

THE CARBON SEQUESTRATION NEWSLETTER

http://www.netl.doe.gov/technologies/carbon_seq/index.html

January 2006

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Sequestration in the News

Department of Energy Press Release, "FutureGen Project Launched." In a press release issued on December 6, Secretary of Energy Samuel W. Bodman announced the official "kick off" of the FutureGen project by the Department of Energy with the signing of the FutureGen Industrial Alliance agreement. The FutureGen Industrial Alliance consists of: American Electric Power (Columbus, OH); BHP Billiton

(Melbourne, Australia); CONSOL Energy Inc. (Pittsburgh, PA.); Foundation Coal (Linthicum Heights, MD.); China Huaneng Group (Beijing, China); Kennecott Energy (Gillette, WY); Peabody Energy (St. Louis, MO); and Southern Company (Atlanta, GA). The Alliance members will contribute \$250 million toward the project to build FutureGen, a prototype of the zero emissions fossil-fueled power plant. The Alliance will issue a site selection solicitation in early 2006, with final site selection in mid-to-late 2007, and the plant is planned to be operational around 2012. The project will integrate testing of emerging energy supply and utilization technologies as well as advanced carbon capture and sequestration systems. The initial goal for carbon sequestration for FutureGen is to capture 90 percent of the plant's CO₂, with 100 percent possible through implementation of advanced technologies. The FutureGen Initiative is funded through the Department's Office of Fossil Energy and will be managed by the National Energy Technology Laboratory. December 6, 2005,

http://www.energy.gov/engine/content.do?PUB-LIC_ID=19301&BT_CODE=PR_PRESSRELEASES&TT_CODE=PRESSRELEASE

FutureGen Project Launched



St Louis Business Journal, "Illinois, Indiana join to attract FutureGen project," Indiana Gov. Mitch Daniels and Illinois Gov. Rod Blagojevich agreed on December 14 to make a united bid to bring FutureGen to the Illinois Coal Basin. US Rep. Jerry Costello (D-Bellefonte) and US Rep. John Shimkus (R-Collinsville) have lead the effort to locate FutureGen in Southern Illinois, which has high-sulfur coal reserves, oil and gas reserves, well-suited geography and the Coal Center at the Southern Illinois University Carbondale. December 15, 2005,

<http://stlouis.bizjournals.com/stlouis/stories/2005/12/12/daily50.html>

The Daily Texan, "CO₂ Use Found in Oil Project," Texas plans to aggressively pursue the bid for FutureGen. The state Legislature has allotted \$2 million to fund a team of researchers at the University of Texas (UT) who are working on a bid proposal. Scott Tinker, director of the UT's Future-

Gen project, said Texas is the best candidate to house the prototype because of its geology, with large coal deposits, oil fields and places to store sequestered carbon dioxide. In addition, the state has a thriving oil industry with the necessary infrastructure, Tinker said. December 8, 2005,

<http://www.dailytexanonline.com/media/paper410/news/2005/12/08/University/Co2-Use.Found.In.Oil.Project-1124534.shtml?no-write&sourcedomain=www.dailytexanonline.com>

The Engineer Online, "North Sea Rim Accord," United Kingdom Energy Minister Macolm Wicks and Norwegian Energy Minister Odd Roger Enoksen pledged to undertake a

HIGHLIGHTS

May 8-11, 2006, **The Fifth Annual Conference on Carbon Capture & Sequestration "Taking Steps Toward Deployment,"** Hilton Alexandria Mark Center, Alexandria, VA. The conference will bring together experts directly involved in developing, demonstrating and deploying carbon capture, separation and sequestration technologies as part of the Administration's Climate Change Technology Program. The Conference is sponsored by EM Publications & Forums, in partnership with the US Department of Energy, the National Energy Technology Laboratory and other federal agencies. Full details are available at <http://www.carbonsq.com/>

CALL FOR PAPERS for the Fifth Annual Conference on Carbon Capture & Sequestration. Abstracts are due January 30, 2006. Full papers are required. For guidelines for abstracts and a registration form, refer to: <http://www.carbonsq.com/>

bilateral effort to explore areas of cooperation to encourage injection and permanent storage of CO₂ beneath the North Sea. Said Wicks, "It is estimated that we have the capacity under the UK continental shelf to store our total carbon emissions for decades to come." Wicks added, "Norway has already taken a significant world lead in offshore geologic storage of CO₂ with the Sleipner project, building up considerable knowledge and experience in the field. Here in the UK, I welcome BP/Scottish and Southern Energy Peterhead project in the North Sea which will demonstrate the full carbon capture and storage process." The Carbon Abatement Technology Strategy, announced in June this year, recognized that incentives may be need to encourage this technology development. The Climate Change Programme Review will review and comment on the incentives, including details on the need and scope of the incentives. November 30, 2005, <http://www.e4engineering.com/Articles/292935/North+Sea+rjm+accord+.htm>

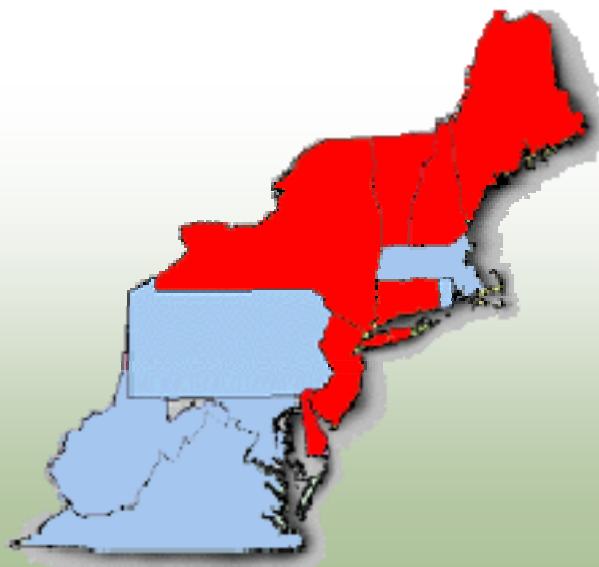
Science Daily and University of Michigan press release, "Crystal Sponges Excel At Sopping Up Carbon Dioxide,"

A new class of materials called metal-organic frameworks (MOFs) have been shown to have great potential for storing hydrogen and methane. On the molecular level, MOFs (also known as crystal sponges) are scaffolds made up of metal hubs with struts of organic compounds, maximizing surface area. One particular "star performer" in the class of compounds, MOF-177, can store 140 percent of its weight in CO₂ at room temperature and at 32 bar pressure. For comparison, in a tank filled with MOFs, one can store as much carbon dioxide as nine tanks that do not contain MOFs; whereas a tank filled with porous carbon—one of the current state of the art materials used for capturing CO₂ in power plant flues—could hold only four tanks worth of CO₂. December 1, 2005, <http://www.sciencedaily.com/releases/2005/12/051201164914.htm>

See Technology section of this newsletter for reference to December 1, 2005 web release of American Chemical Society journal article.

RGGI Press Release, "States Announce RGGI MOU Today,"

On December 20, seven Northeast governors announced a historic regional agreement to reduce greenhouse gas emissions from power plants, an important step to protect the environment and meet the significant challenge of climate change. Under the Regional Greenhouse Gas Initiative (RGGI) "ReGGIe," seven Northeast states have agreed to implement a cap-and-trade program to lower carbon dioxide (CO₂) emissions. This is the first mandatory cap-and-trade program for CO₂ emission in US history. The states signing the regional Memorandum of Understanding for RGGI are: Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York and Vermont. December 20, 2005. Copies of the MOU and related documents are available at: <http://www.rggi.org/agreement.htm>



Associated Press, "Connecticut Governor Says She'll Sign Regional Emissions Deal,"

Connecticut Gov. Jodi Reil said December 15 that she will sign the Regional Greenhouse Gas Initiative (RGGI) agreement. Her decision comes after officials from Connecticut, Rhode Island, and Massachusetts decided after a conference call December 14 that they weren't prepared to sign the RGGI. Reil, in a written statement, called the pact a "historic milestone" that addresses climate change issues while moving the region down the path of energy independence. "The agreement creates incentives that will reduce our reliance on fossil fuels and help free our economy from the price volatility of world oil and gas markets," she said. Adding, "The agreement is also structured in a manner that protects consumers from sharp increases in energy costs." December 15, 2005, http://www.boston.com/news/local/massachusetts/articles/2005/12/15/connecticut_governor_says_shell_sign_regional_emissions_deal?mode=PF

Boston Globe, "No Agreement Reached on Regional Carbon Dioxide Emissions Pact,"

The landmark Regional Greenhouse Gas Initiative (RGGI) multi-state agreement to reduce carbon dioxide emissions in the Northeast was in jeopardy. After the December 14 conference call among the chiefs of staff of all states involved in the program, Massachusetts, Connecticut, and Rhode Island decided they are not prepared to sign the agreement. Jeff Neil, spokesman for Rhode Island's Gov. Don Carcieri, said the Governor is concerned about the costs of the plan. "Ultimately, we don't know how much this plan will raise energy prices," said Neil. Their decision prompted cancellation of the December 15 news conference that had been planned to announce the pact. The draft proposal would freeze utility emissions at current levels through 2015, and then require a 10 percent reduction by 2020. Excess emission "credits" could be sold. Massachusetts Gov. Mitt Romney, in an interview with the Boston Globe, confirmed that he could not endorse a plan that did not include a "safety valve," one that would cap the amount power plants would have to pay if they exceed emission limits—since those costs could be passed onto businesses and consumers. Peter

"The states signing the regional Memorandum of Understanding for RGGI are: Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York and Vermont."

Constakes, a spokesman for New York Governor George Pataki, stated "We are greatly disappointed that after two-and-a-half years of productive work we've been unable to reach a final agreement with all the states that have participated in the process." Seth Kaplan, with the Conservation Law Foundation in Boston disputed concerns that the program would cost consumers money. Matt Vogel, spokesman for Rep. Martin Meehan, D-Mass., said work needs to be continued to make the proposal a reality, stating "Massachusetts ought to be the leader on making the initiative work, but essentially we've become the leader of the opposition." December 15, 2005,

http://www.boston.com/news/local/new_hampshire/articles/2005/12/15/no_agreement_reached_on_regional_carbon_dioxide_emissions_pact/

Reuters, "US States Forge on With Slimmer Plan to Cut CO₂," Massachusetts and Rhode Island did not sign the Regional Greenhouse Gas Initiative (RGGI) agreement along with the remaining seven states.

Massachusetts Gov. Mitt Romney (Republican) refused to sign, saying that the agreement could boost prices for electricity in his state, which are among the Nation's highest. Rhode Island said more studies are needed on how cutting carbon emissions would affect prices for electricity. Environmentalists and carbon emissions brokers are anxious to see RGGI operational because they hope it will link with similar plans being developed in western states and could be a model for a future federal plan. December 19, 2005, <http://www.planetark.com/dailynewsstory.cfm/newsid/34100/story.htm>

The Boston Globe, "BP to Boost Renewable Energy Funds," Europe's largest oil company, BP PLC, plans to double spending on alternate and renewable energy, creating a business unit that may generate about \$6 billion per year in revenue. BP will invest \$1.8 billion over the next three years on solar, wind, hydrogen, and carbon sequestration, focusing on new technologies to replace oil-and-gas-based generation. Under sequestration, CO₂ would be pumped into oil and gas fields, curbing output into the atmosphere. Chief Executive John Brown said, "We're responding to climate change by making a business." The \$600 million investment next year equals 4 percent of BP's total capital expenditure of about \$15 billion in 2006. BP would like about 7 gigawatts of installed capacity around the world within 10 years, enough to supply 10 percent of Britain's power needs. BP Alternate Energy will be headed by Steve Westell. November 29, 2005,

http://www.boston.com/business/technology/articles/2005/11/29/bp_to_boost_renewable_energy_funds/?rss_id=Boston+Globe++Business+News

Greenwire, "Tall buildings could pose threat to carbon sequestration," As the world sees construction of increasingly tall structures, seismic activity has risen. Implications could affect plans for carbon sequestration and nuclear waste storage. Taipei has seen a rise in micro-earthquakes since the construction of the world's tallest building, Taipei 101. Stresses in the earth's outer layer can push the sides of the fault together until rocks plummet and release energy in waves that cause the ground to shake. Geologist Lin Cheng-hong, from the Institute of Earth Sciences, said Taipei 101 weighed 700,000 tons, estimating stress from vertical loading on its foundation at 4.7 bars, of which some would be transferred to the earth's upper crust due to extremely soft sedimentary rocks beneath the Taipei basin. "If a fault is about to crack," says Lin, "then a little pressure can trigger an earthquake. It's like the last straw that breaks the camel's back." In May 2001, the magnitude 5 earthquake in the North Sea is thought to have been caused by a release in pressure from oil and gas extraction. And in 1967, waste injected into the Rocky Mountains set off a magnitude 5.5 earthquake under Denver in Colorado. December 5, 2005,

http://www.eenews.net/Greenwire/searcharchive/test_search-display.cgi?q=tall+buildings&file=%2FGreenwire%2Fsearcharchive%2FNewsline%2F2005%2FDecember5%2F12050516.htm (subscription may be required)

Business Wire, "GreenShift Acquires Rights to Patented Carbon Dioxide Reduction Technology; New Strain of Thermophilic Cyanobacteria Converts Exhaust Carbon Dioxide Into Pure Oxygen and Clean Water," GreenShift Corporation has announced the execution by its wholly-owned technology transfer and industrial design company, GreenShift Industrial Design Corporation ("GIDC"), of a license agreement with Ohio University ("Ohio") for its patented bioreactor process for reducing greenhouse gas emissions from fossil-fuelled combustion processes. The technology was developed by Dr. David Bayless, Director of Ohio's Ohio Coal Research Center, who targeted a carbon-hungry thermophilic photosynthetic organism, which thrives in the mineral hot springs of Yellowstone, for use in a bioreactor. The iron-loving cyanobacterium (blue-green algae), tentatively named *Chroocloeocystis siderophila*, grows on membranes of woven fibers resembling window screens, that are layered with "glow plates"—a system of

parabolic mirrors, fiber optic cables and slabs of acrylic plastic. The membranes allow for growth of the algae on a large surface area, using only 10 percent of "full strength" sunlight. The algae metabolize the carbon dioxide and water, giving off oxygen and water vapor. The organisms

Announcements

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http://www.carbonsq.com/pdf/06ccs_callforpapers.pdf

CALL FOR PAPERS for the Clearwater Coal Conference: The 31st International Technical Conference on Coal Utilization & Fuel Systems. The Conference Committee is seeking papers from all countries worldwide that will deal with technical solutions to problems; specific strategies; projects; innovations; industry trends; and/or regulatory compliance. Abstracts are due January 6, 2006.

Guidelines at:

<http://www.coaltechnologies.com/2006%20Call%20for%20Papers.htm>

also absorb nitrogen oxide and sulfur dioxide, acid rain contributors. A prototype of the technology was built that can handle 140 cubic meters of flue gas per minute, equivalent to the exhaust of 50 cars or a 3 megawatt power plant. GIDC's license with Ohio provides for non-exclusive rights to the technology for the purpose of air pollution control of exhaust gas streams from electrical utility power generation facilities; and exclusive rights to the technology for the air pollution control of exhaust gas streams from all other sources, including mobile applications; and to process carbon-containing compounds from any other source. December 12, 2005, http://home.businesswire.com/portal/site/google/index.jsp?ndmViewId=news_view&newsId=20051212005469&newsLang=en

Nature Conservancy, "First Conservation Initiative Certified for Reducing Greenhouse Gas Emissions," The Noel Kempff Mercado Climate Action Project, a Bolivian project protecting 3.8 million acres of tropical forest, is the first conservation-based initiative in the world to be fully certified for reducing greenhouse gas emissions. The Société Générale de Surveillance (SGS), an internationally accredited society for the CO₂ emission certification, evaluated the project's results from 1997 to 2005. SGS fully certified the emission reductions at 989,622 metric tons, using the rigorous standards detailed in the Clean Development Mechanism initiative of the Kyoto Protocol. December 19, 2005, <http://nature.org/initiatives/climatechange/press/press2192.html>

Science

"2005 Continues the Warming Trend," Scientists in the US and Britain reported that 2005 was one of the hottest on record, putting 8 of the 10 past years at the top of the charts in terms of high temperatures. NASA's Goddard Institute for Space Studies has concluded 2005 was the warmest year in recorded history, while the National Oceanic and Atmospheric Administration and the U.K. Meteorological Office report it the second hottest, after 1998. All three reports agree that 2005 is the hottest year on record for the Northern Hemisphere, at roughly 1.3 degrees Fahrenheit above the historical average. James Hansen, who directs NASA's Goddard Institute, said this year's statistics were particularly significant because in 1998 the world experienced El Niño, which drove up temperatures dramatically, whereas this year the temperature reached record levels without such a dramatic climatic event. Washington Post, December 16, 2005, <http://www.washingtonpost.com/wp-dyn/content/article/2005/12/15/AR2005121501637.html>



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Washington Post, December 16, 2005, <http://www.washingtonpost.com/wp-dyn/content/article/2005/12/15/AR2005121501637.html>

"Most of Arctic's Near-Surface Permafrost to Thaw by 2100," New simulations from the National Center for Atmospheric Research (NCAR), show that over half of the area covered by the topmost layer of permafrost in the Northern Hemisphere could thaw by 2050 and as much as 90 percent by 2100. Scientists expect the thawing to increase runoff to the Arctic Ocean and release vast amounts of carbon into the atmosphere. The study used a fully interactive climate system model, the Community Climate System Model (CCSM), to examine the state of permafrost, including interactions among the atmosphere, ocean, land, sea ice and soil. The new study highlights concern about carbon dioxide and methane being released from thawing soils, since permafrost may hold 30 percent or more of all the carbon stored in soils worldwide. Results appear online in the December 17 issue of *Geophysical Research Letters*. *Ascribe*, December 19, 2005, <http://newswire.ascribe.org/cgi-bin/ behold.pl?ascribeid=20051219.091021&time=09%2028%20PST&year=2005&public=0>

Policy

Numerous articles covering the United Nations Climate Change Conference (UNCCC) appeared in the news this month.

UNCCC Website, "United Nations Climate Change Conference agrees on future critical steps to tackle climate change." The UNCCC closed with the adoption of more than forty decisions that will strengthen climate change. The Conference President, Canadian Environment Minister Stéphane Dion felt that the conference was a success, that the Kyoto Protocol has been switched on, a dialogue about future action has begun, and parties are moving forward to adapt and advance the implementation of the regular work program of the Convention and the Protocol. During the first week of the conference, the rulebook of the 1997 Kyoto Protocol was adopted, the so-called "Marrakesh accords." Developed countries committed to fund the operation of the Clean Development Mechanism (CDM) with over 13 million in US dollars in 2006-2007, and the process for methodologies under CDM was simplified and its governing body strengthened. The second Kyoto mechanism was launched and its governing body set up—Joint Implementation, which allows developed countries to invest in other developed countries and earn carbon allowances they can use to meet their emission reduction commitments. The compliance committee with its enforcement and facilitative branches was elected, a key to ensuring that the Parties to the Protocol have a clear accountability regime in meeting their emissions reductions targets. The conference also agreed on a one-year process to define how the Adaptation Fund will be managed and operated. This fund will draw on money generated by the CDM and will support concrete adaptation activities in developing countries. Technology was at the center of discussion on efforts to reduce emissions and adapt to climate impacts. Countries agreed on further steps to promote the development and transfer of technologies. Carbon capture and storage was estimated to

have the potential to reduce the costs of mitigation by up to 30 percent, based on the recent report by the Intergovernmental Panel on Climate Change (IPCC). Parties agreed to move forward with deeper analysis of Carbon Capture and Storage technology. December 10, 2005. See: http://unfccc.int/meetings/cop_11/items/3394.php for the press release and for pdf files of the final decisions.

Bloomberg, “US Delegates Refuse to Participate in Global Warming Talks,” US delegates to Montreal refused to participate in Kyoto Protocol talks after objecting to non-binding negotiations to limit carbon dioxide emissions. About 10,000 representatives from almost 200 countries gathered in Montreal to plan the next round of greenhouse gas cuts before Kyoto expires in 2012. In 2001 the Bush Administration rejected an agreement to cut carbon dioxide and other gases to 7 percent below 1997 levels as too costly for the US, which emits 25 percent of the world’s greenhouse gases. The other Kyoto parties reached an informal agreement to continue talks on reducing emissions over the next few years without the US. December 9, 2005, http://www.bloomberg.com/apps/news?pid=10000087&sid=al_VP7vXpswU&refer=top_world_news. For the specifics on the UNCCC decisions, see this newsletter’s Policy section.

Business Standard, Economy Bureau, (New Delhi, India), “Draft Proposes 0.1 Percent Cess on Energy Firms,” India’s draft energy policy proposes a National energy fund to be set up through a cess (tax) of 0.1 percent on all petroleum, power, and coal companies. Technology missions will be used for research and development in areas such as carbon sequestration, efficiency improvement, in situ gasification, developing solar technologies for thermal and photovoltaics, bio-fuels such as producing of bio-diesel and ethanol, biomass plantation and wood gasification, and community-based bio-gas plants. A rebate of up to 80 percent of this tax is proposed to firms for in-house research and development. December 16, 2005, <http://www.business-standard.com/common/storypage.php?hpFlag=Y&chlogin=N&autono=208729&leftnm=lmnu2&lselect=0&leftindx=2>

Geology

“Convective stability analysis of the long-term storage of carbon dioxide in deep saline aquifers.” Deep saline aquifers are one of the most suitable geologic formations for carbon sequestration. The linear and global stability analysis of the time-dependent density-driven convection in deep saline aquifers is presented for long-term storage of carbon dioxide (CO₂). The convective mixing that can greatly accelerate the CO₂ dissolution into saline aquifers arises because the density of brine increases upon the dissolution of CO₂ and such a density difference may induce instability. The effects of anisotropic permeability on the stability criteria, such as the critical time for the appearance of convective phenomena and the critical wavelength of the most unstable perturbation, are investigated with linear and global stability analysis. The linear stability analysis provides a sufficient condition for instability while the global stability analysis yields a sufficient condition for stability. The results obtained from these two approaches are not exactly the same but show a consistent

trend, both indicating that the anisotropic system becomes more unstable when either the vertical or horizontal permeability increases. *Advances in Water Resources*, Volume 29, Issue 3, March 2006, Pages 397-407, <http://www.sciencedirect.com/science/article/B6VCF-4GNKS55-2/2/3a236275433494d932f82a227670610a> (subscription may be required)

“TOUGHREACT—A simulation program for non-isothermal multiphase reactive geochemical transport in variably saturated geologic media: Applications to geothermal injectivity and CO₂ geological sequestration,” TOUGHREACT is a numerical simulation program for chemically reactive non-isothermal flows of multiphase fluids in porous and fractured media. The program was written in Fortran 77 and developed by introducing reactive geochemistry into the multiphase fluid and heat flow simulator TOUGH2. A variety of subsurface thermo-physical-chemical processes are considered under a wide range of conditions of pressure, temperature, water saturation, ionic strength, and pH and Eh. Interactions between mineral assemblages and fluids can occur under local equilibrium or kinetic rates. The gas phase can be chemically active. Precipitation and dissolution reactions can change formation porosity and permeability. The program can be applied to many geologic systems and environmental problems, including geothermal systems, diagenetic, and weathering processes, subsurface waste disposal, acid mine drainage remediation, contaminant transport, and groundwater quality. This paper presents two examples to illustrate the applicability of the program. *Computers & Geosciences*, Volume 32, Issue 2, March 2006, Pages 145-165, <http://www.sciencedirect.com/science/article/B6V7D-4GY8752-1/2/dc69951e6d547a839471ae697370c72c> (subscription may be required)

Technology

“Metal-Organic Frameworks with Exceptionally High Capacity for Storage of Carbon Dioxide at Room Temperature.” Metal-organic frameworks (MOFs) show high CO₂ storage capacity at room temperature. Gravimetric CO₂ isotherms for MOF-2, MOF-505, Cu₃(BTC)₂, MOF-74, IRMOFs-11, -3, -6, and -1, and MOF-177 are reported up to 42 bar. Type I isotherms are found in all cases except for MOFs based on Zn₄O(O₂C)₆ clusters, which reveal a sigmoidal isotherm (having a step). The various pressures of the isotherm steps correlate with increasing pore size, which indicates potential for gas separations. The amine functionality of the IRMOF-3 pore shows evidence of relatively increased affinity for CO₂. Capacities qualitatively scale with surface area and range from 3.2 mmol/g for MOF-2 to 33.5 mmol/g (320 cm³(STP)/cm³, 147 wt percent) for MOF-177, the highest CO₂ capacity of any porous material reported. *Journal of the American Chemical Society*, ASAP Article 10.1021/ja0570032 S0002-7863(05)07003-4, Web release December 1, 2005, <http://pubs.acs.org/cgi-bin/sample.cgi/jacsat/asap/abs/ja0570032.html> (subscription may be required)

“Membrane processes for post-combustion carbon dioxide capture: A parametric study.” Much of the research in the area of carbon dioxide recovery and storage focuses on minimizing the energy required for CO₂ capture, as this step corresponds to the major cost contribution of the overall process (capture, transportation, injection). Out of the three traditional methods of CO₂ capture (absorption, adsorption and membrane processes), absorption is considered to be the best available technology for post-combustion application. However, amine absorption requires 4-6 GJ/tonne of recovered CO₂, in a large part due to significant energy consumption associated with the regeneration step. In this paper, [the authors] perform a systematic analysis of the separation performances and associated energy cost of a single-stage membrane module. First, the operational limits are identified in terms of permeate composition and CO₂ recovery ratio via a systematic parametric study for CO₂/N₂ mixtures. The energy consumption of the capture step is then evaluated and compared with the performance of amine absorption. Next, the search for an optimal strategy in terms of compression energy for a combination of membrane capture and CO₂ injection has been addressed. The results allow the identification of an optimal membrane pressure ratio for a given set of conditions. *Energy*, Available online December 5, 2005, <http://www.sciencedirect.com/science/article/B6V2S-4HR72B4-1/2/9de6a0d31c833d7d6e9d57005d18c71b> (subscription may be required)

“Optimization of pipeline transport for CO₂ sequestration.” Capture and disposal of CO₂ has received increased R&D attention in the last decade as the technology promises to be the most cost effective for large scale reductions in CO₂ emissions. This paper addresses CO₂ transport via pipeline from capture site to disposal site, in terms of system optimization, energy efficiency and overall economics. Technically, CO₂ can be transported through pipelines in the form of a gas, a supercritical fluid or in the subcooled liquid state. Operationally, most CO₂ pipelines used for enhanced oil recovery transport CO₂ as a supercritical fluid. In this paper, supercritical fluid and subcooled liquid transport are examined and compared, including their impacts on energy efficiency and cost. Using a commercially available process simulator, ASPEN PLUS 10.1, the results show that subcooled liquid transport maximizes the energy efficiency and minimizes the cost of CO₂ transport over long distances under both isothermal and adiabatic conditions. Pipeline transport of subcooled liquid CO₂ can be ideally used in areas of cold climate or by burying and insulating the pipeline. In very warm climates, periodic refrigeration to cool the CO₂ below its critical point of 31.1°C, may prove economical. Simulations have been used to determine the maximum safe pipeline distances to subsequent booster stations as a function of inlet pressure, environmental temperature and ground level heat flux conditions. *Energy Conversion and Management*, Volume 47, Issue 6, April 2006, Pages 702-715, <http://www.sciencedirect.com/science/article/B6V2P-4GPW9MR-2/2/6c358e0483b096f20b3a5b8d5668db76> (subscription may be required)

Terrestrial

“Trading Water for Carbon with Biological Carbon Sequestration,” Carbon sequestration strategies highlight tree

plantations without considering their full environmental consequences. [The Authors] combined field research, synthesis of more than 600 observations, and climate and economic modeling to document substantial losses in stream flow, and increased soil salinization and acidification, with afforestation. Plantations decreased stream flow by 227 millimeters per year globally (52 percent), with 13 percent of streams drying completely for at least 1 year. Regional modeling of US plantation scenarios suggests that climate feedbacks are unlikely to offset such water losses and could exacerbate them. Plantations can help control groundwater recharge and upwelling but reduce stream flow and salinize and acidify some soils. *Science*, December 23, 2005, Vol. 310. no. 5756, pp. 1944 – 1947. DOI: 10.1126/science.1119282, <http://www.sciencemag.org/cgi/content/full/310/5756/1944>

“Climate change impacts on agriculture and soil carbon sequestration potential in the Huang-Hai Plain of China.” For thousands of years, the Huang-Hai Plain in northeast China has been one of the most productive agricultural regions of the country. The future of this region will be determined in large part by how global climatic changes impact regional conditions and by actions taken to mitigate or adapt to climate change impacts. One potential mitigation strategy is to promote management practices that have the potential to sequester carbon in the soils. The Intergovernmental Panel on Climate Change (IPCC) estimates that 40 Pg (petagrams) of carbon could be sequestered in cropland soils worldwide over the next several decades; however, changes in global climate may impact this potential. [The authors] assess the potential for



soil carbon sequestration with conversion of a conventional till (CT) continuous wheat system to a wheat-corn double cropping system and by implementing no till (NT) management for both continuous wheat and wheat-corn systems.

To assess the influence of these management practices under a changing climate, [the authors] use two climate change scenarios (A2 and B2) at two time periods in the EPIC agroecosystem simulation model. The applied climate change scenarios are from the HadCM3 global climate model for the periods 2015–2045 and 2070–2099 which projects consistent increases in temperature and precipitation of greater than 5 °C and up to 300 mm by 2099. An increase in the variability of temperature is also projected and is, accordingly, applied in the simulations. The EPIC model indicates that winter wheat yields would increase on average by 0.2 Mg ha⁻¹ in the earlier period and by 0.8 Mg ha⁻¹ in the later period due to warmer nighttime temperatures and higher precipitation. Simulated yields were not significantly affected by imposed changes in crop management. Simulated soil organic carbon content was higher under both NT management and double cropping than

under CT continuous wheat. The simulated changes in management were a more important factor in SOC changes than the scenario of climate change. Soil carbon sequestration rates for continuous wheat systems were increased by an average of 0.4 Mg ha⁻¹ year⁻¹ by NT in the earlier period and by 0.2 Mg ha⁻¹ year⁻¹ in the later period. With wheat-corn double cropping, NT increased sequestration rates by 0.8 and 0.4 Mg ha⁻¹ year⁻¹ for the earlier and later periods, respectively. The total carbon offset due to a shift from CT to NT under continuous wheat over 16 million hectares in the Huang-Hai Plain is projected to reach 240 Tg carbon in the earlier period and 180 Tg carbon in the later period. Corresponding carbon offsets for wheat-corn cropping are 675–495 Tg carbon. *Agriculture, Ecosystems & Environment*, Available online 15 December 2005, <http://www.sciencedirect.com/science/article/B6T3Y-4HTCT7T-1/2/c4c308e79e3b7a5200b5bf9c7e21249d> (subscription may be required)

“Slow growth rates of Amazonian trees: Consequences for carbon cycling.” Quantifying age structure and tree growth rate of Amazonian forests is essential for understanding their role in the carbon cycle. Here, [the authors] use radiocarbon dating and direct measurement of diameter increment to document unexpectedly slow growth rates for trees from three locations spanning the Brazilian Amazon basin. Central Amazon trees, averaging only 1 mm/year diameter increment, grow half as fast as those from areas with more seasonal rainfall to the east and west. Slow growth rates mean that trees can attain great ages; across our sites [the authors] estimate 17-50 percent of trees with diameter >10 cm have ages exceeding 300 years. Whereas a few emergent trees that make up a large portion of the biomass grow faster, small trees that are more abundant grow slowly and attain ages of hundreds of years. The mean age of carbon in living trees (60-110 years) is within the range of or slightly longer than the mean residence time calculated from carbon inventory divided by annual carbon allocation to wood growth (40-100 years). Faster carbon turnover is observed in stands with overall higher rates of diameter increment and a larger fraction of the biomass in large, fast-growing trees. As a consequence, forests can recover biomass relatively quickly after disturbance, whereas recovering species composition may take many centuries. Carbon cycle models that apply a single turnover time for carbon in forest biomass do not account for variations in life strategy and therefore may overestimate the carbon sequestration potential of Amazon forests. *Proceedings of the National Academy of Sciences*, Published online before print December 9, 2005, 10.1073/pnas.0505966102, http://www.pnas.org/cgi/content/abstract/0505966102v1?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&fulltext=%22Carbon+Sequestration%22&searchid=1134161639062_7353&stored_search=&FIRSTINDEX=0&sortspec=date&journalcode=pnas

Ocean

“Monitoring the underground migration of sequestered carbon dioxide using Earth tides,” Reliable and cost effective monitoring techniques are required to ensure safe and effective geological sequestration of carbon dioxide (CO₂), one of the promising strategies for mitigating CO₂ emissions. This study proposes and examines a practical technique for monitoring the underground migration of CO₂ using Earth tides. The gravitational attraction of the bodies in the solar system causes tidal deformation of the Earth, and the pore pressure of the geological reservoirs changes in response to such tidal phenomena. With the pressure analysis algorithm adopted in this study, pressure fluctuations can be retrieved from the continuous pressure data obtained at the monitoring well. The diurnal and semi-diurnal features of the pressure fluctuations can be explained by the Earth tides, and it is possible to estimate the poroelastic parameter [chi], a function of the CO₂ saturation in the pore space. By analyzing the [chi] profile, CO₂ migration can be monitored with a reasonable degree of accuracy. *Energy Conversion and Management*, In Press, Corrected Proof, Available online December 27, 2005, <http://www.sciencedirect.com/science/article/B6V2P-4HWXNVH-5/2/54d698703c7f2f9c52bc533f63a27290> (subscription may be required)



Trading

Carbon Market Update, December 23, 2005	
CCX-CFI 2005 (\$/tCO ₂) \$1.65	EU ETS-EUA 2005 (\$/tCO ₂) \$ 25.01 (Converted from € to US\$)

PR Newswire, “New environmental market created: Montreal Climate Exchange,” The Montreal Exchange (MX), Canada's financial derivatives exchange, and Chicago Climate Exchange ® (CCX®), the world's first and North America's only voluntary, legally binding rules-based greenhouse gas emissions allowance trading system, announced the signing of a Letter of Intent to develop a new joint venture, creating the Montreal Climate Exchange, a Canadian environmental products market. CCX® and MX will develop trading, clearing, and registry services for Canadian environmental products. The announcement was made in Montreal during the 11th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). December 7, 2005, <http://www.prnewswire.com/cgi-bin/stories.pl?ACCT=104&STORY=/www/story/12-07-2005/0004229649&EDATE=>

European Climate Exchange, “Shell, TFS, ECX scoop top places in new EU carbon trading scheme: Top brokers, dealers, service providers in fast-growing environmental markets,” The readers of *Environmental Finance* magazine have voted Shell’s environmental products team and inter-dealer broker TFS the top trading company and broker, respectively, in Europe’s carbon emissions trading scheme (ETS). The European Climate Exchange (ECX), which trades carbon contracts via London’s International Petroleum Exchange, won Best Exchange in the EU market. Allowances for more than 230 million tonnes of carbon dioxide – worth some €4.2 billion – have changed hands this year in the EU market. Mark Nicholls, editor of *Environmental Finance* stated, “This year has seen environmental markets enter the mainstream, as evidenced by the major investment banks – including Merrill Lynch, Morgan Stanley, and Barclays Capital – which won categories in the survey. The launch of the EU Emissions Trading Scheme this year has brought the reality of reducing carbon emissions to more than 4,000 companies across Europe and, more importantly, has put a financial value on emissions reductions,” he added. The results are published in the December 2005-January 2006 issue of *Environmental Finance* magazine. To read about the background and context about the various markets, see: www.environmental-finance.com/envfin/05survey.pdf December 19, 2005, <http://www.europeanclimateexchange.com/pages/page332.php>

Recent Publications

“The United States Department of Energy’s Regional Carbon Sequestration Partnerships program: A collaborative approach to carbon management,” This paper reviews the Regional Carbon Sequestration Partnerships (RCSPs) concept, which is a first attempt to bring the US Department of Energy’s (DOE) carbon sequestration program activities into the “real world” by using a geographically-disposed-system type approach for the US. Each regional partnership is unique and covers a unique section of the US and is tasked with determining how the research and development activities of DOE’s carbon sequestration program can best be implemented in their region of the country. Cost effective capture and separation technology must be developed, tested, and demonstrated; a database of potential sequestration sites must be established; and techniques must be developed to measure, monitor, and verify the sequestered CO₂. Geographical differences in fossil fuel use, the industries present, and potential sequestration sinks across the US dictate the use of a regional approach to address the sequestration of CO₂. To accommodate these differences, the DOE has created a nationwide network of seven RCSPs to help determine and implement the carbon sequestration technologies, infrastructure, and regulations most appropriate to promote CO₂ sequestration in different regions of the Nation. These partnerships currently represent 40 states, three Indian Nations, four Canadian Provinces, and over 200 organizations, including academic institutions, research institutions, coal companies, utilities, equipment manufacturers, forestry and agricultural representatives, state and local governments, non-governmental organizations, and national laboratories. These partnerships are dedicated to developing the necessary infrastructure and validating the carbon sequestration technologies

that have emerged from DOE’s core R&D and other programs to mitigate emissions of CO₂. The partnerships provide a critical link to DOE’s plans for FutureGen, a highly efficient and technologically sophisticated coal-fired power plant that will produce both hydrogen and electricity with near-zero emissions. Though limited to the situation in the US, the paper describes for the international scientific community the approach being taken by the US to prepare for carbon sequestration, should that become necessary. *Environment International*, Volume 32, Issue 1, January 2006, <http://www.sciencedirect.com/science/article/B6V7X-4GRH73K-1/2/484284ed4d6288ebc68ebc05f327f1ab> (subscription may be required)

Energy Information Administration’s “Annual Energy Outlook 2006 (Early Release)” The Annual Energy Outlook 2006 (AEO 2006) presents a midterm forecast and analysis of US energy supply, demand, and prices through 2030. The projections are based on results from the Energy Information Administration’s National Energy Modeling System. The AEO 2006 Early Release includes the reference case. The full publication, to be released in early 2006, will include markets. December 2005. View this document at: <http://www.eia.doe.gov/oiaf/aeo/carbon.html>

Legislative Activity

Commonwealth of Massachusetts Press Release, “Romney Announces Strict New Clean Air Regulations to Take Effect January 1,” Massachusetts Governor Mitt Romney announced that strict state limitations on carbon dioxide (CO₂) emissions will take effect on January 1, 2006. Massachusetts is the first and only state to set CO₂ emissions limits on power plants, doing so in 2001. The limits, which target the six largest and oldest power plants in the state, are designed to lower emissions of nitrogen oxides, sulfur dioxide and mercury from power plant smokestacks. The draft regulations were announced December 7th, and reaffirm the existing CO₂ limits. The press release states that the limits contain protections against excessive price increases for businesses and consumers. Power generation companies can implement CO₂ reductions at their own facilities, or fund other reduction project off-site through a greenhouse gas offset and credits program. The new regulations propose a two-tiered system of “triggers and safety valves.” Plants will be able to do offset project in the Northeast region, to keep technology development and environmental benefits closer to home. If the price of available offsets reaches \$6.50/ton of emissions for 12 months, firms would then be able to shop for offsets anywhere in the world. If offsets rise to \$10.00/ton, firms are allowed to meet their emissions obligations by paying into the state’s Greenhouse Gas Expendable Trust, used by the state to purchase new offsets or invest in GHG reduction technology. December 7, 2005, http://www.mass.gov/portal/site/massgovportal/menuitem.b6302844a78a31c14db4a11030468a0c/?pageID=pressreleases&agId=Agov2&prModName=gov2pressrelease&prFile=gov_pr_051207_7_29_regs.xml

Events

January 22-25, 2006, **9th Annual EUEC 2006 Conference on Air Quality, Climate Change & Renewable Energy**, *Westin La Paloma Resort, Tucson, AZ*. This event organized by EPA, DOE, EPRI and EEI has a track devoted to global warming, which includes sessions on GHG mitigation, corporate strategies, carbon sequestration, and carbon trading. For more information, please visit: <http://www.euec.com> or contact EUEC at 520- 615-3535 or: info@euec.com

February 20-21, 2006, **2nd Australia - New Zealand Climate Change and Business Conference**, *Hilton Adelaide, Adelaide, Australia*. This conference will explore business opportunities and risks associated with climate change, especially in the Asia Pacific Region. For more information, see: <http://www.climateandbusiness.com/welcome.html>.

March 7-9, 2006, **Planning for the Future: Climate Change, Greenhouse Gas Inventories & Clean Energy Linkages**, *Sheraton Fisherman's Wharf Hotel, San Francisco, CA*. This International Specialty Conference sponsored by the Air & Waste Management Association will examine the convergence of policies and technical issues that are central to understanding and mitigating GHG emissions and Climate Change impacts. For information regarding relevant topics for paper submissions, visit AWMA's website. For further information on the conference see: <http://www.awma.org/events/confs/GLOBAL/default.asp> or contact Amy Klaus at (412) 232-3444, ext. 3119, or: aklaus@awma.org

March 8-9, 2006, **Environmental Credits Generated through Land-Use Changes: Challenges and Approaches**, *Hyatt Regency Hotel, Baltimore, MD*. The workshop will be used to study and discuss the challenges that arise when market-based mechanisms are used to encourage changes in practices on the land in order to achieve environmental goals. The primary focus will be on carbon sequestration and nutrient run-off reductions, though lessons will be applicable to a wide range of environmental issues. Space is limited. For more information, to reserve a spot, or to ensure that you receive updates on the program, contact Richard Woodward at: r-woodward@tamu.edu, 979-845-5864. Additional information is available at: <http://www.envtn.org/LBcreditsworkshop/>

April 19-21, 2006, **California Climate Action Registry Annual Conference**, *Laguna Cliffs Marriott Resort, Dana Point, CA*. The Registry's annual conference brings together thought leaders on climate change to take a hard

look at developing climate policies, standards and trends. Full details to be announced next month. Visit: <http://www.climateregistry.org/EVENTS/Conference> or contact Rachel Tornek with any questions at rachel@climateregistry.org

May 8-11, 2006, **The Fifth Annual Conference on Carbon Capture & Sequestration "Taking Steps Toward Deployment,"** *Hilton Alexandria Mark Center, Alexandria, VA*. The conference will bring together experts directly involved in developing, demonstrating and deploying carbon capture, separation and sequestration technologies as part of the Administration's Climate Change Technology Program. The Conference is sponsored by EM Publications & Forums, in partnership with the US Department of Energy, the National Energy Technology Laboratory and other federal agencies. Full details are available at: <http://www.carbonsq.com/>

May 10-12, 2006, **Third Annual CARBON EXPO**, *Congress Centre East, Cologne, Germany*. CARBON EXPO is the global carbon market event that combines the up-to-date content of a high-level conference with the advantages of a trade fair. For additional information visit: <http://www.carbonexpo.com/>

May 21-26, 2006, **The Clearwater Coal Conference, 31st International Technical Conference on Coal Utilization & Fuel Systems**. *Sheraton Sand Key Hotel, Clearwater, FL*. Sponsored by: US Department of Energy, Coal Technology Association & American Society of Mechanical Engineers - Power Division, in cooperation with the National Energy Technology Laboratory, and US Department of Energy. The program presents an extensive overview of emerging, evolving, and innovative technologies, fuels and/or equipment in the power generation industry. The presentations will deal with technical solutions to problems; specific strategies; projects; innovations; industry trends; and or/regulatory compliance. Contact Barbara Sakkestad, Coal Technology Association, Phone: 301/294-6080. E-mail: Barbarasak@aol.com; or the website: www.coaltechnologies.com.

June 19-22, 2006, **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. Details at: <http://www.ghgt-8.no>

For subscription details, please visit: http://www.netl.doe.gov/publications/carbon_seg/subscribe.html. To learn more about DOE's Carbon Sequestration Program, please contact Sean Plasynski at: sean.plasynski@netl.doe.gov or Dawn Deel at: dawn.deel@netl.doe.gov.