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CO_2 Capture and Storage Newsletter

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This issue of EPRI's *CO_2 Capture and Storage Newsletter* includes highlights of these recent meetings and activities:

- Visit to the Trona plant MEA CO_2 removal system in Trona, California, in September 2006
- The 30th IEA GHG Executive Committee Meeting, held in Helsinki, Finland, in September 2006
- The DOE meeting for the Regional Carbon Sequestration Partnerships program, held in Pittsburgh, Pennsylvania, in October 2006
- The 2nd Risk Assessment Network meeting held in Berkeley, California in October 2006
- The MIT Carbon Sequestration Initiative Sponsor Meeting, held in Cambridge, Massachusetts, in November 2006
- The Sixth Annual MIT Carbon Sequestration Forum, held in Cambridge, Massachusetts, in November 2006

Visit to the Trona plant MEA CO_2 removal system in Trona, California, in September 2006

This plant is owned by Searles Valley Minerals, Inc. and produces soda ash (sodium carbonate) from solution-mined trona ($Na_3(CO_3)(HCO_3)\cdot 2H_2O$). As part of that process, a source of CO_2 is needed. The CO_2 is recovered from a coal-fired power plant using an MEA solvent recovery process. This is one of the few coal-fired applications of the MEA process in the world and has been in operation for 25 years.

There are two 52-56 MW boilers and CO_2 is only recovered from one boiler at a time. The coal burned is low sulfur from New Mexico and Utah. The scrubbers are sodium carbonate based—no info on SO_2 outlet values was available since they did not have to be measured. The CO_2 (99% pure) is captured in two trains with a total of 36 ton/h for both trains.

Each absorption tower has two stages of polypropylene packing and handles 62,000-63,000 scfm of flue gas at about 100ºF containing 12 % CO_2. About 2000 gpm of 20% MEA solution is circulated through each absorber. The main issue is prevention of MEA from being entrained in the outlet flue gas. A complicated series of steps has been implemented to minimize losses.

The regenerator/stripper operates at 200ºF at the top (CO_2 rich inlet) and 240ºF at the bottom (CO_2 lean outlet). The unit uses bubble-cap trays. Regeneration steam is 300ºF, 40psia. They do have a reclaim system for MEA and add corrosion inhibitors.

They spend about $150,000-200,000/month on MEA makeup. Corrosion occurs, primarily at the top of the stripper, and they must maintain the heat stable salt concentration <1% to help minimize corrosion. The purged heat stable salts are sent to a hazardous waste site. They filter the circulating MEA solution to remove particulates that come from the power plant using a polypropylene filter. Through experience, they learned that they have to change this filter every six weeks.

30th IEA GHG Executive Committee Meeting

The IEA GHG Program was established by the International Energy Agency initially to promote CO_2 capture and storage. Currently the Program produces informative reports on the status of all aspects of GHG control and disposal. In addition, it has created several networks to promote information sharing and cooperation, and also promotes practical R&D projects in GHG control. Members include seventeen countries and seven industrial sponsors, including EPRI.

At this meeting, the following topics were chosen for initiation of new projects:

- **CO_2 capture in the cement industry**. This study will evaluate the options for controlling CO_2 from the cement industry, which accounts for over 1 Gt/y in CO_2 emissions worldwide. This is an area that has had little emphasis in the past. The study will describe technology options for CO_2 capture in cement plants, including post combustion capture using amines and solid sorbents (carbonates), oxy-combustion and pre-combustion capture. The main technical issues for application of CO_2 capture technologies will be assessed. Both new and retrofit applications will be evaluated. One process will be selected for a more detailed evaluation.
- **Improved solvent processes for CO_2 capture.** This study will identify alternative solvent scrubbing processes for post and pre-combustion capture of CO_2. The performance, costs, safety, environmental impacts and other features of selected technologies will be assessed and compared to those of the conventional scrubbing process which were evaluated in IEA GHG's recent studies on post- and pre-combustion capture. Processes that may be included are the aqueous ammonia solution and Cansolv process for post-combustion and the cold methanol (Rectisol-type) scrubbing for pre-combustion capture.
- **Breakthrough capture processes.** This study will carry out high level evaluations of emerging processes that do not warrant the detailed evaluation to be conducted in the previous study. These will be short notes that will be distributed to the program members; when several are complete, they will be assembled into a compendium and published.
- **Safety considerations for carbon capture and storage.** This study will examine all the safety issues that are likely to arise when considering potential safety issues for a CCS project and planning associated emergency procedures. It will focus on hazards resulting from the presence of carbon dioxide in the supercritical state in intermediate storage, pipelines and offshore injection facilities, which are the locations likely to experience the largest inventories and highest pressures. The gaps in knowledge would be identified along with a survey of any current research aimed at filling those gaps. The study will conclude with a set of recommendations for further research.
- **Trans-boundary transmission and storage.** This study will identify all of the agreements, conventions, protocols, etc. which could impact trans-boundary movement of CO_2, including typical toxic impurities, and examine all of the specific restrictions or obligations which might apply. It will evaluate the nature of any restrictions and what changes would be required to remove significant barriers to implementation of trans-boundary projects.

The DOE meeting for the Regional Carbon Sequestration Partnerships program, held in Pittsburgh, Pennsylvania, in October 2006

This annual meeting of the partnerships emphasized the plans for the CO_2 injection pilots in Phase 2. Each partnership presented the status of its pilot projects. In addition, the DOE representatives made their initial presentation of the programmatic content of Phase 3. The geologic storage pilots from each partnership are shown below. The partnerships are abbreviated as follows--West Coast (WESTCARB), Plains (PCO_2R), Midwest (MRSCP), Southwest (SWRPCS), Big Sky (Big Sky), Midwest (MGSC), and the Southeast (SECARB). More information on these pilots can be found at the NETL website. http://www.netl.coe.gov/publications/proceedings/06/rcsp/index.html

- CO_2 Sequestration in Saline Formations
    - Central Valley - Stacked Saline and Gas, WESTCARB
    - Kaiparowits Basin, WESTCARB
    - Michigan Basin, MRCSP
    - Cincinnati Arch, MRCSP

- Appalachian Basin, MRCSP
- Gulf Coast Stacked Test in Saline and Oil, SECARB
- Mississippi Salt Basin, SECARB
- Grand Ronde Basalt, Big Sky
- Paradox Basin, Aneth Field - Saline and Oil, SWPCS
- Illinois Basin, MGSC

- CO_2 Sequestration w/ EOR
    - Zama - Keg River Formation, PCOR
    - Duperow Formation, PCOR
    - Permian Basin, SWPCS
    - Illinois Basin - Heavy Oil and Well Conversion, MGSC
    - Illinois Basin - Pattern Flood Tests, MGSC
    - Lost Soldier Wertz Field, Big Sky
- CO_2 Sequestration in Coal Seams
    - Illinois Basin, MGSC
    - Williston Basin, PCOR
    - Central Appalachian, SECARB
    - Black Warrior Basin, SECARB
    - San Juan Basin, SWPCS

Phase 3. The DOE also announced details of the Phase 3 effort. It will consist of up to seven large (0.4-4 million tons of CO_2 stored over four years) demonstration projects. There would be one per partnership. This will not be a competitive solicitation—only the existing partnerships will be allowed to bid. Funding available for each project from DOE will be $67M over the ten years of the project. DOE will require 20% cost sharing. The procurement request was released December 14th, and the proposals are due April 10th 2007. The DOE would prefer that the CO_2 source be captured CO_2 and that the geologic storage be in a saline reservoir. This is a very rapid schedule for arranging such large projects and will be difficult to achieve.

The 2nd Risk Assessment Network meeting held in Berkeley, California in October 2006

The 2nd Risk Assessment Network Meeting was jointly organized by IEA GHG, Lawrence Berkeley National Laboratory (LBNL) and the Risk Assessment Steering Committee, with the support of EPRI. The research network aims to address what the regulators are expecting and whether risk assessment can provide the answers they require. The scope of the Risk Assessment Network can be divided into a number of smaller and more specific subject areas: Data Management, Risk Analysis, Regulatory Engagement and Environmental Impacts. To continue to promote the progress of the network, it was decided that subgroups should be created that focused on these more specific areas and could run alongside the operation of the network.

Highlights of the meeting include:

- A presentation on the available datasets stressed the limited nature of the information. Thirty datasets were identified, with most being in Europe and North America, but only 11 are actively maintained and managed.
- A presentation discussing the needs for evaluating the impact of leaks on terrestrial ecosystems concluded that there are significant gaps in our knowledge. A plan was proposed to develop the required information, and members of the network were asked to provide comments on the plan.

- Work continues on development of models capable of evaluating all aspects of risk from site selection through long-term monitoring after injection is finished. There is a long way to go before a completed model will be available.
- The early results of the well integrity evaluation as part of the CO2 Capture Project (CCP2) were presented. This was a natural CO_2 source producer well. The tubing was pulled and looks new. The casing looks good, as does the cement. This bodes well for existing wells, although this may be more representative of a dry CO_2 well where minimum carbonic acid would be produced to react with the well components.

The MIT Carbon Sequestration Initiative Sponsor Meeting, held in Cambridge, Massachusetts, in November 2006

Membership in this initiative is on a three year basis, with this year being a renewal year. MIT reported that all 12 existing members renewed and three more joined – Schlumberger, Shell, and Southern Co. A major concern of the participants (as well as the attendees to the follow-on Forum – see below) was future liability of sequestered CO_2. Other presentations included work at MIT to develop approaches to directly measuring any potential leakage (very preliminary, mostly scoping and discussion of the extreme difficulty in separating small leaks from major atmospheric variations), and surveys of attitudes towards climate change and CCS by both the public and stakeholders.

- **Liability.** A doctoral candidate (who is simultaneously obtaining a law degree) reviewed analogous situations (e.g., acid gas injections, secondary recovery and EOR) from the perspective of technical risks, handling of liability, and regulatory/judicial experiences. He concluded that regulatory compliance is not always a safe harbor for liability (e.g., MTBE), that liability rules may change over time, and that no single regulatory analog applies to all CO_2 storage issues but that, as an aggregate, they inform us about a range of mechanisms that could be used. In his PhD thesis, he recommends the following approaches to dealing with this potential show-stopper:
  - Amend the Underground Injection Control (UIC) rules by adding a Class VI category specific to CCS.
  - Create a CO_2 storage fund (levy on each ton CO_2 sequestered) to be used for long term monitoring, remediation, etc.
  - Create a CO_2 Storage Corporation (federal corporation model similar to FDIC) to manage the fund (and ensure that the resources are not siphoned off into the general US Treasury fund).
  - Create an Office of Special Master for CO_2 storage liability issues within the U.S. Federal Court of Claims to mediate claims.

  The presenter suggested a number of conditions that the storage reservoir operator would have to meet before s/he could hand off the liability to the CO_2 Storage Corp. A lively discussion ensued and included the suggestion that these proposals be shared with Congressional staffers to test their political feasibility.

- **Public and Stakeholder Surveys.** The 2006 survey of *public concerns* about global warming and their understanding of mitigation technologies, just conducted, sought any changes since the first study in 2003. The surveyors concluded that there has been a significant increase in concern about global warming and, correspondingly, in a willingness to pay to "solve the problem", but little change in the public's knowledge about CCS technologies (capabilities, uncertainties, or costs). While the environment is not seen as a major issue (ranking 11^{th} out of 22 issues mentioned in the survey (well behind terrorism, Iraq, health care, and oil prices), global warming has become the leading environmental issue by a wide margin. The median acceptable increase in monthly electricity bills was $21 (vs. $14 in 2003), but it was recognized that survey respondents typically say they are willing to pay more than they really are.

The survey of *decision makers* (*stakeholders*) in Europe, Japan, and the US is also a follow-up survey, this time to one conducted last year. The objective is to assess the attitudes of key stakeholders (encompassing industry [by sector] to environmental NGOs) towards global warming and CCS, ranging for agreement that global warming is a critical, major issue to acceptance of different CCS approaches. The responses by region and respondent category were almost predictable, except for general, across-the-board, recognition that global warming is a more, or much more, serious problem than **all** other problems. North American and electricity generation (worldwide) stakeholders believe the fiscal burden will be greater than did the other respondents. Onshore vs offshore storage preferences correlated with availability of onshore underground reservoirs (e.g., onshore favored in US, offshore in Japan). Interestingly, nuclear was more favorably received by these stakeholders in Europe or Japan as an alternative to CCS than in the US. Nearly half the European and US stakeholders anticipate CCS entry into the market within 10 years and most do within 20 years; the Japanese respondents expect a slower market penetration.

The next CSI meeting will take place in Palo Alto, California, on November 12, 2007. Carbon Sequestration Forum VIII will follow on November 13-14 at Stanford University, in collaboration with the Global Climate and Energy Project (GCEP).

The Seventh Annual MIT Carbon Sequestration Forum, held in Cambridge, Massachusetts, in November 2006

This meeting is the annual forum sponsored by the MIT Carbon Sequestration Initiative and held in the two days following the Initiative Sponsor meeting. The topic of this year's meeting was "Pathways to Lower Capture Costs." Separate sessions covered pathways via gasification, oxyfuel combustion, post-combustion capture, and deployment issues. An additional session discussed the challenges of developing large projects, while the wrap-up provided updates of ongoing capture projects. Highlights included the following:

- **Gasifiers.** Larger, lower-cost, higher pressure quench gasifiers are needed soon for IGCC to remain competitive if boiler technology advances as expected. On the other hand, success in the following development efforts, already in the R&D pipeline, could lead to an IGCC system with CO_2 capture/compression that has a lower cost of electricity than current IGCC alone:
  - Dry coal feed pump for the gasifier
  - New, simpler gasifier designs that lead to improved RAM
  - Warm gas cleanup (400–500ºF)
  - Ion transport membranes for oxygen production
  - Advanced combustion turbines
  - Solid oxide fuel cells as toping cycles
  - Membrane shift reactors (combined shift and H_2 separation)

  Also being investigated by the Department of Energy's National Energy Technology Laboratory (DOE/NETL) is the possibility of co-sequestration of other acid gases with the CO_2, as this would reduce the cost of gas cleanup noticeably. The panelists noted that FutureGen (start-up in 2012) would be the logical platform to test any of these advances that are ready by then.

- **Oxyfuel combustion.** Relatively new concepts that were presented are internal gas recycle, dilute oxygen combustion (separate fuel and oxygen ports), and oxygen transport membranes (OTM) directly integrated into the boiler. One design study identified a number of component and systems integration improvements that could reduce costs and energy consumption, including different recycling approaches (hot vs cold, into the boiler or the coal mill), and a new concept for SOx/NOx/Hg removal in the CO_2 compression process (in the presence of water and oxygen). With the uncertainty of success in this last potential advance, it was also recognized that the developers and regulators need to determine if co-sequestration of these impurities with the CO_2 is acceptable. An efficiency target of 36.4% was postulated with coal drying via warm N_2 (from the air separation unit), more O_2 preheat, ad higher temperature gas recycle. At the same time, full-scale burners need to be demonstrated with flue gas recycle, and manageable slagging/fouling and corrosion behavior of a wide range of coals in this different combustion gas environment need to be verified.

- **Post-combustion capture.** A lively debate centered around the question of whether the developers should pursue incremental improvements to amine-based aqueous absorption/stripping processes or seek breakthrough solvents. The key proponent of following the amine path noted that improvements are needed and possible by increasing reaction rates and solvent capacity, and he suggested that blends of solvents could accelerate the reactions and provide greater capacity, while better processes (e.g., split feed and designs to improve mass transfer) could yield smaller, less energy-intensive systems. A few compounds were discussed that were reported to yield these benefits. Less controversial was the opinion that more study is warranted to better integrate the CO_2 capture system with the power plant thermal cycle. Also apparently gaining increasing acceptance is the idea that PC plants being built now should do no more to be "capture ready" than leave space (where it would be optimally needed) for a potential CO_2 capture process. Given the uncertainty on when CO_2 limits will be imposed and what capture technologies will prevail by then, a power producer cannot justify the costs of any changes to the optimized design for today in anticipation of a future CO_2 capture retrofit.

- **Storage.** Concerns were again raised about the need to ensure permanent storage of captured CO_2 injected into underground reservoirs – how can the industry prove to a skeptical public that this can be done effectively and safely. The consensus was that multiple demonstrations are needed and these demonstrations must show, without any failures, that the actual, measured behavior of the CO_2 and reservoir are accurately predicted by the models. One presenter noted that the worldwide capacity for subsurface CO_2 storage is adequate to meet the needs of the world for quite some time, BUT that the storage locations are not uniformly distributed. I.e., there are many places where CO_2 would likely be captured in a carbon-constrained world that do not have adequate storage reservoirs within reach.

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