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Midale CO_2 Monitoring & Storage Project. Weyburn-Midale is North America's most significant CCS research undertaking. It is a project endorsed by the IEA Greenhouse Gas R&D Programme.

The goal of IPAC-CO_2 is to bring together risk assessment (RA) expertise around the world and build the confidence required for implementing CCS on a large scale. IPAC-CO_2 is a facilitating organisation. It will bring together various national and international stakeholders with interests in risk assessment of geological storage of carbon dioxide.

The intent is to create an organization that will provide objective advice on geological storage and thus provide the confidence required by regulators and industry that risk and liability are adequately evaluated. IPAC-CO_2 will not compete with organisations undertaking commercial risk assessment, instead it is hoped that IPAC-CO_2 will provide complementary services.

More funding is being sought to ensure adequate resources are available for IPAC-CO_2 to undertake work in benchmarking, guideline development and capacity building.

About two dozen scientists gathered at the IEA offices in Paris recently to collaborate and help refine the IPAC-CO_2 work plan. Attendees included representatives from Dalhousie University, the University of Alberta and the University of Regina from Canada, Royal Dutch Shell from The Netherlands, Imperial College from the United Kingdom, the South African National Energy Research Institute, the IEA and IEA GHG.

IPAC-CO_2's business model will expand upon what is commonly found at many leading research institutions in that it will provide the overview services needed by industry, the regulator and the public. IPAC-CO_2's technical leadership and far-reaching institutional relationships will allow it to build a networked organisation which harnesses best-in-class skill sets—and makes those skills available to CCS development around the world.

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Saskatchewan and Montana Sign MOU on International CCS Project

By the Office of Energy and Environment, University of Regina

The Governments of Saskatchewan and Montana signed a Memorandum of Understanding in the Saskatchewan Legislature on May 7, 2009, to work together on the development of one of the largest international carbon capture and storage demonstration projects in the world.

The Saskatchewan-Montana project will construct a 300-1000 tonne per day capture unit, which will be attached to an existing coal-fired power plant in Saskatchewan. The pipeline attached to the plant will deliver CO_2 from Saskatchewan to a geological storage site in northeastern Montana in the Williston Basin. The project is intended to deliver as much as one million tonnes of CO_2 over four years of the storage test.

Under the MOU, the Saskatchewan-Montana partnership will work to achieve the following four goals:

- Construction of a technology-neutral CO_2 capture plant (reference plant) at an existing coal-fired electrical generating station in Saskatchewan that would have the flexibility to test a range of post-combustion carbon capture technologies;
- Construction of a North American CO_2 storage facility in eastern Montana including injection infrastructure with the option of using CO_2 for enhanced oil recovery;
- Construction of pipeline infrastructure for the transportation of CO_2 from the reference plant in Saskatchewan to the storage facility in Montana; and
- Development of a North American training facility to meet the needs of a growing CCS industry and regulators, based primarily at the University of Regina and Montana State University.

Construction of the CO_2 reference plant could begin as early as September 2009 and the plant is intended to be operational as early as the summer of 2011.

The estimated total cost of the project in Canadian dollars is $270 million with funding applications to the governments of Saskatchewan, Canada and the USA.

For additional information on this project and for project updates, please visit www.uregina.ca/oee/projects/ A copy of the full Government of Saskatchewan press release can be accessed at www.gov.sk.ca/news?newsId=c06068a6-59d6-40ba-a2f7-43d07b24441c

CO_2ReMoVe Update

Research into Monitoring and Verification of CO_2 Storage Sites

By Karen Kirk (British Geological Survey), Conny Schmidt-Hattenberger (GFZ), Vincent Vandeweijer (TNO) and Alan Paulley (Quintessa).

The CO_2ReMoVe project is a five-year EC and industry funded 6th Framework Programme Integrated Project launched in March 2006. It aims to

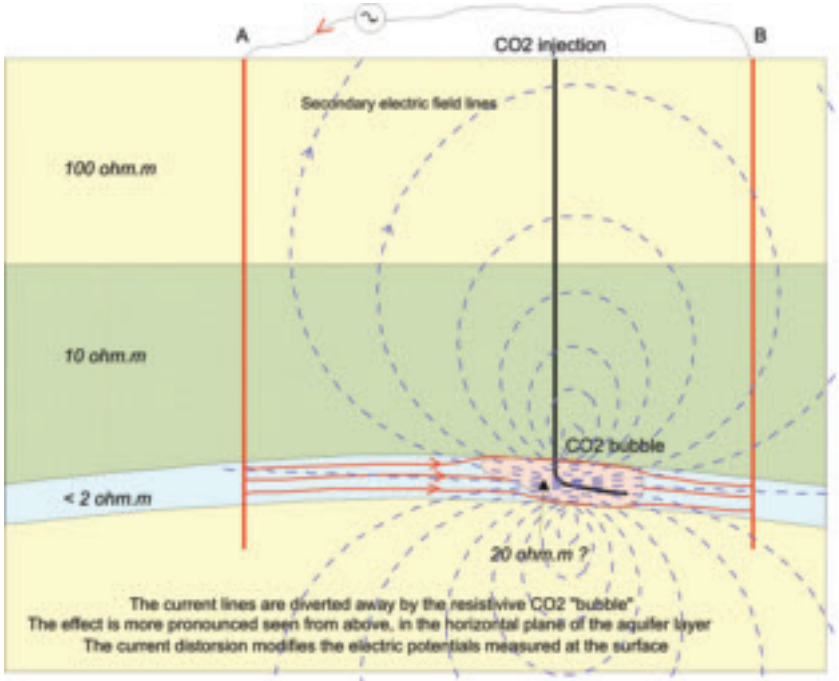

Figure 1: Concept of LEMAM electromagnetic monitoring techniques (BRGM)

demonstrate the long-term reliability of geological storage of CO_2 and to undertake the research and development necessary to establish scientifically based standards for monitoring future CCS operations. This could in turn lead to guidelines for the certification of sites suitable for the deployment of CCS on a wide scale. A key feature of the CO_2ReMoVe project is that its R&D is based on information from real CO_2 storage sites, onshore and offshore, in Europe and North Africa: Sleipner, Snøhvit, In Salah, Ketzin and K12-B. Researchers from across Europe have integrated their efforts in developing understanding of site performance assessment and monitoring methodologies.

A draft Performance Assessment Framework has been developed, which will be used as guidance for the assessments of the individual sites. Approaches for qualitative aspects of performance assessments have been refined (based on the FEP approach). A tool for supporting decisions by integrating qualitative and quantitative PA-relevant information (CO_2TESLA-Excel) has also been developed, based on Quintessa's TESLA code.

A number of monitoring tools and methodologies are being assessed and developed:

- Optimised technologies for atmospheric monitoring are being designed, based around optimal combinations of 1D point sampling, 2D mobile sampling and 3D (areal) monitoring strategies [Jones et al 2008].
- New underwater CO_2 flux monitoring tools are under development, focussing on robust long-term performance in deeper water.
- A new EM tool has been designed, using a novel borehole-surface array, termed LEMAM. Sensitivity and feasibility analyses have been carried out for the In Salah and Ketzin sites and field testing has started with a baseline survey at Ketzin. (Figure 1)
- A number of downhole sampling and logging tools are being developed including multi-parameter hydrochemistry, gas sampling and development of the RST tool.
- Ongoing research is being carried out on advanced seismic methods: AVO analysis, pre-stack imaging, thin-layer quantification via spectral decomposition and velocity / attenuation tomography. The Sleipner time-lapse datasets are central to much of this research.

There has also been significant progress in the understanding and modelling of the research sites:

At *In Salah*, nearly 1 million tonnes of CO_2 per year, separated from produced natural gas, is being injected into a sandstone formation (of Carboniferous age) 2000 metres below the surface. Legacy datasets for In Salah have been gathered, including a full suite of reservoir management data (and also caprock logs and baseline seismic), and a Shared Earth model has been developed. The importance of the data, interpretation studies, and modelling outcomes has been tested through the use of a systematic qualitative assessment. A complete description of the system has been developed, broken down by Features, Events and Processes (FEPs) relevant to performance. The underpinning data and modelling analyses provided the evidence base for the FEP descriptions. Two expert workshops were held to agree the FEPs, and scenarios representing storyboards for future site evolution. Qualitative success criteria were also defined. Recent analysis of satellite-based InSAR data, has shown significant ground displacements at In Salah. In the light of this additional focus will be placed on geomechanical studies.

At *Sleipner*, CO_2 separated from produced natural gas has been injected into a saline aquifer at a rate of nearly 1 million tonnes of CO_2 per year, at a depth of just over 1000 metres since 1996. Legacy datasets for the Sleipner site have been gathered and a Shared Earth model has been constructed. In addition, a comprehensive seismic monitoring programme has been carried out, with repeat time-lapse 3D surveys in 1999, 2001, 2002, 2004, 2006 and 2008, the latter augmented by high resolution 2D seismic and seabed imaging surveys. A controlled source electromagnetic (CSEM) survey was also acquired in the summer of 2008. The seismic data clearly image the progressive development of the CO_2 plume as a prominent multi-tier feature comprising a number of bright sub-horizontal reflections, interpreted as arising from discrete

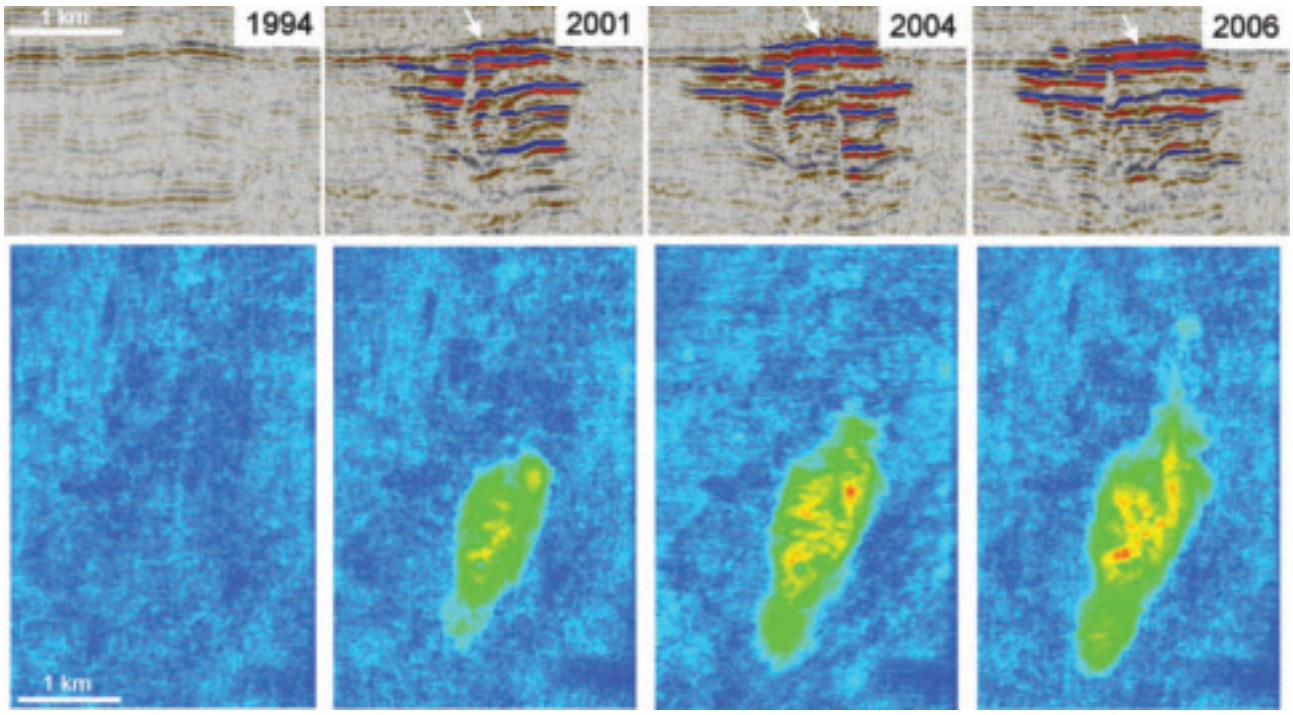

Figure 2: Time-lapse seismic data showing growth of the CO_2 plume to 2006, in cross-section (top) and plan view (bottom). (BGS)

thin layers of CO_2. The upper layers continue to spread laterally and generally increase in brightness (Figure 2), whereas the lower layers have stabilised in size and are growing progressively dimmer. Within the reservoir overburden, there is no evidence of systematic changes in seismic signature, indicating that CO_2 is being contained within the storage reservoir. Recent work in CO_2ReMoVe has concentrated on detailed quantitative analysis of the topmost layer [Chadwick et al 2008], which indicates a steady rise in CO_2 flux arriving at the top of the reservoir, attributable to increasing relative permeabilities in the reservoir.

At *Ketzin* (near Berlin, Germany), the injection process commenced in June 2008. For the first injection phase CO_2 from an industrial gas supplier is used. Presently, up to 70 tonnes of CO_2 per day, in gaseous state at the well head, will be injected to about 600 m depth into the saline sandstone aquifer component of the Stuttgart Formation. The Ketzin pilot study for onshore CO_2 storage in saline aquifers includes monitoring of the storage reservoir and the structures above using physical, chemical, and microbial observations. Seismic and geo-electric measurements have delivered the structural framework and monitor CO_2 propagation between two observation wells. Borehole temperature and pressure aim to detect processes related to the injection and movement of CO_2 in the subsurface. A newly developed Gas Membrane Sensor detects the CO_2 arrival on both monitoring wells.

The work at Ketzin in CO_2ReMoVe has concentrated on the distributed temperature monitoring along the injection string of the Ktzi201 well. Permanent temperature profiling helps to control the injected CO_2 keeping it at supercritical state.

CO_2ReMoVe supports the seismic framework of Ketzin by funding a MSP/VSP repeat in the autumn of 2009. Together with the planned passive seismic monitoring concept from project partners (OGS, BRGM and IFP) the seismic experiments contribute to optimal imaging of the plume development.

The *K12-B gas field* is located in the Dutch sector of the North Sea and is at the tail end of production. Since 2004 CO_2 has been injected into the gas field located at a depth of nearly 4 km. The CO_2 originates from the produced gas and is separated by an amine wash installation on site. Over 60 kilotonnes, divided over 2 compartments, had been injected by the beginning of 2009. Because of the thick salt seal (Zechstein) above the gas field and the currently low pressure of the gas field there is little concern about leakage from the reservoir. Monitoring activities in CO_2ReMoVe focus on two subjects: the behaviour of the injected CO_2 in the reservoir and the integrity of the wells.

In the past, several tests have been performed in order to gain knowledge about the behaviour of CO_2. Among these tests are the injection of tracer chemicals together with the CO_2 stream and analysing the produced gas for these tracers, the reproduction of injected CO_2 in a single well compartment going hand in hand with extensive monitoring activities, chemical analysis of produced gas and numerous pressure and temperature measurements. These tests have proved a valuable addition to the monitoring program and in particular the tracer program has improved the accuracy of reservoir model.

Extensive reservoir modelling activities have resulted in a detailed model with predictive capabilities. It is still too early to conclude about the efficiency of EGR and this subject

is still under examination. The well integrity surveys have not indicated any disturbing signs after several years of CO_2 injection.

Recent work focuses on the usage of new logging tools and the improvement of the reservoir model through incorporating additional measurements and a sensitivity study. The logging tools will electro-magnetically inspect the tubing and take downhole pH measurements as well as samples which will assist in verifying and modelling the conditions in the well.

CO_2ReMoVe is funded by the EC 6th Framework Programme and by industry partners StatoilHydro, BP, Schlumberger, ConocoPhillips, ExxonMobil, Total, DNV, Vector, Vattenfall and Wintershall. R&D partners are BGR, BGS, BRGM, CMI, DNV, ECN, GFZ, GEUS, IEA-GHG, IFP, Imperial College, MEERIPAS, OGS, TNO, URS, Quintessa, Schlumberger SINTEF, Total and Vattenfall R&D. Three R&D institutes outside Europe participate in CO_2REMOVE: CSIR from South Africa, UNDLP from Argentine and ISM from India. For more information please see www.CO2REMOVE.eu and contact the project coordinator Ton Wildenborg (e-mail ton.wildenborg@tno.nl tel. + 31 30 256 4636).

References:

R.A. Chadwick, D.G Noy, R. Arts and O. Eiken. Latest time-lapse seismic datasets from Sleipner yield new insights into CO_2 plume development. Proceedings of the 9th International Conference on Greenhouse Gas Control Technologies, Washington, USA, 17-20 November, 2008, Elsevier, published on CD. (2008).

D.G. Jones, T. Barlow, S.E. Beaubien, G. Ciotoli, T.R. Lister, S. Lombardi, F. May, I. Möller, J.M. Pearce, R.A. Shaw. New and established techniques for surface gas monitoring at onshore CO_2 storage sites. Proceedings of the 9th International Conference on Greenhouse Gas Control Technologies, Washington, USA, 17-20 November, 2008, Elsevier, published on CD. (2008).

CO_2GeoNet Open Forum, March 2009, Venice

A Major International Event on CO_2 Storage

By Isabelle Czernichowski-Lauriol, CO_2GeoNet

CO_2GeoNet, Europe's Network of Excellence on the geological storage of CO_2, held its fourth and final Open Forum under the FP6 EC contract in Venice on 18-20 March 2009. The objective was to present highlights from five years of research and development carried out by hundreds of scientists and to interact with stakeholders on future needs to be addressed by science.

This Open Forum was a major international event with an audience of policy-makers, public authorities, industry executives, regulators, academia, NGOs, EC representatives, engineers and scientists. Some 150 participants attended from 24 countries across Europe, Australia, Canada, Iran, Japan and the USA. Stakeholders were given the opportunity to:

- Share the highlights from five years of collaborative research, carried out by hundreds of scientists from the 13 CO_2GeoNet member institutes, along four topical questions:
  1. What have we learnt about the behaviour of the storage complex?
  2. Enhanced hydrocarbon recovery: is it still an option for CO_2 storage?
  3. Can we detect and quantify CO_2 leakage at ground surface and sea bottom?
  4. What if CO_2 reaches the surface?
- Hear concrete examples of international developments on CO_2 storage from invited high-level speakers,
- Discuss and help shape the future plans for the CO_2GeoNet Association, now an established scientific association under French law, concentrating on CO_2GeoNet's four areas of activity: training and capacity building, scientific advice, research, information and communication.

The most successful result of this EC-founded Network of Excellence is the transformation of CO_2GeoNet into a legal entity. CO_2GeoNet has become the European scientific authority on the geological storage of CO_2, needed to accelerate the deployment of and build confidence in CO_2 storage.

Celebrating the transition from EC contract to legal association