutant Control Project**, located at AES Greenidge Generation Station in Dresden, New York. This project is funded under the Power Plant Improvement Initiative.

### CLEAN COAL TODAY

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*Comments are welcome and may be submitted to the Editor.*

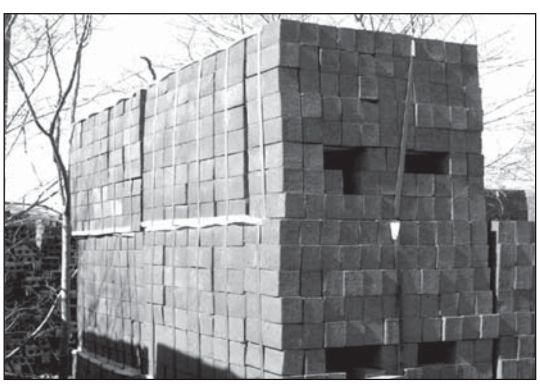
# BYPRODUCTS CONSORTIUM AWARDS NEW PROJECTS

The Combustion Byproducts Recycling Consortium (CBRC), sponsored by the U.S. Department of Energy (DOE) Office of Fossil Energy, through its National Energy Technology Laboratory (NETL), and managed by the West Virginia University Water Research Institute, has been carrying out important R&D projects to identify and examine the potential for new and expanded markets for coal combustion by-products (CCBs). This activity is part of NETL's overall Coal *Utilization* By-products (CUBs) Program, which deals with both combustion and gasification by-products. Once viewed negatively, CCBs are now largely regarded as an untapped, recyclable resource with tremendous industrial market potential. Expansion of markets for CCBs will be critical as demand for coal-fired electrical power increases, with corresponding public objections to landfill disposal. Additionally, implementation of new Federal and State air regulations — such as the Clean Air Interstate Rule and the Clean Air Mercury Rule — produces a greater quantity of CCBs with varying characteristics, for which reuse markets must be found.

## CCB APPLICATIONS

Each year, the U.S. electric utility industry generates over 120 million tons of CCBs. Just over half of this amount is fly ash, which is removed from the boiler flue gas via particulate control devices such as electrostatic precipitators (ESPs) or fabric filters. Another quarter of CCBs are the heavier, coarser solids removed from the bottoms of the boilers — bottom ash or boiler slag. The remaining CCBs are flue gas desulfurization (FGD) by-products, most of which are calcium sulfates or calcium sulfites from wet FGD systems that are installed downstream of the particulate control devices. A small but growing percentage of FGD by-products come from dry FGD systems or fluidized bed combustion (FBC) systems that remove sulfur upstream of the particulate control devices. These CCBs are inseparable mixtures of fly ash, bottom ash, and calcium sulfates/sulfites.

Given their different points of origin within the power plant, each CCB has a unique set of physical and chemical properties determining its suitability for specific reuse applications. Finding the proper application requires a thorough knowledge of the CCB properties and the requirements of the potential end-use markets. CCBs must compete in the marketplace against other raw materials; even when reuse is technically feasible, economic factors such as transportation costs often preclude CCB recycling. CCBs that cannot be reused — more than 70 million tons a year in 2004 — must be disposed of in landfills or surface impoundments.



*The Illinois State Geological Survey will continue its work using a new variety of CCBs to make bricks*

In 2004, approximately 40 percent of CCBs were reused for productive purposes — largely fly ash in Portland cement, and FGD gypsum for wallboard — and CBRC wants to raise that figure to 50 percent by 2010. To achieve its goals, CBRC will focus on increasing FGD by-product use, while continuing to study the environmental impacts of CUB use and disposal, and working to expand the slate of CCB applications.

## CBRC PROJECTS

Since its start in 1998, CBRC has funded 42 projects, totaling over \$8 million (nearly \$4.1 million in Federal funds, and more than \$4.4 million in non-Federal cost-share). In February 2006, 10 new projects valued near \$2 million were selected by CBRC's National Steering Committee from 52 proposals submitted (see table page 7). Criteria for selection include extent of environmental impacts, long-term economic benefits for producers and end-users, and contribution to CCB technology development. Industry is contributing \$687,000 of the total for the current round of projects. Projects range from 1–3 year duration, with values from \$40,000 to over \$300,000. Among the projects selected are five concrete-related projects, two agricultural projects, one *in-situ* treatment of acid mine drainage, one project on brick manufacturing, and one project on CCB marketing strategies. Awards will be made in yearly increments based upon performance and DOE funding availability.

These projects are expected to build on past successes of the CBRC. Small scale CBRC-sponsored tests for using CCBs in paving bricks, composite wall panels, and foundry sand molds have resulted in commercial projects. Other CBRC technologies, such as fly ash-based sorbents for mercury control from power plant flue gas, have been selected for large-scale field demonstrations. Specifically, CCBs have been used successfully as a structural fill for an airport runway extension, as a safe backfill for reclamation of abandoned mine sites, and as a feedstock for manufacture of products ranging from bricks to telephone poles. Fly ash has been used to replace foundry sand, and FGD by-products have been employed in the manufacture of countertops, tiles, and other structural materials for the construction industry. Traditionally hard-to-use CCBs such as high-carbon fly ash have been used to fabricate a permeable roadway base material, while "off-spec" (less than wallboard-grade) FGD by-products can be used as soil supplements to boost soybean and alfalfa crop yields or formed into briquettes to help control beach erosion. Additionally, technical information generated by CBRC projects has also been used to improve the knowledge base of state and federal agencies when developing policy regarding placement of CCBs in mines, quarries, and structural fills.

For more information and the CBRC newsletter, see the CBRC Web site (http://wvwri.nrcce.wvu.edu/programs/cbrc).

**New CBRC Projects**

| Title | Objectives | Funding DOE/Total |
|---|---|---|
| Cold In-Place Recycling of Asphalt Pavements Using Self Cementing Fly Ash, Univ. of Missouri | A demonstration using this fly ash in pavement was conducted in August 2004 on approximately 2.5 miles of low-traffic roadway. Researchers will build upon those results and establish the parameters for engineering design of rehabilitated road pavements with a fly ash-stabilized recycled asphalt base layer. | $24,987 / $55,475 |
| Evaluation of the Durability and Commercial Potential of 100% Fly Ash Concrete, Montana State Univ. | Portland cement is the binder material in traditional concretes for construction applications. Although an excellent performer, Portland cement production is energy-intensive. Researchers will determine the long-term durability and possible economic benefits of using 100% fly ash concrete in construction applications. | $95,900 / $140,366 |
| *In Situ* Stabilization of Gravel Roads with CCBs, Univ. of Wisconsin | Researchers will test feasibility of using low-cost, rapid-application, self-cementing CCBs to stabilize deteriorating gravel roads, an estimated 53% of all U.S. roads. | $130,362 / $178,818 |
| Using Class C Fly Ash to Mitigate Alkali-Silica Reactions in Concrete, Univ. of North Dakota | Researchers will evaluate the performance of several Class C fly ashes (>10% CaO) as a means to mitigate alkali-silica reactions (ASR) in concrete. | $150,000 / $231,034 |
| New Technology-Based Approach to Advance Higher Volume Fly Ash Concrete with Acceptable Performance, National Ready Mixed Concrete Assoc. | Surveys indicate that the average fly ash content in all ready-mixed concrete is only about 10%. Researchers plan novel science-based approaches to address this low percentage by using high fly ash concentrations during warm weather applications for optimal strength gain and setting time. | $199,680 / $304,436 |
| Manufacturing Building Products with Fly Ash and Advanced Coal Combustion, Illinois State Geological Survey (ISGS) | Researchers at the ISGS have been working with the brick industry to develop high-quality, marketable, fired bricks that use high volumes of Class F fly ash as a raw material. Researchers plan to demonstrate the use of CCBs in the production of high-quality fired bricks and innovative autoclaved aerated concrete (AAC) blocks. | $51,000 / $173,130 |
| Field Testing of Arsenic and Mercury Bioavailability Model from Land-Applied CCBs, Tennessee Valley Authority | Researchers will investigate the environmental effects of CCB use, including the potential bioavailability of contaminants to soil organisms, plants, and possibly animals and humans. | $46,000 / $94,290 |
| Community-based Social Marketing: The Tool to Get Target Audiences to Use CCBs, Univ. of Tennessee | Researchers plan to demonstrate community-based social marketing as a method to implement sustainable agricultural uses of FGD-gypsum by farmers and develop a model that can be expanded and applied to other CCB markets. | $200,193 / $275,194 |
| Evaluation of CCBs for *In Situ* Treatment of Acid Mine Drainage, CC Environmental, LLC. | Researchers will follow up the investigation of a 1994 alkaline injection technology project in an abandoned coal mine in eastern Oklahoma, which has been studied for 11 years. Monitoring is necessary to evaluate treatment effectiveness. | $26,940 / $40,032 |
| National Network of Research and Demonstration Sites for Agricultural and Other Land Application Uses of FGC Products, The Ohio State Univ. | With many electric utilities in the process of bringing new scrubbers on line, the amount of FGD products generated in the future in the U.S. will be greatly increased. Researchers propose a national network of sites for research/demonstration of beneficial agricultural and other land application uses of FGD products. | $222,682 / $342,581 |

# DOE Explores Potential for Coal-to-Liquid Fuels

In response to the imperative for affordable energy, the U.S. Department of Energy (DOE) Office of Fossil Energy (FE), as well as other government agencies and the private sector, are taking a fresh look at the potential for deriving liquid fuels from coal. As part of its Hydrogen from Coal Program, FE is exploring an "alternate" production pathway (along with hydrogen and power co-production in central plants) to produce hydrogen-rich, zero-sulfur liquid fuels, and substitute natural gas (SNG) that can be stored and distributed using the existing petroleum fuels and natural gas distribution networks. Other coal-to-liquids work is being carried out under the Clean Coal Power Initiative. Congress also has shown renewed interest in coal-to-liquids by mandating DOE to prepare a background report on the status of coal-to-liquids technology, and asking the Department of Defense to promote a military market for such fuels. Elsewhere, the Southern States Energy Board stakeholder group is examining policies and technologies needed to begin the development of an alternative oil production industry in the Southern states.

## Direct Liquefaction

The U.S. government, through industrial partnerships and international cooperation, has supported R&D for both direct and indirect liquefaction. The government R&D programs produced pilot-scale demonstrations in the 1970s and 1980s, which were successfully completed by the mid 1990s. These efforts resulted in improved processes, catalysts, and reactors that contributed to reduced costs and to improved product quantity and quality.

Direct liquefaction produces a synthetic crude that requires future refining to produce products that meet today's specifications for gasoline, diesel, or other fuels. This compares to indirect liquefaction, which produces zero-sulfur fuels and products but requires an initial gasification step in the coal-to-liquids process.

One commercial direct liquefaction project is under construction using technology developed by DOE and Headwaters Technology Innovations (HTI). In the direct liquefaction method, coal is reacted under high temperature and pressure with hydrogen and a coal-derived solvent to produce a synthetic crude oil (syncrude), which must then undergo substantial upgrading to produce acceptable transportation fuels. The HTI plant is located in Inner Mongolia, China, and is scheduled to begin production in 2007 using coal from the Shenhua coal field. The plant will use a combination of technologies developed in the United States, Japan, and Germany, with modifications and enhancements developed in China. When completed, the plant is expected to produce approximately 20,000 barrels per day of petroleum products.

## Indirect Liquefaction — F-T Fuels

The indirect liquefaction method produces fuels from the Fischer-Tropsch (F-T) process, first developed in the 1920s. The F-T process features a catalyzed chemical reaction in which methane and oxygen (synthesis gas) can be converted to liquid hydrocarbons of various forms. Typical catalysts used are based on iron and cobalt.

No commercial plants have yet combined and integrated state-of-the-art technology — entrained flow gasification and advanced slurry phase F-T synthesis. However, the Sasol company in South Africa has been operating commercial F-T plants since the early 1980s. Their two facilities produce 150,000 barrels per day of transportation fuels using Lurgi fixed-bed gasification and Sasol Advanced Synthesis (SAS) F-T reactors.

Coal liquids produced via F-T synthesis are zero sulfur, paraffinic hydrocarbons with a high cetane rating number necessary for efficient operation of high pressure compression-ignition engines, such as diesels. Their high paraffin content and low aromatic content reduces particulate emissions from diesel engines. Tests of F-T diesel fuel in engines have shown that hydrocarbon emissions can be reduced by almost 50 percent compared to petroleum diesel. Carbon monoxide emissions can be reduced by 50 percent and particulates by about 30 percent. In all, these fuels are cleaner than required by U.S. Environmental Protection Agency Tier II regulations. There are issues of lubricity and pour and cloud points for F-T diesel, but these can be addressed by appropriate additives. Finding a combination of petroleum diesel, F-T diesel, and appropriate additives to make a functional liquid fuel that will work in existing diesel engines is an area of research at both DOE and the Department of Defense. Cost of production of clean liquid fuels from coal in nonsequestration polygeneration plants is estimated to be about $35–40/barrel (bbl); from sequestered plants, CTL cost is estimated to range between $45–50/bbl depending on energy value.

## RECENT LIQUEFACTION PROJECTS

Within the FE Hydrogen-from-Coal Program, two indirect liquefaction research projects have recently started. In association with HTI, researchers are investigating the production of barrel quantities of high-hydrogen content, coal-derived liquids using iron-based F-T synthesis in a process development unit (PDU)-scale reactor at the Flexible Fuel Gasifier operated by the Gas Technology Institute (GTI) in Des Plaines, Illinois. Tests conducted at GTI will be based on optimization studies conducted in bench-scale reactor systems. These systems will evaluate two iron-based F-T catalysts — a high alpha catalyst in a slurry bubble column and a medium alpha catalyst in an ebullated-bed mode of operation. The catalyst holding the most promise for future commercial application will be recommended for PDU-scale reactor testing and the production of barrel quantities of high-hydrogen content, coal-derived F-T liquids.

A second DOE-funded project is being conducted by Integrated Concepts & Research Corporation (ICRC). The team is to investigate the production of research quantities of high-hydrogen content coal-derived liquids using F-T technology in a laboratory-scale reactor. Actual production will take place in Syntroleum Corporation's Tulsa, Oklahoma Gas-to-Liquids plant. A field-evaluation quantity (6,000 gallons) of F-T-derived No. 2 diesel from coal- or simulated coal-derived synthesis gas will be produced. The field-evaluation quantity of high-hydrogen content coal-derived liquids, along with the research quantities, will be used for fleet testing to be conducted in a coal-producing state. The field-evaluation results are expected to enhance public awareness and knowledge of environmental benefits of the high-hydrogen content coal-derived fuels.

A third project, selected and in negotiation, is a coal-derived liquids demonstration plant under DOE's Clean Coal Power Initiative. Waste Management Processors, Inc. (WMPI) is sponsoring the Gilberton Coal-to-Clean Fuels and Power Project in Gilberton, Pennsylvania. The project will integrate a Shell gasifier with a Sasol F-T unit to convert anthracite waste into electricity and transportation fuels. The WMPI team plans to begin construction of a 5,000 bpd plant in late 2006. If this coproduction project proceeds successfully, valuable information will be generated to hasten the learning curve for advanced indirect coal-to-liquid fuels technologies.

## TOWARD A HYDROGEN ECONOMY

F-T fuels can be an introduction into a hydrogen economy and hydrogen energy systems. For example, F-T fuels could be reformed into hydrogen at the point of use. Or, hydrogen could be produced at a coal-to-liquids plant by adding a hydrogen separation unit. In the latter case, the syngas can bypass the F-T unit and proceed to the hydrogen separator. The FE Hydrogen-from-Coal Program is investigating technologies to separate and produce pure hydrogen — technologies that are applicable to the FutureGen Initiative and the President's Hydrogen Fuel Initiative.

In order to maximize hydrogen production, a water-gas-shift reaction can be performed, generating only carbon dioxide and hydrogen and leaving no hydrocarbons in the product stream. Carbon dioxide in the tail gas stream could be captured and sequestered, and the unconverted synthesis gas could be combusted in a gas turbine combined-cycle power plant. In terms of reforming at the point of end use, the vision includes hydrogen fueling stations for automobiles using either Proton Exchange Membrane fuel cells or conventional internal combustion engines updated to accommodate hydrogen or hydrogen-natural gas mixtures. Two qualities of F-T fuels make them amenable for this on-site reforming technology and economics. One F-T attribute is the lack of sulfur and heavy metals, which harm catalysts. Secondly, the paraffinitic nature of F-T liquids, and lack of unsaturated and aromatic hydrocarbons, favors minimal coking in the steam reforming region of the fuel processor.

*One option is to use coal-derived fuels in hydrogen fuel cell vehicles*

In view of domestic coal recoverable reserves equivalent to a 250-year supply, and the high price of imports, promising opportunities exist to revive coal-to-liquids technologies to provide clean transportation fuels for the future.

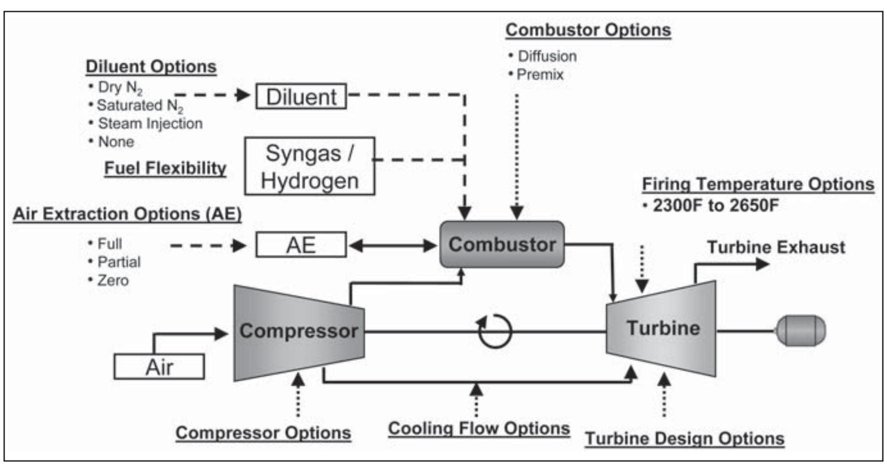
# HYDROGEN TURBINES FOR COAL-BASED IGCC AND FUTUREGEN

To accompany the government-industry FutureGen effort, the U.S. Department of Energy (DOE) is making strides toward developing turbine systems to operate cleanly and efficiently on coal syngas and hydrogen derived from coal. Turbines are an intrinsic part of an Integrated Gasification Combined-Cycle (IGCC) plant, and IGCC is the primary technology component of the Future Gen project. Two key hydrogen turbine projects are under way, awarded last September to GE and Siemens Westinghouse Power Corporation (now Siemens Power Generation). The projects build on key turbine innovations developed by the sponsors, in cooperation with DOE, over a long course of collaboration (see box). Additional projects awarded at the same time complement the large-frame turbine work, and provide alternative approaches to zero-emissions turbines. These additional projects include oxy-fuel turbine cycles fueled by coal-derived syngas, hydrogen combustion technology for smaller (MW-size) industrial turbines, MW-scale turbines for power and hydrogen coproduction in industrial applications, and novel concepts for compression of $CO_2$.

The main goal of the new projects is to utilize advances made to state-of-the-art large-frame natural gas turbines, and then apply and modify these technologies for syngas and hydrogen fuels. The turbines must be capable of integration with coal based sequestration-ready IGCC power plants, allow fuel flexibility for operation on both 100 percent hydrogen, and coal-derived synthesis gas, emit 2 ppm in $NO_x$ emissions (at 15 percent oxygen), and provide combined-cycle efficiency equivalent to that of the state-of-the-art turbine fueled with natural gas.

## THE TURBINE PROGRAM TIMELINE

The large-frame GE and SPG projects are in Phase I — developing the R&D Implementation Plan (now under review at DOE) and conducting system studies. In Phase II, developers will prepare detailed designs, and conduct a validation test program. Phase III work, to build and test a prototype machine, will be awarded based on an additional competitive solicitation. The projects have a nominal 6-year timeline to complete Phase I and II.




*Turbine design options: hydrogen/syngas-fueled turbine*

Project goals are to overcome the technical challenges of burning hydrogen — lower energy content by volume, higher flame speed, broader flammability limits, and high post-combustion moisture content — while achieving Turbine Program milestones. By 2010, the Turbine Program expects the two hydrogen turbine projects to have completed testing of components at varying levels (sub-scale, full-scale, prototype), providing confidence for a demonstration-scale turbine operation. By that time, the project should also have demonstrated the 2–3 percent improvement in combined-cycle efficiency that will contribute to the 45–50 percent efficiency (HHV) goal of the total IGCC plant. Cost goals for 2010 are <$1,000/kW for large utility-scale gas turbines for coal-based IGCC systems.

By 2015, the Turbine Program calls for completion of research that would lead to near-zero emissions coal based power plants with multi-product capability (hydrogen, electric power, and useable byproducts). Hydrogen turbines in coal-based gasification plants should be operating at 60 percent efficiencies HHV without carbon capture — with turbine efficiencies equivalent to current state-of-the-art F- and G-frame turbines operating on natural gas. These advanced machines with reduced $NO_x$ emissions could eliminate the need for selective catalytic reduction (SCR). Eliminating the SCR removes the potential for ammonia slip (ammonia is a PM2.5 precursor), reduces turbine back pressure, and reduces capital and O&M costs. In total, combined-cycle capital costs ($/kW) are expected to be reduced by 20–30 percent while increasing power output.

## GE's Effort

The GE Energy project (Advanced IGCC/Hydrogen Gas Turbine Development) has been awarded \$45.6 million for a 75-month project to develop gas turbine technology for advanced IGCC and FutureGen. GE will reduce emissions through combustion technology advances, with the goal of achieving the same type of emissions improvement achieved with dry-low-$NO_x$ technology for natural gas fueled gas turbines. Based on previous cooperative R&D by DOE and GE, promising combustion technology platforms and enablers were assessed. These results will feed into the GE hydrogen turbine project, be further evaluated in a new context, and contribute to full-scale design and development of an optimum system. Plant level efficiency improvements will be achieved primarily through increased IGCC gas turbine firing temperature to the same levels as today's natural gas-fired gas turbines. This will be enabled through application of high temperature 7FB gas turbine materials/design technology, and development of technologies to allow increased turbine mass flow and output. Testing will evaluate advanced materials and coatings exposed to the expected hot gas environment.

## Siemens Power Generation

Siemens Power Generation Corporation (SPG), with support from Florida Turbine Technologies, major universities, and other participants, intends to advance its state-of-the-art G-class gas turbine by integrating it into a coal-based IGCC power plant for coal-derived hydrogen fuel and syngas. Through its award of \$45.5 million for a 75-month project, SPG will identify and select the advanced technologies needed to achieve the challenging program goals, producing the required new component conceptual designs. Phase II will entail new component detailed designs and technology validation test programs. Engine and system fabrication, with deployment and testing in an IGCC plant, would be carried out in Phase III work, to be awarded through another competitive solicitation.

Key SPG development efforts will focus on the gas turbine combustion system, performance enhancements, and required advances in materials/coatings. Combustion development will concentrate on advanced concepts evaluation, selection, and development to produce operational systems for burning coal-derived hydrogen and syngas fuels, with natural gas as a backup. The project will pick the most promising concepts for improving component efficiencies, enhanced cooling, and maintaining the turbine's rated inlet temperature. Materials/coatings selection and development will support the higher efficiency goal of the Turbine Program, and the extended fuel flexibility, by targeting improvements in component durability and life-cycle costs. Advancements in sensors and controls will be carried out to improve monitoring of flame temperature, emissions, individual component metal temperature, coating durability, and turbine blade tip clearance control.

### DOE FE Turbine Program Accomplishments

**Today's Transition, 2004 – 2005**: FE transitions the Advanced Turbine Program from one of incremental advances to a comprehensive effort addressing Advanced Power Systems goals for turbines in coal-based IGCC systems, hydrogen-fueled turbines for FutureGen, and oxy-fuel turbines for zero-emissions systems.

**Siemens Power Generation Advanced 501 G Turbine, 2001**: Almost 170 of these 501 G turbines are in operation in North America incorporating advanced systems and components.

**GE Power System H Turbine, 2000**: This award-winning, high-efficiency turbine was unveiled, demonstrating higher efficiencies that translate into lower emissions and lower fuel costs, as well as innovative closed-loop cooling system and advanced coating materials capable of withstanding high temperatures. The H Turbine is in the largest combined-cycle power module in the world with commercial operation in Wales, UK. A 775-MW H System plant is scheduled for 2008 in California. Tokyo Electric Power has ordered three H systems.

**Syngas from Coal, 1990s**: Technology developments move traditional natural gas turbines to syngas-fired systems. Two DOE projects funded under the original CCT demonstration program (Tampa Electric Polk Station, and Wabash River Repowering Project) demonstrate gas turbine/coal gasification configurations.

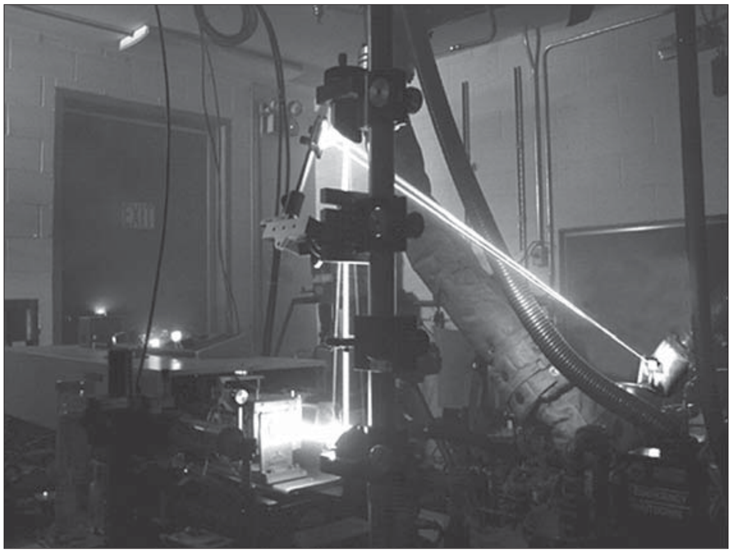
**Temperature and $NO_x$ Control Improvements, 1992–1998**: Development of natural gas-fueled turbine systems capable of operating at 2,500–2,600 °F (nominally 300 °F hotter than conventional turbines). Advanced low-$NO_x$ combustion technology reduces $NO_x$ levels to 9 ppm (at 15% $O_2$ in the exhaust).

**Technology Innovations**: High-efficiency compressors, advanced turbine blades (including 4-row blades) and van materials, high-temperature thermal barrier and abradable coatings, 3-D aero technology, and advanced brush seals. These advances not only led to high performance H- and G-class machines, but allowed improvements in the older F-frame turbine platform.

# LASER IGNITION PLUS HYDROGEN SPARKS CLEANER COMBUSTION

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) has completed a set of tests as part of its in-house research that sheds light on the use of laser spark ignition in engines using hydrogen-enriched natural gas as a fuel. At the heart of this research is the fact that engines can run more efficiently and cleaner if they run "lean" — using less fuel for a given amount of air. This research is exploring the benefits of combining an alternative ignition method with a lean fuel mix using hydrogen, which could be derived from the nation's most abundant fossil fuel — coal.

With typical internal combustion engines, elevated temperatures from fuel combustion result in nitrogen oxides ($NO_x$) emissions — known precursors to smog and an increasingly regulated emission. The continued demand for higher engine efficiencies and lower emissions has led to leaner air/fuel operating conditions. However, lean mixtures are hard to ignite using conventional ignition technology, and therefore require higher ignition voltages and spark energies. Such higher spark energy has a negative impact on the durability and economics of traditional spark plugs, and has impeded development of ultra-low emission, high-efficiency natural gas engines. This limitation has led researchers at NETL to investigate the use of laser ignition as an alternative method for delivering the spark energy required to ignite ultra-lean mixtures.



*Experimental laser ignition system in action*

In addition to improving fuel ignition, a blend of hydrogen and natural gas can further reduce $NO_x$ emissions as it allows even leaner operation of the engine. While hydrogen is considered an optimum fuel for fuel cells, and completely hydrogen-fueled internal combustion engines are feasible, some remaining barriers must be overcome before these technologies are commercial. Thus, as part of DOE's Office of Fossil Energy Hydrogen-from-Coal Program, NETL researchers are exploring transitional technology to make use of hydrogen in today's stationary natural gas engines. Testing of various methods at NETL could bring $NO_x$ emissions down to near-zero in these engines.

## LEAN OPERATION

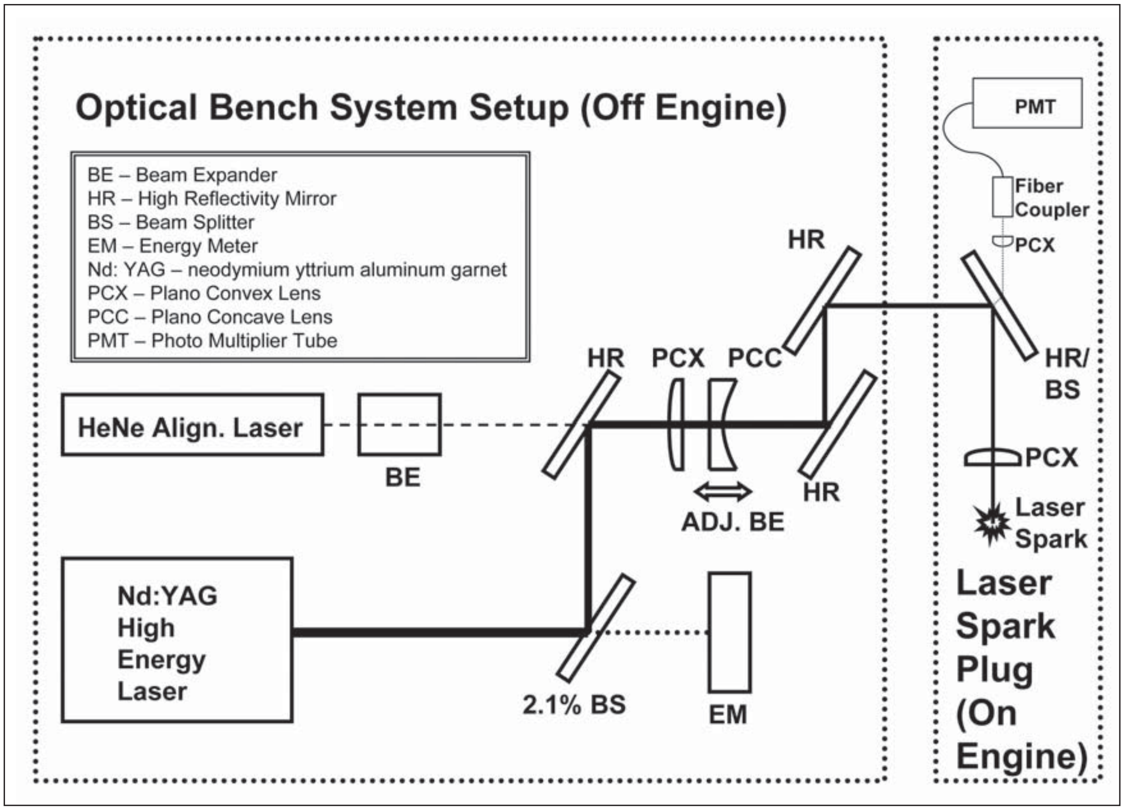
When an engine is operated with excessive amounts of air, heat capacity is added to the in-cylinder fuel air charge, which achieves lower combustion temperatures and lower $NO_x$. Lean operation also has the advantage of a higher thermal efficiency. The improved thermodynamic properties of burned gases increase engine output. Further engine efficiency gains are possible by decreasing pumping losses that result from higher intake pressures generally required for effective dilution. However, the misfire limit — the point at which combustion becomes unstable or unreliable and the engine will tolerate no additional excess air — may be reached before a suitably low $NO_x$ level is achieved.

## HYDROGEN ENRICHMENT BENEFITS

Hydrogen enrichment accelerates combustion, thereby increasing combustion efficiency. The addition of hydrogen results in a higher diffusivity fuel as well as an increase in flame stability and the mixture's flame speed, thereby extending the lean operating limit and improving the combustion efficiency beyond the normal range of an unenriched fuel. For these reasons, hydrogen enrichment makes additional amounts of excess air tolerable and further $NO_x$ emissions reductions possible.

## LASER IGNITION

NETL has found that laser spark ignition — due to its ability to initiate combustion under lean operating conditions — can extend misfire limits by significant margins, with commensurate reductions in NOx. There are other advantages inherent to laser spark ignition when compared to traditional electrical spark ignition. For example, because there are no electrodes to erode, laser spark ignition has the potential to be more durable than conventional spark plugs, where laser energy is applied as an ignition source for high pressure natural gas-fueled internal combustion, reciprocating engines. Another benefit of laser spark ignition is that the spark can be positioned anywhere in the combustion chamber. This can increase the apparent flame speed of the fuel mixture, because it allows the fuel to be consumed in a shorter amount of time. It also positions the spark away from energy-robbing heat sinks like the chamber walls and spark plug electrodes. Further, since optical access to the combustion chamber is required, the spark can be optically monitored.




*Schematic of the laser ignition system experimental setup*

## COMBINED IMPROVEMENTS

NETL researchers have been experimenting with the synergy of these two individually successful techniques, resulting in even greater improvements. Hydrogen has been blended with natural gas at five different levels ranging from 0–40 percent by volume in a single cylinder engine. The mixtures are fired using a conventional spark plug-based ignition system and then again with an open beam path laser-induced breakdown spark ignition system. $NO_x$ emissions measurements were made at different levels, including misfire conditions for each level of hydrogen enrichment with both ignition systems.

The NETL laser ignition system is coupled with a fully instrumented internal combustion engine (see schematic). Focusing a 10 nanosecond, 1.06 micron, laser pulse into the cylinder through the spark plug port generates a laser ignition spark. The laser pulse comes from an Nd:YAG laser directed to the cylinder with high energy laser mirrors. The lens is positioned in an optical spark plug tube aligned radially to the crankshaft axis of the engine. The final mirror directing the laser beam to the lens is positioned directly above the tube. Data have been collected, and the emissions and engine performance of two configurations were compared to determine the benefits of combining the two techniques.

Beyond these combustion improvements, tests also showed that the laser ignition system required less air dilution than a traditional spark system to obtain an equivalent $NO_x$ emission level. Similarly, for the same equivalence ratio and level of hydrogen enrichment, a lower $NO_x$ emission was realized using the laser ignition system. The laser ignition system also exhibited a slightly lower thermal efficiency at identical $NO_x$ emission levels for an equivalent hydrogen enrichment level. This result is likely due to the system's higher equivalence ratio for the given $NO_x$ emission level, and slight differences in combustion phasing.

# Demonstration of a 285-MW Coal-Based Transport Gasifier

The U.S. Department of Energy (DOE) has awarded $235 million to Southern Company, in partnership with the Orlando Utilities Commission (OUC) and Kellogg, Brown and Root (KBR), to develop one of the cleanest coal-fired power plants in the world. This cooperative agreement launches the design, construction, and demonstration of an integrated gasification combined-cycle (IGCC) power generation system at the Orlando Utilities Commission's Stanton Energy Center near Orlando in Orange County, Florida. The system will produce 285 megawatts (MW) of electricity for the Orlando area — which will power approximately 285,000 households — and is scheduled to begin operations in 2010. The project is one of four selected in October 2004 under the President's Clean Coal Power Initiative, a $2 billion, 10-year effort to advance technologies that can help meet the Nation's growing demand for low-cost electricity while protecting the environment.

IGCC technology, which produces a coal-derived synthesis gas for power generation, is considered today's environmentally preferred source of electricity from coal. In addition, the technology to be used in Orlando is unique in that it will cost-effectively use low-rank, high-moisture, and high-ash content coals. These coals, which include lignite and sub-bituminous (*e.g.*, Powder River Basin) coals, make up half of the proven reserves in the United States and the world.

The DOE Office of Fossil Energy's National Energy Technology Laboratory will manage the project for DOE. The gasification system cost is $568.7 million: Federal share is $235.0 million (41.32 percent) and non-Federal share is $333.7 million (58.68 percent). The combined-cycle system is to be built without any Federal cost share. Southern Company Services, a subsidiary of the Southern Company, is the prime contractor with overall project management responsibility. The plant will be co-owned by Southern Power Company Orlando Gasification LLC (SPCOG) (a subsidiary of the Southern Power Company) and the OUC.

## Stanton Energy Center

The Stanton site — some 3,300 acres — was certified as a power plant site through the Florida Electrical Power Plant Siting Act (FEPPSA) in December 1982 with an ultimate site generating capacity of 2,000 MW. Approximately 1,100 acres at the site have been licensed by the state of Florida and already developed for power generation. Two pulverized coal units (Units 1 and 2) are operating, each rated at 468 MW, along with a natural gas-fired combined-cycle unit (Unit A) rated at approximately 633 MW. The IGCC plant is to be located between the existing coal-fired units and the natural gas-fired combined-cycle unit. This center is a zero-discharge facility and the process water is recycled on-site.

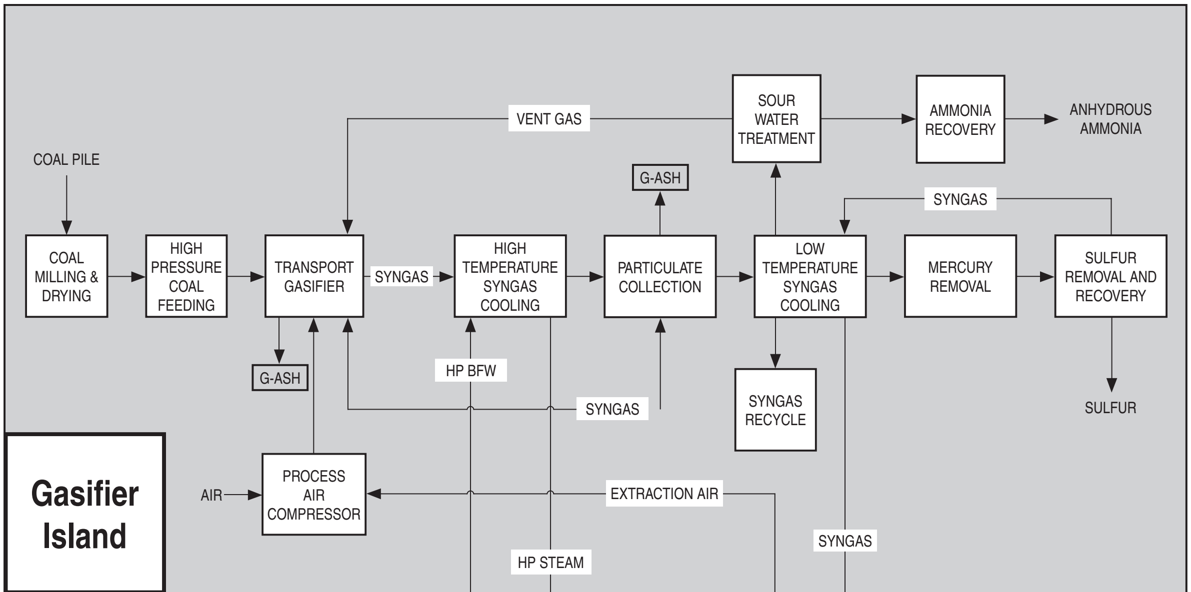
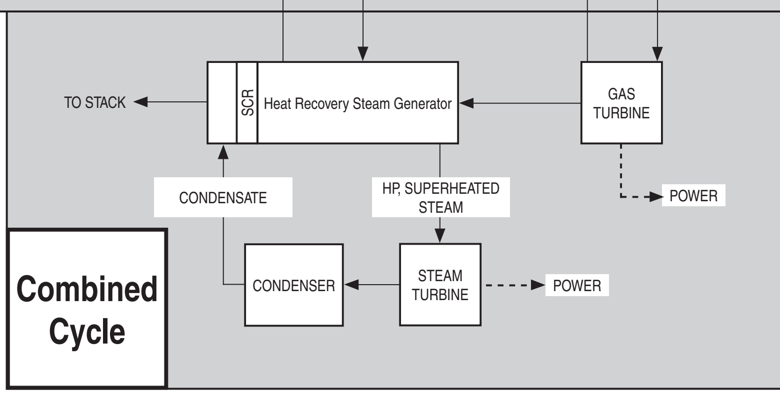
*Existing gas-fired combined-cycle unit*

The project is now in the Project Definition phase, which includes front-end engineering design, environmental permitting activities, simulated syngas evaluation, and the preparation of an Environmental Impact Statement. A public environmental scoping meeting was held in August 2005. Beginning Spring of 2007, and extending for three years, will be Detailed Design and Construction. That phase includes detailed design engineering, equipment procurement, and construction (gasification island construction, installation, commissioning, startup, integration with the combined-cycle island, and continued engineering and environmental activities). The final phase, demonstration, is scheduled for mid-2010 to late 2014.

## Transport Reactor IGCC Process

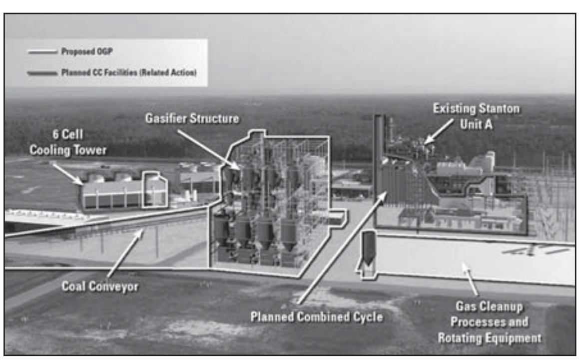
The Orlando IGCC plant, referred to as the transport reactor integrated gasification (TRIG™) plant, will have two main islands: a gasification island and a combined-cycle island. The gasification island will use air-blown transport gasifier technology to generate syngas from U.S. coal. The syngas, cleaned in the gasification island, will be used for fueling the combined-cycle island (a new combined-cycle power generating facility) planned for installation in 2010 by OUC and SPCOG.

An air-blown, coal-based transport gasifier train is to be designed and constructed for the base loaded TRIG™ plant. The transport reactor, which has been used successfully for over 50 years in the petroleum


refining industry, was tailored to coal gasification at the FE-sponsored Power Systems Development Facility in Wilsonville, Alabama. Both SCS and KBR have been involved in this R&D facility over the last decade (http://psdf.southernco.com/).

At full capacity, the new gasifier is expected to use a total of up to 3,300 tons of subbituminous coal per day to produce syngas. Particulate-laden syngas leaves the gasifier and is cooled indirectly producing high-pressure superheated steam. The syngas stream is sent to a high-temperature, high-pressure filter that removes essentially all the particulate matter. Following ash removal, the syngas stream is cooled further using high- and medium-temperature cooling systems to condense water and certain hydrocarbons. The condensed water in turn dissolves almost all the nitrogen-containing compounds, chloride, and fluoride along with lesser amounts of hydrogen sulfide, carbonyl sulfide, carbon monoxide, and carbon dioxide. The water is removed from the syngas in a knock-out drum and passed to the sour-water treatment plant. The syngas is sent to a fixed-bed adsorption column packed with sulfur-impregnated activated carbon for mercury removal.




*Proposed IGCC plant configuration*

After the mercury adsorber, the syngas stream is sent to a sulfur removal and recovery system. Most of the reheated clean syngas is sent to the gas turbine. Small portions of the syngas are recycled to pulse clean the particulate filters and to aerate the gasifier.

The gas turbine compressor provides the combustion air for the syngas and a portion of the air required by the gasifier at full load. The remaining air required is delivered by a motor-driven process air compressor. The flue gas discharged from the gas turbine passes into the heat recovery steam generator (HRSG). High-pressure superheated steam from the HRSG is combined with steam from the gasifier island and passed to the steam turbine.

The project features state-of-the-art emission controls and reduced water use. The overall heat rate and efficiency of the IGCC plant are expected to be 8,400 Btu/kWh and 40.6 percent, respectively.

# 2006 NETL Environmental Controls Conference

The National Energy Technology Laboratory (NETL) held the 2006 Environmental Controls Conference in Pittsburgh on May 16–18, 2006. Session 1 — Selective Catalytic Reduction (SCR)/Selective Non-Catalytic Reduction (SNCR) for $NO_x$ Control, and Session 2 — Techniques for Managing Sulfur Trioxide ($SO_3$), combined two previous conferences last held in 2003 and 1998, respectively. Conference registration was about 290, including 14 foreign visitors from 10 countries.

The primary focus of the conference was commercialization of SCR and SNCR, both vital in helping coal-fired utilities meet new environmental requirements. By 2009, implementation of the Clean Air Interstate Rule (CAIR), the Clean Air Visibility Rule, and the Clean Air Mercury Rule will reduce $SO_2$ and mercury (Hg) emissions by more than 70 percent, and nitrogen oxides ($NO_x$) emissions by more than 60 percent from 2003 levels. The CAIR reduces power plant $NO_x$ limits from 0.15 lb/million Btu to 0.125 lb/million Btu.

*NETL Director Carl Bauer addressing opening session*

NETL Director Carl Bauer gave the keynote address for Session 1, providing a background on advances made in clean coal technologies that have resulted in reduced emissions of $SO_2$ and $NO_x$ despite increased coal-fired power generation. NETL is the primary National Laboratory dedicated to coal utilization technology. Various utility speakers and vendors then shared their considerable operation experience in SCR and SNCR. A complete SCR system is costly; less expensive alternatives include compact in-duct SCRs, hybrid SCR/SNCR systems, and tail-end systems. SCR systems today have 85–97 percent $NO_x$ removal efficiency and 99 percent availability. In the United States, less than 1,000 MW of SCR units were operating on coal-fired power plants in 1998; this figure has grown to 85,000 MW in 2005 and is projected to reach 140,000 MW by 2009. For coal-fired SNCR installations, capacity in 2005 was about 15,000 MW and projected capacity for 2010 is about 35,000 MW.

Several papers discussed SCR catalyst management. In coal-fired power generation, catalyst activity decreases over time due to ash deposition and poisoning by trace metals in the feedstock. A variety of baffle and screen systems have been demonstrated commercially that minimize deposition of ash, especially the larger particles. *In-situ* replacement techniques have been developed to compete with total catalyst removal. Operating data were presented on the use of acoustic energy to clean SCR catalyst in place as an alternative to traditional sootblowing.

A recent advancement in $NO_x$ control is layered technology, including low-$NO_x$ burners, overfire air, and SNCR. Several modified processes were described, including High Energy Reagent Technology (HERT) and Advanced Layered Technology Approach (ALTA). In plant-scale demonstrations, these processes have successfully reduced $NO_x$ emissions to the current target level of 0.15 lb/million Btu.

Bill Ellison of Ellison Consultants presented the keynote address on $SO_3$ for Session 2. An important concern with SCR is oxidation by the catalyst of $SO_2$ to $SO_3$, creating visible stack plumes. $SO_3$ emissions from the electric utility industry rival emissions from the chemical industry, and surprisingly high $SO_3$ concentrations in stack gases have been observed, especially with high-sulfur coals. One paper provided an estimate that 75–85 percent of U.S. bituminous coal-fired power plants equipped with SCR and/or wet FGD controls are likely to have sufficiently high levels of $SO_3$ emissions to experience significant stack opacity.

One speaker described a new low $SO_2$-to-$SO_3$ conversion catalyst that has greatly reduced $SO_3$ emissions at the American Electric Power (AEP) Gavin power plant at Cheshire, Ohio. In addition, AEP now injects the mineral trona ($Na_2CO_3$•$NaHCO_3$•$2H_2O$) into the flue gas upstream of the SCR unit to minimize the plume. Other papers reported on the successful use of other sodium-based chemicals for sorbent injection, as well as approaches involving modifications to electrostatic precipitators. Computational fluid dynamics modeling also was discussed as an important tool for designing systems to mitigate the effects of $SO_3$ formation.

Conference presentation materials are posted at: www.netl.doe.gov/publications/proceedings/.

## INTERNATIONAL INITIATIVES

# DELEGATION OF CHINESE SCIENTISTS VISITS NETL

As part of a study sponsored by the U.S. National Academies of Science (NAS) examining urban energy use and air pollution, the National Energy Technology Laboratory (NETL) hosted a delegation composed of 20 researchers from Beijing and Huainan, along with U.S. representatives from the NAS study committee, leading universities, and non-governmental organizations. The group visited the Pittsburgh campus March 29, 2006, to discuss clean coal and related energy/environmental technologies. The Chinese delegation was particularly interested in FutureGen, gasification and IGCC technology, carbon sequestration, and air pollution control for utility and industrial plants.

Industrial coal-fired boilers and district energy systems represent a particularly large market in China. The country has over 500,000 industrial boilers burning over 400 million metric tons of coal per year. Last year, China's National Development Reform Commission (NDRC) published its national plan for addressing energy efficiency/conservation needs during 2006–2010. Modernizing coal-fired industrial boilers along with combined heat and power (CHP) district energy are the first two priorities. A strong impetus also exists to reduce air pollution as Beijing prepares for the 2008 Summer Olympics.

The joint study headed by NAS is examining urban energy use, policies, and associated air pollution challenges faced today by China and the United States. The study will assist Chinese cities in addressing environmental, public health, and economic issues related to continued coal consumption, and a rapidly increasing number of private vehicles. It also will identify technology and institutional options and associated costs and benefits, and will identify areas of mutual interest for cooperative R&D.

*Joint U.S./Chinese delegation participating in tour of NETL's in-house research facilities*

In addition to a full-day of presentations on NETL R&D, and a tour of in-house laboratory and test facilities, the delegation visited a spectrum of local plants during March 27–31, 2006. The group met with local leaders such as Allegheny County Chief Executive Dan Onorato, and representatives from Carnegie Mellon University, University of Pittsburgh, FirstEnergy, US Steel, Heinz, DQE Energy Solutions, Allegheny County Health Department, Allegheny County Sanitary Authority, Air & Waste Management Association, and local environmental groups. The dialogue enabled the delegation to gain a solid perspective on modern technology applications, city planning, business development, and policy issues surrounding the transformation of Pittsburgh from its industrial past to a model of clean energy use.

The Chinese delegation represented such organizations as the Chinese Academy of Sciences, Chinese Academy of Engineering, Tsinghua University, China Coal Research Institute, Peking University, and the Huainan Municipal Government. The 10 U.S. NAS committee members also included leading researchers from the University of Texas, Georgia Tech, Clark University, Desert Research Institute, Natural Resources Defense Council, and Environmental Defense. Incorporation of DOE-sponsored programs and initiatives into the NAS study is expected to expand on the already fruitful cooperative R&D efforts by the two countries.

# ACTIVE CCT DEMONSTRATION, PPII, AND CCPI PROJECT STATUS

## CCT DEMONSTRATION STATUS

**JEA** – *ACFB Demonstration Project.* This project has been successfully completed. The final report is posted on the Clean Coal Technology Compendium, and the project is in closeout. (Jacksonville, FL)

**Kentucky Pioneer Energy (KPE), L.L.C.** – *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.* DOE has concurred with TIAX's request that the project be terminated. The Final Report is currently being prepared. (Fairbanks, AK and Beloit, WI)

## PPII STATUS

**Otter Tail Power Company** – *Demonstration of a Full-Scale Retrofit of the Advanced Hybrid Particulate Collector (AHPC) Technology*. The period of performance of the cooperative agreement ended January 31, 2006. Following final project deliverables, the project will proceed to the close-out phase. After completing more than 2 years of commercial demonstration, Otter Tail Power Company made modifications to the unit to provide more ESP and fabric filter surface for particulate removal. While the project achieved superior particulate removal when the integrity of filter bags remained intact, operating costs increased due to increasing overall pressure drop or premature bag failure. (Big Stone City, SD)

**Sunflower Electric Power Corp.** – *Demonstration of a 360-MWe Integrated Combustion Optimization System***.** Due to larger than anticipated costs for installation of new low-$NO_x$ burners and overfire air systems, Sunflower has withdrawn the continuation application to DOE for proceeding to Phase III Budget Period 2 of the project, and DOE has accepted Sunflower's withdrawal position. The project is now in closeout. A final report is in progress. (Garden City, KS)

**Tampa Electric Company** – *Big Bend Power Station Tampa – Neural Network Sootblower Optimization Project.* This project has concluded and the final project report has been completed. (Apollo Beach, FL)

**Universal Aggregates, LLC** – *Commercial Demonstration of the Manufactured Aggregate Processing Technology Utilizing Spray Dryer Ash.* The project is in the operations phase. Universal Aggregates has successfully run the entire plant process including mixing, extrusion, curing, crushing, screening, and recycling screened fines. The plant has shipped finished product to its distributor on a limited basis. Efforts are being made to adjust material additives and equipment configurations to produce a consistent product using the spray dryer ash removed from the Birchwood Power Generation Facility. Universal Aggregates has requested and been granted a no-cost extension until June 30, 2006, to allow modifications and improvements intended to increase throughput capacity and extend the continuous run time of the plant. (King George, VA)

## CCPI STATUS

**CONSOL Energy Inc.** – *Greenidge Multi-Pollutant Control Project.* Negotiations were completed on the Greenidge Multi-Pollutant Control Project and NETL signed the corresponding Cooperative Agreement on May 19, 2006. DOE will provide cost-shared funding support for the design, construction, and demonstration of an integrated multi-pollutant control system at the AES Greenidge Generating Station in Dresden, New York. The system will be installed on the existing, coal-fired, 107-MW Unit 4. The project includes a unique "hybrid" non-catalytic (SNCR) and catalytic (SCR) system for $NO_x$ reduction, a circulating dry scrubber for $SO_2$, $SO_3$, mercury, and acid gas reduction, and a baghouse for particulate control. This combination of technologies will demonstrate advanced emissions control at a lower cost than traditional retrofits at a plant of this size and age. (Dresden, NY)

**MEC-I LLC (Excelsior Energy Inc.)** – *Mesaba Energy Project.* A Cooperative Agreement was awarded in May 2006 to MEC-I LLC, a wholly-owned project company of Minnetonka-based Excelsior Energy, Inc. The project will design, construct and demonstrate a commercial-scale, next-generation IGCC plant at nominal 600 MWe (net) size, utilizing ConocoPhillips E-Gas™ technology substantially updated since its highly successful but smaller-scale DOE demonstration eight years ago at Wabash River, IN. The plant will use an advanced full-slurry quench multiple-train gasifier system having an operational availability of 90% or better. It will also use a first-of-a-kind air separation unit that extracts bleed air from the gas turbine to reduce the parasitic load of the ASU main air compressor. Greater efficiency and lower emissions will rank the project among the cleanest coal-based electric power generating plants in the world when it enters service in 2012. The Project Definition and Development phase runs through April 2008. (Itasca & St. Louis Counties, MN)

**NeuCo, Inc.** – *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 by using their SCR Optimization module, they are reducing 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. Approval has been granted for this project to transition to Budget Period 2, which will focus on improvement of the individual modules as well as their integration. (Baldwin, IL)

**University of Kentucky Research Foundation** – *Advanced Multi-Product Coal Utilization By-Product Processing Plant.* Approximately 150 tons of pond ash were excavated from the 2,200 MW Ghent Generating Station, Kentucky for pilot tests using primary classification, secondary classification, and froth flotation equipment. Primary classification was shown to be effective for rejecting coarse (plus 100 mesh) material from the pond ash while maintaining high recovery of minus 100 mesh. The primary classifier provided efficient separation under a variety of feed rates and slurry densities. Froth flotation was evaluated to reduce the loss on ignition of the primary classifier overflow to below 3 percent. Secondary classification of the primary classification overflow was effective for producing an ultra-fine ash product. Inclined lamella plates provided an effective settling surface for coarser ash particles. The characteristics of the separated ash products are being evaluated. (Ghent, Carroll County, KY)

**We Energies** – *TOXECON™ Retrofit for Mercury and Multi-Pollutant Control***.** Project operation began in January 2006 when activated carbon was injected into the flue gas stream. Baseline testing was performed to characterize the flue gas. Two new, commercial “i-series” Mercury Freedom™ Continuous Emission Monitors (CEMs) supplied by ThermoElectron were installed and integrated with the plant control and data systems. Parametric testing to establish a correlation between activated carbon injection was initiated in February 2006. Initial results were promising, showing 80% to 95% mercury emission reduction with injection of two pounds of activated carbon per million actual cubic feet of flue gas. The TOXECON™ baghouse is ready for operation and is scheduled to come on line during mid-May. (Marquette, MI)

**Western Greenbrier Co-Generation, LLC** – *Western Greenbrier Co-Production (WGC) Demonstration Project*. WGC continues to work to develop key project areas including the waste coal resource plan, coal upgrading processes, and arrangements for sale of power to support a public tax-exempt bond sale to fund the project. The preliminary process design is nearly completed. The project received its air permit from the State of West Virginia, and a Draft Environmental Impact Statement is under way. Transmission and interconnection agreements are expected to be finalized in late June 2006. WGC requested and was granted a no-cost extension of the cooperative agreement until the end of October 2006 to complete their Phase 1 milestones, particularly with respect to project financing and bond sales. (Rainelle, WV)

**Great River Energy (GRE)** – *Lignite Fuel Enhancement*. GRE has identified significant benefits of coal drying during the initial tests with the first dryer operating at 75 tons per hour feed rate. For the 546-MW unit, the performance of the unit operating seven pulverizers on ‘as-is’ coal (38.5 percent moisture content) was compared with the unit operating six pulverizers on ‘as-is’ coal and one pulverizer on dried coal (29.5 percent moisture content). Early results show that with just one pulverizer using dried coal, the stack flow rate from the unit decreased 0.9 percent, boiler efficiency increased 1 percent, $SO_x$ emissions fell 2.1 percent, and pulverizer power consumption as well as $NO_x$ emissions decreased significantly. GRE is continuing the tests to further establish these benefits. (Underwood, ND)

**Pegasus Technologies, Inc.** – *Mercury Specie and Multi-Pollutant Control.* The cooperative agreement (CA) was signed with Pegasus Technologies Inc. in April 2006. The project — to take place at the 890-MW Texas Gencom Limestone Station — will demonstrate non-intrusive advanced sensors and neural network-based optimization and control technologies for enhanced mercury and multi-pollutant control. Plant data are provided to a neural network optimization system which controls plant subsystems to provide the lowest possible pollutant emissions, highest heat rate, and least risk of non-compliance with minimal capital expenditure. This 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. Performance testing will begin in October 2008. (Jewett, TX and Cardon, OH)

**Southern Company Services, Inc.** – *Demonstration of a 285 MW Coal-Based Transport Gasifier.* The cooperative agreement was signed on January 30, 2006. The demonstration plant will be built at the Orlando Utilities Commission’s Stanton Energy Center near Orlando, Orange County, Florida, and will be co-owned by Orlando Utilities Commission and Southern Power Company. The transport gasifier — based on Kellogg Brown and Root’s catalytic cracking technology — will gasify sub-bituminous coal and generate 285 MW of electricity (net) at a heat rate of 8,400 Btu/kWh (40.6 percent efficiency higher heating value basis). The plant will employ state-of-the-art emission controls and is expected to be among the cleanest and most efficient coal-fired power plants in the world. (Orlando, FL)

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