

# THE CARBON SEQUESTRATION NEWSLETTER

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June 2006

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## Sequestration in the News

### *Twelve Sites Proposed for FutureGen Plant*

1	Effingham, Illinois
2	Marshall, Illinois
3	Mattoon, Illinois
4	Tuscola, Illinois
5	Henderson County, Kentucky
6	Bowman County, North Dakota
7	Meigs County, Ohio
8	Tuscarawas County, Ohio
9	Odessa, Texas
10	Jewett, Texas
11	Point Pleasant, West Virginia
12	Gillette, Wyoming



## HIGHLIGHTS

**DOE Techline, "Twelve Sites Proposed for FutureGen Plant."** Secretary Samuel Bodman announced the 12 candidate sites for the FutureGen project that were submitted in response to the Request for Proposals, issued by the FutureGen Alliance (the Alliance). The announcement was made at the Fifth Annual Conference on Carbon Capture and Storage held in Alexandria, Virginia. The proposals would host the project in or near: 1. Effingham, Illinois; 2. Marshall, Illinois; 3. Mattoon, Illinois; 4. Tuscola, Illinois; 5. Henderson County, Kentucky; 6. Bowman County, North Dakota; 7. Meigs County, Ohio; 8. Tuscarawas County, Ohio; 9. Odessa, Texas; 10. Jewett, Texas; 11. Point Pleasant, West Virginia; and 12. Gillette, Wyoming. The Alliance, which is overseeing the site selection process, plans to deliver a list of finalist sites to the Department of Energy this summer, following a rigorous evaluation and review of the site in accordance with the National Environmental Policy Act. Final site selection is scheduled for the fall of 2007, and plant start-up is planned for 2012. Secretary Bodman's remarks and a video of his presentation can be accessed at: <http://www.netl.doe.gov/publications/press/2006/bodman-remarks.html>. May 9, 2006, [http://www.fossil.energy.gov/news/techlines/2006/06024-FutureGen\\_Sites\\_Proposed.html](http://www.fossil.energy.gov/news/techlines/2006/06024-FutureGen_Sites_Proposed.html).

## Announcements

**Release of the Film “An Inconvenient Truth.”** Coinciding with the May 24, 2006 release of Al Gore’s book on global warming, *An Inconvenient Truth*, is the showing of the film production by the same name. The film was released in Los Angeles and New York with expansion to other theaters to occur in June 2006. To locate a theater or watch the film trailer, go to: <http://www.climatecrisis.net>.

**New for 2007—the International Journal of Greenhouse Gas Control.** The publisher Elsevier, in association with the IEA Greenhouse Gas R&D Programme, is launching a new journal in 2007 that will cover developments in greenhouse gas control in the power sectors, and major manufacturing and production industries. It will cover all greenhouse gas (GHG) emissions and the range of abatement options available, and be comprised of both technical and non-technical related literature. The scope of the journal will include emissions, capture, transmission, and storage of CO<sub>2</sub>, as well as alternative mitigation options, non-CO<sub>2</sub> GHGs, technology implementation, and economic considerations. The quarterly journal will be available in print and online, with online submissions and peer review, and an international board of editors. Online via ScienceDirect in 2007 at: [www.sciencedirect.com](http://www.sciencedirect.com). See: [www.elsevier.com/locate/ijggc](http://www.elsevier.com/locate/ijggc).

**Public Comments Accepted on Wisconsin DNR and PSC “Integrated Gasification Combined-Cycle Technology Draft Report.”** The Department of Natural Resources (DNR) and the Public Service Commission of Wisconsin (PSC) released a draft report on June 1 reviewing the benefits, costs and future prospects of integrated gasification combined-cycle (IGCC) technology (with and without carbon dioxide capture) for Wisconsin. Their draft report says that without controls to capture carbon dioxide, IGCC appears \$5-\$7 per megawatt hour more expensive than conventional coal technology, and with controls to capture carbon dioxide, IGCC appears approximately \$10 per megawatt hour less expensive, given their current understanding of control equipment. Public comments are being accepted on this draft report until 4 pm, Friday, June 30, 2006 at: <http://psc.wi.gov/CleanCoal/comments.htm>

**DOE Techline, “PPL Corporation Joins FutureGen Industrial Alliance.”** PPL Corporation has become the tenth member of the FutureGen Industrial Alliance (the Alliance), the non-profit consortium of global electric utilities and coal companies working with the US Department of Energy to site and develop the FutureGen power plant. PPL Corporation, headquartered in Allentown, Pennsylvania, controls about 12,000 megawatts of generating capacity in the US, sells energy in key US markets and delivers electricity to more than 5 million customers in Pennsylvania, the United Kingdom and Latin America. The Alliance represents some of the world’s largest coal companies and electric utilities including: American Electric Power, Anglo American, BHP Billiton, the China Huaneng Group, CONSOL Energy Inc., Foundation Coal, Rio Tinto Energy America, Peabody Energy and Southern Company. May 23, 2006, [http://www.fossil.energy.gov/news/techlines/2006/06028-PPL\\_Joins\\_FutureGen\\_Alliance.html](http://www.fossil.energy.gov/news/techlines/2006/06028-PPL_Joins_FutureGen_Alliance.html).

**DOE Techline, “Coal Gasification Plant Returns \$79 Million to DOE in Revenue-Sharing Gas Sales.”** In 1998, the Dakota Gasification Company (DGC) purchased the Great Plains Synfuels Plant from the Department of Energy (DOE) and signed a revenue sharing agreement. DGC announced a payment of \$79 million payment to the DOE as part of that agreement—the third such payment with revenue share to DOE from gas sales totaling more than \$241 million to date. Carbon dioxide (CO<sub>2</sub>) from the plant is transported from the Great Plains Synfuels Plant to the Weyburn Oil field via a 200-mile pipeline for sequestration and/or enhanced oil recovery. The Weyburn project was started in July 2000 by the Petroleum Technology Research Centre of Regina, Saskatchewan, Canada, and cosponsored by the oil field operator, EnCana Resources of Calgary, Alberta, Canada. The project is funded by at least 15 sponsors from government and industry, including DOE, and 10 industrial sponsors in the United States, Canada, and Japan. The project has sequestered about five million tons of CO<sub>2</sub> into the Weyburn oil field since its beginnings. While much of the injected CO<sub>2</sub> is permanently sequestered, some of it is injected into the reservoir for enhanced oil recovery (EOR). The EOR has doubled the field’s oil recovery rate, increasing the field’s oil production by an additional 10,000 barrels per day. Phase II of the project is underway, a \$27 million project including a \$4 million share by DOE over a four year time frame. May 12, 2006, [http://www.fossil.energy.gov/news/techlines/2006/06025-Dakota\\_Gasification\\_Revenue\\_Sharing.html](http://www.fossil.energy.gov/news/techlines/2006/06025-Dakota_Gasification_Revenue_Sharing.html).

**Albany Democrat-Herald, “Pulling CO<sub>2</sub> Out Of Thin Air.”** Research in carbon sequestration conducted at the National Energy Technology Laboratory in Albany, Oregon was highlighted in this article. Geologist Bill O’Connor was quoted, saying “Our research has focused on converting carbon dioxide from coal-fired power plants into a solid or slurry solution and keeping it out of the atmosphere.” The Department of Energy’s goal is to develop cost-effective technology in the next 10 to 15 years. Various sequestration technologies are also described. May 3, 2006, <http://www.gazettetimes.com/articles/2006/04/30/news/community/local03.txt>.

**Air Liquide Press Release, "Air Liquide Announces New Program to Promote the Use of Carbon Dioxide for Enhanced Oil Recovery."**

Air Liquide Canada Inc., an industrial gas supplier to the oil and gas industry, has announced a program to promote carbon dioxide (CO<sub>2</sub>)-based enhanced oil recovery (EOR) projects in Western Canada. A pilot project will be launched to boost oil production rates from the Swan Hills reservoir, by injecting liquid CO<sub>2</sub> into the reservoir to improve the fluidity of the oil, thereby making it easier to force the oil to the producing wells. This will be the first phase of a potentially large-scale project, unique in Alberta, combining EOR and CO<sub>2</sub> sequestration at extreme depths and temperatures. May 1, 2006, <http://www.ccnmatthews.com/news/releases/showRelease&searchText=false&showText=all&actionFor=592105>.

**AP, "UW Scientists Seek Ways to Store Excess Carbon."**

University of Wyoming scientists are partnering with other scientists in the Northern Plains and northwestern states to study carbon sequestration. The Big Sky Carbon Sequestration Partnership—comprised of universities, government agencies and businesses from Idaho, Montana, Oregon, South Dakota, Washington and Wyoming, including the University of Wyoming—focuses on studying geological sequestration. Regarding geological sequestration, said Jim Steidtmann, director of the Enhanced Oil Recovery Institute, "(We want) to see how well carbon dioxide stayed put, and (whether) anything happened over the longterm that would give us clues as to how well carbon dioxide could be sequestered over time." April 23, 2006, <http://www.missoulian.com/articles/2006/04/23/breaker/doc444bad915f3c6228719164.pt>.

**Greenwire, "E.ON US to Partner with University of Kentucky to Study Sequestration."**

The utility company E.ON US is partnering with the University of Kentucky's Center for Applied Energy Research. The three-year, \$1.5 million grant and partnership will examine technology that separates and captures carbon dioxide emitted by coal-fired power plants for either geologic storage or a terrestrial sequestration application. April 29, 2006, <http://www.eenews.net/Greenwire/print/2006/04/28/8>. (Subscription may be required.)

**Zeenews.com, "Japan to Capture CO<sub>2</sub> at Australian Power Plant."**

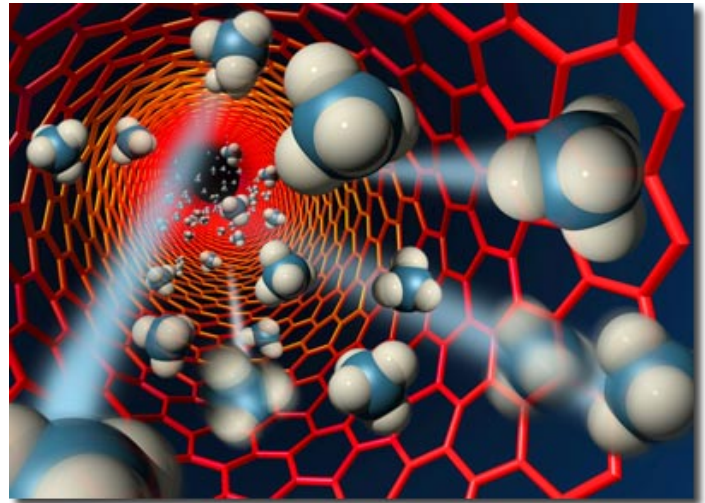
A Japanese consortium is planning construction of a carbon dioxide (CO<sub>2</sub>) liquefying facility, slated to cost about \$124 million, with construction to begin in 2007, and startup by 2009. Twenty percent of the CO<sub>2</sub> from a power plant in Queensland, Australia would be captured, liquefied and geologically stored. The consortium would be led by J Power and Ishikawajima-Harima Heavy Industries, alongside the Japanese industry ministry and Australian, US and European firms. May 4, 2006, <http://www.zeenews.com/znews/articles.asp?aid=292761&ssid=51&sid=BUS>.

## Science

**Reuters, "Greenhouse Gases Showed Steady Rise in 2005."**

The US National Oceanic and Atmospheric Administration (NOAA) reported on May 1, 2006 that carbon dioxide levels increased from 2004 to 2005, according to the agency's Annual Greenhouse Gas Index, or AGGI. Nitrous

oxide levels also rose, but methane and chlorofluorocarbon levels decreased. The AGGI showed a 1.25 percent rise in overall greenhouse gases in 2005. The AGGI stood at 1.215 in 2005 compared to the 1990 baseline value of 1.00, showing a steady rise in greenhouse gases over the past 15 years. The 1.25 percent rise in greenhouse gases was comparatively smaller than the increases of previous years, with the largest annual increase at 2.8 percent (1987 to 1988), and the smallest of .81 percent (1992 to 1993). Global levels of carbon dioxide increased from an average of 376.8 parts per million in 2004 to 378.9 parts per million in 2005. To access the NOAA AGGI website, go to: <http://www.cmdl.noaa.gov/aggi/>. May 3, 2006, <http://www.planetark.com/dailynewsstory.cfm/newsid/36210/story.htm>.



Scott Dougherty, Lawrence Livermore National Laboratory (LLNL). **Artist's rendering of methane molecules flowing through a carbon nanotube less than two nanometers in diameter.**

**Contra Costa Times, "Livermore Lab's 'Nanotube' Work Could Help Curb Global Warming."**

Scientists from Lawrence Livermore and Lawrence Berkeley laboratories have created a filtration membrane comprised of carbon nanotubes, which could be useful for removing carbon dioxide directly from power plant emissions. The carbon nanotubes that comprise the membrane are 50,000 times thinner than a human hair and over a trillion microscopic pores per square inch, but have a greater than expected flow rate for gasses and liquids passing through it. The research team is not sure of why the rate is faster than one would expect, but postulated that it is because the carbon atoms that make up the tubes fit together perfectly, and the surface of the tubes is extremely slippery. The technical paper describing the nanotubes transport process is in the May 19, 2006 issue of Science. ("Fast Mass Transport Through Sub—2-Nanometer Carbon Nanotubes, Science, May 19, 2006, Vol. 312. no. 5776, pp. 1034 – 1037, doi:10.1126/science.1126298.) May 19, 2006, [http://www.smalltimes.com/document\\_display.cfm?document\\_id=11557](http://www.smalltimes.com/document_display.cfm?document_id=11557).

**“Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences.”** The Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC, has released the first of a series of 21 reports aimed at providing current evaluations of climate change science to inform public debate, policy, and operational decisions. This first Synthesis and Assessment Product addresses previously identified discrepancies between observations and simulations of surface and atmospheric temperature trends. Previously reported discrepancies between the amount of warming near the surface and higher in the atmosphere have been used to challenge the reliability of climate models and the reality of human induced global warming. Specifically, surface data showed substantial global-average warming, while early versions of satellite and radiosonde data showed little or no warming above the surface. This significant discrepancy no longer exists because errors in the satellite and radiosonde data have been identified and corrected. New data sets have also been developed that do not show such discrepancies. This Synthesis and Assessment Product is an important revision to the conclusions of earlier reports from the US National Research Council and the Intergovernmental Panel on Climate Change. For recent decades, all current atmospheric data sets now show global-average warming that is similar to the surface warming. While these data are consistent with the results from climate models at the global scale, discrepancies in the tropics remain to be resolved. Nevertheless, the most recent observational and model evidence has increased confidence in the understanding of observed climatic changes and their causes. Further information on the process for preparing Synthesis and Assessment products and the CCSP itself can be found at: [www.climatechange.gov](http://www.climatechange.gov). April 2006. Download the report or sections of the report at: <http://www.climatechange.gov/Library/sap/sap1-1/finalreport/default.htm>.

## Policy

**Globe and Mail, “Ottawa Now Wants Kyoto Deal Scrapped.”** According to private instruction for negotiators at a climate change conference in Bonn, Germany, Canada will not support stricter emissions for the second phase of the Kyoto Protocol, which begins after 2012. The Canadian Foreign Affairs Department sent the negotiation instructions to the Canada delegation at the talks in Bonn, which were then obtained by Globe and Mail. "Canada will not support ... agreement on language in the work program that commits developed countries to more stringent targets in the future," states a line contained in 22 pages of instructions. The document also shows that Canada is threatening to pull out of the United Nations climate-change process unless it includes the United States and all other major polluters. From May 15-26, two sets of talks are taking place in Bonn, Germany, the UN Framework Convention on Climate Change (UNFCCC) talks and the talks regarding the Kyoto Protocol. The UNFCCC is a 1994 international treaty supported by 189 countries involving voluntary commitments to address climate change. One hundred and sixty three countries are in the Kyoto protocol, but only Canada and 34 other countries took on targets for the first phase. May 20, 2006, <http://www.theglobeandmail.com/servlet/story/LAC.20060520.KYOTO20/TPStory>. (Subscription or registration may be required.)

**Earth Negotiations Bulletin, “UNFCCC Sessions of the Subsidiary Bodies (SB-24), May 2006, Bonn, Germany.”** The twenty-fourth sessions of the Subsidiary Body for Scientific and Technological Advice (SBSTA) and the Subsidiary Body for Implementation (SBI) of the United Nations Framework Convention on Climate Change (UNFCCC) were held from May 18-26, 2006. Also the first session of the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol (AWG) took place from May 17-25. These sessions were preceded by the dialogue on long-term cooperative action to address climate change by enhancing implementation of the convention, held from May 15-16, 2006. All of these meetings were held in the Hotel Maritim in Bonn, Germany. On May 20, a workshop on carbon capture and storage was held, with the objective of improving understanding of carbon capture and storage through an overview of the document “Intergovernmental Panel on Climate Change (IPCC) Special Report on Carbon Dioxide Capture and Storage.” The workshop covered relevant provisions of the forthcoming 2006 IPCC Guidelines for National Greenhouse Gas Inventories and discussed demonstration and pilot projects, and capacity-building for the development and use of the technology. See: <http://unfccc.int/meetings/sb24/in-session/items/3623.php> for an agenda of the CCS workshop, and the following link: <http://www.iisd.ca/vol12/enb12301e.html> to scroll down for a summary of the workshop as reported by Earth Negotiations Bulletin. On May 22, a workshop on carbon capture and storage as development mechanism (CDM) project activities was held to consider carbon dioxide capture and storage as clean development mechanism project activities while taking into account issues relating to the projects including boundaries and permanence. See: <http://unfccc.int/meetings/sb24/in-session/items/3716.php> for the agenda of the workshop on CCS as CDM project activities, and the following link: <http://www.iisd.ca/vol12/enb12302e.html> to scroll down for the workshop’s coverage by Earth Negotiations Bulletin. <http://www.iisd.ca/climate/sb24/>.

## Geology

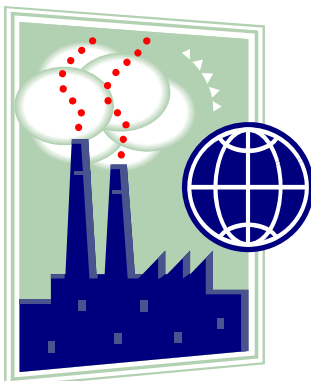
**“In situ CO<sub>2</sub>-coal reactions in view of carbon dioxide storage in deep unminable coal seams.”** Injection of carbon dioxide (CO<sub>2</sub>) in coalbed is considered to be an attractive option for storage. Large amounts of carbon dioxide are generated during the burial history of coal. In commercially produced coalbed gas, however, only small amounts of CO<sub>2</sub> are found. This has motivated the present investigation of the long-term stability of sequestered CO<sub>2</sub> in coal seams. Thus, the purpose of this study is to examine whether reactions with carbon dioxide can occur in coal at reservoir temperatures. The question is whether a relatively small decomposition of CO<sub>2</sub> to form carbon monoxide (CO) can become significant in periods of 10,000 years. High pressure high temperature static and dynamic experiments with CO<sub>2</sub> and coal were performed, which led to the opinion that chemical reactions involving CO<sub>2</sub> cannot be ruled out. All CO concentrations from CO<sub>2</sub> dynamic pressure experiments appear elevated compared to the nitrogen dynamic pressure experiment. The experiments do strongly point towards the reactivity of CO<sub>2</sub> to

form CO but because of limited experimental data the chemical involvement cannot be articulated in detail. *Fuel*, Volume 85, Issues 12-13, September 2006, Pages 1904-1912, available online April 18, 2006. <http://www.sciencedirect.com/science/article/B6V3B-4JRV77S-5/2/63e5f8cc6f3b7f9d4e073201bc08adfe>

## Technology

### **“Global challenges and strategies for control, conversion and utilization of CO<sub>2</sub> for sustainable development involving energy, catalysis, adsorption and chemical processing.”**

Utilization of carbon dioxide (CO<sub>2</sub>) has become an important global issue due to the significant and continuous rise in atmospheric CO<sub>2</sub> concentrations, accelerated growth in the consumption of carbon-based energy worldwide, depletion of carbon-based energy resources, and low efficiency in current energy systems. The barriers for CO<sub>2</sub> utilization include: (1) costs of CO<sub>2</sub> capture, separation, purification, and transportation to user site; (2) energy requirements of CO<sub>2</sub> chemical conversion (plus source and cost of co-reactants); (3) market size limitations, little investment-incentives and lack of industrial commitments for enhancing CO<sub>2</sub>-based chemicals; and (4) the lack of socio-economical driving forces. The strategic objectives may include: (1) use CO<sub>2</sub> for environmentally-benign physical and chemical processing that adds value to the process; (2) use CO<sub>2</sub> to produce industrially useful chemicals and materials that adds value to the products; (3) use CO<sub>2</sub> as a beneficial fluid for processing or as a medium for energy recovery and emission reduction; and (4) use CO<sub>2</sub> recycling involving renewable sources of energy to conserve carbon resources for sustainable development. The approaches for enhancing CO<sub>2</sub> utilization may include one or more of the following: (1) for applications that do not require pure CO<sub>2</sub>, develop effective processes for using the CO<sub>2</sub>-concentrated flue gas from industrial plants or CO<sub>2</sub>-rich resources without CO<sub>2</sub> separation; (2) for applications that need pure CO<sub>2</sub>, develop more efficient and less-energy intensive processes for separation of CO<sub>2</sub> selectively without the negative impacts of co-existing gases such as water (H<sub>2</sub>O), oxygen (O<sub>2</sub>), and nitrogen (N<sub>2</sub>); (3) replace a hazardous or less-effective substance in existing processes with CO<sub>2</sub> as an alternate medium or solvent or co-reactant or a combination of them; (4) make use of CO<sub>2</sub> based on the unique physical properties as supercritical fluid or as either solvent or anti-solvent; (5) use CO<sub>2</sub> based on the unique chemical properties for CO<sub>2</sub> to be incorporated with high ‘atom efficiency’ such as carboxylation and carbonate synthesis; (6) produce useful chemicals and materials using CO<sub>2</sub> as a reactant or feedstock; (7) use CO<sub>2</sub> for energy recovery while reducing its emissions to the atmosphere by sequestration; (8) recycle CO<sub>2</sub> as carbon-source for chemicals and fuels using renewable sources of energy; and (9) convert CO<sub>2</sub> under either bio-chemical or geologic-formation conditions into “new fossil” energies. Several cases are discussed in more detail. The first example is tri-reforming of methane versus the well-known CO<sub>2</sub> reforming over transition metal catalysts such as supported nickel catalysts. Using CO<sub>2</sub> along with H<sub>2</sub>O and O<sub>2</sub> in flue gases of power plants without sepa-



ration, tri-reforming is a synergetic combination of CO<sub>2</sub> reforming, steam reforming and partial oxidation and it can eliminate carbon deposition problem and produces syngas with desired hydrogen/carbon monoxide (H<sub>2</sub>/CO) ratios for industrial applications. The second example is a CO<sub>2</sub> “molecular basket” as CO<sub>2</sub>-selective high-capacity adsorbent which was developed using mesoporous molecular sieve MCM-41 and polyethylenimine (PEI). The MCM41-PEI adsorbent has higher adsorption capacity than either PEI or MCM-41 alone and can be used as highly CO<sub>2</sub>-selective adsorbent for gas mixtures without the pre-removal of moisture because it even enhances CO<sub>2</sub> adsorption capacity. The third example is synthesis of dimethyl carbonate using CO<sub>2</sub> and methanol, which demonstrates the environmental benefit of avoiding toxic phosgene and a processing advantage. The fourth example is the application of supercritical CO<sub>2</sub> for extraction and for chemical processing where CO<sub>2</sub> is either a solvent or a co-reactant, or both. The CO<sub>2</sub> utilization contributes to enhancing sustainability, since various chemicals, materials, and fuels can be synthesized using CO<sub>2</sub>, which should be a sustainable way in the long term when renewable sources of energy are used as energy input. *Catalysis Today*, available online May 16, 2006. [doi:10.1016/j.cattod.2006.02.029](http://www.sciencedirect.com/science/article/B6TFG-4JYKP82-1/2/15643dd129e6f04a5aa0ab9d56107077), <http://www.sciencedirect.com/science/article/B6TFG-4JYKP82-1/2/15643dd129e6f04a5aa0ab9d56107077>.

### **“Technoeconomic evaluation of IGCC power plants for CO<sub>2</sub> avoidance.”**

This paper is a technical and economic comparison of the performance of five plant designs in the 500 megawatt (MW) output range: IGCC without CO<sub>2</sub> capture, IGCC with 80 percent capture, IGCC with CO<sub>2</sub> emissions equal to those of a NGCC, IGCC with CO<sub>2</sub> and hydrogen sulfide (H<sub>2</sub>S) co-capture, and NGCC without capture. ASPEN Plus™ models of the above plants were developed and the following plant performance results are discussed: net power output, efficiency, plant ancillary energy requirements and overall CO<sub>2</sub> emissions. Economic evaluations for all cases are presented, including the cost methodology and economic basis. The capital investment, cost of electricity and carbon dioxide mitigation costs for all plants are detailed and compared. The simulation results show that the economics favor higher capture levels in new IGCC plants. The CO<sub>2</sub> mitigation costs corresponding to IGCC plants with 80 percent capture are slightly lower than those corresponding to IGCC plants with equal emissions to those of NGCC plants (28 vs. 30 \$/tonne CO<sub>2</sub> avoided). The capital cost difference (per kilowatt (kW) of net installed capacity) between the above plants is 7 percent, while the CO<sub>2</sub> emissions of the former are almost half those of the latter. IGCC plants with CO<sub>2</sub> and H<sub>2</sub>S co-capture have substantial technoeconomic advantages over IGCC plants that capture CO<sub>2</sub> and H<sub>2</sub>S separately. Based on a 577 MW IGCC, the power output decreases only to 552 MW for the co-capture case, whereas it drops to 488 MW when CO<sub>2</sub> and H<sub>2</sub>S are captured separately. The incremental capital cost of co-capture plants is 6 percent, and their electricity production cost increase is less

than half a cent, with respect to an IGCC without capture. The CO<sub>2</sub> mitigation cost of co-capture plants is at least four times lower than their separate CO<sub>2</sub> and H<sub>2</sub>S capture counterparts. *Energy Conversion and Management*, Volume 47, Issues 15-16, September 2006, Pages 2250-2259, available online February 9, 2006, <http://www.sciencedirect.com/science/article/B6V2P-4J7B0PF-1/2/3a67a6636f5dd0ec347122e9383b2714>

**“Oxygen efficiency with regard to carbon capture.”** Carbon capture is often discussed in the literature with the sole focus on power processes, despite the fact that carbon dioxide emissions from other sources are just as relevant for the impact on the atmosphere. Furthermore, some carbon capture methods are relatively inefficient when applied to power production processes. Carbon capture should preferably be performed where the cost is as low as possible, i.e. not necessarily from power production processes. As an example, carbon capture using combustion with pure oxygen is far more energy efficient if it is used together with lime kilns or cement kilns than together with power production processes. A new concept termed “oxygen efficiency” is introduced in this paper. It describes the amount of carbon dioxide that can potentially be captured per unit of oxygen. As such, the oxygen efficiency quantifies the value of a certain unit of oxygen for carbon capture reasons. The base concept is that the energy penalty for the production of one part of oxygen is the same no matter where it is produced; hence, if this unit of oxygen can be used to capture more carbon dioxide, it is more efficient. Typically, the oxygen efficiency would be five times greater for carbon capture when utilizing pure oxygen together with cement kilns rather than together with methane-fired power plants. Furthermore, the concept of oxygen efficiency illustrates the importance of considering how carbon capture methods can be utilized in the most efficient way, in addition to evaluating which carbon capture method is the most suitable for a particular technology. *Energy*, available online April 8, 2006, <http://www.sciencedirect.com/science/article/B6V2S-4JRVFS9-2/2/a26c96289e400e62be0b0cba3a18c02c>.

**“A quantitative comparison of gas turbine cycles with CO<sub>2</sub> capture.”** Nine different concepts for natural gas fired power plants with carbon dioxide (CO<sub>2</sub>) capture have been investigated, and a comparison is made based on net plant efficiency and emission of CO<sub>2</sub>. The cycles are one post-combustion, six oxy-fuel and two pre-combustion capture concepts. A 400 megawatt (MW) combined cycle plant is applied as a reference case. A common basis for the comparison of all concepts is defined and employed in heat- and mass-balance simulations of the various concepts. As gas turbine cooling impacts the net plant efficiency at high turbine inlet temperatures, a simplified turbine cooling model has been applied in the simulations. It is found that the concepts, in which novel technology (the methane steam reformer with hydrogen separation (MSR-H<sub>2</sub>), the advanced zero emission process power plant— (AZEP), the solid oxide fuel cell combined with a gas turbine—SOFC+GT and the chemical looping combustion—CLC concepts) is employed, exhibit the best performance with respect to both efficiency and in most cases also CO<sub>2</sub> capture (capture rates close to 100 percent). Post-combustion capture and pre-combustion capture with auto-thermal reforming, which are based on more mature technology, show a lower efficiency and a capture rate of

typically 90 percent. The SOFC+GT concept exhibits the best cycle performance and even better than a standard combined cycle plant, however, any realization of a SOFC-GT 400 MW plant has a very distant future perspective. In order to conduct a complete assessment of these diverse concepts, other criteria for comparison such as e.g. technology level and costs should also be considered. This is not, however, included in the present work. *Energy*, available online, April 17, 2006, <http://www.sciencedirect.com/science/article/B6V2S-4JRKCTS-1/2/12016c77a4c8106910ef9d002d70d791>.

**“Chemical fixation of CO<sub>2</sub> in carbonates: Routes to valuable products and long-term storage.”** Carbon dioxide emissions to the atmosphere can be reduced by chemical fixation in organic or inorganic carbonates. Many compounds can be commercially produced on an industrial scale using carbon dioxide (CO<sub>2</sub>), allowing for turning a (nowadays problematic) waste gas into economic profit. Besides this, the carbonation of magnesium silicates and calcium silicates is an option for long-term storage of CO<sub>2</sub> at a capacity that exceeds that of other options for CO<sub>2</sub> storage by several orders of magnitude, with the inherent benefit that post-storage monitoring of the stored CO<sub>2</sub> is not necessary. The first part of this paper gives an overview of commercial carbonate chemical production routes that do (or in a near future can) make use of the CO<sub>2</sub> that is produced at a large scale from human activities. The second part addresses the process technology, market potential and other aspects of mineral carbonation for long-term CO<sub>2</sub> storage as an alternative for, for example, storage in underground aquifers. *Catalysis Today*, available online March 22, 2006. <http://www.sciencedirect.com/science/article/B6TFG-4JJ2BNR-2/2/ef069deabba02b1e84721ac45544dd13>.

## Terrestrial/Ocean



**“Cost efficient rotation and tillage options to sequester carbon and mitigate GHG emissions from**

**agriculture in Eastern Canada.**” The economic efficiency of cropping options to mitigate net greenhouse gas (GHG) emissions from agriculture in Eastern Canada was analyzed. Data on yield response to tillage (moldboard plow and chisel plow) and six-corn (*Zea mays* L.)-based rotations were obtained from a 20-year field experiment in Ontario. Budgets were constructed for each cropping system while GHG emissions were accounted for by soil carbon measurements and estimates of nitrous oxide according to Intergovernmental Panel on Climate Change methodology. Complex crop rotations with legumes, such as corn–corn–soybeans (*Glycine max.* L.)–wheat (*Triticum aestivum* L.) with red clover (*Trifolium pratense* L.) underseeded, have higher net returns and substantially lower GHG emissions than continuous corn. Conservation tillage reduces GHG emissions due to lower input use but sequestration levels did not vary significantly between tillage systems. Rotation had a much bigger effect on the mitigation potential of GHG emissions than tillage. However, opportunity costs of more than \$200 per megagram of carbon dioxide equivalent per hectare per year (Mg CO<sub>2</sub> eq ha<sup>-1</sup> year<sup>-1</sup>) indicate the limits to increase the mitigation potential beyond the level of the most profitable cropping system. *Agriculture, Ecosystems & Environment*, available online May 2, 2006. doi:10.1016/j.agee.2006.03.023, <http://www.sciencedirect.com/science/article/B6T3Y-4JVTBHS-2/2/c2ce339e0b664deb68ea1ada7fbb2027>.

**"Do Recent Scientific Findings Undermine the Climate Benefits of Carbon Sequestration in Forests?: An Expert Review of Recent Studies on Methane Emissions and Water Tradeoffs."** Two recent papers in the scientific literature have generated speculation regarding the benefits of terrestrial carbon sinks. One study, led by Frank Keppler from the Max Planck Institute found that plants emit significant amounts of methane, a potent greenhouse gas. Another study, led by Robert Jackson of Duke University found that forest plantations can reduce stream flow and increase salinization of soils more than previously thought. Some media and interested parties have speculated that this research calls into question the value of carbon sequestration from trees and plants as a climate change mitigation strategy. Others viewed this speculation as far overblown. What did the research say? What do scientific experts think about its significance? And should current policy be altered as a result? To answer these questions a group of experts gathered at Duke University. They assessed the science and its implications and came to the consensus discussed in this document. Nicholas Institute for Environmental Policy Solutions, Consensus from an Expert Roundtable held February 9, 2006 at Duke University, April 2006, <http://www.env.duke.edu/institute/methanewater.pdf>.

## Trading

### Carbon Market Update, May 16, 2006

CCX-CFI 2006 (\$/tCO <sub>2</sub> ) <b>\$3.60</b>	EU ETS-EUA DEC 2006 (\$/tCO <sub>2</sub> ) <b>\$ 21.61</b>  (Converted from € to US\$)
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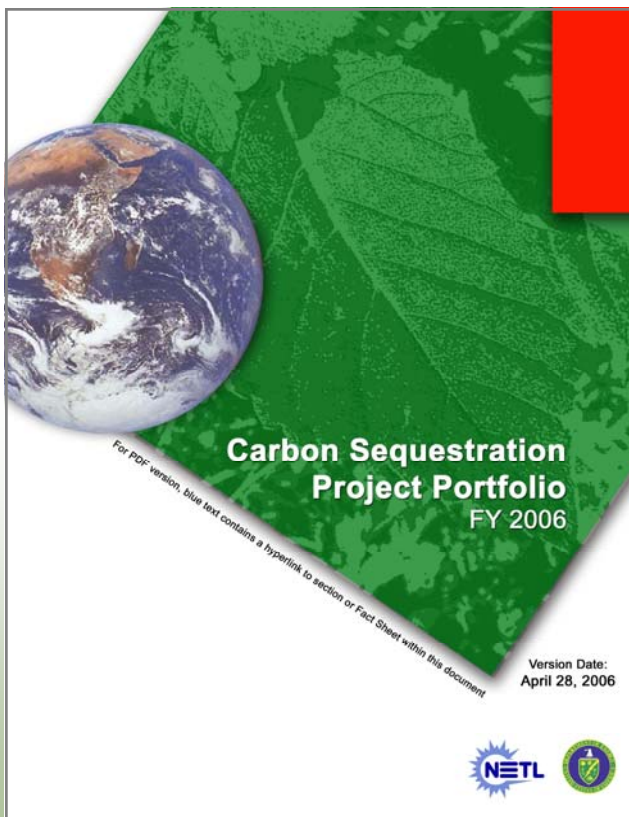
**The New York Times, “Data Leaks Shake Up Carbon Trade.”** On May 12, an online database accidentally listed a complete set of the carbon emissions data from the European Commission, three days before it was to be officially released. As a result, the carbon trading prices for the European Union Emissions Trading Scheme (EU ETS) sank to 8.60 euros (\$11) per metric ton, down from a high of 31 euros (\$40) in mid-April. **(EU ETS market values are listed monthly in the Trading section’s Carbon Market Update in this newsletter.)** Critics question whether governments and industry overestimated their carbon emissions when originally allocating the credits, causing companies to sell large amounts of their extra credits, resulting in the drop in trading value. The EU ETS is now facing criticism from both traders and environmentalists; those trading on the ETS are now asking the commission to release ETS data quarterly instead of annually, and environmentalists are asking for tougher limits for phase two of the scheme (2008-2012). Traders are also asking to have the same oversight that any securities or bond market would, along with the same warnings and fines for leaking information. The EU ETS is thinly traded with only about 30 or 40 companies trading on the market on a given day, resulting in a more volatile market. Despite the upheaval, many are still optimistic about the carbon market. Said Louis Redshaw, head of environmental products at Barclays Capital, “Trading is the only way to reduce emissions economically and efficiently. I am confident this market will be around in 5 or 10 years.” May 16, 2006, <http://www.nytimes.com/2006/05/16/business/16place.html>. (Subscription required.)

**AP, “EU Carbon Dioxide Emissions Below Limit”, and EU Press Release, “EU Emissions Trading Scheme Delivers First Verified Emissions Data for Installations.”** The carbon emissions data which appeared on the European Commission website was intended to be posted on May 15, but was accidentally posted on May 12. The emissions quotas are part of the European Union Emissions Trading Scheme, and covers more than 9,400 installations. Carbon dioxide (CO<sub>2</sub>) emissions in 21 European Union countries were 44.1 million metric tons (2.4 percent) below the limit allocated to the region during the first year of trading. Germany had the largest surplus of credits, after emitting 21.4 million tons (4.3 percent) below its allowable limit. The 21 countries have a maximum of 1.83 billion tons of emissions (2005-2007), with approximately 9,400 industries permitted to sell any of their excess allowances. France, the Czech Republic, and Finland also did not exceed their limits after emitting 19.3 million tons, 14.5



million tons, and 11.5 million tons, respectively. For a summary table of the emission and allocations, see: [http://ec.europa.eu/environment/climat/pdf/citl\\_pr.pdf](http://ec.europa.eu/environment/climat/pdf/citl_pr.pdf). Member State reports can be downloaded from the Commission's Climate Change website at: [http://ec.europa.eu/environment/climat/emission/citl\\_en.htm](http://ec.europa.eu/environment/climat/emission/citl_en.htm). The searchable database on verified emissions and surrendered allowances (the Community Independent Transaction Log) can be found at: <http://ec.europa.eu/comm/environment/ets/>. [To view the data, click <http://www.ec.europa.eu/comm/environment/ets/welcome.do> to access the EU's community transaction log Web site. Click on the allocation/compliance search icon on the left-hand menu. Choose a nation in the "registry" box. Click the search box and, then, click the "export" box and choose a format for the download.] For information on the Commission's infringement action against Member States without an active registry see: <http://europa.eu/rapid/pressReleasesAction.do?reference=IP/06/469&format=HTML&aged=0&language=EN&guiLanguage=en>. For general information of the EU emission trading scheme see: <http://europa.eu.int/comm/environment/climat/emission.htm>. May 15, 2006, [http://msnbc.msn.com/id/12800327/from/RL\\_3/](http://msnbc.msn.com/id/12800327/from/RL_3/), and May 15, 2006, [http://ec.europa.eu/environment/climat/pdf/citl\\_pr.pdf](http://ec.europa.eu/environment/climat/pdf/citl_pr.pdf).

**CCX Press Release, "Chicago Climate Exchange Announces Fourth Consecutive Record Trading Month."** Chicago Climate Exchange (CCX) had its highest trading volume for the CCX Carbon Financial Instrument contracts for the first half of May (1-15) at 2,435,400 metric tons carbon dioxide (CO<sub>2</sub>), double the volume of April 2006. The total volume of trades in April 2006 was 1,069,400 metric tons of CO<sub>2</sub>. May 15, 2006, [http://www.chicagoclimateexchange.com/news/press/release\\_20060515\\_MayRecord.pdf](http://www.chicagoclimateexchange.com/news/press/release_20060515_MayRecord.pdf)



## Recent Publications

**"Carbon Sequestration Project Portfolio 2006."** The Carbon Sequestration Project Portfolio 2006 is a comprehensive document, designed to serve as a key resource of the National Energy Technology Laboratory's Carbon Sequestration Program. The portfolio includes maps of project distribution; a copy of the new "Carbon Sequestration Technology Roadmap and Program Plan 2006"; budget information; details about each individual research project; programmatic papers; and an index of project participants. The Portfolio is designed to be printed for use in a three-ring binder, or to be viewed online. Frequent updates will be posted to ensure that any new information is incorporated. To view and/or download the various sections of this document, go to the pdf table of contents: [http://www.netl.doe.gov/publications/carbon\\_seq/project%20portfolio/project\\_portfolio3/table\\_contents.pdf](http://www.netl.doe.gov/publications/carbon_seq/project%20portfolio/project_portfolio3/table_contents.pdf).

**"Canada's CO<sub>2</sub> Capture & Storage Technology Roadmap (CCSTRM)."** Natural Resources Canada has released Canada's Carbon Dioxide (CO<sub>2</sub>) Capture & Storage Technology Roadmap. The CCSTRM seeks to establish a robust architecture for addressing the technical risks and economic costs, with scientific understanding of geological, geotechnical, reservoir management, and engineering aspects of CO<sub>2</sub> capture and storage. The CCSTRM (March 2006) is available for download at: [http://www.nrcan.gc.ca/es/etb/cetc/combustion/co2trm/htmldocs/co2trm\\_e.html](http://www.nrcan.gc.ca/es/etb/cetc/combustion/co2trm/htmldocs/co2trm_e.html).

**"Carbon Dioxide Capture and Geologic Storage: A Core Element of a Global Energy Technology Strategy to Address Climate Change."** The findings presented in this report stem from more than ten years of research at Battelle's Joint Global Change Research Institute (JGCRI) to better understand the significant potential of carbon dioxide capture and storage (CCS) technologies in addressing climate change. A significant portion of the research was supported by the National Energy Technology Laboratory. A central focus of this report is on actions that will allow CCS technologies to transition from their current status as potential solutions to climate change to the point where these systems are deployed widely and have become safe, effective, and trusted cornerstones of the global energy system. This report was presented by the lead author of the report and Senior Scientist at JGCRI, James J. Dooley, at the Fifth Annual Conference on Carbon Capture and Sequestration in Alexandria, Virginia, held May 8-11, 2006. To read the full report, see: [http://www.battelle.org/news/06/CCS\\_Climate\\_Change06.pdf](http://www.battelle.org/news/06/CCS_Climate_Change06.pdf). To obtain a hard copy of the report, contact Jim Dooley via email at: [dooleyj@battell.org](mailto:dooleyj@battell.org). To read the May 10, 2006 press release regarding key points of the report see: <http://www.battelle.org/news/06/05-10-06ClimateChange.stm>.

**"Los Alamos Energy Security, Los Alamos National Laboratory, The Carbon Sequestration Issue, Winter, 2006, Vol. 2. No. 1."** *Los Alamos Energy Security*, produced by Los Alamos National Laboratory's Of-



office of Energy and Environmental Initiatives, presents energy issues of critical national and global importance and highlights the Laboratory's energy security research and development. The Winter 2006 issue covered various Carbon Sequestration projects, technologies, publications, events, and websites. To download a pdf of the publication see: [http://www.lanl.gov/energy/energysecurity/LANL\\_energysecurity2\\_1\\_hi.pdf](http://www.lanl.gov/energy/energysecurity/LANL_energysecurity2_1_hi.pdf).

## Legislative Activity

**Burlington Free Press (Vermont), "Governor Signs Bill to Reduce Greenhouse Gas Emissions."** Governor Jim Douglas signed a bill on May 2, 2006 that formally commits Vermont to the Regional Greenhouse Gas Initiative (RGGI) agreement, joining New Hampshire, Maine, Connecticut, New York, New Jersey and Delaware. RGGI will develop a cap on carbon dioxide emissions from power plants for member states, and create a trading market within the region. Vermont is scheduled to receive its allowances in 2009. May 5, 2006. <http://www.burlingtonfreepress.com/apps/pbcs.dll/article?AID=/20060502/NEWS/60502015>.

**Reuters, "Ten States, DC Sue EPA Over Power Plant Emissions."** Ten states (New York, California, Connecticut, Maine, Massachusetts, New Mexico, Oregon, Rhode Island, Vermont and Wisconsin) plus New York City and Washington, DC filed a lawsuit against the US Environmental Protection Agency (EPA) on April 27, claiming that newly adopted emissions standards do not do enough to regulate carbon dioxide emissions from power plants. The states said that the EPA is refusing to regulate carbon dioxide emissions under the Clean Air Act, despite what they feel is clear evidence that the emissions contribute to global warming, thereby harming "public health and welfare." The suit was filed in the federal appellate court for Washington, DC, and is being handled by the office of New York Attorney General Eliot Spitzer. EPA officials defended their emissions policy saying in a statement that they "will review all options and make an informed decision on how to proceed." "EPA's climate protection programs continue to exceed the agency's greenhouse gas emissions goals and are on target to meet the President's 18 percent goal to reduce greenhouse gas intensity by 2012," a spokeswoman stated.

To view the states and cities petition for review see: [http://www.eenews.net/features/documents/2006/04/27/document\\_gw\\_01.pdf](http://www.eenews.net/features/documents/2006/04/27/document_gw_01.pdf), and for the environmental group's petition for review see: [http://www.eenews.net/features/documents/2006/04/27/document\\_gw\\_02.pdf](http://www.eenews.net/features/documents/2006/04/27/document_gw_02.pdf) (Subscription may be required to view petitions.) April 28, 2006, <http://www.planetark.com/dailynewsstory.cfm/newsid/36170/story.htm>.

**Greenwire, "Senator Carper Picks Up Fresh Support for GHG Emissions Bill."** Senator Tom Carper's bill (D-DE), the Clean Air Planning Act, is to be co-sponsored by Senator Dianne Feinstein (D-CA), Lamar Alexander (R-TN), Lincoln Chafee (R-RI) and Judd Gregg (R-NH). The bill would require a cap on greenhouse gases emitted from power plants, including carbon dioxide (CO<sub>2</sub>) emissions. Senator John McCain, who has introduced a bill regarding greenhouse gas limits across the US economy as opposed to just focusing on power plants, said he was inclined to support

the Carper bill while maintaining leadership on his own bill. Senator Feinstein felt the Carper bill would "dovetail" with her upcoming legislation for control of greenhouse gas emissions across the US economy. Senator Jim Jeffords (I-VT), the ranking member of the Senate Environment and Public Works Committee, said he supported Carper's bill but is still going to unveil his own plan to more aggressively limit CO<sub>2</sub> emissions. May 3, 2006, <http://www.eenews.net/eenewspm/print/2006/05/03/2>. (Subscription may be required.)

## Events

June 14-15, 2006, **Carbon Markets Asia**, *Excelsior Hotel, Hong Kong*. As the amount of carbon mitigation activity builds rapidly across the region with both the Clean Development Mechanism and domestic emissions trading, this 2nd annual event brings together the region's key experts to discuss methodologies, best practice project development, linking and carbon trading. Register online at: [http://www.greenpowerconferences.com/carbonmarkets/carbonmarkets\\_hongkong06\\_book.html](http://www.greenpowerconferences.com/carbonmarkets/carbonmarkets_hongkong06_book.html).

June 19-22, 2006, **Eighth International Conference on Greenhouse Gas Technologies (GHGT-8)**, *Norwegian University of Science and Technology (NTNU), Trondheim, Norway*. The aim of this conference is to provide a forum for the discussion of the latest advances in the field of greenhouse gas control technologies. Full papers online and an updated preliminary conference program can now be found on the website: <http://www.ghgt-8.no>.

June 25-30, 2006, **SPE CO<sub>2</sub> Capture and Storage Forum**, *Omni Interlocken Resort, Broomfield (Denver), CO*. Opportunities exist in the oil and gas industry to use enhanced oil recovery (EOR) with CO<sub>2</sub> captured from anthropogenic sources. This forum will discuss the requirements for CO<sub>2</sub> capture and storage to become a way of contributing to the reduction of emissions as well as enhancing the production of oil and gas fields. It aims at bringing together the practitioners who are currently using CO<sub>2</sub> in their EOR projects, the brownfield asset managers, and geoscience experts, along with the technology developers and suppliers. The forum would also benefit from the participation of representatives from the power and downstream sectors. For additional information, visit: [http://www.spe.org/spe/jsp/meeting/0,2460,1104\\_1535\\_4242542,00.html](http://www.spe.org/spe/jsp/meeting/0,2460,1104_1535_4242542,00.html).

June 28, 2006, **Kyoto - At What Price?: How GHG Markets Are Impacting The Power Industry**, *The IEE, Savoy Place, London, UK*. Greenhouse gas reduction targets are set in the Kyoto Accord that formally came into effect on February 16, 2005. Climate change is high on the agenda for Tony Blair's term as leader of the G8 group of industrialized nations and he has identified that science and technology must play a major role in addressing this issue. This seminar will bring together stakeholders in the electricity industry ranging from gen-

## Events cont...

eration (renewables, combined heat and power (CHP), gas, coal, nuclear), transmission system and electricity supply (demand side management/metering) plus customer representatives (energy watch, large users, etc.). See registration and program information at: <http://www.iee.org/Events/kyoto.cfm>.

June 28-29, 2006, **Preparing for a Carbon Constrained Future**, *Hyatt Regency Crystal City, Arlington, VA*. This conference will spotlight topics such as: technologies that address carbon dioxide; timeline for when a full scale power plant demonstration will be online; timeline until technology is ready for commercial use; major market drivers that affect the price of carbon internationally; successful carbon disclosures; RGGI update; European market model; NETL's Regional Carbon Sequestration Partnerships program; and utilities from various regions sharing their climate policy strategies. Early bird rate before June 16. See: <https://www.eucf.com/conferences/june-06/0606-carbon-future.php> for a full agenda and registration information.

June 28-29, 2006, **Russia and the Carbon Market 2006**, *Moscow, Russia*. This conference will focus on the general and particular issues of Kyoto protocol implementation in Russia, and practical aspects of meeting Kyoto requirements for emission reductions trade. This conference will bring together decision-makers, investors, technology providers, project hosts and developers. Conference speakers will include members of the Russian State Duma and representatives of key Russian Ministries. For more information, see: [http://www.ncsf.ru/conf/en\\_index.php](http://www.ncsf.ru/conf/en_index.php).

August 22- 23, 2006, **G8 Workshop Short Term Opportunities for CO<sub>2</sub> Capture and Storage in the Fossil Fuel Sector**, *San Francisco, CA*. The workshop's goal is to foster introduction of carbon dioxide (CO<sub>2</sub>) capture and storage (CCS) technologies to the market. Its objectives include investigations and promotion of early opportunities for CCS, such as separation of CO<sub>2</sub> from natural gas and CO<sub>2</sub> enhanced oil recovery. The workshop will gather professionals working in these areas and serve as a platform for information exchange and as a preparatory event for a bigger dissemination and popularization workshop to be organized in 2007. Organizers of the conference are IEA, Chevron, USEA, IEA Greenhouse Gas R&D Programme, IEA EOR IA. Contact Jacek Podkanski, [jacek.podkanski@iea.org](mailto:jacek.podkanski@iea.org), for more information.

September 5-7, 2006, **Sixth European Conference on Coal Research and its Applications**, *University of Kent, Kent, UK*. The purpose of this conference is to bring together researchers at universities with participants from industry who also conduct research or who are interested in the application of this research in industry. Papers are invited on many topics that describe applications in coal technology, including carbon dioxide removal and storage technology. Email Dr. A. W. Thompson for information: [alan.thompson@nottingham.ac.uk](mailto:alan.thompson@nottingham.ac.uk) or see: <http://www.coalresearchforum.org/>.

September 25-28, 2006, **The 23rd International Pittsburgh Coal Conference**, *David L. Lawrence Convention Center, Pittsburgh, PA*. The Twenty-Third Annual International Pittsburgh Coal Conference will focus on environmental emissions issues and technologies surrounding the continued use of coal and the development of future coal-based energy plants to achieve near-zero emissions of pollutants, reduced costs, and high thermal efficiency while producing a suite of products to meet future energy market requirements. A proposed topic area of "Global Climate Change: Science, Sequestration, and Utilization" includes possible subtopics of: Kyoto protocol and policy issues; CO<sub>2</sub> capture technologies; sequestration in geological sinks; Enhancing natural sinks; modeling and assessments; non-CO<sub>2</sub> greenhouse gas capture and storage; multi-pollutant capture and storage; and CO<sub>2</sub> utilization. Pay before July 16, 2006 for a discount. For more information, see: <http://www.engr.pitt.edu/pcc/2006%20Conference.htm>.

September 26-27, 2006, **Sixth Annual Workshop of Greenhouse Gas Emission Trading**, *IEA Headquarters, Paris, France*. This workshop, organized jointly between the IEA, IETA, and EPRI, will provide an opportunity for government, industry, brokers, finance, and NGO delegates to discuss some of the key issues relating to emissions trading for climate policy. The workshop will combine presentations of recent research with discussion sessions on the following topics: 1. Country roundtable: highlights of regulatory developments; 2. Market news; 3. Exploring the implications of design options (price caps, intensity targets, etc.) on CO<sub>2</sub> market; 4. Linking: technical issues; and 5. Green investment schemes and Joint Implementation. Please note: participation is by invitation only. Email [etworkshop@iea.org](mailto:etworkshop@iea.org) for more information. [http://www.iea.org/Textbase/workshopdetail.asp?WS\\_ID=231](http://www.iea.org/Textbase/workshopdetail.asp?WS_ID=231).

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To learn more about DOE's Carbon Sequestration Program, please contact Sean Plasynski [sean.plasynski@netl.doe.gov](mailto:sean.plasynski@netl.doe.gov), or Dawn Deel at [dawn.deel@netl.doe.gov](mailto:dawn.deel@netl.doe.gov)