

THE CARBON SEQUESTRATION NEWSLETTER

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April 2006

- Sequestration in the News
- Science
- Policy
- Geology
- Technology
- Terrestrial/Ocean
- Trading
- Recent Publications
- Legislative Activity
- Events & Announcements
- Contact Information

Sequestration in the News

Environmental News Service, “Europe Tests Carbon Capture at Coal-Fired Power Plant.” The world’s largest pilot plant for carbon dioxide capture from a conventional power station was opened in Denmark on March 15, 2006. The Elsam plant near Esbjerg, Denmark is the site of the CASTOR project (CASTOR, which stands for “CO₂ from CAPture to STORage,” is a European initiative grouping 30 partners from industry, research institutes, and 11 European countries.) The pilot CO₂ capture unit, coordinated by the Institut Français du Pétrole, will be in demonstration phase for 2 years to ensure reliable industrial application. The pilot unit absorbs 90 percent of the CO₂ in the flue gases emitted by the station. The pilot installation is designed to capture one metric ton of CO₂ per hour. Comparing to CO₂ capture costs of flue gases of large industrial facilities already operational in Japan, this project is expected to halve the cost per ton of CO₂ avoided to between 20 and 30 Euros.

The total cost of the project is 16 million euros, with half of the funding coming from the European Commission and half from private partners. The strategic objective of CASTOR is to enable the capture and geological storage of 10 percent of the CO₂ emissions of Europe, which corresponds to 30 percent of the CO₂ emitted by European power and industrial plants. Seventy percent of the project budget is allocated to capture technology and 30 percent to storage.

March 15, 2006, <http://www.ens-newswire.com/ens/mar2006/2006-03-15-06.asp>.

Industrial Alliance Searches for FutureGen Host Site



Reuters, “Statoil, Shell Set World’s Biggest CO₂ Seabed Plan.” Norway’s Statoil and Anglo-Dutch Shell are planning a \$1.2-\$1.5 billion project off the coast of Norway—the world’s first project to use carbon dioxide (CO₂) to boost oil recovery offshore. Statoil will capture CO₂ from a 860-megawatt gas-fired power plant to be built at the company’s Tjeldbergsodden methanol complex in mid-Norway, and then

HIGHLIGHTS

DOE Techline, “Industrial Alliance Searches for FutureGen Facility Host Site.” The FutureGen Industrial Alliance, Inc. (Alliance) invites proposals for sites upon which the Alliance will build and operate the world’s first coal-based, zero emissions power plant. The FutureGen power plant will produce electricity and hydrogen-rich synthetic gas from coal while capturing and permanently storing carbon dioxide (CO₂) in a deep geologic formation. The Request for Proposals (RFP) describes the site requirements including site access, ownership, CO₂ storage potential, and other related issues. Based on the responses to the RFP and using the selection process described in the RFP, the Alliance will identify candidate sites for the FutureGen facility. After the conclusion of the Department of Energy’s National Environmental Policy Act compliance process, the Alliance expects to select a preferred host site. For the host site, the Alliance will determine the final design for the power plant and the specifications for safe and permanent CO₂ storage based on the specific characteristics of the selected site. Proposals submitted in response to the RFP must be received by the Alliance no later than 4:00 p.m. Eastern Time on May 4, 2006. Download the RFP at: http://www.fossil.energy.gov/programs/powersystems/futuregen/futuregen_siting_final_rfp_3-07-2006.pdf. Also see <http://www.futuregenalliance.org/news.stm> for more information, including RFP amendments. March 8, 2006, http://www.fossil.energy.gov/news/techlines/2006/06016-Alliance_Seeks_FutureGen_Host_Site.html.

pipe the CO₂ to Shell's Draugen oilfield off of Norway to inject it into subsea reservoirs. Plans are for: (1) a final decision to invest by the end of 2008; (2) the power plant to be started in 2010-2011; and (3) the first CO₂ delivered to Draugen in 2011-2012. Future plans are to also include injection into Statoil's Heidrun field. Estimates are that 2 to 2.5 million metric tons of carbon per year will be sequestered. Substantial governmental funding and support will be needed. March 8, 2006, <http://today.reuters.com/news/articlebusiness.aspx?type=naturalResources&storyid=nL08362188&imageid=&cap=>

DOE News Release, "New CO₂ Enhanced Oil Recovery Technology Could Greatly Boost US Oil Supplies." The Department of Energy has determined that the use of state-of-the-art enhanced oil recovery with carbon dioxide (CO₂) could add 89 billion barrels to the recoverable reserves of the US. The current level of proved reserves is 21.9 billion barrels. Longer term, multiple advances in technology and widespread sequestration of industrial carbon dioxide could eventually add as much as 430 billion additional barrels. Efforts to develop the additional reserves would depend on availability of large volumes of commercial CO₂. Next-generation enhanced recovery with CO₂ was judged to be a "game-changer" in oil production, one capable of doubling recovery efficiency. Geologic sequestration of industrial CO₂ in declining oil fields was endorsed last year as a potential method of reducing greenhouse gas accumulation in the atmosphere by the Intergovernmental Panel on Climate Change. The findings are consolidated in the February 2006 report "Undeveloped Domestic Oil Resources: The Foundation for Increasing Oil Production and a Viable Domestic Oil Industry." (See Publications section of this newsletter for this and related reports.) March 3, 2006, http://www.fossil.energy.gov/news/techlines/2006/06015-Oil_Recovery_Assessments_Released.html.

DOE Techline, "United States and India Reach Historic Agreement on FutureGen Project." President Bush announced that India will become the first nation to participate on the government steering committee for FutureGen. The Indian government will contribute \$10 million to the Future-



Gen Initiative and Indian companies will be invited to participate in the private sector segment of the project. Secretary Bodman has invited government leaders of the Carbon Sequestration Leadership Forum (CSLF) to become active participants in the FutureGen project. The CSLF is a voluntary climate initiative that includes 20 nations and the European Commission, working cooperatively on technology development for the

early reduction and steady elimination of carbon dioxide. India is the first CSLF member to participate in FutureGen, building on the US-India Energy Dialogue launched in May of 2005. The Dialogue aims to increase US-India trade and investment in the Indian energy sector by bringing together public agencies and private industries to develop secure, clean, reliable and affordable sources of energy. March 2, 2006, http://www.fossil.energy.gov/news/techlines/2006/06014-US_and_India_FutureGen_Agreement.html.

Reuters, "US Hopes to Reverse Oil Decline by Burying CO₂." In order to utilize carbon dioxide (CO₂) for enhanced oil recovery, and increase oil reserves in the US (as reported in the February 2006 report "Undeveloped Domestic Oil Resources: The Foundation for Increasing Oil Production and a Viable Domestic Oil Industry") the US would need to use 350 trillion cubic feet of carbon dioxide, more than 10 times the amount in natural underground deposits of CO₂. Vello Kuuskraa, president of Advanced Resources International, who authored the February 2006 study for the Department of Energy, stated that the greatest portion of the carbon dioxide is going to have to come from industrial sources. Commenting on costs, Kuuskraa said that the use of carbon sequestration technology makes sense so long as the oil price remains above \$30 a barrel. The price of CO₂ itself, now at \$1 per thousand cubic feet, would have to fall to 75 to 80 cents per cubic feet to be cost effective. March 13, 2006, http://news.yahoo.com/s/nm/20060313/sc_nm/energy_crude_carbon_dc_1.

Oil and Gas Journal Online, "Otway Basin CO₂ Sequestration Trial Advances." The Australian Cooperative Research Centre for Greenhouse Gas Technologies (CO₂CRC) has been awarded two production licenses in the onshore Otway basin of western Victoria to conduct its first carbon dioxide geosequestration trial. The pilot gas injection, storage and monitoring demonstration project will begin by the end of 2006, subject to environmental approvals. The Otway project is thought to be the only project in the world where researchers own the petroleum leases, the CO₂ source, and the depleted storage reserve. The Australian government has allocated \$2.96 million to the trial with funding also coming from petroleum companies and overseas research groups. About 30 researchers will be involved in the project. February 27, 2006. http://ogj.pennnet.com/articles/article_display.cfm?Section=ONART&C=DriPr&ARTICLE_ID=249013&p=7. (Subscription may be required.)

Environmental Finance, "Companies Join Forces On Carbon Capture and Storage." On March 13, thirteen companies formed the Carbon Capture & Storage Association (CCSA) with an aim to promote technology for geologic sequestration. The members will work with the government of the United Kingdom to resolve regulatory issues to avoid delay of technology deployment, and to develop fiscal and legislative support for demonstration projects. The members are Air Products, Alstom, AMEC, BP, ConocoPhillips, E.ON UK, Mitsui Babcock, Progressive Energy, Schlumberger, Scottish & Southern Energy, Shell, RWE and Chevron. March 16, 2006, <http://www.environmental-finance.com/onlines/16marccs.htm>.

Bloomberg, "Xstrata and Other Coal Miners to Invest A\$300 Million in Green Fund," and Dow Jones Newswires, "DJ Australian Coal Miners Agree to a A\$300M Greenhouse Levy." Coal producers in Australia have agreed to set up a \$222 million demonstration project fund, the Coal21 Fund, for demonstration and development of technologies aimed at reducing greenhouse gas emissions from coal-fired power stations. The fund will be

the world's first whole-industry approach to greenhouse gas abatement. Mining companies, including Xstrada, Plc; Rio Tinto Group, BHP Billiton, Excel Coal Ltd., and Macarthur Coal, accounting for 90 percent of Australia's coal production will contribute to the fund for five years. Projects being studied include capture and geological storage of CO₂, coal gasification, oxy-fuel combustion technology, and post-combustion capture of CO₂. March 16, 2006, <http://www.bloomberg.com/apps/news?pid=10000102&sid=aQ6bAmnOkcD0&refer=uk#> and <http://www.tmcnet.com/usubmit/2006/03/15/1461395.htm>.

Gasification News, "Shell: Coal Gasification to Boom in US: CO₂ Sequestration Risks Will be Low." In his keynote speech in Dubai at the Middle East Petro-Tech conference in January, Greg Lewin, president of Shell Global Solutions,

predicted the strong growth of coal gasification and that carbon sequestration risk will be "low." He stated that Shell has been a pioneer in both geological carbon storage and in "mineralization." Lewin outlined what he felt were the four most important points regarding carbon sequestration: 1.) That there is significant CO₂ storage capacity available, but without using that capacity, "stabilization" of CO₂ levels in the atmosphere will be difficult to achieve; 2.) CO₂ storage mechanisms are known, and storage can be safe if sites are properly selected and monitored; 3.) CO₂ can be stored for thousands of years or longer; and 4.) Much work has been performed to understand the hazards involved and the probability of failure, with results indicating that the risks involved will be low. He stated that although geologic sequestration can store more carbon, mineralization of

Announcements

Request for Proposals for FutureGen Facility Host Site. The FutureGen Industrial Alliance, Inc. (Alliance) invites proposals for sites upon which the Alliance will build and operate the world's first coal-based, zero emissions power plant. Proposals submitted in response to the RFP must be received by the Alliance no later than 4:00 p.m. Eastern Time on May 4, 2006. Download the RFP at: http://www.fossil.energy.gov/programs/powersystems/futuregen/futuregen_siting_final_rfp_3-07-2006.pdf. See <http://www.futuregenalliance.org/news.stm> for more information, including RFP amendments. (Also see Highlights section of this newsletter "Industrial Alliance Searches for FutureGen Facility Host Site.")

Call for Papers: Carbon Capture/Storage. The International Power Generation (IPG) '06 conference to be held in Leipzig, Germany, November 15-16, 2006, has issued a call for papers. The conference will focus on the implementation of the European Commission Emissions Directives. New topics for 2006 include: "Carbon Capture/Storage." The deadline to submit papers is April 21, 2006. See instructions at: http://www.ipg.antfx.com/index.php?option=com_akoforms&func=showform&formid=4.

Call for Papers: Research and Commercialization Strategies for Carbon Sequestration. The 26th USAEE/IAEE North American Conference to be held September 24-27, 2006 in Ann Arbor, Michigan, has issued a call for papers. Within their "Science and Technology" topic area is a request for papers on basic research and commercialization strategies for carbon sequestration. The submission deadline for abstracts is April 28, 2006. See website for details: <http://www.usaee.org/usaee2006/callforpapers.html>.

EM Magazine Looking for Authors. Air & Waste Management Association's *EM* magazine is focusing on the topic of "Carbon Sequestration and Renewable Energy" for its upcoming November 2006 issue. Articles of interest may include topics such as the Department of Energy's Voluntary Greenhouse Reporting Program established by section 1605(b) of the Energy Policy Act of 1992, and the Administration's initiative to combat global warming via the Asia Pacific Partnership for Clean Development (APPCD). Deadline for submissions is August 15, 2006. Interested authors should first contact Lisa Bucher, Managing Editor at 1-412-232-3444 ext 3159 or email: lbucher@awma.org to discuss the process. <http://www.awma.org/em/guidelines.asp>.

"Enhanced Oil and Natural Gas Production Through Carbon Dioxide Injection, Advanced Notice on Proposed Rulemaking." The Department of the Interior's Bureau of Land Management (BLM) and the Minerals Management Service (MMS) request comments and suggestions to assist in preparing a proposed rule governing carbon dioxide injection for increased production and recovery of oil and natural gas. The rule would provide for royalty relief incentives to promote the capture, transportation, and injection of produced CO₂, natural CO₂, and other appropriate gases or other matter for injection/sequestration into oil and gas fields, to promote oil and natural gas production from the Outer Continental Shelf and onshore Federal leases. Members of the public are encouraged to provide comments and suggestions to help clarify and define the requirements for enhanced oil and natural gas recovery production incentives as described in the Energy Policy Act of 2005. Comments and suggestions will be accepted until April 7, 2006. For details see Volume 71, Number 45, *Federal Register*, Pages 11557-11559, March 8, 2006, at this link: http://www.blm.gov/nhp/news/releases/pages/2006/pr060308_og_06-2170.pdf.

Opening of Call for Public Input on Draft JI PDD Form and Draft Guidelines for Users. At its first meeting, the Joint Implementation Supervisory Committee (JISC) agreed on a draft joint implementation project design document (JI PDD) form. At its second meeting, it agreed on draft guidelines for users of the JI PDD form and requested the United Nations Framework Convention on Climate Change (UNFCCC) secretariat to launch a call for public input on the structure and content of the JI PDD form and the respective draft guidelines as well as on the need for development of a separate JI PDD form for land-use, land-use change and forestry (LULUCF) projects. Public comments should be sent to the UNFCCC secretariat by April 16, 2006 (17:00 Greenwich Mean Time). The call for public input is available through the main page of the UNFCCC Joint Implementation website or under the following link: http://ji.unfccc.int/CallForInputs/Pub_Input_PDD.html.

CO₂ using calcium or magnesium, for example, also plays a role. In addition to its projects in geologic sequestration, Shell is pursuing proprietary mineralization technology. To read the transcript of the speech, see: http://www.shell.com/static/globalsolutions-en/downloads/news_and_library/2006/press_petrotech_130206.pdf. February 2006, <http://www.worldfuels.com/sample.php?GTLN#A9>.

Great Falls Tribune Online, “Farmers Poised to Harvest Profit from Carbon ‘Crop.’” One of the partners of the National Energy Technology Laboratory’s Big Sky Carbon Sequestration Partnership program, the National Carbon Offset Coalition, is working on a pilot project to link industries that produce carbon dioxide with landowners who store carbon in the ground through conservation practices. The National Carbon Offset Coalition is based in Butte, Montana, and is working with farmers and landowners to assist them in earning carbon credits which they could in turn sell to industries to offset their CO₂ emissions. Dave Gettel is one of several farmers near Power, Montana who participate in the program. The research effort for the Big Sky Carbon Sequestration Partnership is led by Montana State University (MSU). As part of this project, a variety of farming techniques are being used on side-by-side plots on land, including crop rotation and no-till farming. The MSU staff members conduct measurements on the soil carbon levels to determine how much carbon is kept in the soil in order to determine how many carbon offsets the farmer can sell. Currently, a metric ton, which trades for \$1.50 to \$3, is the amount of carbon saved in about 10 acres of no-till cropland. Carbon credits may not generate large amounts of income for the landowners but may serve as incentive for additional conservation practices. March 9, 2006, <http://www.greatfallstribune.com/apps/pbcs.dll/article?AID=/20060309/BUSINESS/603090335/1046>.

Science

BBC News, “Huge Polar Initiative Announced.” Activities are underway for the planning and launch of International Polar Year (IPY) 2007-2008. This international polar science research initiative will conduct scientific research and observations focusing on the Earth’s polar regions. IPY will involve over 50,000 participants from more than 60 countries, with a cost of \$3 to 3.6 billion. IPY is sponsored by the International Council of Science and the World Meteorological Organization, and is to take place from March 2007 to March 2009. Dr.



David Carlson, IPY’s program director, says understanding the polar region is essential in order to understand the global carbon cycle, the global water cycle, the global weather cycle, or global economics. Proposed activities

include various ice coring projects and projects involving CO₂ monitoring. See <http://www.ipy.org/> for further information. March 15, 2006, <http://news.bbc.co.uk/1/hi/sci/tech/4806146.stm>.

WMO Press Release, “First WMO Greenhouse Gas Bulletin: Greenhouse Gas Concentrations Reach New Highs in 2004,” The globally averaged concentrations of carbon dioxide (CO₂), methane, and nitrous oxide in the planet’s atmosphere reached their highest recorded levels in 2004, according to the World Meteorological Organization’s (WMO) first annual Greenhouse Gas Bulletin. CO₂ was recorded at 377.1 parts per million (ppm). The level of CO₂ supersedes the value from the late 1700’s by 35 percent, largely due to emissions from the combustion of fossil fuels. In 2004, CO₂ increased by 1.8 ppm or 0.47 percent when compared with the previous year. WMO secretary-general Michel Jarraud said the atmospheric CO₂ levels continue to increase and show no sign of leveling off. Download the first annual Greenhouse Gas Bulletin at: <http://www.wmo.int/web/arep/gaw/ghg/ghg-bulletin-en-03-06.pdf>. See http://www.wmo.int/web/arep/gaw/gaw_home.html for more information. March 14, 2006, http://www.wmo.int/web/arep/gaw/ghg/press_release_744_en.doc.

AP, “Carbon Dioxide Hit Record in 2005.” The Office of Atmospheric Research at the US National Oceanic and Atmospheric Administration has said that the concentration of carbon dioxide in the atmosphere climbed to a record 381 parts per million last year, up 2.6 parts per million from the previous year. Final calculations from reporting stations around the world will not be available until later in the spring when a final report will be released. March 14, 2006, <http://abcnews.go.com/Politics/print?id=1725818>.

Ceres Press Release, “BP and DuPont Receive Top Scores in First-Ever Ranking of 100 Global Companies on Climate Change Strategies.” The business environmental stewardship group Ceres, Coalition for Environmentally Responsible Economies, has released a report to present an analysis of how 76 US companies and 24 non-US companies are addressing the business challenges of climate change. The study ranks the largest companies with operations in the US in 10 business sectors including: oil/gas, electric power, auto, chemical, industrial equipment, mining/metals, coal, food products, forest products, and air transportation. Five broad areas were evaluated using a “Climate Governance Checklist”: board oversight, management performance, public disclosure, greenhouse gas emissions accounting, and strategic planning. The report was requested by over two dozen institutional investors, and prepared by the Investor Responsibility Research Center, as part of an action plan announced at the Institutional Investor Summit on Climate Risk in May 2005 at the United Nations. Visit the Ceres website to see the rankings and details in the report named “2006 Corporate Governance and Climate Change: Making the Connection”: <http://www.ceres.org/pub/>. March 21, 2006, http://www.ceres.org/news/news_item.php?nid=154.

Greenwire, "Princeton Professor Lays Out Broad Strategy on Greenhouse Emissions." At World Bank Energy Week 2006 on March 3, 2006, Professor Robert Socolow explained a broad blueprint to deal with global warming—his "wedge technology" theory—and why he is so optimistic about the potential for carbon sequestration. The theory is from the paper "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies" which he wrote with Steve Pacala last year. (The paper can be found in the August 13, 2004 issue of *Science*, Volume 305, Number 5686, Pages 968-972, DOI: 10.1126/science.1100103, <http://www.sciencemag.org/cgi/content/full/305/5686/968?ijkey=K6cRPbiYRFwus&keytype=ref&siteid=sci> or at <http://www.s-e-i.org/polreports/pswedgedes.pdf>.) For more information on the topic, also see: <http://www.princeton.edu/~cmi/>. View a video of Socolow's talk on E&E TV online at: <http://www.eande.tv/main/?date=030906>. March 9, 2006, <http://www.eenews.net/Greenwire/2006/03/09/#25>. (Subscription may be required.)

Policy

Bloomberg, "Canada, Head of UN Kyoto Group, May Not Meet Emission Targets." Canada's Environment Minister Rona Ambrose said in an interview that Canada is unlikely to meet its emissions reduction targets set under the Kyoto Protocol. In 2002, Canada set a target to decrease emissions by 6 percent from 1990 levels by 2012. Canada serves as chair of the Conference of Parties to the United Nations Framework Convention on Climate Change, which created the Kyoto Protocol. Canada will have less credibility in talks to add conditions to the treaty or convince other nations to sign if that country does not meet its targets, said John Bennett, senior policy advisor at the environmental lobby group Sierra Club of Canada. March 9, 2006, <http://www.bloomberg.com/apps/news?pid=10000082&sid=a02Zv4lWmW38&refer=canada#>. (Subscription may be required.)

Slovene Press Agency STA, "Slovenia Will Meet Kyoto Obligations, Minister Says." Slovenian Environment minister Janez Podobnik said that Slovenia is on course to meet its targets for 2008-2012 under the Kyoto Protocol, despite the findings published to the contrary in mid-February by the European Commission. Slovenia plans to implement additional reduction measures including carbon sequestration in forests. "Slovenia is currently in an unequal position as it is not part of the joint strategy for lowering emissions that was adopted...in 2002 by the EU-15," Podobnik pointed out. March 13, 2006, <http://www.gzs.si/eng/news/sbw/head.asp?idc=20913>.

Newsroom Finland, "Statistics Finland says CO₂ emissions near Kyoto level in 2005." In 2005, Finnish carbon dioxide (CO₂) emissions fell by 17 percent to about 54 million metric tons, putting them close to their Kyoto target level, *Statistics Finland* said in a statement. The fall in CO₂ emissions was attributed to decreased use of fossil fuels and peat. Also, a record 17 terawatt-hours of power, a fifth of total consumption, was imported in 2005, due to a good water reservoir situation in Norway and Sweden. Warm weather and a seven week dispute in the pulp and paper industries also

contributed to the lower levels of emissions. February 24, 2006, <http://newsroom.finland.fi/stt/showarticle.asp?intNWSAID=11868&group=Business>.

"Trade-offs in assessing different energy futures: a regional multi-criteria assessment of the role of carbon dioxide capture and storage." The authors examine the responses of stakeholders from the public and private sectors to future energy scenarios for the year 2050 for the North West of England. The main focus of the paper is to examine the stakeholders' reactions to the mitigation option of capturing CO₂ from power stations and storing it in suitable off-shore geological reservoirs. Five energy scenarios were developed which involved a range of levels of CO₂ capture and storage (CCS): Fossilwise, Nuclear Renaissance, Renewable Generation and Spreading the Load high and low scenarios. A multi-criteria assessment method (MCA) was used as a way of elucidating stakeholders' views on the desirability or otherwise of each scenario against nine stakeholder-derived criteria. The authors found that stakeholders were either business-focused or environment/society-focused with respect to weighting of the criteria. Scoring of the scenarios did not follow such a straightforward pattern. Most respondents scored and weighted strategically and tended to express a clear preference for a form of energy generation. The results suggest that there is unlikely to be a wide-ranging consensus amongst energy stakeholders on the desirability of specific future forms of energy generation. On balance, the results support the inclusion of CCS within scenarios of a low-carbon energy system. *Environmental Science and Policy*, doi:10.1016/j.envsci.2006.01.006, Available online February 28, 2006. <http://www.sciencedirect.com/science/article/B6VP6-4JCCM8V-2/2/0573827d9d24c007249b398df68461d9>.

"Atmospheric and geological CO₂ damage costs in energy scenarios." Geological carbon dioxide (CO₂) capture and storage (CCS) is currently seriously considered for addressing, in the near term, the problem of climate change. CCS technology is available today and is expected to become an increasingly affordable CO₂ abatement alternative. Whereas the rapidly growing scientific literature on CCS as well as experimental and commercial practice demonstrate the technological and economic feasibility of implementing this clean fossil fuel option on a large scale, relatively little attention has been paid so far to the risks and environmental externalities of geological storage of CO₂. This paper assesses the effects of including CCS damage costs in a long-term energy scenario analysis for Europe. An external cost sensitivity analysis is performed with a bottom-up energy technology model that accounts not only for CCS technologies but also for their external costs. The authors' main conclusion is that in a business-as-usual scenario (i.e. without climate change intervention or externality internalization), CCS technologies are likely to be deployed at least to some extent, mainly in the power generation sector, given the economic benefits of opportunities such as enhanced coal bed methane, and oil and gas recovery. Under a strict



climate (CO₂ emissions) constraint, CCS technologies are deployed massively. With the simultaneous introduction of both CO₂ and CCS taxation in the power sector, designed to internalize the external atmospheric and geological effects of CO₂ emissions and storage, respectively, the authors find that CCS will only be developed if the climate change damage costs are at least of the order of 100 euros per ton of carbon dioxide (€/t CO₂) (approximately \$119) or the CO₂ storage damage costs not more than a few €/t CO₂. (One Euro = approximately \$1.1905 US dollars.) When the internalized climate change damage costs are as high as 67 €/t CO₂ (approximately \$80), the expensive application of CCS to biomass-fuelled power plants (with negative net CO₂ emissions) proves the most effective CCS alternative to reduce CO₂ emissions, rather than CCS applied to fossil-based power plants. *Environmental Science and Policy*, Available online March 6, 2006, doi:10.1016/j.envsci.2006.01.004, <http://www.sciencedirect.com/science/article/B6VP6-4JDMR64-1/2/9646bdbb9f0577166033edb961f4b205>. (Subscription may be required.)



Geology

“Experimental identification of CO₂–water–rock interactions caused by sequestration of CO₂ in Westphalian and Buntsandstein sandstones of the Campine Basin (NE-Belgium).” Geological sequestration of carbon dioxide (CO₂) is one of the options studied to reduce greenhouse gas emissions. Although the feasibility of this concept is proven, apart from literature data on modeling, still little is known about the CO₂–water–rock interactions induced by CO₂ injection. To evaluate the effect of CO₂–water–rock interactions on three sandstone aquifers in Northeastern Belgium, an experimental setup was built. Eighteen experiments were performed in which sandstones were exposed to supercritical CO₂. CO₂–water–rock interactions were deduced from the evolution of aqueous concentrations of 25 species and a thorough characterization of the sandstones before and after treatment. The results show that dissolution of ankerite/dolomite and aluminum silicates could enhance porosity/permeability. The observed precipitation of end-member carbonates could increase storage capacity if it exceeds carbonate dissolution. Precipitation of the latter and of potassium-rich clays as ob-

served, however, can hamper the injection. *Journal of Geochemical Exploration*, Available online March 9, 2006, doi:10.1016/j.gexplo.2005.11.005, <http://www.sciencedirect.com/science/article/B6VCP-4JF97BJ-2/2/d1a57de4882cf5730bc850ebdf5bfff5>. (Subscription may be required.)

Technology

“A Novel Adsorption Cycle for CO₂ Recovery: Experimental and Theoretical Investigations of a Temperature Swing Compression Process.” A novel adsorption cycle is examined experimentally and theoretically for recovering carbon dioxide (CO₂) from a 50 mole percent (mol%) mixture with carbon monoxide. Several adsorbents are considered, and zeolite sodium-yttrium (NaY) is chosen for the process due to its high capacity and selectivity for CO₂ in the presence of carbon monoxide. The process consists of three steps. The bed is fed the gas mixture at 273 degrees Kelvin (°K) until CO₂ breakthrough occurs. The bed then undergoes countercurrent blowdown of CO₂ while heating at 391 °K and is finally cooled to the initial feed temperature once the bed has been depleted of CO₂. Results are presented from laboratory scale experiments and are described using numerical simulations. This novel cycle provides a method for capturing and producing CO₂ without the need for a purge gas and has low energy requirements if waste heat is available. *Separation Science and Technology*, Volume 41, Number 3, Number 3/2006, pages 485-500 (16), doi:10.1080/01496390500524834, <http://journalonline.tandf.co.uk/openurl.asp?genre=article&issn=0149-6395&volume=41&issue=3&page=485>. (Subscription or purchase may be required.)

“A simulation study for the hybrid reaction of methane steam reforming and in situ CO₂ removal in a moving bed reactor of a catalyst admixed with a CaO-based CO₂ acceptor for H₂ production.” A hybrid reaction system of catalytic methane steam reforming (MSR) and in situ non-catalytic removal of CO₂ by the carbonation of calcium oxide (CaO) to calcium carbonate (CaCO₃) in a moving bed reactor where reforming catalyst and CaO-based CO₂ acceptor in pellets move co-currently with gaseous reactants has been simulated through a mathematical model. The model has been developed at non-isothermal, non-adiabatic, and non-isobaric operating conditions assuming that the rate of the CaO carbonation in a local zone of the reactor bed is governed by kinetic limitation or by the CO₂ limitation in bulk gas phase. The effects of major operating parameters such as the feed rates of CaO and methane (CH₄), and the reactor bed temperature on steady-state behavior of the hybrid reaction in a moving bed reactor have been determined. It was revealed that the feed rate of CaO for a given feed rate of CH₄ should be optimized in order to maximize the utilization degree of CaO carbonated through the reactor while producing the reformed gas in the possible lowest concentration of CO₂ at a given temperature of reaction. *International Journal of Hydrogen Energy*, Volume 31, Issue 5, Pages 649-657. April 2006, <http://www.sciencedirect.com/science/article/B6V3F-4GHSGF7-3/2/0dc1340b939f0ccd47d4a9de5572a72e> (Subscription may be required.)

“Separation of CH₄/CO₂/N₂ mixtures by layered pressure swing adsorption for upgrade of natural gas.” A novel compact adsorption-based process for removal of carbon dioxide (CO₂) and nitrogen (N₂) from low and medium natural gas flowrates is discussed. The layered pressure swing adsorption (LPSA) process studied is composed of a zeolite 13X to selectively remove carbon dioxide followed by a layer of carbon molecular sieve 3K to make the separation of nitrogen from methane (CH₄). The advantage of the process is the removal of two different contaminants in the feed step, delivering methane at high pressure without recompression requirements. A four-step cycle was studied comprising countercurrent pressurization, feed, countercurrent blowdown and countercurrent purge with product. The blowdown step was performed in vacuum to remove carbon dioxide from zeolite 13X. Experiments were performed in a single-column LPSA unit at different temperatures and using different ratios of adsorbent layers to study the effects of these parameters in overall performance of the unit. Feeding a mixture of 60 percent CH₄/20 percent CO₂/20 percent N₂, methane purity of 86.0 percent with 52.6 percent recovery was obtained at ambient temperature while 88.8 percent purity with 66.2 percent recovery was obtained at 323 °K. At both temperatures there was a ratio of adsorbent layers where purity reaches a maximum, while product recovery always decreases for larger zeolite 13X layers. *Chemical Engineering Science*, Available online March 9, 2006, <http://www.sciencedirect.com/science/article/B6TFK-4JF97PV-3/2/f6277e4641a80424b44a393748b59724>. (Subscription may be required.)

Terrestrial

“Global potential for carbon sequestration: Geographical distribution, country risk and policy implications.” The authors have provided a framework for identifying least-cost sites for afforestation and reforestation and deriving carbon sequestration cost curves at a global level in a scenario of limited information. Special attention is given to country risk in developing countries and the sensitivity to spatial datasets. The authors’ model results suggest that within 20 years and considering a carbon price of \$50 per ton of carbon, tree-planting activities could offset 1 year of global carbon emissions in the energy sector. However, if the authors account for country risk considerations—associated with political, economic and financial risks—carbon sequestration is reduced by approximately 60 percent. With respect to the geography of supply, illustrated by grid-scale maps, the authors find that most least-cost sites are located in regions of developing countries such as the Sub-Saharan, Southeast Brazil and Southeast Asia. *Ecological Economics*, Available online March 9, 2006, doi:10.1016/j.ecolecon.2005.12.015, <http://www.sciencedirect.com/science/article/B6VDY-4JF97MF-2/2/6cb451553cd7200978374c6990add65>. (Subscription may be required.)

“Temperature sensitivity of soil carbon decomposition and feedbacks to climate change.” Significantly more carbon is stored in the world’s soils—including peatlands, wetlands and permafrost—than is present in the atmosphere. Disagreement exists, however, regarding the effects of climate change on global soil carbon stocks. If carbon stored belowground is transferred to the atmosphere by a warming-

induced acceleration of its decomposition, a positive feedback to climate change would occur. Conversely, if increases of plant-derived carbon inputs to soils exceed increases in decomposition, the feedback would be negative. Despite much research, a consensus has not yet emerged on the temperature sensitivity of soil carbon decomposition. Unraveling the feedback effect is particularly difficult, because the diverse soil organic compounds exhibit a wide range of kinetic properties, which determine the intrinsic temperature sensitivity of their decomposition. Moreover, several environmental constraints obscure the intrinsic temperature sensitivity of substrate decomposition, causing lower observed ‘apparent’ temperature sensitivity, and these constraints may, themselves, be sensitive to climate. *Nature*, Vol. 440, Pages 165-173, March 9, 2006, doi:10.1038/nature04514, <http://www.nature.com/nature/journal/v440/n7081/abs/nature04514.html>. (Subscription may be required.)

Trading

Carbon Market Update, March 17, 2006	
CCX-CFI 2005 (\$/tCO ₂) \$2.05	EU ETS-EUA 2005 (\$/tCO ₂) \$ 32.79
(Converted from € to US\$)	

Greenwire, “New Mexico Formally Becomes First State to Make Binding Commitment to Reduce Emissions.” New Mexico became the first state in the US to join the Chicago Climate Exchange, the US-based carbon emissions trading credit market. Several cities have joined the exchange, including Chicago, Oakland and Boulder, but New Mexico is the first state to do so. Credits are traded over the internet daily at a cost of about \$2 per metric ton, (as reported in the Trading section of this newsletter monthly). February 23, 2006, <http://www.eenews.net/Greenwire/2006/02/23/#15>. (Subscription may be required.)

Reuters, “UK Wants Transport Included in EU CO₂ Trade Scheme.” The United Kingdom wants to expand the European Union’s emissions trading scheme to cover surface transportation emissions, one of the greater sources of carbon dioxide (CO₂) emissions. The trading scheme imposes limited on carbon dioxide emissions on approximately 12,000 factories and power plants, but does not cover air or surface transportation. The European Commission, the trading scheme’s official administrator, is in the process of reviewing the scheme and may consider other sectors and even other greenhouse gases. A Commission official said that substantial changes, such as the inclusion of more industries would not be possible until 2010. Changing to an auctioning format for the scheme, which currently distributes emissions credits for free, may also be explored by the Commission for phase two (2008-2012) of the scheme. March 1, 2006, <http://www.planetark.com/dailynewsstory.cfm?newsid=35367&newsdate=01-Mar-2006>.

Reuters, "China's Waste Could Be Treasure for Kyoto Scheme." Development of landfill projects in China could help counties meet their quotas under the Kyoto protocol's Clean Development Mechanism trading scheme. Lu Guoqiang, an official at China's State Environmental Protection Administration, announced at an emissions trading conference in Denmark—Point Carbon's Carbon Market Insights 2006—that there are 700 registered landfill sites in China but only 10 of them have gas recovery and utilization systems installed. Foreign investors could earn Certified Emission Reduction credits under CDM by investing in projects to stream-off greenhouse gases from degrading landfills for conversion into an energy source. March 2, 2006, <http://www.planetark.com/dailynewsstory.cfm?newsid=35391&newsdate=02-Mar-2006>.

CCX Press Release, "Chicago Climate Exchange, Inc. (CCX) announces formation of the New York Climate Exchange (NYCX) and the Northeast Climate Exchange (NECX)." CCX announced the formation of the NYCX and NECX to develop financial instruments for the Regional Greenhouse Gas Initiative (RGGI). Product development for the exchanges will begin shortly and the exchanges will be ready for operation in accordance with the evolution and needs of RGGI. The current schedules for RGGI call for a first compliance period from 2009 through 2012. March 14, 2006, http://www.chicagoclimatex.com/news/press/release_20060314_NYCX.html



Recent Publications

"Undeveloped Domestic Oil Resources Provide Foundation For Increasing US Oil Supply." This Department of Energy, Office of Fossil Energy report provides an estimate of total undeveloped and future technically recoverable domestic oil resources in the US. Undeveloped domestic oil resources still in the ground total more than one trillion barrels. The resource includes undiscovered oil, "stranded" light oil amenable to carbon dioxide enhanced oil recovery (CO₂-EOR) technologies, unconventional oil and new petroleum concepts. This assessment originally examined the resource potential for applying state-of-the-art CO₂-EOR technologies in only six basins/areas of the United States. It did not include the additional resource potential outlined in the ten basin-oriented assessments, or the recoverable resources from residual oil

zones, as discussed in related reports issued by the Department of Energy in February 2006. February 2006, http://www.fossil.energy.gov/programs/oilgas/eor/Undeveloped_Domestic_Oil_Resources_Provi.html.

"Stranded Oil in the Residual Oil Zone." Five reports on Stranded Oil in the Residual Oil Zone introduce one of the most exciting new, unconventional oil resources that can be added to the US domestic oil resource base. This is "stranded (or residual) oil" in the transition zone below the traditional oil-water contact that exists in many domestic oil reservoirs. This resource has not previously been included in any official domestic oil resource databases. Work was undertaken in three U.S. oil basins—the Permian, Williston and Big Horn—to more rigorously define the size and potential of this new resource, and how much may be recoverable using carbon dioxide enhanced oil recovery techniques. February 2006, http://www.fossil.energy.gov/programs/oilgas/eor/Stranded_Oil_in_the_Residual_Oil_Zone.html.

"Game Changer Improvements Could Dramatically Increase Domestic Oil Resource Recovery." This report illustrates that the wide-scale implementation of "next generation" carbon dioxide enhanced oil recovery (CO₂-EOR) technology advances have the potential to increase domestic oil recovery efficiency from about one-third to over 60 percent, doubling the technically recoverable resources in six domestic oil basins/areas studied to date. Application of next generation CO₂-EOR technologies extrapolated to other U.S. oil basins and regions could bring about truly "game changing" advances in oil recovery efficiency and domestic oil production. February 2006, http://www.fossil.energy.gov/programs/oilgas/eor/Game_Changer_Oil_Recovery_Efficiency.html.

"Voluntary Reporting of Greenhouse Gases 2003 – Summary." The Energy Information Administration has released the report for the 2003 reporting year under the Voluntary Reporting of Greenhouse Gases Program, required by Section 1605(b) of the Energy Policy Act of 1992. Two hundred thirty-four U.S. companies and other organizations reported 2,188 projects to reduce or sequester greenhouse gases with reductions of: 268 million metric tons carbon dioxide equivalent of direct reductions, 81 million metric tons of indirect reductions, 7 million metric tons of reductions from carbon sequestration, and 16 million metric tons of unspecified reductions. Total US greenhouse gas emissions in 2003 are estimated at 6,936 million metric tons carbon dioxide equivalent. March 2006. Download pdf or html files at: <http://www.eia.doe.gov/oiat/1605/vrrpt/summary/index.html>.

"Energy Market Impacts of Alternative Greenhouse Gas Intensity Reduction Goals." The Energy Information Administration (EIA) released this report in response a request from Senator Ken Salazar that the EIA analyze the impacts of implementing alternative variants of an emissions cap-and-trade program for greenhouse gases. March 8, 2006, [http://www.eia.doe.gov/oiat/servicrpt/agq/pdf/sroiif\(2006\)01.pdf](http://www.eia.doe.gov/oiat/servicrpt/agq/pdf/sroiif(2006)01.pdf)

Legislative Activity

Environment News Service, “States Ask Supreme Court Review of Global Warming Car Emissions Case.” A coalition of 12 US states, three cities, an island government, and several environmental groups has appealed to the US Supreme Court a case to force the US government to regulate carbon dioxide emissions from cars and trucks. A lower court had ruled in July 2005 to uphold the ruling that the Environmental Protection Agency did not have to regulate carbon dioxide and some other greenhouse gasses. March 6, 2006, <http://www.ens-newswire.com/ens/mar2006/2006-03-06-05.asp>.

Greenwire, “Senate Global Warming Summit Set for April 4.” The Senate Energy and Natural Resources Committee is holding a public summit on April 4, 2006 to address the responses received from the broad call for proposals made in March regarding creating a market-based greenhouse gas regulatory system. Participants to the meeting will be selected from the responses that were received from the various stakeholders, though the meeting itself will be open to the public and the media. The submittals to be discussed at the meeting are posted at: http://energy.senate.gov/public/index.cfm?FuseAction=Conferences.Detail&Event_id=4&Month=4&Year=2006. To view some comments covered by Greenwire, go to the subscriber website at: <http://www.eenews.net/Greenwire/2006/03/15/#11>. February 23, 2006, <http://www.eenews.net/EEDaily/2006/02/23/#4>. (Subscription may be required.)

Greenwire, “Senator Feinstein Unveils Mandatory Cap-And-Trade Bill.” Senator Diane Feinstein (D-California) has outlined a draft bill outlining a mandatory cap-and-trade system that would reduce company greenhouse gas (GHG) emissions by 7.25 percent from this year’s levels. Caps would be implemented for GHG emissions at current levels from 2006 to 2010. In 2011, each company would have to reduce emission by 0.5 percent until 2015, and by just under 1 percent from 2015 to 2020. Reductions could be made by installing controls at the plants, implementing new practices, or purchasing credits. The Feinstein bill differs from the McCain-Lieberman bill in not placing limits on domestic agricultural sequestration, where McCain-Lieberman place a 15 percent cap on the number of credits that can be purchased from farmers domestically. This bill would also allow up to 25 percent of the credits to be purchased from international sources, with McCain-Lieberman’s limit at 15 percent. Feinstein is releasing her bill ahead of the Senate Energy and Natural Resources Committee April 4 climate conference (mentioned in the previous article in this newsletter, “**Senate Global Warming Summit Set for April 4**”). For additional information see: http://www.yubanet.com/artman/publish/article_33120.shtml. March 20, 2006, <http://www.eenews.net/Greenwire/print/2006/03/20/10>. (Subscription may be required.)

Greenwire, “New Power Plants, Industrial Boilers See Stricter Controls with Final EPA Rule.” The Environmental Protection Agency (EPA) has issued its final “new source performance standard” (NSPS) rule: “Standards of Performance for Electric Utility Steam Generating Units, Industrial– Commercial–Institutional Steam Generating Units, and Small Industrial– Commercial–Institutional Steam Generating Units; Final Rule,” Federal Register, Volume 71, Number 38, Pages 9866-9886, February 27, 2006. This new rule sets limits for emissions of nitrogen oxides, sulfur dioxide, and particulate matter (from certain coal, oil and natural gas utilities, and certain large scale boilers), but does not regulate carbon dioxide. Though it was urged to consider new limits on greenhouse gas emissions from power plants, the EPA has concluded that it does not presently have the authority to set NSPS to regulate CO₂ or other greenhouse gases that contribute to global climate change. The EPA’s statement agrees with previous Bush administration directives that CO₂ is not legally considered an air pollutant under the Clean Air Act. See comments and response on greenhouse gases on page 9869 of the rule: <http://www.smartpdf.com/register/2006/Feb/27/9866A.pdf>. February 27, 2006, <http://www.eenews.net/eenewspm/2006/02/27/#1>. (Subscription may be required.)

Events

April 4-5, 2006, **The Wall Street Green Trading Summit, The Bloomberg Headquarters, New York City.** This event is the only global conference that embraces the triple convergence of the capital markets and all environmentally traded markets including greenhouse gases, renewable energy and "negawatts." Topics of sessions include carbon market developments; carbon sequestration and enhanced oil recovery; and new advances in renewable energy trading. For further information, please go to https://www.hedgeconnection.com/atlas/event_viewer.php?eid=2 or call Lisa Vioni at +1-941-240-0153.

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. For full details and agenda visit: <http://www.climateregistry.org/EVENTS/Conference> or contact Rachel Tornek with any questions at ra-chel@climateregistry.org.

May 10-12, 2006, **Climate Change Technology Conference "Engineering Challenges and Solutions in the 21st Century," Ottawa Congress Center, Ottawa, Ontario, Canada.** This conference is sponsored by the Engineering Institute of Canada, its Member Societies and other Collaborators. Its purpose is to deal with the need to mitigate against and adapt to the negative effects of climate change, recognizing that such is the role of engineering. A preliminary program is available. Register online at: <http://www.ccc2006.ca/eng/register.html>.

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, 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 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. Con-

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://listserv.netl.doe.gov/mailman/listinfo/sequestration> and enter your email address to receive the newsletter as text and a pdf at no cost. (If you prefer not to receive the pdf file in your email, choose "yes" for the daily digest option.) To view the archive of newsletters, see: http://www.netl.doe.gov/publications/carbon_seq/subscribe.html.

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