THE NETL CARBON SEQUESTRATION NEWSLETTER: ANNUAL INDEX

AUGUST 2001 – AUGUST 2002

This is an indexed compilation of the past year's monthly National Energy Technology Laboratory Carbon Sequestration Newsletter. It highlights the primary news and events that have taken place in the carbon sequestration arena over the past year. To subscribe to the newsletter, please send a message to majordomo@list-manager.netl.doe.gov with "subscribe sequestration" in the body of the message.

SEQUESTRATION IN THE NEWS

August 2001

President Bush announces eight new carbon sequestration R&D awards On July 13th, President George Bush delivered an address on a "scientifically sound and effective global effort to reduce the buildup of greenhouse gases in the atmosphere." As a part of that speech the President announced recent R&D awards made by the DOE's Carbon Sequestration R&D Program. He highlighted two projects, one led by the Nature Conservancy and another by an international consortium of major energy companies. Other winning proposals are described in more detail on the DOE website, and are led by Alstom Power, Praxair, Consol, Dakota Gasification, Advanced Resources International, and Yolo County, CA. Overall, industry is offering 40% cost share to the efforts.

Science Daily An ocean sequestration demonstration study has been proposed in the Norwegian Sea. The article, Norwegian Sea Proposed As Storage Site for Carbon Dioxide, originally appeared June 27th in *Geophysical Research Letters*.

The Environmental Protection Agency's web site now has a page that speaks directly to carbon sequestration. The Methane and Sequestration Branch within EPA "serves as the principal point of contact in the Agency for carbon sequestration policy and program development."

September 2001

Science Magazine A profile of ocean chemist Peter Brewer of MBARI in the August 3 edition of the journal Science explains Brewer's role in advocating research on direct CO2 injection into the deep ocean. The article is called "Peter Brewer: Fathoming the Chemistry of the Deep Blue Sea."

PBS News-Hour with Jim Lehrer On August 6, Spencer Michaels presented a fifteen minute report on carbon sequestration, emphasizing MBARI's work on ocean sequestration research and the Weyburn geologic sequestration project. For a transcript or video of the report, see CO2: Burial at Sea?

EPA Web Site EPA has updated the State and Local Climate Change Capacity Building Program website with the summer edition of the newsletter Inside the Greenhouse. The State and Local Climate Change Program works with States to produce non-binding greenhouse gas action plans. To date, 35 states and Puerto Rico have greenhouse gas inventories, and 25 states have initiated or completed GHG Action Plans. Carbon sequestration is one component of many State action plans. Several states are beginning to lay the groundwork for establishing concrete policy initiatives, many involving terrestrial sequestration.

October 2001

A Greener Greenhouse Satellites show plant growth in northern regions has been more vigorous over the past two decades. The greenness data from satellites correlates strongly with temperature data. "A Greener Planetary Greenhouse", *NASA,* September 7.

November 2001

Grasslands Adapt to Climate Change. Climate-change models assume that soil microbes accelerate global warming in a positive feedback cycle. Rising temperatures are expected to speed bacteria respiration, burning energy and releasing CO_2 in a natural growth process. University of Oklahoma researchers found that grassland soil respiration did not increase in response to climate warming as much as previously modeled. Soil microbe respiration contributes significant amounts of carbon to the atmosphere, and a revision in respiration rates could mean climate models must also revise global warming forecasts, according to the study. Nature, October 11.

Deep Sea Sequestration Editorial. A survey of relevant literature suggests that if ocean sequestration projects (such as fertilization and/or direct injection) alter the CO_2 concentration or pH of the ocean, the projects could adversely affect deep-sea organisms. According to the survey, detailed studies into the effects are needed before the risks and benefits of ocean sequestration can be assessed appropriately. Science Daily, October 15

December 2001

U.S. CO_2 emissions up in 2000. The Energy Information Administration recently released the Annual Energy Outlook 2002, which reports a CO_2 emissions increase of 3.1 percent in 2000, up from a 1.6 percent increase in 1999. Contributing to the large jump was a 4.7 percent increase in CO_2 emissions from electricity generation, as well as an 11 percent reduction in electricity generation from renewable fuels. Electric generators used a larger percentage of coal in 2000, partially in response to high natural gas prices. *Reuters*, US carbon dioxide emissions up 3.1 pct in 2000, November 12, 2001.

Ocean sequestration controversy. An article in the New York Times calls out some of the points in the debate over ocean carbon sequestration, citing a small-scale study at the Monterey Bay Aquarium Research Institute in which sea organisms died when caged very near pools of liquid CO_2. New York Times, Science Section, Plan Calls for Using Oceans to Soak up CO_2, Critics Cite Perils, November 20, 2001.

The permanence of terrestrial sequestration questioned. Forests and oceans exchange carbon with the atmosphere in fluxes varying from year to year. Net carbon exchange between the atmosphere and terrestrial systems was largely neutral in the 1980s, but in the 1990s terrestrial uptake of carbon was high, due in part to land use changes. A team of 13 researchers from around the world conclude that the rate of terrestrial carbon uptake will probably plateau in the future, no longer providing a buffer for increasing atmospheric concentrations. Saturation of CO_2 and N fertilization, maturation of second growth forests, and the global ecological effects of climate change could decrease or eliminate carbon sinks. *Nature*, "Recent patterns and mechanism of carbon exchange by terrestrial ecosystems", November 8, 2001.

Renting a positive terrestrial carbon flow. Assessing the permanence of terrestrial carbon sequestration is not necessary if the offsets are rented, says Roger Sedjo of Resources for the Future. In a presentation at RFF, he outlined the key advantages of renting carbon offsets, in comparison to other proposals such as the ton per year approach, which allots credits in proportion to the time period over which carbon is sequestered, or an approach which provides reasonable assurance of indefinite sequestration, which also provides partial credits according to the perceived risk that they will be temporary. To address possible impermanence of terrestrial sinks, Dr. Sedjo proposes structuring the transaction as a temporary lease, where a CO_2 emitter makes payments based upon the volume and duration of carbon uptake. RFF, November 28, 2001.

Climate sensitivity to solar forcings. Solar radiation goes through a cycle of brightening and dimming, which has been linked to changes in sea temperature and climate. Researchers at the Lamont Doherty Earth Observatory think the change in radiation is enough to trigger severe climate changes, such as the Little Ice Age. Using 12,000 years of data, the researchers were able to observe a very subtle 1,500 year pattern. The difference from the top of the cycle to the bottom is very small, less than 0.1 percent difference in energy levels. The researchers say that the sensitivity of climate to a weak force, such as subtle solar variability, should add urgency to the climate change debate, which is driven by concern that GHG forcings could have a severe climatic response. MSNBC, "Sea warmth has been linked to solar cycles", November 15, 2001.

January 2002

Measuring the terrestrial carbon sink. Using maps of carbon storage derived from NASA-developed satellite data sets, earth science researchers studied 19 years of data to conclude that forests in the United States, Europe and Russia have been storing nearly 700 million metric tons of carbon a year during the 1980s and 1990s. The relatively high spatial resolution of these estimates permits direct validation with ground data and contributes to a monitoring program of forest biomass sinks under the Kyoto protocol. The research is published in the Proceedings of the National Academy of Sciences December 18th edition, and the overview article, Goddard Space Flight Center, December 11, 2001.

Ocean fertilization for indirect sequestration. Based on initial results from an expedition in the Southern Ocean (a body of water that extends from Australia's island state of Tasmania to Commonwealth Bay in Australia's Antarctic territory), a team of 70 scientists have explored the idea that increasing iron levels could cause increased CO_2 net absorption. The expedition was headed by Steve Rintoul, an oceanographer for Australia's Commonwealth Scientific and Industrial Research Organization. Three follow-up Japanese-led trips over the next four months will give the scientists data from spring to autumn. "Scientists recommend iron supplements for Southern Ocean to curb global warming," Environmental News Network December 14, 2001.

Landfill gas-to-energy technology innovation. An NETL techline features a landfill gas recovery project developed by Acrion Technologies Inc. has developed a method of collecting and purifying methane using liquid CO_2 also from the landfill. The excess CO_2 is 99.99 percent pure and can be sold as a food additive or piped out to fertilize greenhouses. See the December 11th Techline.

Gathering climate data. The European Space Agency will launch Envisat, a new satellite capable of orbiting the earth fourteen times a day, and operate it for the next 10 years. The satellite will measure and analyze greenhouse gases in the atmosphere, locate environmental polluters, identify ocean currents and algae growth, and track the size of the ozone hole. "Envisat will flood earth with data" Space Daily, November 27, 2001.

February 2002

Technology roadmap. The Carbon Sequestration Technology Roadmap has been posted on the NETL website. The roadmap defines technology goals and a timeline for the next 10 years for the five areas: Separation and Capture, Geologic, Terrestrial, Ocean, and Novel Sequestration Systems.

Voluntary commitment to cut CO_2 emissions. PSEG Fossil and the NJ Department of Environmental Protection announced a voluntary agreement to reduce CO_2 emissions by 15% below 1990 levels by 2005 at in-state power plants. In terms of CO_2, this is a reduction from a 1990 baseline of 1,706 pounds per MWh to 1,450 pounds per MWh. PSEG also committed a $1.5 million grant to NJDEP to assist in the

development of landfill gas projects, and will implement a $300 million, ten year program to reduce NO_x, SO_x and mercury at its New Jersey coal-fired generating stations. *Financial Times*, January 11, 2002, and *Financial Times*, January 24, 2002.

Alternate climate scenario. A new report highlights data that show the growth rate of climate forcing by GHG emissions slowing over the past decade, because of concerted efforts by governments around the world. According to this new study, an "alternate scenario" might provide guidance for successfully curtailing climate altering factors without requiring unreasonable demands of both industrialized and developing countries. See "An Alternate Scenario for Climate Change," *NASA Goddard Institute for Space Studies*, January 14, 2002, and "Limiting Methane Soot Could Quickly Curb Global Warming," For the original paper by Hansen and Sato, see "Trends of Measured Climate Forcing Agents," *Proceedings of the National Academy of Sciences*, December 18, 2001.

Iron ocean effect. Did the algal blooms help to magnify cooling of the atmosphere by sinking CO_2 into the ocean, and were the blooms caused by a sudden increase of dissolved iron in the water? Seven MBARI researchers left for New Zealand at the end of December to gather data to help answer this question. The Southern Ocean Iron Experiment results will contribute to our understanding of biogeochemical processes of the global carbon cycle.

Ocean's internal nutrient distribution. Two researchers at Indiana University suggest that the amount of iron delivered during the ice ages was ten times the amount that could possibly be blown in by dust. Therefore, the fertilization was caused by internal systems of upwelling. See "Study Challenges Idea of Seeding Oceans with Iron to Curb Global Warming," *National Geographic News*, January 8, 2002.

Ocean fertilization debate. Two researchers from the University of California Santa Cruz and Lawrence Livermore National Lab wrote a letter to *Science* in support of researching the option of carbon sequestration in the ocean. "The potential of the oceans as a repository should not be ignored," they said, and recommended ways to counteract acidification which should be explored. *Science Magazine*, January 11, 2002.

Meteorological data. Last year had the second warmest global surface temperatures in more than 100 years, according to an analysis by James Hansen and other scientists at NASA. Global warmth in 2001 is particularly notable because it occurred at a phase of the southern oscillation in which the tropical Pacific Ocean is cool. *Science Magazine*, January 11, 2002.

March 2002

New High-Pressure Water Tunnel Facility (HWTF). NETL designed and constructed a laboratory that can duplicate deep-ocean conditions. It is used to investigate the chemical, physical and thermodynamic behavior of CO_2 when it is injected into the ocean for sequestration, at depths of over 500 meters.

Plant Response to High Levels of CO2. According to research conducted by the University of California-Davis, increased levels of CO2 in the atmosphere resulted in a less-than-expected increase in plant productivity. Researchers hypothesized that long-term CO2 fertilization weakened the ability of plants to incorporate certain forms of nitrogen. *Proceedings of the National Academy of Sciences*, February 5, 2002.

U.S. Terrestrial Carbon Absorption May Decrease in the Future. Researchers from the University of New Hampshire, Princeton University, and Woods Hole Research Center used two models to estimate patterns of carbon stocks and fluxes resulting from land-use changes from 1700 to 2100. The results indicate that ecosystem recovery processes are primarily responsible for the contemporary U.S. carbon sink, but will slow over the next century, significantly reducing the sink. "Projecting the Future of the

U.S. Carbon Sink," *Proceedings of the National Academy of Sciences*, February 5, 2002. This trend has also been identified in the EPA "Climate Action Report."

Ocean Research. Three recent studies have generated more than the usual amount of news about oceans. The studies are: documentation of a slowing ocean circulation system that brings cool water from ocean depths to the surface causing an increase in sea surface temperatures along the equator in the Pacific Ocean and a decrease of CO2 released into the atmosphere ("Slowdown of the meridional overturning circulation in the upper Pacific Ocean," NOAA, *Nature*, February 7, 2002); a study using seven decades of temperature data shows mid-depth water in the Southern Ocean has warmed nearly twice as much as the world ocean average ("Warming of the Southern Ocean Since the 1950s," Scripps Institute of Oceanography, *Science*, February 15, 2002); and a report that the level of the world's oceans will rise more than twice the amount predicted by the IPCC due to a higher rate of glacial melting (AAAS, University of Colorado, February 14, 2002).

Observations from Space. After examining 22 years of satellite measurements, NASA researchers find that more sunlight entered the tropics and more heat escaped to space in the 1990s than in the 1980s. Their findings indicate less cloud cover blocked incoming radiation and trapped outgoing heat. Though not completely sequestration-related, the website contains impressive animations and photos from space.

NASA Climate Data Available. Researchers at NASA Goddard Space Flight Center released the Global Change Master Directory (GCMD) for 2002. The GCMD contains more than 10,600 descriptions of Earth and environmental science data, providing the most up-to-date data sets and services relevant to global climate change research.

The Work-week and CO2 Link. Researchers at the Moana Loa Observatory have observed a weekly cycle in CO2 concentrations. They find that CO2 measurements rise to a peak on Mondays and then decline steadily to a minimum on Saturdays. "Moana Loa weekly link with CO2 emissions," *Nature*, February 15, 2002.

GHG Technology Performance Verification Testing. Operating as a public/private partnership under the U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) Program, the Greenhouse Gas Technology Center offers performance verification testing on technologies that reduce GHG emissions and makes the verification results available to stakeholders and the public. Vendors and state-level partners are being sought to participate in the program.

Prototype Carbon Fund Swings into Gear. The World Bank Prototype Carbon Fund was established as a temporary entity to contribute learning experience in the market for project-based emissions reductions. At a meeting mid-February, project preparations in the Czech Republic, Mauritius, Colombia, Romania, Poland, and Bulgaria on a variety of energy efficiency or carbon sequestration (terrestrial) technologies were moved forward.

April 2002

New Sequestration Research Projects. Three universities were selected by DOE's Carbon Sequestration R&D Program to receive research grants. The University of Texas at Austin will develop an alternative solvent that captures more CO2 than MEA (monoethanol amine, a conventional state-of-the-art sorbent) scrubbing at less cost. The University of Massachusetts will test a method for deep ocean sequestration. The test will blend liquid CO2, water, and finely ground limestone into an emulsion that could be pumped into the ocean for long-term storage. The University of Kentucky proposes to displace natural gas from shale, and store CO2 in the shale. "New Projects to Explore 'Breakthrough' Ideas for Capturing, Storing Carbon Gases," *DOE Techline,* March 6, 2002.

NETL Carbon Measurement Testing. Recent restoration projects sponsored by The Nature Conservancy (TNC) in the Brazilian Atlantic Rainforest serve as testing grounds for researchers measuring soil carbon. Using a laser-induced breakdown spectroscopy (LIBS) device developed by Los Alamos National Laboratory (LANL), NETL is working to develop new approaches to carbon measurement. The research is organized into two primary groups. The Applied Terrestrial Carbon Sequestration Partnership, led by NETL and LANL, is a multi-disciplinary team of scientists, and the Climate Action Project Research Initiative is a cooperative agreement between NETL and TNC. Both partnerships work with government and non-government organizations in Brazil. "NETL, LANL and TNC Measure Terrestrial Carbon," NETL, March 8, 2002.

Six More Companies Join EPA's Climate Leaders Program. Alcoa, Alcan Aluminum, British Petroleum, International Paper, Johnson & Johnson, and DOE's NREL (National Renewable Energy Laboratory) have joined the other 11 charter partners in the Environmental Protection Agency's voluntary Climate Leaders Program. The Climate Leaders Program announced the new entries at the Earth Technologies Forum, on March 25th. A few companies have made preliminary commitments to reduce greenhouse gas emissions, including Alcoa, a leading producer of primary aluminum, by 25% from 1990 levels by 2010, and General Motors by 10% from current levels by 2005.

EPA recognizes 729 top energy-performing buildings in America. Energy Star awards were presented to large commercial institutions, healthcare facilities, supermarkets, schools and government facilities in 40 states. Buildings qualify for Energy Star by earning a score of 75 or higher on a 100-point national energy performance rating scale. The buildings saved $134 million in energy costs since 1999 and released 1.9 billion fewer pounds of carbon dioxide into the air. "Whitman Announces 729 of The Nation's Top Energy Performing Buildings," EPA, March 21, 2002.

May 2002

Weyburn Field EOR. Canadian public television recently aired a segment on the Weyburn enhanced oil recovery project. The project involves importing CO2 from a synthetic fuel factory in North Dakota and injecting the CO2 into the aging Weyburn reservoir 320 kilometres north in Saskatchewan. Results indicate that the project has increased oil production by twenty percent over eighteen months. "Production at Saskatchewan oil field up due to innovative idea," *The National*, CBC-TV, March 22, 2002.

Capturing CO2 from Air. Researchers from Los Alamos National Laboratory (LANL) are developing a process to extract CO2 from air using a chemical cycle (e.g. quicklime to calcium carbonate). The current cost of the process is roughly equivalent to 20 cents per gallon of gasoline. The research was presented at the annual meeting of the American Chemical Society in Orlando. "Researchers Look to Mop Carbon Dioxide from Air," *Environment News Service*, April 10, 2002.

Transporting CO2 over Sea. The Norwegian oil company Statoil's shipping division has engineered a tanker design that could help Norway meet CO2 emission targets. The design will allow liquefied CO2 to be carried from power plants to sites where it can be sequestered in enhanced oil recovery operations. The CO2 would be transported under pressure at a temperature of -50 degrees C. "Shipping CO2 could help Norway hit Kyoto targets," *Reuters*, April 23, 2002.

BP Benefits from Early Reductions. BP sold 1,000 carbon credits to IMERYS, the international white pigments processing group, using the U.K.'s recently introduced emissions trading scheme. "BP Makes First Emissions Trades," BP, April 10, 2002.

Non-linear CO2 Absorption by Trees. A four-year experiment by researchers at Duke University found that trees in a 100% enriched CO2 atmosphere (double today's concentration of 370 parts per million by volume) grew 27 percent faster than at control sites without CO2 enrichment. This correlates to an absorption of only 10 percent of human-generated CO_2 in 2050, less than previously anticipated. *Oecologia*, "Forest Experiment Questions Greenhouse Gas Strategy," *New Scientist*, April 2002.

Rainforests May Balance Carbon Accounting. Scientists from the University of Washington, the University of California, and an institute in Brazil, report that previous estimates of terrestrial carbon sequestration by ecosystems in the humid tropics may be overestimated, due to overlooked outgassing of CO_2 from rivers and wetlands. The authors suggest that the overall carbon budget of rainforests, summed across terrestrial and aquatic environments, appears close to reaching a carbon equilibrium. "Outgassing from Amazonian rivers and wetlands as a large tropical source of atmospheric CO_2," *Nature*, April 11, 2002.

ESI and Industry Reforestation Collaboration. Environmental Synergy, Inc. planted its 15 millionth tree in the Lower Mississippi River Valley as part of an ongoing effort to restore bottomland hardwood habitat to the area while sequestering CO2. The reforestation program, implemented on behalf of companies like Dynegy, Inc., American Electric Power, ChevronTexaco, and the UtiliTree Carbon Company, has restored 55,000 acres of forests over the past three years. "ESI Reforestation Effort Combats CO2 Emissions," ESI, April 2002.

Long-term Climate Modeling. Two articles in the April 25 issue of the journal Nature address climate change uncertainties. "Constraints on radiative forcing and future climate change from observations and climate model ensembles" and "Origins and estimates of uncertainty in predictions of twenty-first century temperature rise." *Nature*, April 25 2002.

June 2002

Saturated grasslands. Researchers from Duke University and the University of Texas at Austin found evidence to suggest that past soil carbon storage and nitrogen cycling in a grassland ecosystem was more responsive to increasing atmospheric carbon than the ecosystem will be in the coming century. The researchers studied enclosed chambers of grassland exposed to a gradient of CO2 concentrations ranging from the expected future level of 550 parts per million (ppm) down to 200 ppm (pre-industrial revolution level). According to the study, primary production and soil carbon storage saturated above 400 ppm. The study was supported by DOE and USDA. "Nonlinear grassland responses to past and future atmospheric CO_2," *Nature* 417, 279 – 282, May 16, 2002, and "End of 'free ride' on ecosystem CO2 absorption", May 15, 2002, Duke University.

Rain and terrestrial carbon storage. A new NASA-funded study discusses the relationship between the hydrogeologic cycle and carbon sequestration. The U.S. terrestrial carbon sink has been increasing since the latter half of the 1900s, and previous research suggested this rise may be due to forest re-growth, higher concentrations of atmospheric CO2, and warmer temperatures. Computer model results show that from 1950 to 1993 higher humidity and an 8 percent precipitation increase led to a 14 percent increase in plant growth. The study appears in *Geophysical Research Letters* later this month. "Changes in rainfall patterns spur plant growth, carbon absorption across U.S.," NASA, May 16, 2002.

July 2002

Los Alamos High-Temperature Polymer Captures CO2 from Industrial Processes. A high-temperature composite membrane, combined with a porous metallic support, separates and captures CO2 from industrial processes. The membrane has high selectivity; a demonstrated operating temperature of

370 degrees Celsius; is chemically resistant; and is easily processed. Collaborators with LANL, through the DOE Carbon Sequestration Program, include Pall Corporation, the University of Colorado, Idaho National Engineering and Environmental Laboratory and Shell Oil Co. Los Alamos National Laboratory, "Hot polymer catches carbon dioxide better," May 29, 2002.

Toshiba develops CO2 adsorbent. A powdered ceramic, developed by researchers at Toshiba Corp., absorbs CO2 at room temperature and releases it when heated. The lithium silicate material absorbs 400 to 500 times its volume in CO2 at temperatures up to about 700 degrees C. When heated above 700 degrees, the reaction is reversed. According to the article, the researchers expect to develop a system for capturing CO2 generated in industrial processes within 1 to 2 years. In the future, it says, larger systems could capture CO2 from smokestacks, and cartridges could capture CO2 from car tailpipes and be exchanged at gas stations. *Global Design News*, "Ceramic captures CO2," June 1, 2002. Contact Kazuaki Nakagawa, who leads the Toshiba research, at kazuaki.nakagawa@toshiba.co.jp .

Canadian clean coal feasibility study. The Government of Saskatchewan is contributing $333,000 of $5 million to the Canadian Clean Power Coalition (CCPC), for the feasibility study phase of a clean coal project. A full-scale demonstration plant with near zero emissions (including CO2) will be completed by 2007. The CCPC's seven participating companies represent 90 percent of Canada's coal-fired electricity capacity. CCPC founding member SaskPower actively supports carbon capture and zero emissions research organizations. For more information, contact Peter Symons at psymons@telusplanet.net. *Canadian Corporate Newswire*, "Saskatchewan Joins National Clean Coal Effort," June 5, 2002.

China – Canada CBM cooperation. The Chinese Government will use Canadian enhanced coal bed methane recovery technology to tap the country's 33,000 billion cubic meters of CBM resources. CO2 from nearby energy production and industries will be injected 2,000 meters underground into the coal beds. The project's budget includes Canada's contribution of $ 3.1 million and China's contribution of $ 3 million. In the next three years, the project will perform pilot tests. According to the article, China emits 6 billion cubic meters of methane from mines a year. *China Daily,* "Coal project gets Canadian aid," March 29, 2002.

Enhanced coal seam methane. Rival Resources Inc. and Golder Associates Inc. of Washington State applied for a $500,000 grant from the US Department of Energy to develop sequestration technology on Rival leases in the Bellingham basin. The $700,000 program will develop and demonstrate technologies to permanently store large volumes of CO2 while simultaneously displacing coal seam methane for power generation. A pilot well would be used for CO2 injection and methane recovery. *Oil & Gas Journal*, "Area drilling," June 10, 2002.

Capturing CO2 from nylon processing. Airgas will build a $10 million liquid CO2 and dry ice manufacturing plant at Honeywell's caprolactam plant in Virginia, purchasing the gaseous CO2 as a feedstock source from Honeywell. Airgas operates 16 dry ice plants nationwide. The poultry industry, which is heavily concentrated in North Carolina, Maryland, and Delaware, will be the plant's largest customer. *Chemical Week,* "Airgas to Build CO2, Dry Ice Unit at Honeywell Site," May 29, 2002.

Sequestration spotlight. A Boston Globe article covered carbon sequestration issues on ocean, terrestrial, geologic, novel systems, and capture technologies. Robert Kane of DOE is quoted emphasizing the supportive role of sequestration activities within a climate change policy. The article divided proposed technologies for capturing and storing carbon into two subcategories - technologies that work right at the smokestack, and technologies that attempt to draw down CO2 already dispersed throughout the atmosphere. Boston Globe, "Cooling the Earth," June 11, 2002.

Direct ocean sequestration to move from Hawaii to Norway. The Pacific International Center for High Technology Research in Honolulu is withdrawing its permit application to conduct a $5 million carbon sequestration experiment off the coast of Hawaii and plans to move the project off the coast of Norway. The timing to obtain a permit for Hawaii was becoming excessive; thereby, leading to project delays and budget constraints. The researchers are in the process of applying for permitting in Norway. The project is supported by a consortium of organizations from Japan, Canada, the U.S. and Norway. *Nature*, "Ocean carbon study to quit Hawaii," June 27, 2002.

CO2 and ozone pollution alter northern forest ecology. An international group of researchers working in Wisconsin found that high levels of CO2 increases the growth of young aspen and birch, high levels of ozone decreases their growth, and the combined effects on growth cancel each other out when both are elevated. Long-term exposure to varying concentrations of the gases may change forest diversity. *Environment News Service*, "Air pollution affects tree growth," June 13, 2002.

August 2002

Indonesian CO2 Capture, Recycling, and Injection. Two Japanese firms plan to build a plant in Indonesia to separate and capture CO2 from power plant facilities. Nissho Iwai Corporation and Mitsubishi Heavy Industries will conduct a feasibility study in September and hope to have the plant operational by 2006. They plan to recover 30,000 tons CO2/day, which will be sold to oil field operators for CO2 injection projects in the region. The total cost of the plant is estimated at $836 million. *Reuters*, "Nissho, Mitsubishi Heavy in Indonesian CO2 Project," July 1, 2002.

Carbon Sequestration and Coal. *The Economist* featured several articles on carbon sequestration, climate change, and fossil energy. The articles mentioned clean coal technology, value-added geologic storage, capture technologies, terrestrial and ocean sequestration. IGCC technology, Dakota Gasification Company, saline aquifers, Statoil, and the CO2 Capture Project were also mentioned in the text. *The Economist,* "Fired up with ideas; Carbon sequestration," July 6, 2002.

Ocean Carbon Cycling. An article in *Scientific American* focuses on the science and potential storage of carbon in the oceans. According to the article, the 1997 launch of the NASA Sea Wide Field Sensor (SeaWiFS), improved mathematical estimates of ocean phytoplankton productivity. Phytoplankton incorporate approximately 45 to 50 billion metric tons of inorganic carbon into their cells each year. This is twice previous estimates. Oceanographic research has also revealed phytoplankton sensitivity to changes in global temperatures and nutrient availability. *Scientific American*; "The ocean's invisible forest," August 2002.

Carbon Dynamics in a Boreal Forest. Simulations of different harvesting intensities and rotation lengths on carbon and nitrogen dynamics of boreal forests in central Canada suggest that intensive harvesting regimes would decrease total ecosystem carbon compared with conventional harvesting. Longer rotations (120 years) and less intensive harvesting could increase carbon sequestration about 36–40%. *Ecological Modeling*, "Effects of harvesting regimes on carbon and nitrogen dynamics of boreal forests in central Canada: a process model simulation," October 1, 2002.

Agricultural Carbon Sequestration. A nine-university Consortium for Agricultural Soil Mitigation of Greenhouse Gases (CASMGS) is conducting a $15 million research program to determine the potential for sequestering carbon in agricultural soils and look at ways to reduce NOx and CH4. The program will also develop a web-based system to facilitate the sale of carbon credits between farmers and industry. CASMGS is administered by Kansas State University. DOE Battelle Pacific Northwest National Laboratory and USDA are also involved in the research project. U.S. Department of State, "Researchers Say New Farm Practices Will Help Fight Climate Change," July 2, 2002.

CO2 Capture Project Receives Additional Funding. The CO2 Capture Project (CCP), a consortium of eight energy companies led by BP, received an additional $1.8 million from the European Union Research Directorate. The new two-year CCP project entitled Grangemouth Advanced Capture (GRACE) began January 2002 and will cost a total of $2.8 million. Areas of research will include the development of chemical looping combustion technology and new materials for hydrogen membrane reactors. The consortium was formed in 2000 to reduce the cost of CO2 separation, capture and geologic storage technologies and is being funded in part by NETL. "CO2 Capture Project Receives a Further 2.1 Million Euros (US$1.8 million) From European Commission," March 2002.

Geologic Sequestration in France. A French state-owned geological and mining agency and an independent fossil energy research centre have signed an agreement to study geological sequestration, geological analysis of regional sedimentary basins, and environmental pollution technology. For more information email Daniele Roblin at d.roblin@brgm.fr. *The Mining Journal*, "French geological research alliance," July 19, 2002.

SEQUESTRATION POLICY & TRADING

August 2001

Kyoto Protocol and sequestration One of the significant outcomes of the agreement achieved at Bonn was a relaxation of the limits on the use of terrestrial sequestration to achieve emissions targets under the Protocol. This could enable terrestrial sequestration to play a greater role in worldwide GHG emissions reduction. The Pew Center's website contains a summary of the agreement at Bonn.

September 2001

Washington Post On August 19th Eileen Claussen and Elliot Diringer of the Pew Center on Global Climate Change published an editorial, "The Climate Challenge Begins at Home," which highlights bills currently in congress, including Jefford's four pollutant bill, the Stevens/Byrd Climate Change Act, and McCain and Lieberman's Cap-and-Trade proposal.

October 2001

Carbon Trading in the UK The United Kingdom completed work on a voluntary GHG trading program, which provides incentives for industry participants and penalties for non-participants. The UK government has allocated roughly $304 million over five years for the program. The trading system, like the UK's climate tax, is based on energy consumption. *Clean Air Compliance*, September 5, affiliated with *AIR Daily*.

New England and Canada Join GHG Targets Six New England states and five eastern Canadian provinces adopted an action plan to reduce GHG emissions to 1990 levels by 2010. Read the full text of the August 28th Resolution and Action Plan.

A New Agricultural Commodity? Carbon could become a new agricultural commodity, in the potential event of GHG trading in the U.S. "No-till" and other sustainable farming methods increase soil carbon content, and could be part of the $171 billion farm bill in congress. For the full story, see "In Global Warming War, Plowshares are Swords." *Chicago Tribune* September 5.

December 2001

Turning treaties into law. Two weeks of negotiations in Marrakesh have produced a detailed rulebook governing the 1997 Kyoto Treaty. A major debating point in the negotiations was the amount of sink credits a country can receive. Russia, which had been charted for 17 million tons of terrestrial sequestration credits at the Bonn negotiations, bargained for and received an increase to 33. Kyoto will come into force when it is ratified by the governments of at least 55 countries representing 55% of 1990 global anthropogenic CO_2 emissions. *Reuters*, November 12, 2001.

Postponing the proposal for power generation pollution regulations. The Environmental Protection Agency is unlikely to issue a proposal for multipollutant emissions reductions legislation from power plants by the end of the year, instead aiming for early next year. The article says that the administration vowed to oppose Jefford's four pollutant bill S556. *Reuters*, "EPA said to admit pollution rule unlikely this year", November 12, 2001.

Cautionary approval for a European trading plan. The European Union has approved a voluntary British pollution trading plan, but may seek changes before the mandatory European trading scheme is launched in 2005. *Reuters*, "EU approves UK pollution trading, may seek changes", November 29, 2001.

Expanding the voluntary carbon market. Chicago and Mexico City have joined the Chicago Climate Exchange, a trading scheme based on voluntary GHG limits. The creation of a market for carbon emissions would help reveal the price of cutting carbon emissions. The Exchange is currently in its design phase, and includes 36 participating entities, including BP, Cinergy Corp, DuPont, Ford Motor Company, PG&E, and the Nature Conservancy. EyeForEnergy.com, Chicago, Mexico City Attack Global Warming, Join Carbon Trading Exchange, November 15, 2001.

January 2002

Developments in the carbon market. The Dutch environment ministry said it has signed an agreement with Panama to buy up to 20 million tons of carbon credits through the construction of clean energy projects there. The story, "Dutch sign CO_2 cutting agreement with Panama," *Reuters*, December 6, 2001.

February 2002

Carbon regulation uncertainty. The debate in Congress over multi-pollutant legislation conveys a larger context of uncertainty of the regulatory future of electric utilities. This period of possible modification has given rise to intense speculation on a number of fronts. An article on Jefford's bill S556 portrays some of them. See "Will the U.S. regulate CO_2 from power plants, giving a massive lift to the fledgling market in the trade of greenhouse gas emissions?", *Eyeforenergy*, January 17, 2002.

International cooperation. The United States and Italy have agreed to cooperate on more than 20 research projects to investigate climate change. The projects include research in the areas of global and regional climate modeling, atmospheric studies, carbon cycle research, and low-carbon technologies. See "US, Italy Agree to Climate Change Research Projects", *Space Daily*, January 23, 2002. NETL is working with Italy on carbon sequestration research with the IEA GHG Programme and the CO_2 Capture Project.

March 2002

U.S. Climate Policy. On February 14th President Bush released the U.S. Global Climate Change Policy Book, which seeks to reduce the GHG intensity of the U.S. economy by 18 percent in ten years. The Policy Book focuses on terrestrial sequestration throughout (terrestrial-targeted tax incentives will be included in the Farm Bill), but also calls on carbon capture, geologic storage, and measurement and verification as part of the National Climate Change Technology Initiative. The Policy will create "…world-class standards for measuring and registering emission reductions." President Bush also announced the Clear Skies Policy Book, which contains targets for multi-pollutant emissions from power plants.

EPA Climate Leaders. On February 20th Christie Whitman launched EPA's new program, Climate Leaders, which is part of the Bush administration's new climate policy. Ten participating companies, including PSEG, Lockheed Martin, and General Motors, will create emissions inventories and set long-term GHG reduction strategies. The companies may also report emissions reductions from investments in offset projects. February 20, 2002.

Sequestration a High Priority within DOE. Assistant DOE Secretary for Fossil Energy Robert Kripowicz told Senate lawmakers January 29 that the Bush administration is committed to developing

carbon sequestration to ensure climate protection and the continued use of coal for electricity. He said carbon sequestration is "one of the highest priorities of our program." The administration committed $32 million to 50 CO2 sequestration projects in the current fiscal year Kripowicz told the Senate Environment & Public Works clean air subcommittee. "Bush Energy Official Backs CO2 Sequestration To Maintain Dominant Role For Coal," *Inside EPA*, February, 2002.

Economic Analysis of GHG Reduction. Researchers at Penn State used a model to analyze the economic impacts of marketable permits for GHG reductions in the U.S. Their results indicate that a permit price of $128 per ton carbon would be needed to comply with the Kyoto Protocol, leading to a roughly one percent GDP reduction in 2010. According to the study, expansion of trading to include carbon sequestration could significantly lower these impacts. "Greenhouse gas reduction policy in the United States: identifying winners and losers in an expanded permit trading system," *Energy Journal (1)*, February 2002.

April 2002

Sequestration Time Frames. Researchers from Iowa State University created a dynamic model to investigate the optimal time paths of carbon emissions and sequestration. The researchers conclude that carbon sinks should be utilized as early as possible, and carbon flow into sinks should last until the atmospheric carbon concentration is stabilized. The researchers rule out any cyclical patterns of carbon sequestration and release, and assess three mechanisms to introduce sequestration into a carbon permit trading market. "The Time Path and Implementation of Carbon Sequestration," *American Journal of Agricultural Economics*, February 2002, vol. 84.

Incentives for Coal Compliance. EPA will begin changing a clean air enforcement initiative begun under President Clinton in 1999. The Bush Administration has formally decided to discourage new government lawsuits against operators of coal-fired power plants in favor of incentives for mandatory emissions reductions. "EPA Will Ease Coal Plant Rules Incentives to Replace Pollution Lawsuits," *Washington Post*, March 18, 2002.

Earth Technologies. The 13th Annual Earth Technologies Forum, an international conference and exhibition on global climate change and ozone protection technologies and policies, featured U.S. EPA Administrator Christine Todd-Whitman at the Keynote Address. Robert Kane, of DOE's Office of Fossil Energy, presented a talk on carbon sequestration called "Carbon Sequestration: A Third Pathway for Mitigating Global Climate Change," March 25, 2002, Washington DC.

European Carbon Trading Market. At least 55 million tons of greenhouse gas emissions have been traded since 1996, as Britain, Denmark, Norway and the European Union enter the emissions trading market for carbon. The UK target is to cut greenhouse gas emissions by 23 percent from 1990 levels by 2010. In the U.S., roughly forty five U.S. Midwestern companies plan to launch the Chicago Climate Exchange by the third quarter of 2002, which proposes to cut regional emissions of six greenhouse gases by 2 percent below 1999 levels during 2002, and reduce them 1 percent annually. "Greenhouse trading takes off, U.S. on sidelines," *Reuters*, March 19, 2002.

Japan and the U.S. The governments of Japan and the U.S. released a statement of cooperation on a broad range of joint climate change science and technology research activities. The identified priority research areas include: improvement of climate models; research on greenhouse gas sinks including LULUCF (land use, land-use change and forestry); and development of mitigation and prevention technologies such as separation, recovery, sequestration and utilization of carbon and GHGs. U.S. Department of State, February 25, 2002.

Australia and the U.S. The governments of Australia and the U.S. announced an agreement to establish a Climate Action Partnership. The Partnership will focus on emissions measurement and accounting, stationary energy technologies, agriculture and land management, and other issues. U.S. Department of State, February 27, 2002.

Canada and the U.S. The governments of Canada and the U.S. announced an agreement to expand existing bilateral efforts to address global climate change. Cooperation will focus on technology development, carbon sequestration, emissions measurement and accounting, carbon sinks, and other approaches. Examples of opportunities for cooperation include clean coal technology and CO2 capture and storage technology development. U.S. Department of State, March 7, 2002.

Italy and the U.S. The governments of Italy and the U.S. identified priority climate change research activities in the areas of global and regional climate modeling, carbon cycle research, low-carbon technologies, and others. U.S. Department of State, January 22, 2002.

May 2002

U.K. – U.S. Carbon Trade. The Pacific Forest Trust, a non-profit organization based in California, sold 7,500 tons of CO2 emissions offsets to UK-based Future Forests, Ltd. Natsource LLC facilitated the international transaction, which was completed independent of a recognized international emissions trading system. The emissions offsets are based on conservation and long-term sustainable forest management, and are secured in perpetuity by a conservation easement. "International Carbon Trade Mitigates Global Warming," Natsource, April 22, 2002.

Clear Skies NPR Air Time. NPR's Talk of the Nation featured a segment on President Bush's Clear Skies Initiative. Howard Herzog, of MIT's Laboratory for Energy and the Environment, was a guest of the show. The discussion focused on CO2, mercury, particulate matter and sulfur emissions. NPR, April 26, 2002.

June 2002

Sale of Australian salt bush carbon credits to Japan. An Australian mining company has agreed to sell carbon credits to a major Japanese power utility, as part of a package of coal. Landholders in Western Australia will be paid to grow salt bush, which will generate the carbon credits. "Salt bush carbon credits sale to Japan," *ABC News*, May 29, 2002.

International carbon trade. Royal Dutch/Shell and Elsam, Denmark's largest electricity generator, traded carbon pollution permits, establishing the first trading link between the two government-backed emission trading schemes. "Shell and Elsam in first pollution permit swap," *Financial Times*, May 6, 2002.

July 2002

70th Annual U.S. Conference of Mayors. More than 125 local governments have committed to assessing GHG emissions. Among the resolutions adopted by the mayors was a request for state and federal government to provide new resources to local governments to implement GHG reduction measures and foster innovative technologies. Madison WI, June 14-18, 2002.

European Union stabilizes CO2 emissions. The total CO2 emissions in 2000 from the 15 member countries were 0.5 percent lower than the total of ten years earlier, according to the latest emissions

inventory from the European Environment Agency (EEA). Under the terms of the Protocol, the EU is to cut the combined emissions of the six gases to 8 percent below their 1990 level by 2008-2012. The EU greenhouse gas inventory is 3.5 percent below the level in 1990. *Modern Power System,* "Europe stabilizes CO2 emissions," May 31, 2002.

Modeling the link between science and policy. The "tolerable windows" approach is an analytical concept developed by researchers at the International Institute for Applied Systems Analysis (IIASA) and others. The ICLIPS (Integrated Assessment of Climate Protection Strategies) model generates a range of suitable climate protection strategies, determining what emission reductions are necessary under different scenarios to avoid unacceptable climate change impacts on ecosystems. *Environment*, "Exploring options for global climate policy: a new analytical framework," May 2002.

Emissions trading: constraints and market mechanisms. A paper exploring the distributional consequences of alternative emissions trading schemes simulated their introduction in the Kyoto protocol. The simulation shows that the imposition of emission constraints by country may not significantly change social welfare from the introduction of a market mechanism, and that various market regimes have quite different distributional implications. *Environmental Modeling and Assessment*, "Carbon emissions trading and equity in international agreements," May 2002.

August 2002

Largest Ever Forward-Trade of GHG Emissions Reductions. CO2e.com facilitated a trade of 6 million tons of CO2 equivalent reductions between Blue Source, a U.S.-based greenhouse gas market company, and Ontario Power Generation. The two companies also completed a smaller option transaction for 3 million tCO2eq. "CO2e.com Completes Largest Ever Publicly Announced Forward-Trade of Greenhouse Gas Emission Reductions," July 2, 2002

U.S. – Australian Carbon Cooperation. The U.S. and Australia have announced plans to develop a bilateral agreement, which includes joint projects in renewable energy and climate change monitoring. "Australia and the US Working Together on Climate Change," July 9, 2002. U.S. Global Change Research Information Office

Japan – Kazakhstan CO2 Pact. In a recent agreement Japan will help Kazakhstan modernize its power facilities and reduce greenhouse gas emissions from power plants. In return, Japan will receive 60,000 tons of CO2 emission rights per year from Kazakhstan between 2008 and 2012. It has not been determined whether this agreement will involve using joint implementation or clean development mechanisms. "Japan, Kazakhstan in CO2 Pact," July 9, 2002.

GHG Registry Recommendations Sent to White House. The Secretaries of Energy, Commerce and Agriculture, and the EPA Administrator delivered a set of ten recommendations to the President to improve the voluntary greenhouse gas registry. The recommendations include providing transferable credits for carbon mitigation and emissions reduction. According to the letter, incentives and recognition given for actions to remove CO2 from the atmosphere will facilitate meeting the President's 2012 goal of an 18% reduction in carbon intensity. DOE, July 2, 2002.

Australia Formally Rejects Kyoto. The Australian Federal Cabinet reaffirmed its decision not to ratify the Kyoto Protocol. Sources say the Government remains opposed to a carbon tax. *Australian Financial Review* "Cabinet Formally Rejects Kyoto Protocol," July 24, 2002.

SEQUESTRATION EVENTS & ANNOUNCEMENTS

September 2001

NETL's Coal Research Program On August 13th, NETL announced awards for the DOE University Coal Research Program. Nineteen universities in 15 States won $3 million in coal research program awards. The federal grants provide a maximum of $200,000 for projects lasting up to three years. The academic institutions committed nearly $416,000 in matching funds. Ten out of the 23 winning projects are aimed toward carbon management and sequestration. These are listed below. For more complete project descriptions and contact information, please see the DOE techline.

- West Virginia University, Morgantown, WV, will develop a gas sensor and temperature measurement array to analyze multi-pollutants including carbon oxides.
- North Carolina State University, Raleigh, NC, will characterize and engineer a new class of polymer/inorganic membrane materials which purify hydrogen while capturing CO2.
- Arizona State University, Tempe, AZ, will use advanced diagnostic techniques to engineer enhanced carbonation minerals that permanently and benignly dispose of CO2.
- University of Southern California (USC), Los Angeles, CA, will develop a computer model to determine the feasibility of storing CO2 in coalbeds while simultaneously producing clean methane.
- University of Cincinnati, Cincinnati, OH, proposes to develop and evaluate low-cost, poison–tolerant sorbents that remove CO2 from gas streams.
- University of Arizona, Tucson, AZ, will study the potential of injecting CO2 into coalbed methane reservoirs while enhancing methane recovery.
- Pennsylvania State University, University Park, PA, will investigate storing CO2 in carbonate feedstocks while studying their physical and catalytic surface activity.
- Duquesne University, Pittsburgh, PA, will help scientists better understand how to sequester CO2 by generating a 3-dimensional molecular model of a low-volatile bituminous coal.
- Arizona State University, Tempe, AZ, will use advanced simulation techniques to engineer improved carbon-based feedstocks for sequestering CO2 and develop a detailed understanding of key aspects of carbonation.
- University of Akron, Akron, OH, will investigate the reactivity of adsorbates and their role in photosynthesis reactions.

October 2001

R&D Award for Advanced Conversion and Re-Use NETL will fund SRI International to investigate two concepts for converting CO_2 emissions back into fuel. Researchers will investigate using solar energy to convert CO_2 into methanol, and study ways to use heat to convert CO_2 into fuel-grade chemicals. NETL awarded $50,000 for the 12 month project, while SRI will cost-share $13,000. See the August 21 techline.

Interagency Team NETL signed an agreement with the Department of Interior Office of Surface Mining to promote reforestation of Abandoned Mine Land. Under a cooperative project with Stephen F. Austin State University, NETL will create outreach materials to promote a market-based approach to mined land reclamation.

SEQUESTRATION PUBLICATIONS

August 2001

The Energy Information Administration published a report, Analysis of Strategies for Reducing Multiple Emissions from Electric Power Plants: Sulfur Dioxide, Nitrogen Oxides, Carbon Dioxide, and Mercury and a Renewable Portfolio Standard, July 2001. This service report estimates the market price of carbon emissions credits under scenarios where caps are imposed on power sector emissions. The analysis does not appear to consider carbon sequestration implicitly.

Congressional Budget Office prepared a report at the request of the Senate Committee on Environment and Public Works entitled An Evaluation of Cap-and-Trade Programs for Reducing U.S. Carbon Emissions, June 2001. The report evaluates four variants of the proposal to set a mandatory cap on carbon emissions. The outcomes are evaluated based on ease of implementation, degree of certainty about achieving the target level of emissions, cost-effectiveness, and distributional effects.

September 2001

Resources for the Future released a paper August 13th entitled The Effect of Allowance Allocation on the Cost and Efficiency of Carbon Emissions Trading, by Resources for the Future's Senior Fellow Dallas Burtraw et al. The paper investigates the cost-effectiveness and distributional effects of alternative approaches to tradable emissions allowances, such as a revenue-raising auction, grandfathering, or a generation performance standard, using a national electricity market model.

Iowa Department of Natural Resources – Greenhouse gas phase III – Carbon Storage Quantification and Methodology Demonstration. The report was prepared by the Center for Global and Regional Environmental Research at the University of Iowa and includes information on agroforestry of poplars, switch grass and prairies as a means to sequester CO2.

National Research Council recently published Carbon Management: Implications for R&D in the Chemical Sciences and Technology: A Workshop Report to the Chemical Sciences Roundtable. The 220 page workshop report includes a chapter on CO2 as a feedstock.

October 2001

National Academy Press *Atmosphere Biosphere Interactions: Toward a Better Understanding of the Ecological Consequences of Fossil Fuel Combustion*. This report combines research on health consequences of pollutants, CO2 build-up leading to climate warming, and acid deposition.

November 2001

The first Journal of Energy and Environmental Research. Published by NETL, the November issue of the Journal of Energy and Environmental Research is devoted to carbon sequestration research in the Office of Science and Technology, and contains ten papers on capture, separation, conversion and utilization. The 150 page journal can be downloaded online under publications.

The Energy Information Administration Multi-pollutant Analysis. EIA issued two reports on the impact of simultaneous reductions of multiple emissions (SO_2, NO_x, Hg and CO_2). The first report was conducted at the request of Senators Smith, Voinavitch and Brownback, and in addition to the three

pollutants, analyzes the potential impacts of requiring power suppliers to acquire offsets for any increase in CO_2 emissions that occur beyond the level expected in 2008. The second report was issued at the request of Senators Jeffords and Lieberman, and analyzes the potential impacts of reductions on the four emissions from electricity generators starting in 2002 with targets achieved by 2007. The target for CO_2 is 1990 emissions levels. Economical technologies to capture and sequester CO_2 are considered unlikely, and sequestration technologies are included in the analysis but do not penetrate the market because they are presently not economical.

The International Energy Agency Trading Analysis. The IEA issued International Emissions Trading: from Concept to Reality, which offers a comprehensive review of international emission trading.

Review of Landfill Gas (LFG) Recovery Projects. The Greenhouse Gas Emission Reduction Trading (GERT) pilot programs completed reviews of two landfill gas recovery projects. The GERT pilot has registered its first project with traded LFG recovery emission reductions as well as an LFG "offer-to-sell" project.

The European Commission on Environment. The ECE published the results of a two-year study, Economic Evaluation of Sectoral Emission Reduction Objectives for Climate Change, Bottom-Up Analysis, which identifies the (least-cost) contribution of different sectors and gases for meeting the European community's quantitative reduction for GHGs under the Kyoto protocol. The study also determines a package of cost-effective policies and measures towards meeting the goals. CO2 removal and storage are mentioned as emission reduction options for the energy sector.

Climate Strategies. Three new reports on the Kyoto Protocol and climate strategies, Rejecting Kyoto: a study of proposed alternatives to the Kyoto Protocol, Carbon Sinks and Biomass Energy Production: A Study of Linkages, Options and Implications, and Keeping Kyoto: A study of approaches to maintaining the Kyoto Protocol on Climate Change are now available.

Pew Center on Global Climate Change. A paper titled An Overview of Greenhouse Gas Emissions Verification Issues describes the evolving approaches of corporate GHG emissions verification. The authors discuss the experiences of leading firms that inventory and verify GHG emissions and the factors that drive verification.

December 2001

The EPA multipollutant legislation analyses. The Environmental Protection Agency Office of Air and Radiation posted three papers on their website pertaining to proposed limitations of GHG and pollution emissions from power plants. They are: "Analysis of Multi-Emissions Proposals for the U.S. Electricity Sector", "Economic Analysis of a Multi-Emissions Strategy" (requested by Senator Jeffords), and "Comparison of the Jeffords-Lieberman and Smith-Voinovich-Brownback Bills." EPA predicts that caps on SO_x, NO_x, mercury and CO_2 will cause a 30 to 50% increase in electricity prices and massive fuel switching, but no major change to GDP. October 31, 2001.

Energy research is a good investment. The National Research Council released an analysis of energy research at DOE. The historical report examines 17 R&D programs in energy efficiency and 22 programs in fossil energy. These programs yielded economic returns of an estimated $40 billion from an investment of $13 billion. Large environmental gains were identified chiefly in the fossil energy arena, where two technologies - atmospheric fluidized bed combustion, and nitrogen oxides control resulted in more than $60 billion in avoided damage and mitigation costs. Carbon sequestration is mentioned in Appendix E: Case Studies for the Energy Efficiency Program. Energy Research at DOE: Was it Worth It? July 2001.

January 2002

Abrupt climate change. New evidence shows that periods of gradual change in Earth's past were punctuated by episodes of abrupt change, including regional temperature changes of about 18 degrees Fahrenheit, in only a decade. National Academies Press, *Abrupt Climate Change: Inevitable Surprises*, prepublication copy.

Carbon sequestration in sinks: An overview of potential and costs. Previous climate negotiations were often derailed by disagreement on the inclusion of land use, land-use change, and forestry (LULUCF) activities. This paper explores the possible contribution of LULUCF activities in promoting greenhouse gas emissions reductions. Published by the Center for International Climate and Environmental Research – Oslo (CICERO).

EPA's Climate Action Report. The United States' third formal communication under the Framework Convention on Climate Change has been released by the US EPA as a draft open for public comment. The document contains chapters on the U.S. greenhouse gas inventory, policies, projections, vulnerability, financial resources, research, and awareness. The report was posted on December 4th.

February 2002

Deforestation and methane release. Researchers at the Marine Biological Laboratory studying deforestation in Brazilian rainforests found that soil becomes much wetter when forest is converted to pasture (trees take up water from the soil). The water in the soil excludes oxygen; thus, more anaerobic decay and more methane production occur. So, not only does deforestation increase net CO_2 emissions, it also increases net methane emissions. Results would vary based on soil type and region. *NPR Earth and Sky* January 9, 2002.

Terrestrial sequestration research. Thirteen articles in the journal *Environmental Pollution* report on research concerning terrestrial sequestration in forests, agriculture, and soil. A few interesting tidbits from the articles: most soils in the Midwest have lost 30 to 50 percent of their original pool, which can be resequestered through adoption of recommended soil and crop management practices; urban trees in the United States currently store approximately 700 million tonnes of carbon, with a gross carbon sequestration rate of 22.8 $x10^6$ tC/yr; and semi-arid grasslands which had been grazed by livestock showed significantly higher soil carbon. *Environmental Pollution*, March, 2002.

April 2002

International Carbon Trading Market Analysis. The Pew Center on Global Climate Change recently released a report on the carbon trading market. The report concludes that although the market is fragmented, international trading activity has increased over the past five years. Progress in international climate talks, new carbon trading systems in Europe, private sector trading initiatives in the U.S., and a precedent of successful emissions trading with SO2, have helped accelerate the market. Pew Center on Global Climate Change, *The Emerging International Greenhouse Gas Market*, March 19, 2002.

RFF "Safety Valve" Emissions Trading Scheme. Richard Morgenstern of Resources for the Future released a paper on a cap and trade approach applied to GHGs. According to the report, the impact of GHG emissions trading could extend throughout the economy, so to eliminate the risk of major economic disruption a relief mechanism, or "safety valve," is examined. When the price of the permits rises above a set amount, additional permits would be provided to cap the costs of the policy. "Reducing Carbon Emissions and Limiting Costs," RFF, February 2002.

Owners of Electric Generation in the U.S. A report which shows the relative emissions of the 100 largest owners of electric generation is a collaborative effort between the Natural Resources Defense Council (NRDC), Public Service Enterprise Group (PSEG) and the Corporate Climate Accountability Project of the Coalition for Environmentally Responsible Economies (CERES). It focuses on four emissions: CO2, Mercury, NOx and SOx. *Benchmarking Air Emissions of the 100 Largest Electric Generation Owners in the U.S. – 2000*, March 2002.

May 2002

Physics of Enhanced Oil Recovery. An article on petroleum engineering mentions the Sleipner CO2 enhanced oil recovery project as an example of a physical technique to exploit petroleum reservoirs in increasingly remote and complicated geological environments. "Physics in Oil Exploration," *Physics Today,* April 2002.

Enhanced Oil Recovery. The April Oil and Gas journal features EOR in several articles, including "Special Report: Enhanced Oil Recovery," "CO_2 membrane technology matures," and "California steam EOR produces less; other EOR continues." Oil & Gas Journal April 15, 2002.

NETL's Coal - Carbon - Oil Interface. A fact sheet on the capture of CO2 from coal-based IGCC for use in enhanced oil recovery operations has been posted on the NETL website. "Coal-Based IGCC Offers CO2 Capture Benefits for Oil Recovery," NETL, April 2002.

Capture and Sequestration Economics. An NETL technical report on CO2 emissions and economic feasibility comparing coal-based Integrated Gasification Combined Cycle (IGCC) and Natural Gas Combined Cycle (NGCC) with and without capture and storage mechanisms finds that coal-based IGCC with CO2 capture and sequestration would yield one fifth the specific carbon emissions and could be economically feasible if there were a market value for the captured CO2, such as for enhanced oil recovery. "Prospects for Early Deployment of Power Plants Employing Carbon Capture" NETL, April 2002.

June 2002

Greenhouse gas source relativity. A paper by researchers at the Carbon Dioxide Information Analysis Center analyzes greenhouse gas emissions from many sources, on scales ranging from global to national (from country submissions in accordance with the Framework Convention on Climate Change) to state (from individual state emissions inventories). Individual country and state perspectives exhibit some commonalities but differ in detail. "The Relative Importance of Sources of Greenhouse-Gas Emissions: Comparison of Global Through Sub-national Perspectives," *Environmental Management*, Volume 29, No. 3, pp. 360-372.

Global Warming Potentials. A new background document on Greenhouse Gases and Global Warming Potential (GWP) Values from the U.S. Greenhouse Gas Inventory Program describes the characteristics of each of the various greenhouse gases and discusses the concept of Global Warming Potential (GWP) values. Overall, revisions to GWP values do not have a significant effect on U.S. emission trends. "Greenhouse Gases and Global Warming Potential Values," May 2002.

July 2002

NETL accomplishments in FY 2001. A report on NETL accomplishments of last year enumerates carbon sequestration science activities. Accomplishments in this program area include national and regional workshops on carbon sequestration technology, the development of a high-pressure water tunnel for studying deep ocean environments, experimental and theoretical estimates of parameters needed to stabilize drops of CO2 in sea water, better understanding of monoethanolamine degradation pathways, insights and physics-based models of carbon sequestration flows in porous rock, and basic laboratory information on interactions of CO2 with coals. NETL also funded three multi-national projects to study CO2 capture and storage, terrestrial sequestration, and storage of CO2 in oil reservoirs. *NETL Accomplishments FY 2001*, June 25, 2002.

U.S. climate change response. The Pew Center on Global Climate Change released a publication summarizing climate change efforts in the U.S. in the past year. Particular focus is placed on efforts in Congress, where twice as many climate change proposals were introduced in the past year as in the previous four years combined; at the state level and in the business community, where a growing number of corporations are setting GHG targets. Pew Center on Global Climate Change, *Climate Change Activities in the United States*, June 11, 2002.

Clean Development Mechanism (CDM) booklet. The International Institute for Environment and Development (IIED), the Edinburgh Centre for Carbon Management (ECCM), and EcoSecurities have published a booklet of information on the CDM and how it affects forestry and landuse audience activities, principally in developing countries. *Laying the Foundation for Clean Development: Preparing the Land Use Sector*, June 2002.

State and local climate action. The 2001 progress report of EPA's State and Local Climate Change Program, "Partnerships and Progress," highlights the accomplishments of states and communities across the country that have taken action to assess and reduce GHG emissions. The 28-page report talks about state GHG inventories and action plans, legislative items, state and local demonstration projects, and education and outreach campaigns. EPA, June 26, 2002.

Clear skies numbers discussion draft: 3P. A 3 pollutant bill that incorporates the targets set forth by President Bush in the Clear Skies Initiative has been drafted for discussion. The 91-page GOP draft calls for a 2017 deadline to cut SO2 emissions to 4.5 million tons, NOx emissions to 2.1 million tons and

mercury emissions to 26 tons. For comparison, S. 556 sets a 2008 deadline to cut SO2 emissions to 1.98 million tons in the eastern U.S. and 275,000 tons in the western U.S., and NOx emissions to 1.51 million-tons. The S556 caps for CO2 and mercury would fall at 2.05 billion tons and 5 tons, respectively. The discussion draft also stands apart from S556 by tying the new NOx and SO2 trading programs into the existing CAA; allowing for states to call for tighter emission limits, and harmonizing the trading program with state permits. *Greenwire*, "GOP floats Clear Skies numbers," June 25 2002.

New Hampshire's multi-pollutant legislation. In April New Hampshire became the first state to regulate four pollutants from the state's 3 power plants. The new rules have strong support from Republican leadership in both houses of the Legislature, the business community, and the state's major utility. By 2007, Public Service Company of New Hampshire (PSNH) must reduce NOx and SOx emissions by roughly 70 percent below federal requirements, and CO2 emissions by three percent levels by 2010. The bill provides for an additional seven percent cut below 1990 levels. If PSNH cannot meet the standards with actual emissions reductions, it can buy pollution credits from utilities in other states that have already reduced emissions. *Environment News Service*, "New Hampshire Passes Nation's First CO2 Cap," April 22, 2002.

North Carolina multi-pollutant legislation. North Carolina is the first southern state to pass multi-pollutant legislation restricting emissions from the state's 14 coal fired power plants. The law mandates NOx and SOx emissions reductions and requires the North Carolina Division of Air Quality to conduct a study of mercury and CO2 emissions. The state joins CT, IL, MA and NH in requiring deeper than Federal emissions cuts. National Caucus of Environmental Legislators, "North Carolina House Passes Bill to Clean Up Old Power Plants," June 13, 2002.

August 2002

Federal Agency Global Change Data Sets Available. An on-line, searchable Federal agency research data-set for 2001 is now available to researchers, industry and private businesses, policy makers, and the public. This publication is the fifth in a series of annual reports of Federal agency data related to the U.S. Global Change Research Program. USGCRP, July 2002.

NAFTA Carbon Emissions Mitigation Report. In a report on the environmental impacts of an integrated North American electricity market, the Commission for Environmental Cooperation (CEC) recommends the development of a carbon trading regime and implementation of compatible carbon reduction strategies for Canada, Mexico, and the U.S. The suggested strategies include GHG emissions inventories; a North American trading regime; and an aggressive long-term renewable energy program in the U.S. CEC, *Environmental Challenges and Opportunities of the Evolving North American Electricity Market*, June 2002.

Pew Center Energy Policy. The Pew Center on Global Climate Change released a report which considers energy policies that position the US to reduce GHG emissions. The report supports research and development in carbon capture and sequestration technologies. Pew Center on Global Climate Change, *Designing a Climate-Friendly Energy Policy: Options for the Near Term*, July 2002.

Point Carbon 2002 Quarterly Report. Important market developments affecting the value of carbon over the last three months: The Netherlands and Norway both decided to launch national GHG emissions trading systems in 2005. The European Union and Japan ratified the Kyoto Protocol, while Australia rejected ratification. The present carbon value under the Kyoto framework (PCV Kyoto) has been adjusted downwards, because probability for entry into force of the Kyoto Protocol has been reduced. Point Carbon, *Quarterly Report*, July 14, 2002.

CDM and Carbon Sequestration in Soils of Sub-Saharan Africa. A new publication documents the improvements in agricultural practices and land-use management in sub-Saharan Africa that could increase agricultural productivity and sequester soil carbon. *Climatic Change*, "Soil Carbon Sequestration and the CDM: Opportunities and Challenges for Africa," September 2002.

UNEP Coal Sustainability Report. In a profile written for the UNEP by the World Coal Council, the sector's main long-term environmental challenge is identified to be greenhouse gas emissions from combustion. The proposed solution is to use clean coal technologies and to capture and sequester emitted CO2. UNEP, The World Coal Institute, "Industry as a Partner for Sustainable Development: Coal," July 8, 2002

Standards for California GHG Reporting. The California Climate Action Registry has set standards for the voluntary reporting of greenhouse gas (GHG) emissions, establishing new procedures and a third party certification process. July 2002.

GAO Power Plant Study. Senators Jeffords and Lieberman requested a General Accounting Office (GAO) study comparing emissions from old and new power plants. The study found that older plants release twice as much S02 and 25% more NOx than new plants, while CO2 emissions rates are comparable. 57% of fossil fuel generating plants were online before 1972. They account for 59% of SOx emissions, 47% of NOx, and 42% of C02 in 2001, while producing 42% of all electricity produced by fossil fuel plants. GAO, July 2002.

SEQUESTRATION LEGISLATION

November 2001

Clean Air Act Amendments: Multi-pollutant Bill Meeting. Stakeholders met to discuss Senator Jeffords' 4 Pollutant Bill (S556) October 4 – 5. Environmental organizations, health organizations, power utilities and lawmakers discussed emission reductions for NO_x, SO_x, CO_2 and Hg beginning in 2002, including flexibility, trading, allocation, technology, and compliance. See details and statements.

August 2002

California GHG Bill Passed and Signed. The California Assembly passed a bill that will regulate GHG emissions from cars and trucks. The State Senate approved the bill in April, directing the California Air Resources Board to reduce tailpipes GHGs by the 2009 model year. The auto industry (except Honda), is strongly opposed, concerned that the legislation will be used as a template by other states. California is the first state to enact legislation reducing GHG emissions from passenger vehicles sold in the state. *Washington Post*, "California Takes Lead on Auto Emissions," July 22, 2002.

President Bush's Clear Skies Legislation. H.R. 5266 would set emission reductions by 2010 of 4.5 million tons for SO2, 2.1 million tons for NOx and 26 million tons for mercury. By 2018, Clear Skies calls for a 3-million-ton SO2 cap, 1.7-million-ton NOx cap and 15-ton mercury cap. Included in H.R. 5266 is a call for the phaseout of several CAA programs, including the New Source Review permit program. *New York Times,* "Bush Energy Proposal Seeks to 'Clear Skies' by 2018," July 29, 2002.

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NETL Carbon Sequestration Page @
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