

# THE CARBON SEQUESTRATION NEWSLETTER

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## HIGHLIGHTS

**Fossil Energy Techline, “Secretary of Energy Announces Nearly \$24 Million in Grants for Carbon Sequestration Research.”** On October 23, US Department of Energy Secretary Samuel W. Bodman announced grant recipients for carbon capture projects. Nine projects will receive a total of almost \$24 million toward the development of novel and cost effective technologies utilizing carbon dioxide (CO<sub>2</sub>) capture from coal-fired power plants, and sequestration of the CO<sub>2</sub>. Recipients of the funds will contribute \$8 million in cost sharing funds. The projects support the President’s Global Climate Change Initiative, which requires an 18 percent reduction in US greenhouse gas intensity (a ratio of greenhouse gas emissions to economic output) by 2012. Established by the Department of Energy’s Office of Fossil Energy and managed by the National Energy Technology Laboratory, the Carbon Sequestration Program aims to develop safe, effective, low-cost carbon sequestration technologies; as well as reduction of greenhouse gas emissions and controlling climate change. Grant recipients are working on three methods of CO<sub>2</sub> capture: 1.) Precombustion capture, in which fuel is gasified to form a mixture of hydrogen and CO<sub>2</sub>, called synthesis gas or ‘syngas,’ where CO<sub>2</sub> is captured from the syngas before it is combusted; 2.) Post-combustion, which involves capturing CO<sub>2</sub> from flue gas after fuel has been combusted in air; and 3.) Oxycombustion, in which fuel is combusted in pure, or nearly pure, oxygen rather than in air, producing an exhaust mixture of CO<sub>2</sub> and water that can easily be processed to produce pure CO<sub>2</sub>. See the news link below for a list of the recipients of the grants and a description of the projects. October 23, 2006, [http://www.fossil.energy.gov/news/techlines/2006/06061-Sequestration\\_Research\\_Grants.html](http://www.fossil.energy.gov/news/techlines/2006/06061-Sequestration_Research_Grants.html).



**Fossil Energy Techline, “Department of Energy Advances Commercialization of Climate Change Technology.”** On October 31, the US Department of Energy (DOE) Assistant Secretary Jeffrey D. Jarrett announced plans to provide \$450 million in federal funding to support seven tests for the advancement of carbon sequestration technologies in the United States. The announcement was delivered during the Assistant Secretary’s attendance at the Asia-Pacific Partnership on Clean Development and Climate, a multilateral

## HIGHLIGHTS (continued)

partnership comprised of government and private sector partners from Australia, China, India, Japan, the Republic of Korea, and the United States. DOE will distribute the funding over the next ten years and will work with the seven Regional Carbon Sequestration Partnerships to develop large volume sequestration tests. This will be a follow-on activity to the current work being completed by the Partnerships, which has involved working to characterize their regions' opportunities and existing infrastructure for carbon sequestration. Results from the newly funded development phase will then be used to identify deployment opportunities for carbon sequestration technologies throughout North America. Additionally, the results will be applied to further development of DOE's FutureGen power plant, a zero emissions coal-fired power plant and potential sites for other plants similar to FutureGen. DOE's seven Regional Carbon Sequestration Partnerships currently include more than three hundred organizations in forty states, three Indian nations, and four Canadian provinces. They have collaborated to establish NATCARB, a comprehensive mapping tool which has identified sources that produce carbon dioxide and sinks where it can be stored. (For more information concerning the Regional Carbon Sequestration Partnerships and links to their current activities, please refer to the following: Midwest Regional Carbon Sequestration Partnership (Battelle Columbus Laboratories, Ohio), <http://198.87.0.58/>; Midwest Geological Sequestration Consortium (The Board of Trustees of the University of Illinois, Illinois State Geological Survey), <http://www.sequestration.org/>; West Coast Regional Carbon Sequestration Partnership (California Energy



Commission), <http://www.westcarb.org/>; Big Sky Regional Carbon Sequestration Partnership (Montana State University), <http://www.bigskyco2.org/>; Southwest Regional Partnership on Carbon Sequestration (New Mexico Institute of Mining and Technology), <http://www.southwestcarbonpartnership.org/>; Southeast Regional Carbon Sequestration Partnership (Southern States Energy Board), <http://www.secarbon.org/>; Plains CO<sub>2</sub> Reduction Partnership (University of North Dakota Energy and Environmental Research Center), <http://www.undeerc.org/pcor/>.) October 31, 2006, [http://www.fossil.energy.gov/news/techlines/2006/06062-Carbon\\_Sequestration\\_Testing\\_Suppo.html](http://www.fossil.energy.gov/news/techlines/2006/06062-Carbon_Sequestration_Testing_Suppo.html).

## Sequestration in the News

**FutureGen Alliance Press Release, "E.ON U.S. Joins FutureGen Alliance News."** E.ON U.S., a leading US utility, joined the FutureGen Alliance, the non-profit consortium of global electric and utility companies working with the US Department of Energy to develop FutureGen, the near-zero emissions power plant. E.ON is a subsidiary of E.ON A.G., the world's largest investor-owned energy services provider. E.ON U.S. owns and operates Louisville Gas and Electric Company, a utility that serves 321,000 natural gas and 394,000 electric customers in Louisville, Kentucky, and Kentucky Utilities Company, a utility based in Lexington, Kentucky that serves 525,000 customers in 77 Kentucky counties and 5 counties in Virginia. E.ON U.S. joins 10 other members of the FutureGen Alliance including American Electric Power, Anglo American, BHP Billiton, the China Huaneng Group, CONSOL Energy Inc., Foundation Coal, Rio Tinto Energy America, Peabody Energy, PPL Corporation, and Southern Company. Four sites are candidates for FutureGen, 2 located in Texas and 2 located in Illinois, with a National Environmental Policy Act review occurring prior to the site selection scheduled for late summer of 2007. October 31, 2006, [http://www.futuregenalliance.org/news/releases/pr\\_10-31-06.pdf](http://www.futuregenalliance.org/news/releases/pr_10-31-06.pdf).

**Washington Business Journal, "NM Tech Gets \$67 Million for Carbon Sequestration Research."** Through a cost-share program, the US Department of Energy's National Energy Technology Laboratory awarded the New Mexico Institute of Mining and Technology \$67 million to conduct carbon sequestration (CO<sub>2</sub>) research. The goal of this project is to sequester hazardous emissions by injecting an estimated 1 million tons of CO<sub>2</sub> into geological formations. The remaining \$17 million of the \$84 million total cost must be provided by New Mexico Tech and could be in the form of loans or through contributions made directly to the project. The funding to New

## Announcements

**Regional Carbon Sequestration Partnership Annual Review Meeting presentations available.** On October 3-4, 2006, NETL hosted the Regional Carbon Sequestration Partnerships Initiative Annual Review Meeting in Pittsburgh. The attendees received presentation on NETL programmatic highlights including oil and natural gas research and development. The attendees to the meeting received presentations on each of the 25 geologic and 11 terrestrial Validation Phase pilot tests. To view the presentations, see: <http://www.netl.doe.gov/publications/proceedings/06/rcsp/index.html>.

**Scientific Discovery Through Advanced Computing: Climate Change Prediction Program, DE-PS02-07ER07-06.** The Office of Biological and Environmental Research (BER) of the Office of Science (SC), US Department of Energy (DOE), hereby announces its interest in receiving applications for research grants in the Climate Change Prediction Program (CCPP), which is a component of the U.S. Climate Change Science Program (CCSP). Applications should describe research projects supporting the development and application of climate models for climate change projections on time scales of decades to centuries. Proposals should clearly describe how that research will contribute to a measurably improved ability to use high-end computing for climatic change projections. Applications due January 25, 2007. To download full announcement, see: <http://www.grants.gov/search/search.do?mode=VIEW&oppld=11276>.

Mexico Tech will be distributed over a ten-year period. October 30, 2006, <http://washington.bizjournals.com/albuquerque/stories/2006/10/30/daily4.html>.

**E&E News, "Asia-Pacific Partnership Spawns 98 New Projects, Administration Says."** On October 31, the Bush Administration revealed plans for 98 new clean energy products as part of the US commitment to reduce harmful carbon dioxide (CO<sub>2</sub>) emissions into the atmosphere. The unveiling coincided with the meeting of participant countries at American Electric Power Corporation headquarters in Columbus, Ohio. The US will implement these projects through its membership in the Asia-Pacific Partnership on Clean Development and Climate, which is comprised of six countries whose common objective is to address climate change issues through private sector investment and technology exchange among the member countries. This public-private initiative involves technology exchange visits between the member countries to see firsthand what is being done to provide clean power generation and reduced emissions, as well as specific project endorsements. Two such projects include a joint Australia-Japan venture to build a 30-megawatt pulverized coal plant that will demonstrate the capture and storage of carbon dioxide emissions and use of an Australian-developed solar technology in China and the United States. For links to the projects, refer to a list of US Department of State fact sheets at: <http://www.state.gov/g/oes/climate/app/c19376.htm>. October 31, 2006, <http://www.eenews.net/eenewspm/print/2006/10/31/2>. (Subscription may be required.)

**ExxonMobil Corporation Press Release, "ExxonMobil Supports European Research Initiative into Reducing Greenhouse Gas Emissions."** Exxon Mobil Corporation, a leader in carbon capture and storage (CCS) technology, announced that it will contribute 1 million Euros and provide expert technical guidance to participate in a project called CO<sub>2</sub>ReMoVe. CCS technology removes carbon dioxide from flue gases, compresses it to reduce the volume, and then transports it by pipeline to a site for sequestering in geologic formations. The purpose of this project is to evaluate a range of technologies to monitor the injection and storage of carbon dioxide (CO<sub>2</sub>) from various sites and then establishing guidelines that will be used for the certification of future sites where CO<sub>2</sub> will be sequestered. Over the next five years, Exxon Mobil will partner with other energy industry partners, including BP, ConocoPhillips, Schlumberger, Statoil, Total, Vattenfall and Winterhall in the CO<sub>2</sub>ReMoVe project, which is being sponsored by the European Commission Directorate General for Research. The International Energy Agency, DNV (an organization specializing in risk management in the oil and gas industry), and other national agencies and academic research organizations will also participate in the research. Sites identified for this initiative include the Sleipner and Snohvit fields in the Norwegian North Sea, at In Salah in the southern Saharan desert in Algeria, and in the German locality of Ketzin. The effort will involve the participation of technical experts from ExxonMobil's Up-

stream Research Company, which will be important to the success of the project. Successful use of the CCS technology could be applied to many other large scale sources of CO<sub>2</sub> emissions and play a significant role in reducing greenhouse gas emissions. November 2, 2006, <http://www.csrwire.com/PressRelease.php?id=6715>.

**International Herald-Tribune (Asia-Pacific), “Australia Pledges \$500 Million Australian (\$379 Million US) to Fight Global Warming.”** Australian Prime Minister John Howard announced that the country plans to invest \$379 million in new technologies aimed at reducing greenhouse gas emissions. Although the package does not elaborate on exactly which technologies will be designated to receive the funds, Australia has made previous investments in carbon sequestration projects in recent years. The country’s economy relies heavily upon profits from coal exports, a major source of greenhouse gas emissions. Rainfall levels have consistently fallen below average over the past several years in Australia, and the country is currently plagued by draught. Even with growing concerns of global warming, Australia has refused to pledge their participation in the Kyoto Protocol. October 22, 2006, [http://www.ihf.com/articles/ap/2006/10/22/asia/AS\\_GEN\\_Australia\\_Climate\\_Change.php](http://www.ihf.com/articles/ap/2006/10/22/asia/AS_GEN_Australia_Climate_Change.php).

## Science

**The New York Times “New Culprit in Climate Change? Try Airlines.”** The airline industry, under recent scrutiny from environmentalists and consumer advocacy groups, is making efforts to address concerns that air travel is a major contributor to carbon dioxide (CO<sub>2</sub>) emissions linked to global warming. Public awareness of the problem is being addressed through such “green” initiatives as offering airline passengers the option to purchase carbon credits at the time of booking. British Airways operates such a program whereby money earned on ticket surcharges for carbon credits are donated to sustainable energy programs. The airline industry is expected to raise further awareness of the issue by redirecting the focus of their advertising campaigns whereby emissions reduction will take the forefront to lower fares or other enticements. October 29, 2006, <http://select.nytimes.com/gst/abstract.html?res=F70F14FE395B0C738FDDA90994DE404482>

**The Independent (UK), “Flat Screen Televisions ‘Will Add to Global Warming’.”** Research conducted by Britain’s Liberal Democrats reported that the recent increase in the purchase of flat screen televisions in Great Britain could result in an increase in carbon emissions by as much as 70 percent. Contrary to the Stern report’s (a UK report on the economics of climate change) objective to spur changes in consumer behavior, the 700,000 ton per year increase in carbon dioxide (CO<sub>2</sub>) would only hamper the country’s attempts to reduce global warming. November 1, 2006, <http://news.independent.co.uk/environment/article1945758.ece>.

**Reuters, “Californian Greenhouse Emissions Up 14 Percent 1990-2004.”** According to a report released this week by the California Energy Commission, California’s greenhouse gas emissions rose more than 14 percent between 1990 and 2004. Dan Kammen of the energy and resources group at the Uni-



University of California-Berkeley says that an increase is the wrong direction for a state that has made a law to cut emissions, the Global Warming Solutions Act of 2006, though the level is considerably less than the national average (which is about double the rate of California's increase). The report is significant since it is the first time the state has accounted for emissions in such detail. The Global Warming Solutions Act of 2006 sets caps on emissions at 25 percent by 2020, and for 2000 levels of emissions by 2010. For the 15 years covered by the study, 81 percent of the greenhouse gas emissions were due to fossil fuels usage. The emissions percentages were 40.7 percent due to mobile sources, 22.2 percent due to electricity generation, 20.5 percent due to industrial emissions, 8.3 percent due to agriculture and forestry, and 8.3 percent due to other sources. Economic growth does not mean a comparable increase in emissions of greenhouse gases. The report entitled "Inventory of California Greenhouse Gas Emissions and Sinks: 1990 to 2004," and supporting figures can be seen at: [http://www.climatechange.ca.gov/policies/greenhouse\\_gas\\_inventory/index.html](http://www.climatechange.ca.gov/policies/greenhouse_gas_inventory/index.html). November 6, 2006, <http://www.planetark.com/dailynewsstory.cfm?newsid=38824&newsdate=06-Nov-2006>.

## Policy

**E&E News, "U.N. Conference Opens in Kenya."** The 12<sup>th</sup> UN Framework Convention on Climate Change (UNFCCC) meeting opened on November 6 in Nairobi, Kenya. More than 6,000 participants from 189 countries are meeting to discuss climate change and the urgent actions needed to combat the consequences of global warming. Attendees are planning to pressure the US and Australia, two countries that have not ratified the Kyoto Protocol, to pledge to reduce their emissions. For more information on the November 6-17 conference, see the UNFCCC website at: [http://unfccc.int/meetings/cop\\_12/items/3754.php](http://unfccc.int/meetings/cop_12/items/3754.php), November 11, 2006, <http://www.eenews.net/Greenwire/print/2006/11/06/10>.

**Reuters, "Verification Problems May Delay '07 Kyoto Projects."** Project evaluations aimed at decreasing global warming and redirecting funds to poorer nations in 2007 are being delayed due to delays in the Clean Development Mechanism (CDM) review process. The CDM is an arrangement under the Kyoto Protocol allowing industrialized countries to invest in global warming reduction projects in developing nations, rather than making reduction in their own countries, which are often more costly. However, determining whether projects meet CDM rules, a more than 50 percent increase in the number of projects up for review, complaints of bureaucratic delays, and a lack of uniform review guide-

lines are only some of the recurring problems causing backlogs in the system. Additionally, applications that are rejected are often not accompanied by suggestions for corrective measures, making it difficult for the applicants to amend their applications to fit proper guidelines. The current CDM arrangement is due to expire in 2012, which is forcing many project developers to push for validation of their applications before then. October 30, 2006, <http://www.planetark.com/dailynewsstory.cfm/newsid/38719/newsDate/30-Oct-2006/story.htm>.



**Reuters, "US, EU Hold Climate Talks Despite Kyoto Rift."** and **Finland EU Presidency Press Release, "EU and U.S. Will Continue Dialogue on Climate Change, Clean Energy and Sustainable Development."** The US and the European Union met in Helsinki, Finland on October 24-25 for a two-day dialogue on climate change, clean energy and sustainable development, despite the lack of participation in the Kyoto Protocol by the US. Carbon capture and storage was also among the topics discussed, including capturing CO<sub>2</sub> from power plants. The meeting was hosted by Finnish Environment Minister Jan-Erik Enestam, who holds the current presidency of the European Union. The US delegation was headed by Paula Dobriansky, US Under Secretary of State for Democracy and Global Affairs. An outcome of the meeting was that the EU and US delegations agreed to strengthen bilateral cooperation in several areas including promoting the "commercial deployment of clean coal and carbon sequestration technologies, including through the Carbon Sequestration Leadership Forum." October 24, 2006, <http://www.planetark.com/dailynewsstory.cfm/newsid/38622/story.htm>, and October 25, 2006, [http://www.eu2006.fi/news\\_and\\_documents/press\\_releases/vko43/en\\_GB/172262/](http://www.eu2006.fi/news_and_documents/press_releases/vko43/en_GB/172262/).

**Reuters, "Rare Russian CO<sub>2</sub> Data Shows 11 Percent Rise Since 1999,"** According to an official document submitted by the Russian environmental monitoring agency, Roshydromet, to the United Nations on Oct 23, Russia's emissions of greenhouse gases rose about 11 percent between 1999 and 2004, from 1.873 billion tons in 1999 to 2.074 billion tons in 2004. This is the first time in 5 years that Russia has submitted its greenhouse gas emissions data. Russia is the world's third largest polluter, and had previously submitted data in 1998 and 1999. After the 1991 collapse of the Soviet Union, Russia's emissions levels have dropped nearly 40 percent. Though it is still awaiting official UN verification, Russia's document to the UNFCCC is available online in Russian, at: [http://unfccc.int/essential\\_background/library/items/3599.php?rec=j&preref=5698&suchen=n](http://unfccc.int/essential_background/library/items/3599.php?rec=j&preref=5698&suchen=n). See the news item link for a small table of emissions data. October 24, 2006, <http://www.planetark.com/avantgo/dailynewsstory.cfm?newsid=38618>.

## Geology

No items this month.

## Technology

**"Layered Double Hydroxides for CO<sub>2</sub> Capture: Structure Evolution and Regeneration."** Mg-Al-CO<sub>3</sub> layered double hydroxide (LDH) was synthesized, and its thermal evolution was investigated using X-ray diffraction, FTIR (Fourier Transform Infrared Spectroscopy) spectroscopy, and thermogravimetric analysis (TGA). The resultant LDH derivatives showed excellent carbon dioxide (CO<sub>2</sub>) adsorption capabilities, especially suitable for high-temperature CO<sub>2</sub> separation from flue gases. Calcination of crystalline LDHs at 400 degrees Celsius led to phase transformation yielding amorphous Mg-Al mixed oxides having a CO<sub>2</sub> sorption capacity of 0.49 micromoles per gram (mmole/g) at 200 degrees Celsius. Reversible and irreversible CO<sub>2</sub> sorption was determined to be approximately 88 percent and approximately 12 percent of the total CO<sub>2</sub> sorption, respectively. Regeneration restored the Mg-Al mixed oxide to 98 percent of its initial CO<sub>2</sub> sorption after several cycles of CO<sub>2</sub> adsorption testing. This clearly indicates the desirable properties of Mg-Al mixed oxide for CO<sub>2</sub> capture from flue gases at high temperatures (up to 200 degrees Celsius). **M. K. Ram Reddy, Z. P. Xu, G. Q. (Max) Lu, and J. C. Diniz da Costa**, *Industrial and Engineering Chemistry Research*, **45** (22), 7504 -7509, 2006, 10.1021/ie060757k S0888-5885(06)00757-3, Web release date, October 4, 2006. <http://pubs.acs.org/cgi-bin/abstract.cgi/iecred/2006/45/i22/abs/ie060757k.html>. (Subscription required.)

**"Characterization and Activity of K, CeO<sub>2</sub>, and Mn Promoted Ni/Al<sub>2</sub>O<sub>3</sub> Catalysts for Carbon Dioxide Reforming of Methane."** Reforming of methane with carbon dioxide into syngas over Ni/<sup>γ</sup>-Al<sub>2</sub>O<sub>3</sub> catalysts modified by potassium, MnO, and CeO<sub>2</sub> was studied. The catalysts were prepared by impregnation technique and were characterized by BET surface area, pore volume, X-ray diffraction, scanning electron microscopy, transmission electron microscopy, temperature-programmed studies, and pulse chemisorption. The performance of these catalysts was evaluated by conducting the reforming reaction in a fixed-bed reactor. Results of the investigation suggested that stable Ni/Al<sub>2</sub>O<sub>3</sub> catalysts for the carbon dioxide reforming of methane can be prepared by the addition of both potassium and CeO<sub>2</sub> (or MnO) as promoters. The results of the various characterization techniques were used to relate the observed catalytic activity and stability to the catalyst property. The stability and lower amounts of coking on promoted catalysts were attributed to partial coverage of the surface of nickel by patches of promoters, strong metal-support interaction (TPR, H<sub>2</sub> pulse chemisorption, H<sub>2</sub>-TPD), and their increased CO<sub>2</sub> adsorption (CO<sub>2</sub>-TPD). For the stable 13.5Ni-2K/10CeO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub> catalyst, the effect of reaction temperature and contact time on conversion and product yield was studied. It was found that the conversion and product yield increased with increasing reaction temperature and  $W/F_{CH_4,0}$  and reached equilibrium at  $W/F_{CH_4,0} = 1.7$  kg-cat·h/kg<sub>methane</sub>. The mechanism of the CH<sub>4</sub>/CO<sub>2</sub> reaction has been proposed, based on which a kinetic model was developed to estimate the kinetic parameters. The estimated kinetic parameters predicted the product yields satisfactorily. CH<sub>4</sub> activation to form CH<sub>x</sub> and CH<sub>x</sub>O decomposition are suggested to be the rate-determining steps of the CH<sub>4</sub>/CO<sub>2</sub> reaction over the 13.5Ni-2K/10CeO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub> catalyst. The activation energy for methane adsorption and dissociation ( $E_{K1L}$ ), CH<sub>x</sub>O decomposition ( $E_{K7L}$ ), and reverse water gas shift reaction ( $E_{kr}$ ) were estimated to be  $113.8 \pm 5.5$ ,  $119.3 \pm 4.7$ , and  $155.3 \pm 7.0$  kilojoules per mole (kJ/mol), respectively. **Nandini A. Pechimuthu, Kamal K. Pant, Subhash C. Dhingra, and Rohit Bhalla**, *Industrial and Engineering Chemistry Research*, **45** (22), 7435 -7443, 2006. 10.1021/ie060661q S0888-5885(06)00661-0, Web release date, September 29, 2006, <http://pubs.acs.org/cgi-bin/abstract.cgi/iecred/2006/45/i22/abs/ie060661q.html>. (Subscription required.)

**"Feasibility Assessment of Microalgal Carbon Dioxide Sequestration Technology with Photobioreactor and Solar Collector."** The aim of this study was to develop a feasibility model for microal-

gal carbon dioxide (CO<sub>2</sub>) biofixation using photobioreactors equipped with solar collectors, which would evaluate the unit net cost of CO<sub>2</sub> mitigation as a function of the target total CO<sub>2</sub> mitigation cost, the available solar radiation, and the biological conversion efficiency, among others. The results showed that, to achieve the target CO<sub>2</sub> mitigation price of 30 \$ t<sup>-1</sup> [CO<sub>2</sub>] at 40 percent biological conversion efficiency, the allowable net cost should be less than \$252 m<sup>-2</sup> yr<sup>-1</sup> at low-light intensity (average US location), and should be less than \$3.24 m<sup>-2</sup> yr<sup>-1</sup> at high light intensity (sunbelt region). The model made evident the importance of using microalgae with commercially valuable byproducts (e.g. biofuel), especially in achieving the smaller allowable unit net costs corresponding to more stringent CO<sub>2</sub> mitigation costs. **E. Ono and J.L.**

**Cuello**, *Biosystems Engineering*, doi:10.1016/j.biosystemseng.2006.08.005, Available online October 16, 2006, <http://www.sciencedirect.com/science/article/B6WXV-4M4CN5S-1/2/2515673106115b3686f3d15355322e82>. (Subscription may be required.)

**“High efficiency electric power generation: The environmental role.”**

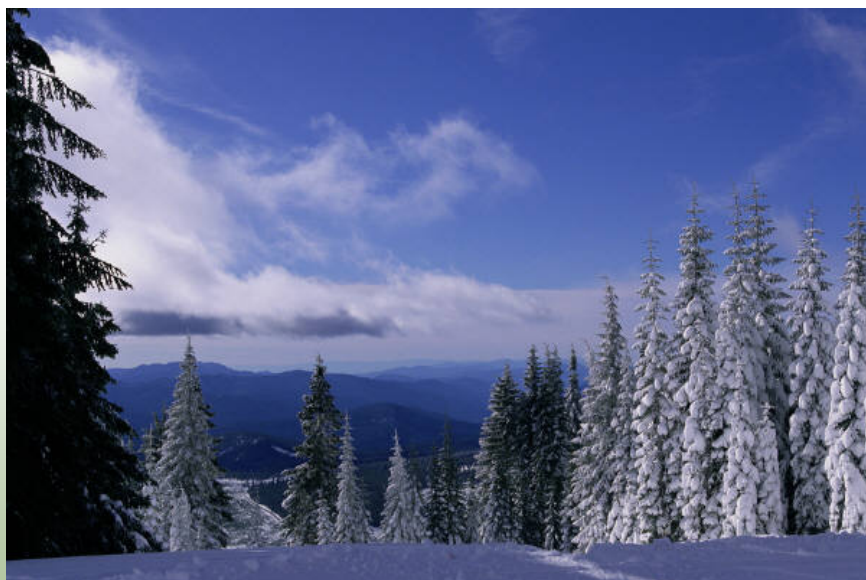
Electric power generation system development is reviewed with special attention to plant efficiency. It is generally understood that efficiency improvement that is consistent with high plant reliability and low cost of electricity is economically beneficial, but its effect upon reduction of all plant emissions without installation of additional environmental equipment, is less well appreciated. As carbon dioxide (CO<sub>2</sub>) emission control is gaining increasing acceptance, efficiency improvement, as the only practical tool capable of reducing CO<sub>2</sub> emission from fossil fuel plant in the short term, has become a key concept for the choice of technology for new plant and upgrades of existing plant. Efficiency is also important for longer-term solutions of reducing CO<sub>2</sub> emission by carbon capture and sequestration (CCS); it is essential for the underlying plants to be highly efficient so as to mitigate the energy penalty of CCS technology application.

Power generating options, including coal-fired Rankine cycle steam plants with advanced steam parameters, natural gas-fired gas turbine-steam, and coal gasification combined cycle plants are discussed and compared for their efficiency, cost and operational availability. Special attention is paid to the timeline of the various technologies for their development, demonstration and commercial availability for deployment. **János M. Beér**, *Progress in Energy and Combustion Science*, Available online October 17, 2006, <http://www.sciencedirect.com/science/article/B6V3W-4M4KK3C->

[1/2/7d6d3f50dc78ea92b377cfe4a860409f](http://www.sciencedirect.com/science/article/B6V3W-4M4KK3C-1/2/7d6d3f50dc78ea92b377cfe4a860409f).

(Subscription may be required.)

**“Combustion processes for carbon capture,”** A review of the technologies for coal-based power generation closest to commercial application involving carbon capture is presented. Carbon capture and storage (CCS) developments are primarily adaptations of conventional combustion systems, with additional unit operations such as bulk oxygen supply, CO<sub>2</sub> capture by sorbents, CO<sub>2</sub> compression, and storage. They use pulverized coal combustion in entrained flow—the dominant current technology for coal-based power, or gasification in entrained flow, although similar concepts apply to other solid-gas contacting systems such as fluidized beds. Currently, the technologies have similar generation efficiencies and are associated with efficiency penalties and electricity cost increases due to operations required for carbon capture. The R&D challenges identified for the combustion scientist and engineer, with current understanding being detailed, are those of design, optimization and operational aspects of new combustion and gasification plant, controlling the gas quality required by CCS related units and associated emission compliance, and gas separations. Fundamental research needs include fuel reactions at pressure, and in O<sub>2</sub>/CO<sub>2</sub> atmospheres, as few studies have been made in this area. Laboratory results interpreted and then included in CFD models of combustion operations are necessary. Also identified, but not detailed, are combustion issues in gas turbines for IGCC and IGCC-CCS. Fundamental studies should be a component of pilot-plant and demonstrations at practical scale being planned. Concepts for new designs of combustion equipment are also necessary for the next genera-



tion of technologies. The challenges involved with the design and operation of these integrated systems, while supplying electricity on demand, are considerable. **Terry F. Wall**, *Proceedings of the Combustion Institute*, Available online October 2, 2006, <http://www.sciencedirect.com/science/article/B7GWS-4M1DBB6-4/2/7e801408e48d6a0a6cc8b09aa9bbb02d>.

**“Narrow fluidized beds arranged to exchange heat between a combustion chamber and a CO<sub>2</sub> sorbent regenerator.”** Experiments in a cold model have been conducted to determine lateral solid diffusion coefficients in a narrow fluidized bed. The experimental data have been obtained using an image analysis technique that traces the dispersion of phosphor coated particles in the bed. A diffusion model has been used to describe lateral solids mixing in the configuration proposed for the narrow fluidized bed. The equation proposed by Shi and Fan [1984. *Lateral mixing of solids in batch gas–solids fluidized beds. Industrial and Engineering Chemistry, Process Design and Development* 23, 337–341] to calculate the diffusion coefficient in the radial direction fits well the available experimental data. The solid diffusion coefficients obtained have been used to solve a heat transfer problem and discuss the feasibility of a fluidized bed system that makes use of narrow fluidized beds arranged to transfer heat from bed to bed through a separating wall between them. This novel configuration of fluidized bed reactors could find application in some emerging systems that make use of solid regenerable sorbents to capture CO<sub>2</sub>. **G.S. Grasa and J.C. Abanades**, *Chemical Engineering Science*, Available online September 15, 2006, <http://www.sciencedirect.com/science/article/B6TFK-4KWT6D5-5/2/d1ed9eccc5f6d3e7e456942e8a5d4ce0>.

## Terrestrial/Ocean

**“How strongly can forest management influence soil carbon sequestration?”** The authors reviewed the experimental evidence for long-term carbon (C) sequestration in soils as consequence of specific forest management strategies. Utilization of terrestrial C sinks alleviates the burden of countries which are committed to reducing their greenhouse gas emissions. Land-use changes such as those which result from afforestation and management of fast-growing tree species, have an immediate effect on the regional rate of C sequestration by incorporating carbon diox-

ide (CO<sub>2</sub>) in plant biomass. The potential for such practices is limited in Europe by environmental and political constraints. The management of existing forests can also increase C sequestration, but earlier reviews found conflicting evidence regarding the effects of forest management on soil C pools. The authors analyzed the effects of harvesting, thinning, fertilization application, drainage, tree species selection, and control of natural disturbances on soil C dynamics. The authors focused on factors that affect the C input to the soil and the C release via decomposition of soil organic matter (SOM). The differentiation of SOM into labile and stable soil C fractions is important. There is ample evidence about the effects of management on the amount of C in the organic layers of the forest floor, but much less information about measurable effects of management on stable C pools in the mineral soil. The C storage capacity of the stable pool can be enhanced by increasing the productivity of the forest and thereby increasing the C input to the soil. Minimizing the disturbances in the stand structure and soil reduces the risk of unintended C losses. The establishment of mixed species forests increases the stability of the forest and can avoid high rates of SOM decomposition. The rate of C accumulation and its distribution within the soil profile differs between tree species. Differences in the stability of SOM as a direct species effect have not yet been reported. **Robert Jandl, Marcus Lindner, Lars Vesterdal, Bram Bauwens, Rainer Baritz, Frank Hagedorn, Dale W. Johnson, Kari Minkkinen and Kenneth A. Byrne**, *Geoderma*, Available online October 31, 2006, <http://www.sciencedirect.com/science/article/B6V67-4M7KB1B-1/2/417832004a3fec643e32303a400054a9>.

## Trading

Carbon Market Update, November 7, 2006	
CCX-CFI 2006 (\$/tCO <sub>2</sub> ) <b>\$4.20 (Vintage 2006)</b>	EU ETS-EUA DEC 2006 (\$/tCO <sub>2</sub> ) <b>\$ 12.01</b>  <b>(Converted from € to US\$)</b>

**Greenwire, “Market for CO<sub>2</sub> Credits Reaches \$22B.”** The carbon dioxide emissions trading market grew to \$22 billion worldwide, which equates to more than double its size last year. These figures are according to a report by the World Bank

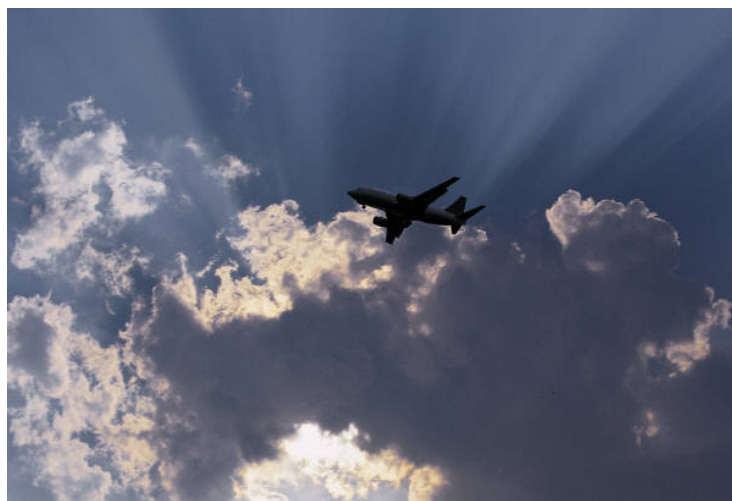


and the International Emissions Trading Association entitled: "State and Trends of the Carbon Market 2006: Update: January 1 – September 30, 2006." (**See Recent Publications section of this Newsletter for a link to the report.**) For the first nine months of 2006, the market totaled \$21.47 billion in comparison to the level for all of 2005 which stood at under \$11 billion. Launched at the start of 2005, the European Union's Emissions Trading Scheme accounted for \$19 billion dollars of trade this year. The report pointed out the noteworthy developments in carbon markets including the northeastern U.S.'s Regional Greenhouse Gas Initiative and California's efforts to establish a trading system. The report also warned of an uncertain future for carbon emissions trading past the year 2012 which is when the Kyoto Protocol expires. October 27, 2006, <http://www.eenews.net/Greenwire/2006/10/27/archive/12/?terms=co2>. (Subscription may be required.)

**Reuters, "Japan Firms Win OK For \$24 Million Carbon Projects."** On October 24, the Japanese government approved seven joint Clean Development Mechanism (CDM) projects that will be implemented by five of the country's companies in efforts to reduce greenhouse gas emissions. Under the CDM scheme, the companies will receive 360,000 tons of carbon dioxide (CO<sub>2</sub>) emission credits, through investments via a World Bank Fund, with \$24 million given to countries where the projects will be carried out. The host countries include Honduras, Peru, Moldova, Nepal and Argentina. One project identified is a wind power plant that is expected to produce less CO<sub>2</sub> emissions by operating on reduced amounts of fossil fuels. The five Japanese companies receiving the approval include Fujifilm Corporation, a wholly owned subsidiary by Fujifilm Holdings Corporation, Daiwa Securities SMBC Principal Investments Company, Nippon Oil Corporation, Idemitsu Kosan Company, and Okinawa Electric Power Company. Redirecting funds to poorer nations is one way that Japan will try to meet its goal to reduce emission levels by 6 percent from their 1990 level. Nonetheless, Japan has fallen short of that goal, since emission levels in 2005 were fourteen percent above its Kyoto reduction target. October 26, 2006, <http://www.planetark.com/dailynewsstory.cfm/newsid/38680/story.htm>.

**The Age (Australia), "Qantas Plan to Offset Its Carbon Emissions."** The Australian airline Qantas is making plans to allow its customers to offset the carbon emissions from their flights taken. Qantas is working with its code share partner British Airways to allow customers to pay a fee to offset their carbon emissions via a link from the British Airways website. For example, a flight from Melbourne to Singapore on a 747 produces about

1.36 tons of carbon dioxide, and the offset charge would be approximately \$19.46. Fees raised by this program will go to sustainable energy projects via a company called Climate Care. November 2, 2006, <http://www.theage.com.au/news/business/qantas-plan-to-offset-its-carbon-emissions/2006/11/01/1162339917973.html>



## Recent Publications

**"GHG Data Highlights from Greenhouse Gas (GHG) Emissions Data for 1990-2004 for Annex I Parties."** Every year, Parties included in the Annex I to the United Nations Framework Convention on Climate Change (UNFCCC), which are often called Annex I Parties or "industrialized countries", submit their greenhouse gas (GHG) emissions data to the UNFCCC secretariat, which then publishes an annual report on the latest available data on GHG emissions from the Annex I Parties. This report presents some findings on the data reported in 2006, both Annex I Parties and for those Annex I Parties that are Parties to the Kyoto Protocol. One key finding is that for all Annex I Parties taken together, GHG emissions in 2004 were 3.3 percent below the 1990 level. The overall decrease is composed of 36.8 percent decrease for Parties with economies in transition (EITs) and an 11.0 percent increase for non-EIT Parties. In 22 Annex Parties GHG emissions decreased from 1990 to 2004 whereas in 19 Parties the emissions increased. In general, the message from the 2006 data is that industrialized countries will need to intensify their efforts to reduce greenhouse gas emissions. Transport remains a sector where emissions reductions are needed but seem to be especially difficult to achieve. But the challenge is well understood, and the Kyoto Protocol, which is now firmly in place, is guiding Annex I

Parties in identifying and implementing policy option, including the flexibility mechanisms, for meeting their targets under the Protocol. To access the document directly go to: [http://unfccc.int/files/essential\\_background/background\\_publications\\_htmlpdf/application/pdf/ghg\\_booklet\\_06.pdf](http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/ghg_booklet_06.pdf). To access a table of "Changes in GHG emissions from 1990 to 2004 for Annex I Parties," go to: [http://unfccc.int/files/essential\\_background/background\\_publications\\_htmlpdf/application/pdf/ghg\\_table\\_06.pdf](http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/ghg_table_06.pdf).

**State and Trends of the Carbon Market 2006: Update: January 1 – September 30, 2006.** This report by the World Bank and International Emissions Trading Association was released in October 2006. It states that the carbon market grew in value to an estimated \$21.5 billion in the first three quarters of the year, more than doubling in value over the previous year. The market was dominated by the European Union Emissions Trading Scheme (EU ETS), which shrugged off signs of weakness following the sharp declines that accompanied the release of verified emissions data in May 2006. The project-based mar-



ket also grew in value to \$2.41 billion in just the first nine months of the year. The volume of European Union Allowances (EUAs) transacted on major exchanges and over-the counter rose to 764 million tons of carbon dioxide equivalent (tCO<sub>2</sub>e) by the end of September 2006 compared to approximately 324 million tCO<sub>2</sub>e in 2005. EUAs traded at a market value of \$18.9 billion so far in 2006, more than twice the previous year's \$8.2 billion. The Chicago Climate Exchange (CCX), the New South Wales Greenhouse Gas Abatement Scheme (NSW) and the United Kingdom Emissions Trading Scheme (UK ETS) all grew sharply, as did the trendy but non-standardized retail carbon market. Developing countries supplied 214 million tCO<sub>2</sub>e of primary project-based credits or 21 percent of total volumes traded for a total market value of \$2.3 billion. China continued to have a dominant market-share of the Clean Development Mechanism (CDM) with 60 percent and exerted its market power to try and influence prices of Certified Emission Reductions (CERs), while Ukraine supplied one third of Joint Implementation (JI) volumes. CERs and Emission Reduction Units (ERUs) transacted at average prices of \$10.50 and about \$8 respectively across a range of prices varying with the terms of the contracts entered into. Buyers found it easier to close transactions than six months ago, while sellers managed carbon price risk by favoring fixed price forward contracts. **(Also see Trading section of this Newsletter for the news item "Market for CO<sub>2</sub> credits reaches \$22B.")** View the report online at: [http://carbonfinance.org/docs/StateandTrendsMarketUpdate-Jan1\\_Sept30\\_2006.pdf](http://carbonfinance.org/docs/StateandTrendsMarketUpdate-Jan1_Sept30_2006.pdf).

**"Powering a Sustainable Future."** World Business Council for Sustainable Development (WBCSD), along with eight of the world's leading electric utility companies, released this report which contains an "agenda for concerted action" to secure future electricity generation, to bring more power to more people and to decrease the industry's greenhouse gas emissions. The eight companies warn that unless there is a marked shift in the way electricity is generated and regulated worldwide, increased energy production will have serious environmental impacts. The group also urges that business and government alike need to reverse the trend of declining resources for energy research and development, to make sure that carbon capture and storage, among other technologies, will be ready for deployment in time. October 24, 2006, <http://www.wbcd.org/Plugins/>

[DocSearch/details.asp?DocTypeId=33&ObjectId=MjEyMzE](http://DocSearch/details.asp?DocTypeId=33&ObjectId=MjEyMzE).

**“Climate Change 101.”** In an effort to enhance the quality of the climate dialogue, The Pew Center on Global Climate Change and the Pew Center on the States have developed a series of brief reports entitled Climate Change 101: Understanding and Responding to Global Climate Change. These brief reports are meant to provide a reliable and understandable introduction to climate science and impacts, technological solutions, and recent action in the US. Report subtopics include Science and Impacts, Technological Solutions and State Actions. Download pdfs of the report at: [http://www.pewclimate.org/global-warming-basics/climate\\_change\\_101/index.cfm](http://www.pewclimate.org/global-warming-basics/climate_change_101/index.cfm).

**“At loggerheads? Agricultural expansion, poverty reduction, and environment in the tropical forests.”** The World Bank’s report states that a system of international payments – “forest carbon finance” can be an incentive to stop deforestation and in turn slow global warming. According to the report, a majority of people in rural tropical areas — about 800 million — live in or around vulnerable forests or woodlands, depending on them heavily for survival. Yet deforestation at five percent a decade is steadily depleting this resource base, contributing to 20 percent of annual global CO<sub>2</sub> emissions and seriously threatening biodiversity. The report argues that with stronger financial incentives for avoiding cutting down trees, poor farmers in Madagascar and other forest countries could invest in sustainable agriculture in already-cleared fields, rather than cutting down more forest for paltry and often temporary gains. But current carbon markets do not tap the potential benefits of forest carbon. The report reviews the obstacles impeding the use of global carbon finance to reduce deforestation, and offers workable solutions. The report offers a simple framework for policy analysis by identifying three forest types-frontiers and disputed lands, lands beyond the agricultural frontier, and mosaiclands where forests and agriculture coexist. It collates geographic and economic information for each type that will help formulate poverty-reducing forest policy. The report highlights distinct priorities for each forest type, where deforestation incentives, remoteness, forest rights, and environment interact differently. The report and associated materials are available at: <http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/EXTPRRS/EXTTROPICALFOR-EST/0,,menuPK:2463898~pagePK:64168092~piPK:64168088~theSitePK:2463874,00.html>.

## Legislative Activity

**E&E News, “Senator Coleman Floats Plan to Set ‘Clean Energy’ Standard, Nix GHG Programs,” and Clean Air Report, “Senator Prompts Debate Over Draft Plan Blocking EPA, State CO<sub>2</sub> Rules.”** Senator Norm Coleman (R-MN) is proposing legislation which would mandate clean energy purchases and promote low-carbon fossil technologies while blocking EPA and state driven climate policies. Colman’s plan was first reported in the publication InsideEPA, and would require major electric utilities to transfer an increasing percentage of their energy portfolio to low and zero-carbon production methods, including wind, solar, nuclear or integrated gasification combined cycle coal plants. Preliminary proposed limits would set a national portfolio standard at 10 percent in 2015, 15 percent in 2020 and 20 percent in 2025. Caps on emissions are not included in the proposed plan. The proposal would also serve to preempt the *Massachusetts et al. v EPA* Supreme Court case, due to stating that carbon dioxide is not a pollutant under the Clean Air Act and is that “any harm allegedly caused by carbon dioxide emissions is not actionable under federal or state common law.” The proposal would also weigh a prohibition on any laws or regulations set up in states such as California, New York and across the Northeast United States which are designed to reduce carbon dioxide emissions from power plants. October 20, 2006, <http://www.eenews.net/eenewspm/2006/10/20/archive/1/?terms=climate>, and November 2, 2006, <http://epa.iwpnewsstand.com/showdoc.asp?docnum=CLEANAIR-17-22-1>. (Subscription may be required for both sources.)

## Events

December 11-15, 2006, **2006 American Geophysical Union (AGU) Fall Meeting**, *Moscone Center West, San Francisco, CA*. The Fall meeting of the American Geophysical Union will include several presentations regarding carbon geosequestration. Registration deadline is December 6, 2006. See: <http://www.agu.org/meetings/fm06/>.

January 17-18, 2007, **North America and the Carbon Markets**, *Ronald Regan Building and International Trade Center, Washington, DC*. This event is designed to introduce North American stakeholders to lessons and opportunities in the global carbon markets and will include public and private sector delegates from across the United States and Canada for an innovative forum of speakers, panel discussions and workshops. Register online at: <http://www.pointcarbon.com/Events/Workshops%20%20Seminars/North%20America%20and%20the%20carbon%20markets/category1307.html>.

January 21-24, 2007, **Electric Utilities Environmental Conference (EUEC), 10th Annual EPA, DOE, EPRI, EEI Conference on Clean Air, Mercury, Global Warming & Renewable Energy**, *Westin La Paloma Resort, Tucson, AZ*. EUEC is one of the best recognized annual technical meetings in US where over 1000 professionals network in a 150+ exhibit area with 250 presentations in 5 tracks, including a Climate Policy Track. The Climate Policy Track includes topics of Carbon Capture and Storage, and Carbon Markets and Trading. For information, see: <http://www.euec.com/default.html>.

February 5-8, 2007, **Fourth USDA Greenhouse Gas Conference**, *Baltimore Marriott Camden Yards, Baltimore, MD*. The purpose of this conference is to provide a forum for presentation of scientific, technical, and policy information related to the impacts of climate change on agriculture and forestry, and the potential role of management practices in related ecosystems and product use in mitigating climate change. The conference will feature a combination of plenary sessions, technical breakout sessions, and poster sessions organized to maximize interactions, discussion, and dialogue. For information, see: <http://www.acsmeetings.org/carbon/index.php?Token=&check=1&page=>

February 12-14, 2007, **Time to Adapt-Climate Change and the European Water Dimension**, *BMW i (Federal Ministry of Economics and Technology), Berlin, Germany*. The Symposium aims to provide a platform for representatives from governments, science and research, stakeholder groups and non-governmental organizations to discuss the likely impacts of climate change on water management and water dependent sectors such as agriculture, energy, inland navigation and tourism, as well as options for adaptation, and to strengthen the political profile of these issues. For further information, see:

<http://www.climate-water-adaptation-berlin2007.org/contact.htm>

March 13-15, 2007, **Carbon Markets Insights 2007**, *Copenhagen, Denmark*. This year's event will reflect on, amongst other major issues, the opening up of the EU emissions trading scheme to the global carbon markets. Carbon Market Insights is set to be the largest carbon market conference to date. For information, see: <http://www.pointcarbon.com/Events/Carbon%20Market%20Insights/category401.html>

March 22-23, 2007, **Optimising the Back Office in the Energy Trading Market**, *Central London, England*. This conference will examine the issues affecting the back office and provide strategies from energy firms and financial institutions. Looking across power, gas, oil and CO2 asset classes, the event will provide solutions in order to get closer to the standardization required to significantly automate back office processes. For further information or to receive a brochure, see: <http://www.marcusevans.com/events/CFEventinfo.asp?EventID=11740>

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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).