CO_2 Capture Project®

ANNUAL REPORT 2010

PREPARING FOR INDUSTRIAL DEPLOYMENT


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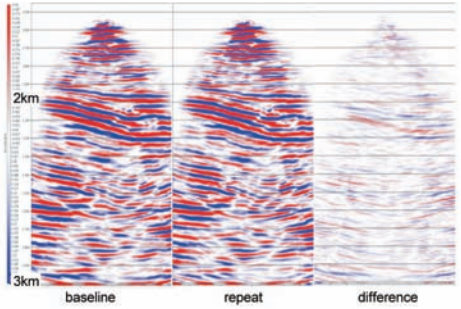

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A CCS In Depth leaflet (detail) B Kuparuk oil field, Alaska, USA C COP16 Climate Change Conference, Mexico D Refinery
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The CO_2 Capture Project (CCP) is a partnership of several major energy companies working together to advance the technologies and to improve operational approaches in order to reduce costs and accelerate the deployment of CO_2 Capture and Storage (CCS). The CCP is dedicated to advancing and sharing the industry's knowledge to ensure that CCS can make a significant impact on CO_2 emissions. CCS has an important role to play in reducing emissions from power plants and heavy industrial processes such as oil and gas refining, gas processing and cement manufacture.

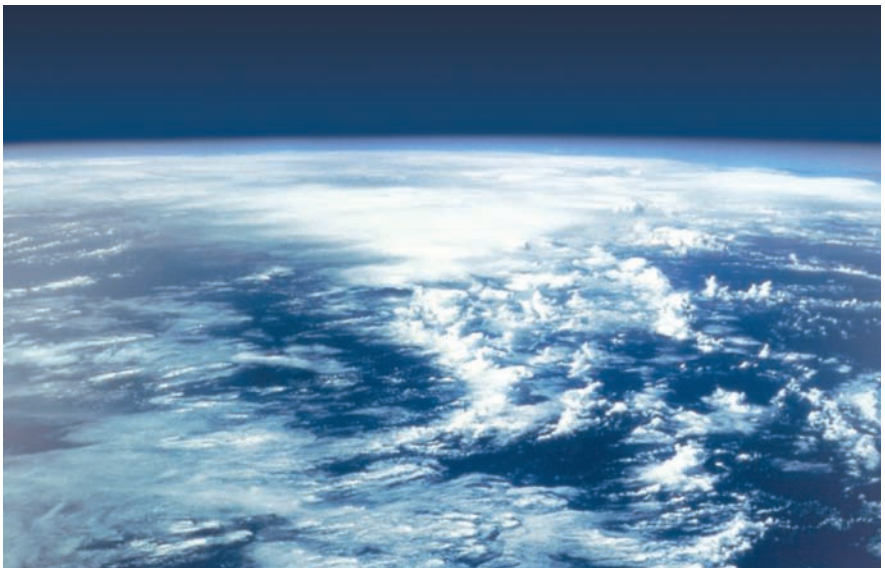
Download further copies of the report from the CCP website
WWW.CO2CAPTUREPROJECT.COM

INTRODUCTION

Gardiner Hill, BP
CCP Chairman

A warm welcome to the CCP 2010 Annual Report.

2010 has undoubtedly been a significant year, both for the CO_2 Capture Project (CCP) and for CO_2 Capture and Storage (CCS) as a whole.



The CCP has continued its innovative work in building understanding and developing next generation CCS technologies, with the aim of demonstrating their economic viability. The work has been set against a backdrop of a number of positive legislative and economic developments on the world stage, aimed at encouraging commercial large scale CCS demonstrations. However, we also have to accept that the world has yet to develop economically practical frameworks to ensure a low carbon future - much remains to be done to stimulate development and catch up on lost time.

For the CCP, 2010 was the first full calendar year of activity in Phase Three of the program. During the course of CCP3 (2009-13), the program will culminate in at least two field demonstrations of capture technologies and a series of monitoring field trials which will provide a clear understanding of how best to monitor CO_2 in the subsurface. Also, landmark studies into economics and legislation will lead to a robust understanding of broader aspects of CCS. All of this will take CCS closer to being operationally available for the oil, gas and power industries. Our work and expertise will be crucial in helping shape much needed regulation and policy without which CCS cannot happen.

As reported by our Capture, Storage and Policy Teams later in this report, important foundations were laid for this work in 2010. Installation was completed for the first of the capture field demonstrations, which will take place in Brazil in 2011, and contracts were awarded for a second oxy-firing capture demonstration in 2012. The first phase of important work in benchmarking the cost of capture in oil and gas scenarios was completed and will eventually inform a more extensive study of the end-to-end economics of CCS for the oil and gas industry. Important studies were also published on the effects of paleo-fluids on fault seals and on global CCS financing schemes and further studies were undertaken into economics and regulatory frameworks.

There have been some areas where progress has not been as strong as hoped for – most notably in the development of cost effective capture solutions for natural gas fired power stations and in the identification of injection wells for further well integrity studies. But on the whole, progress has kept us on track to meet the CCP's long-term vision - *to develop the technologies and operational approach that will reduce the cost and accelerate the deployment of CCS as a safe, secure and cost effective carbon mitigation option, through robust scientific and economic analyses, active communication of our knowledge, and advocacy for supporting policies.*

Gardiner Hill, Chairman CCP

How does this work play out for CCS in a global context? In my view, what might have been seen as a slow 'drift' towards CCS deployment has, in 2010, started to take some shape. Policy frameworks have been put in place in the EU, US, Canada, Australia and China, and significant funds pledged to allow companies to invest in the first wave of full scale demonstration projects to become operational by the middle of this decade. A number of projects are now in various stages of planning and design in these countries. In Mexico at the COP16 in December, a significant breakthrough was achieved with the Cancun Accord paving the way for CCS to be included in the United Nation's Clean Development Mechanism offsetting scheme.

What is now critical is that high quality CCS projects that will work must be picked for demonstration. If good projects do materialize, I believe that 2010 will eventually be seen as the pivotal year for the demonstration of CCS technology – a year when CCS began to get real traction as a practical solution in the fight against climate change.

However, challenges undoubtedly lie ahead for the longer-term commercial development of CCS. In particular, much remains to be done on the policy front to provide companies with the confidence that longer-term market incentives will exist. Consistent long-term, regulatory frameworks are required across most jurisdictions.

A strong dose of realism is required on both the costs and timescales needed to structure what will be complex commercial-scale projects and the exploration, appraisal and development of the necessary commercial-scale storage sites. It will be a real challenge to meet the targets set out in the 2009 IEA CCS Roadmap, even with appropriate policy developments.

On top of these issues, the geopolitical world also provides its own set of challenges, not least the potential slowdown in progress on the climate change agreement post-Copenhagen and Cancun, after US mid-term elections. And with much of the world still suffering from the effects of the financial crisis and with some new voices of scepticism around the science of climate change, it will require the focus of everyone involved to keep CCS on track and to ensure that the significance of the work carried out by the CCP is not unrecognised.

A momentous year lies ahead for the CCP. We remain committed to working with industry, government and non-governmental organizations (NGOs) to share our unique expertise and ensure that CCS does indeed develop into a commercial reality that can play its part in mitigating climate change.

2010 HIGHLIGHTS

Capture:

New baselines established for a range of scenarios using post-combustion state-of-the-art technology.

Essential preparation undertaken for 2011 Fluid Catalytic Cracking (FCC) field trial, including delivery and approval of contracts, delivery, installation and integration of skids.

Laid groundwork for field demonstration of once-through steam generators (OTSG) including completion of feasibility study.

Storage:

Well integrity field experiment started with post-survey work to investigate impacts on long-term barrier performance, carried out on a 30+year CO_2 producer well.

Studies carried out to understand physico-chemical phenomena and their impact on CO_2 injection efficiency, migration and containment.

Field trials undertaken to better understand emerging and integrated CO_2 monitoring technology including Bore Well Gravity techniques, Through Casing Resistivity, Microseismic and InSar satellite detection of ground movement.

P&I:

Independent survey of regulatory issues in core markets commissioned, with the P&I Team providing a regulatory environment update at a side-event at COP16, Cancun, Mexico.

Joined consortium to establish a financial value for the potential risks and damages associated with CCS, to aid discussions with regulators and financers.

Communications:

Exhibited at US DoE NETL conference in Pittsburgh and GHGT-10 in Amsterdam.

Produced a range of information resources to be used by NGOs, industry, media and policy makers – including project factsheets, overview brochure and a revised In Depth brochure, providing a spatial perspective on CO_2 storage.

The CCP website www.CO_2captureproject.com was reviewed and refreshed to aid usability.

TECHNICAL ADVISORY BOARD

2010 Members of the CCP3 Technical Advisory Board

Vello Kuuskraa, Chairman CCP3 Advisory Board, President, Advanced Resources International, Inc. Arlington, VA, USA

Olav Bolland, Head of Department/ Professor, NTNU - Norwegian University of Science and Technology Department of Energy and Process Engineering, Trondheim, Norway

Michael Celia, Professor and Chair, Civil and Environmental Engineering, Princeton University, Princeton, NJ,USA

David Coleman, Business Development Leader, Carbon Capture and Storage, DNV Energy North America, Katy, TX, USA

Dr. Pierpaolo Garibaldi, independent consultant, Borromeo, Italy

Christopher Higman, independent consultant, Schwalbach, Germany

Larry Myer, independent consultant, Benicia, CA, USA

Dale Simbeck, Vice President Technology, SFA Pacific, Inc., Mountain View, CA, USA

The CCP Technical Advisory Board (TAB) plays a vital role in providing independent assessment of the progress of the CCP program and helping shape its future direction. The TAB is comprised of eight independent assessors from industry and academia and its latest review took place in May 2010. A summary of its recommendations can be found below:

TECHNICAL ADVISORY BOARD RECOMMENDATIONS OVERVIEW

Storage, Monitoring & Verification (SMV) Program:
The TAB made the following recommendations:

- Increased emphasis on CO_2 transport and CO_2 storage: The TAB strongly supported giving more emphasis to CO_2 transport and CO_2 storage (particularly in saline formations), and to communications, policy and incentives. With an expanded budget and the high priority given to work on wellbore integrity and the development of advanced wellbore integrity testing tools the Board remained confident that the CCP SMV program will remain at the leading edge
- Addressing critical issues: The TAB recommended that SMV Team addresses more of the critical issues – for example, the capacity of 'closed' saline formations, and the nature and fluid composition of saline reservoir seals.

Capture Program:
The TAB supported the Capture Team's narrowed focus on the main CO_2 emission areas of highest concern to the oil and gas industry – oxy-firing in the refinery Fluid Catalytic Cracking Unit (FCC) and the use of oxygen for the once-through steam generator for oil sand recovery.

The TAB also made the following recommendations:

- Examine alternative CO_2 capture options for oil refinery heaters and boilers: conducting a rigorous comparative evaluation of the use of oxygen versus other options for low cost capture of CO_2 emissions from refinery heaters
- Pursue low cost CO_2 capture options for refinery hydrogen plants: continuing to monitor and evaluate the emerging technologies for producing pure CO_2 from converting natural gas to hydrogen
- Maintain involvement with capture of CO_2 from NGCC power generation: monitoring and evaluating the work by others on NGCC power generation with post-combustion capture of CO_2
- Other Capture Topics: re-examine the pursuit of some of the longer-term CO_2 capture technologies handed over from CCP2, for example the development of Chemical Looping Combustion technologies that offer a potential breakthrough for application to the heavy oil scenario.

Communications:
The TAB made the following recommendations:

- Increasing linkage with EPRI – the Board would like to see closer links between the CCP and EPRI and its members, particularly the independent power producers
- More active engagement – of government decision makers, NGOs and industry – especially towards electric power generators who have limited background on CO_2 geological storage issues.

GLOBAL OVERVIEW

Harnessing the power of CO_2 Capture and Storage (CCS) to reduce global CO_2 emissions

Encouraging progress was made at the COP16 UN conference hosted by Mexico in the last days of 2010. The agreements reached did much to increase confidence in the ability of the UN to orchestrate global action on climate change.

However, as the IEA warned, a gap still remains between global CO_2 reduction targets and practical progress being made on the ground. IEA studies showed us that the world was not on track to limit temperature increases to 2 degrees Celsius (°C) above pre-industrial levels – a limit agreed by global leaders in Copenhagen as being critical. Instead, as the IEA predicted, the world was on course for rises in global emissions of 21% above 2008 levels by 2035, a trend that would commit the world to a 3.5°C warming (see *IEA World Energy Projections for 2010*).

CCS has a critical role to play to get the world on the right track. Currently the world relies on fossil fuels to meet 80% of its energy needs. The demand from a growing population is increasing and cannot be met in the medium-term solely by renewables. A portfolio of solutions is needed, including greater energy efficiency, increased renewable energies and decarbonization of fossil fuel-based power generation – using CCS. According to the IEA, CCS could contribute 20% of the emission reductions needed by 2050. In fact, without CCS, the IEA estimates that the cost of stabilizing emissions would be 70% greater (see *IEA Energy Technology Perspectives 2008*).

In 2010 there was growing recognition of the role CCS must play if the world is to meet critical emission reduction targets, offering hope that CO_2 mitigation on a global scale is economically viable.

PROGRESS TOWARDS MAKING AN IMPACT

According to the vision provided by the *IEA CCS Technology Roadmap 2009*, some 100 commercial-scale CCS projects must be operational worldwide by 2020 and 3,400 by 2050 if global warming is to stay below 2°C. A challenging target – but there were encouraging signs of progress in 2010.

A report by the Global CCS Institute (GCCSI) in April 2010 showed that 238 projects involving CO_2 capture, transport and/or storage were either active or planned worldwide. Of these, 80 were large-scale integrated projects (>1 million tonnes of CO_2/year for coal; >500,000 tonnes of CO_2/year for gas), in which the entire CO_2 capture-transport-storage chain was demonstrated: nine (mainly storage-oriented projects) are already operational, two are under construction and 69 are at planning stages:

- 21 projects are performing feasibility studies and preliminary engineering design (most mature)
- 24 projects are conducting pre-feasibility studies and initial cost estimates (moderately mature)
- 24 projects are undertaking scoping studies (least mature).

INTERNATIONAL RECOGNITION

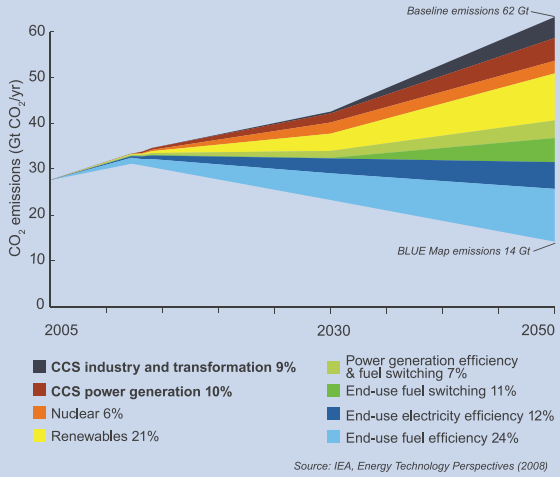
In 2010 CCS was recognized in international financing mechanisms. A deal reached in Cancun at COP16 opened the door to CCS offset projects. The Cancun Accord will allow CCS projects to be included in the UN's Clean Development Mechanism (CDM) offsetting scheme. The CDM allows developing countries to earn certified emission reduction (CER) credits which can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol. The decision in Cancun shows the greater understanding of the important role CCS has to play in reducing emissions.

COP16, Cancun

REGULATION DEVELOPMENT

At a national level, legal and regulatory frameworks are emerging, bringing greater clarity. In November, the government of Alberta introduced legislation that will see the province assuming long-term liability for CO_2 storage. The same month in New South Wales, a new bill was introduced giving the ministers the power to declare subsurface geological formations as approved reservoirs for the permanent storage of CO_2. The bill would establish a regime for the closure of sites, with the eventual transfer of its long-term monitoring to the public authority. In the US, the EPA published the final rules for CO_2 geological storage wells, establishing standards for the siting, construction, testing, monitoring, closure and stewardship of closed CO_2 storage sites.

Sources of CO_2 savings in power generation, with CCS providing one-fifth by 2050



Source: IEA, Energy Technology Perspectives (2008)

In Europe there was movement with the European Commission issuing its first call for project proposals to receive 'NER 300' funding. This has been widely welcomed as a first step towards creating the world's largest CCS demonstration program. The NER 300 will co-fund at least eight projects across the EU as part of a competitive process, selecting projects put forward by member states.

However, major progress in the development of government regulation will need to be made in 2011 if CCS is to make a real impact on global CO_2 reduction targets. Consistent and robust regulatory and policy frameworks need to be put into place on both a national and international level to manage risk and attract investment. Key regulatory issues such as CO_2 storage permitting and licensing, impurities in injected CO_2 streams, pipeline access, pore space ownership, liability issues and monitoring need to be addressed. For every year that passes without significant progress, reaching the global CO_2 mitigation targets will become more expensive.

PUBLIC ACCEPTANCE

2010 showed just how important it is for industry and governments to work together to engage the general public. After months of public protest, it was announced in November 2010 that the demonstration project in Barendrecht, the Netherlands, was to be cancelled, largely due to local opposition.

However there were signs that industry and government were beginning to work together more effectively to share knowledge and best practices on engaging the public and communicating scientific knowledge. The US Department of Energy, for example, published its *Best Practices Manual for Public Outreach and Education for Carbon Storage Projects* – sharing its experience gained from the six years of the Regional Carbon Sequestration Partnerships (RCSP).

THE CHALLENGE IN 2011

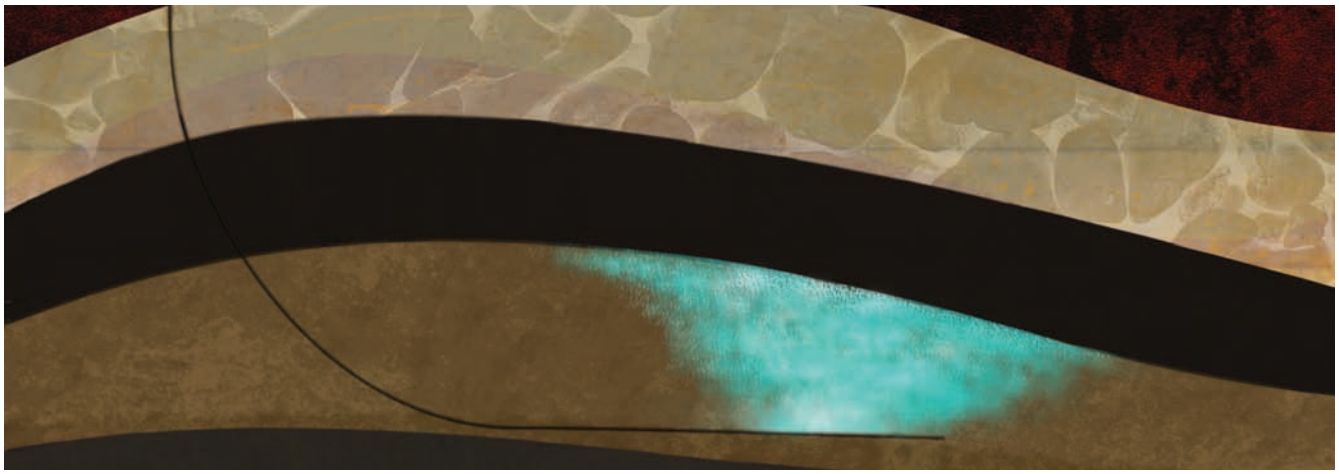
In 2011, industry will need to work more closely than ever with government and NGOs to ensure that the standards and criteria to provide assurance that CCS is safe and viable are put in place. For CCS to become a reality, the world needs to move rapidly in 2011 towards a policy framework to support the market.

CCS, alongside renewable and energy efficiency technologies, is giving the world hope that ambitious CO_2 targets set by world leaders are achievable. As Steven Chu, the US Energy Secretary, stated: "The potential of carbon capture and sequestration is enormous. Aside from a few other things… nothing ranks as high as CCS (among the) tools that could be used to decrease carbon emissions."

CCP 2010

THE CCP STORAGE, MONITORING & VERIFICATION PROGRAM

Scott Imbus, Chevron
CCP SMV Team Lead



BUILDING CONFIDENCE IN CO_2 STORAGE

Although CO_2 capture and storage (CCS) is widely recognized as a key potential greenhouse gas mitigation technique, there has been considerable discussion centring on questions of the safety and permanence of the CO_2 stored deep underground. The progress of CCS rests on addressing these concerns through research, development and demonstration and the timely introduction of regulatory frameworks which appropriately address risk.

CO_2 Capture Project (CCP) member companies – and the oil and gas industry as a whole - have a unique understanding of managing underground production and injection of gases, gained from more than 100 years of oil and gas exploration. The industry has decades of experience injecting CO_2 into geological formations as part of a process used to enhance oil recovery (EOR).

Drawing on this experience, the SMV Team has been working since 2000 to close gaps in existing knowledge. The focus has been on addressing those issues critical to making CO_2 storage a practical reality and which complement the efforts of other organizations. This has been accomplished by harnessing the expertise of member company specialists and leading academic and private researchers. The CCP has played a significant role in building and deploying the science and technology of CO_2 storage through systematic R&D efforts.

PROGRESS IN 2010

The CCP3 storage program encompasses a range of activity from fundamental and applied R&D to field deployment of instrumentation that tracks CO_2 behaviour in the subsurface. In 2010 important progress was made around the key themes of storage assurance and field trialing.

2010 HIGHLIGHTS

- Well integrity field experiment started with post-survey work to investigate impacts on long-term barrier performance, carried out on a 30+year CO_2 producer well
- Studies carried out to understand physico-chemical phenomena and their impact on CO_2 injection efficiency, migration and containment
- Field trials undertaken to better understand emerging and integrated CO_2 monitoring technology including Bore Well Gravity techniques, Through Casing Resistivity, Microseismic and InSar satellite detection of ground movement

THE 2010 SMV PROGRAM

1. STORAGE ASSURANCE

The Storage Assurance R&D projects aim to address key remaining geological uncertainties around CO_2 storage, through a mix of experiments, analysis and modelling.

Well integrity is a key area of focus, with the wellbore recognized as a potentially vulnerable part of the storage system. The team is tasked with carrying out further work to understand processes impacting long-term barrier performance and to develop detection and remediation technology.

The project identifies CO_2-experienced wells for surveying, sampling and analysis and builds on studies carried out in CCP2, which had illustrated that good well installation practices were more important to long-term integrity than use of resistant materials. The team aims to identify 3-4 wells to survey: it will conduct selected post-survey modeling and simulation in order to predict long-term integrity given observed types and extent of alteration.

In 2010, post-survey work was carried out on a 30+ year CO_2 producer well in Colorado. Experimental work was able to duplicate the processes observed in the well material acquired and modeling and simulation continues to project how these processes will impact long-term barrier performance. Completion of this work is expected in the first quarter of 2011.

Depending on data availability from CCP3 and other studies, the team plans to commission a CO_2 Well Design Best Practices and Standards study in conjunction with other industry groups.

Subsurface Processes: A number of studies are underway to better understand physico-chemical phenomena and how they could impact CO_2 injection efficiency, migration and containment.

These include:

- A field-based study into fault seals which analyzed paleo-fluid flow across faults in order to understand diagenetic reactions capable of sealing faults in CO_2-rich environments
- Best practice protocols to reliably determine relative permeability in reservoir rocks and capillary entry pressures in seal rocks. Accurate determination of these parameters is essential to improve input into reservoir flow and seal mechanics models
- A crucial study into the subsurface impacts of CO_2 impurities, which will determine to what extent capture costs can be reduced by transporting and storing less pure CO_2. The project is due to be completed in the third quarter of 2011
- Where the opportunity arises, the team will commission field deployable experiments to validate models and tests of subsurface processes (e.g. in situ relative permeability, CO_2-water-rock interactions) at field scale. Pending the results of the laboratory (or field) experimental work, the team will determine if data gathered might justify developing code to depict more accurately subsurface processes in commercial simulators.

Other work under the Storage Assurance theme includes several leveraged projects with other organizations aimed at the identification, development and integration of existing surveillance technologies. Ongoing development is also underway of a systematic approach (Certification Framework) to assess storage sites, field development, operations and closure. Further activity includes the assessment of pressure as a risk factor, validating and applying gravity number correlations to plume spreading predictions and the development of fault density / connectivity and percolation theory as an approach to fault transmissivity of fluids. To date, the Certification Framework methodology has been applied in three case studies, including a two-stage study (using pre- and post-injection data) at the In Salah storage site in central Algeria.

2. FIELD TRIALS

Field trial activity involves the deployment and assessment of emerging and integrated CO_2 monitoring technology at third party injection sites. Highlights include:

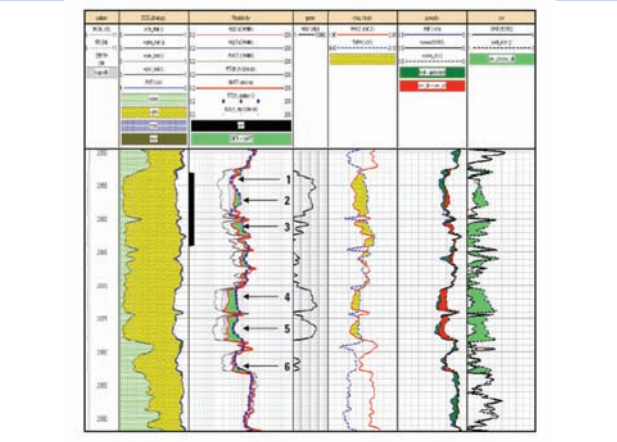
A. Well Logging

1.Borehole Gravity (SECARB – Cranfield Field EOR Project)
Demonstrating that the borehole gravity approach has sufficient resolution to detect CO_2 would provide a means to confirm mass balance deep in the reservoir through a non-invasive technology.

In September 2009, BP funded pre-injection surveys. In 2010, taking BP work further, the team funded a post-injection time-lapse survey and has contracted the Colorado School of Mines Gravity Magnetics Research Group to invert the observed data. The results are expected at the end of first quarter 2011.

2.Through Casing Resistivity (TCR) (CO2CRC Otway Phase 1)
Resistivity logging to detect CO_2 has low resolution due to the interference of metal casing. An improved approach using through casing resistivity technology developed by Schlumberger, was considered viable by the CCP2-SMV Team. Prior to injecting CO_2, the CO2CRC conducted an open hole (no casing) resistivity survey as a baseline.

In 2010 the SMV Team co-funded a post-injection repeat survey in the subsequently cased hole. Analysis by Schlumberger showed clear evidence of CO_2 saturation in some zones (see figure top right, page 11). The data was ambiguous, however, as to whether or not water was displaced by CO_2. A survey using the RST Sigma/Tphi logging tool is under consideration to resolve this ambiguity. Acquisition of this through casing resistivity and comparison with the pre-injection resistivity survey has not been attempted before for any CO_2 injection project. Its potential is to provide a means of evaluating long-term CO_2 dissolution processes at the well bore.



Well logs indicating presence of CO_2 (light green). The black bar represents the perforated interval. The dark green indicates residual gas (methane) and red possible indication of water displacement by CO_2 (image: Schlumberger)

3.Modular Borehole Monitoring (MBM) System (SECARB – Citronelle Field)

CCP has initiated a project to evaluate and design a flexible monitoring system which can deploy a number of diverse sensing and fluid sampling technologies on a suitable completion, such as tubing, sucker rods or coiled tubing. This project is called the Modular Borehole Monitoring system (MBM).

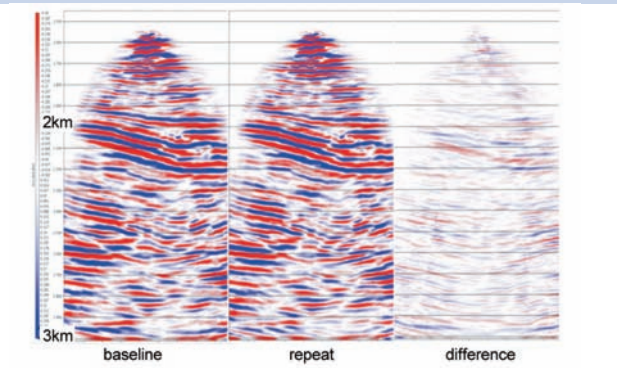
In 2010, the Citronelle enhanced oil recovery site in Alabama, USA, was identified as suitable to test multiple high priority monitoring and verification technologies. This also represented an opportunity to focus the design options for the MBM system. It is expected to include fiber optics for pressure and temperature measurements, seismic sensors for microseismic and walkaway VSP data, an isolation packer as well as steel tubing for fluid sampling, all clamped to production tubing.

The team is planning to deploy this system for running baseline and repeat surveys at Citronelle Field in 2011.

B. Well-Based Seismic

1. 3D VSP (CO_2CRC Otway Phase I)

The SMV Team co-funded acquisition and interpretation of time-lapse 3D VSP data and its correlation to a surface seismic 4D survey, at the Otway Basin pilot CO_2 storage site in Victoria, Australia. The aim is to evaluate the relative sensitivity and cost effectiveness of each survey type.



Time lapse imaging of baseline and post injection 3D VSP with differencing (image: Schlumberger)

In 2007, the CO2CRC acquired a 3D VSP seismic data prior to CO_2 injection (using a weight drop source) and after injection (2010) using a vibrating source. The CCP3 SMV Team committed to co-funding the acquisition and processing by Schlumberger and was provided with interpretation reports of the time-lapse data and a comparison with the 4D surface seismic results by Curtin University, Perth, Australia.

2. Crosswell Seismic (SECARB Citronelle Field)

CCP3 will have access to SECARB funded crosswell seismic (contracted to Z-Seis) across the ~1000 ft distance between source and detection wells. This distance is substantially greater than that normally applied in cross well surveys.

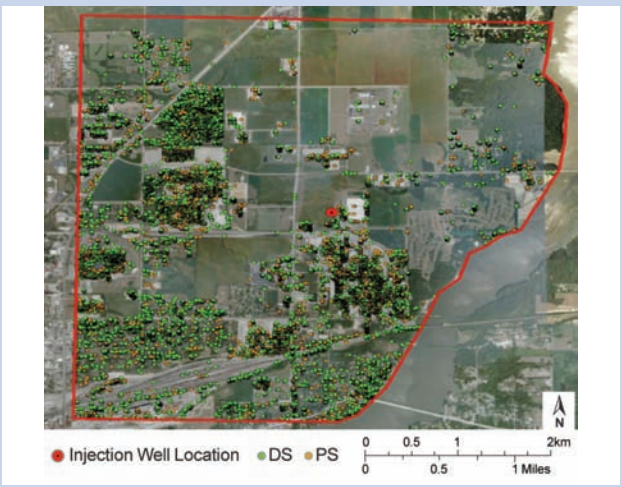
3. Microseismic (TBD)

As part of the integrated MBM design, the team plans to include an array of triaxial receivers to monitor for microseismic events, where they occur during the injection.

C. Remote Methods

1. PS InSAR (MSGC Decatur)

InSAR (satellite detection of ground movement associated with CO_2 injection) has been shown to detect small (multi-mm scale) surface movement due to hydrocarbon production and CO_2 injection (for example at In Salah). In 2010, an exploratory InSAR survey, carried out from February to April, was acquired for the central Illinois ADM-Decatur site (see figure below). An array of engineered reflectors will be fabricated and deployed to optimize the signal detection in a vegetated environment (CCP3 co-funded). The team now has a budget estimate for conducting the pre- and post-injection surveys scheduled for 2011. This will be the first application of InSAR to CO_2 injection at a vegetated and variable land use site.



PS InSAR feasibility study at Decatur site, Illinois (image: TRE)

D. Other Field Trials

Other field trials, which might include monitoring technologies such as microseismic monitoring experiments on, for example, field-scale relative permeability at third party sites, will be identified in the future.

CCP 2010
THE CCP CAPTURE PROGRAM

Ivano Miracca, ENI
CCP Capture Team Lead

PREPARING FOR THE FIELD

The oil and gas industry has been using CO_2 separation techniques for years. The challenge we face is how to identify and develop CO_2 capture technologies that can be used, economically, on a much larger scale and for typical combustion effluents.

The CO_2 Capture Project (CCP) Capture Team has made significant progress towards answering these questions. Since 2000, we have been working to develop a suite of economically viable next generation technologies. Much of this work has focused on applications in three critical areas for the oil and gas industry: refining operations, steam production for heavy oil extraction and natural gas power generation. This has involved conducting research into reducing cost uncertainties and identifying the best options to take forward for field demonstration.

2010 PROGRESS OVERVIEW

In 2010 we prepared for our first field demonstration of oxy-firing technology on a Fluid Catalytic Cracking (FCC) unit to start in Brazil, in 2011. We also awarded contracts for a second oxy-firing capture demonstration on a once-through steam generator (OTSG) – an important project for managing CO_2 emissions from heavy oil production.

NEW BASELINES FOR CCP3

The Capture Team commissioned Foster Wheeler to establish new baselines for a range of scenarios using post-combustion state-of-the-art technology. Delivered at the end of 2010, the baseline research forms part of the critical work the CCP is undertaking to produce baseline costs for the entire CO_2 Capture and Storage (CCS) chain.

The scenarios include:

- Oil Refinery
  - Set of three fired heaters with a duty of 100 million BTU/hr (British Thermal Units) each
  - Fluid Catalytic Cracking unit with a capacity of 60,000 barrels per day of feed
  - Steam Methane Reformer (SMR) producing 50,000 Nm^3/hr of hydrogen (approx 44.8 million standard cubic feet/day (MMSCFD)).
- Oil Production
  - Set of four once-through steam generators (OTSG), each with a firing duty of 250 millions BTU/hr, producing steam for Steam Assisted Gravity Drainage (SAGD) oil extraction.
- Power Generation
  - 400 MW Natural Gas Combined Cycle (NGCC) power station.

2010 HIGHLIGHTS

- New baselines established for a range of scenarios using post-combustion state-of-the-art technology
- Essential preparation undertaken for 2011 FCC field trial, including delivery and approval of contracts, delivery, installation and integration of skids
- Laid groundwork for field demonstration of once-through steam generators (OTSG) including completion of feasibility study

THE 2010 CAPTURE PROGRAM

1. REFINERIES

Fluid Catalytic Cracking unit

Project Overview: As significant emitters of CO_2, oil refineries face specific and considerable challenges in managing their emissions. Tackling emissions from the regenerator of the FCC unit has been a key focus of the Capture Team's work – with emissions from this unit equating to 20-30% of total CO_2 emissions from a typical refinery. In the first two phases of CCP activity, the Capture Team identified oxy-firing as a preferred technology for FCC emissions through technical and economical studies. A number of issues – such as thermal balance, catalyst attrition, coke burn rate and effect on reactor yield – still remain to be addressed.

Goal: Address issues (including thermal balance) with a demonstration at a large pilot-scale FCC unit at a Petrobras research complex in Parana state, Brazil. The demonstration is expected to confirm the technical and economic viability of retrofitting an FCC unit to enable CO_2 capture through oxy-combustion.

Schedule: The demonstration is scheduled to start in the first quarter of 2011, with completion due in May 2011.

Progress in 2010: The team undertook essential preparation activities for 2011. Retrofit of the FCC unit was carried out and included delivery and approval of technical documents and contracts, delivery of skids and installation and integration with the FCC unit.

Fired Heaters

Project Overview: In 2010 the demonstration of oxy-firing techniques on oil refinery process heaters was identified as an important area of focus for the CCP and its members, complementing the work being carried out on FCC units.

Goal/Progress in 2010: During 2010 the CCP worked to agree the scope of work to test different conventional burners in oxy-firing mode at lab scale to prove the feasibility of the concept.

Schedule: The test program will take place in 2011, with plans to further develop the technique to ensure it is ready for demonstration.

Fluid Catalytic Cracking unit - Oxy-firing demonstration, Brazil (image: Petrobras)

2. HEAVY OIL EXTRACTION

Once-through steam generators

Project Overview: Following initial work carried out in the earlier phases of the CCP, it was decided to pursue the demonstration of OTSGs, which are used for steam production in the in-situ extraction of bitumen and heavy oils using the Steam Assisted Gravity Drainage (SAGD) technique.

OTSG boilers are the primary source of CO_2 emissions from in-situ production of heavy oil.

Goal: To evaluate the integration of oxy-fuel combustion CO_2 capture technology into the operation of an OTSG boiler and provide design and cost estimates for a commercial-scale unit with CO_2 capture, purification and compression.

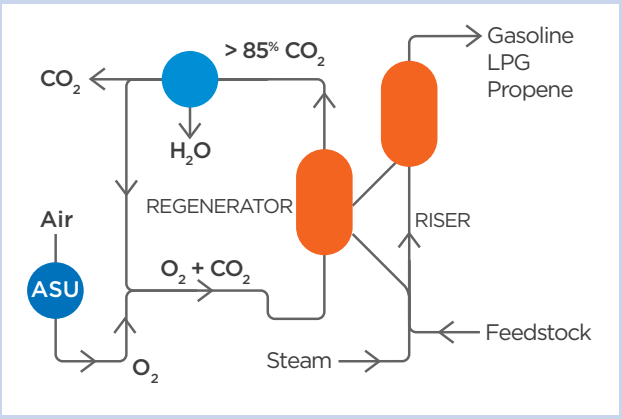
Schedule: The demonstration is scheduled for 2012.

Progress in 2010: During 2010, the Capture Team focused on laying the groundwork for the field demonstration, with phase one of the project completed.

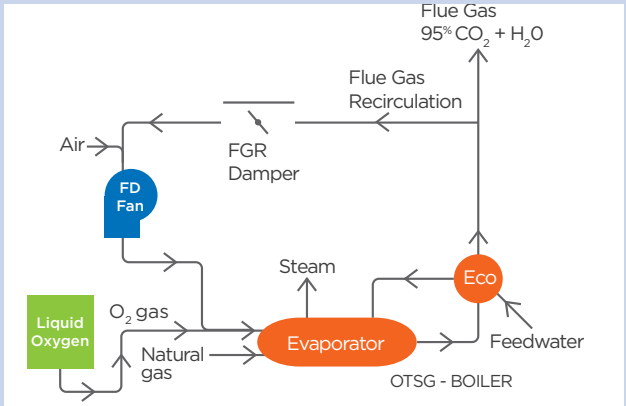
Highlights include:

- Completion of a feasibility study by Praxair, with no major obstacles identified
- The design and costs of retrofit for both the unit selected for demonstration (50 millions BTU/hr unit owned by Cenovus in Christina Lake), and a larger scale commercial boiler (250 millions BTU/hr) were completed
- The group secured up to CAD $2.5 million in funding from the Climate Change and Emissions Management Corporation (Alberta)
- The results of this phase indicate that the cost of capturing CO_2 with oxy-firing is likely to be significantly less than post-combustion capture technologies for this application.

OTSG Boiler. Cenovus Energy, Christina Lake, Canada (image: Cenovus)



Process diagram of the FCC unit, Petrobras research complex, Parana state, Brazil (image: Petrobras)



Process diagram for the OTSG trial, Canada (image: Cenovus)

3. NATURAL GAS POWER GENERATION

The lower concentrations of CO_2 in natural gas fired power station's flue gas make capture a challenging – but important – area for technology development. The CCP's work during CCP1 and CCP2 did not identify short-term technologies with potential for significant cost reduction. Some long-term pre-combustion technologies with high potential were analyzed, but possible field demonstration of these technologies is still very far away (~ 10 years) and expensive. It was therefore concluded that post-combustion, for retrofit as well as new build units, remains the preferred technology for natural gas fired power generation in the short to medium-term.

Given the emergence of substantial new natural gas supplies, a new start was required for the NGCC scenario in CCP3 and the team has re-focused its activities on commercial, emerging and new technologies.

Regarding commercial technologies, a state-of-the-art benchmarking study for post-combustion baselines was commissioned (see section *New Baselines for CCP3,* p12).

For emerging technologies, dynamic benchmarking will be applied on technologies that should be commercialized by 2013, to verify their potential for improvement over state-of-the-art technology.

Finally, a process is close to completion to identify promising technologies that may be ready for field demonstration by 2013, with the target to support large scale testing for natural gas derived flue gas in 2012-2013. A wide screening started in 2009 identified three promising lines of work (adsorption, ionic liquids, dual phase liquid-liquid). The assessment will be concluded in 2011, using both engineering studies and bench scale testing.

4. OTHER ACTIVITY

In 2010, the team designed programs for projects to start in 2011. A number of projects identified in CCP1 and CCP2 will be progressed including:

Membrane Water Gas Shift: is a pre-combustion technology characterized by the use of metallic membranes selectively permeable to hydrogen to enhance the water gas shift reaction achieving a complete and efficient separation between hydrogen and CO_2. In previous evaluations, the technology showed potential for application in the refinery scenario. A consortium with strong industrial focus will develop and fabricate membrane modules applicable to a field pilot unit.

Chemical Looping Combustion: is an oxy-firing technology characterized by a solid carrier that may alternately adsorb oxygen from air and release it for combustion of a gaseous fuel. This technology represents a potential breakthrough for application to the heavy oil extraction scenario. The aim is to prepare the technology to be ready for field demonstration by 2013.

CCP 2010

THE CCP POLICY & INCENTIVES PROGRAM

Arthur Lee, Chevron
Policy & Incentives Team Lead

ENGAGING TO ADVANCE CO_2 CAPTURE AND STORAGE (CCS)

If CCS is to develop into an attractive, long-term commercial prospect, consistent and enabling regulatory and policy frameworks need to be put in place at a national and international level to manage risk and attract investment.

Legal and regulatory frameworks for CCS are at last beginning to emerge in several jurisdictions worldwide. There have been some significant developments in recent months which could well provide a lead to others; for example in December 2010, the government of Alberta passed legislation that will see the province assume post-closure liability for CO_2 stored underground.

But there is still much to do. There are a number of key regulatory issues, associated mainly with the capture and the storage stages of CCS, that need to be addressed. The CCP Policy and Incentives Team (P&I) has examined the development of policies and incentives around the world, with a particular focus on the European Union, the US, Canada, and Australia. Topical areas of interest include:

- Licensing and permitting procedures which, if not formulated appropriately, could impose unnecessary delays on CCS deployment. Getting the correct procedures in place is important to provide public assurance that the sites approved are safe and secure
- Long-term liability, transfer and financial provisions, which if not formulated appropriately could hinder commercial investments, delaying widespread CCS deployment
- The development of legal frameworks at different levels of government (e.g. federal and state/province level), which if not formulated and aligned appropriately could lead to inconsistent policy-making and regulation, which could lead to significant uncertainty for CCS project investors and operators.

The P&I Team works to provide technical and economic insights needed by a range of stakeholders, most notably governments and regulators, to inform the development of these legal and policy frameworks which are so vital for the deployment of CCS.

THE 2010 POLICY & INCENTIVES PROGRAM

In 2010, the P&I Team has presented at key conferences, contributing peer-reviewed papers addressing the safety of CO_2 storage. It has also undertaken two major projects - a Regulatory Issues Update and a Risk Valuation Study.

2010 HIGHLIGHTS

- Independent survey of regulatory issues in core markets commissioned, with the P&I Team providing a regulatory environment update at a side-event at COP16, Cancun, Mexico
- Joined consortium to establish a financial value for the potential risks and damages associated with CCS, to aid discussions with regulators and financiers

THE 2010 POLICY & INCENTIVES PROGRAM

1. REGULATORY ISSUES UPDATE

The CO_2 Capture Project (CCP) commissions regular reviews of government and institutional policies and incentives influencing the development of CCS. In 2010 the P&I Team commissioned an independent and comprehensive survey of existing regulatory issues in core markets – Europe, the US, Canada and Australia. The report focused on a number of key regulatory issues including CO_2 storage permitting and licensing; liability issues and monitoring, reporting and verification requirements.

The P&I Team provided a regulatory environment update at a side-event at the United Nations Climate Change Conference (COP16) Cancun, Mexico and at GHGT-10.

2. RISK VALUATION STUDY

The CCP has joined a consortium to put a financial value on the potential risks and damages associated with CCS. The potential risks and damages will be analyzed on a maximum exposure basis, as well as on a probability basis. The objective of the work is to quantify potential CCS risks (which initial assessments put as being relatively small overall – in the range of less than $0.50/t of CO_2) to aid CCS investment discussions with the financial community and CCS risk/liability transfer discussions with government.

The analysis will span the CCS technology segments to include capture, transport, injection and storage. Existing CCS risk analysis work will be used to assess technical probabilities and the effects of possible risk and damage scenarios. This information will then be used to establish valuation assessments to layer on associated costs. The communication of the final results from this report will also be formulated in a communication plan by the consultants, with input from the sponsors of the study.

CCP 2010
THE CCP COMMUNICATIONS PROGRAM

Mark Crombie, BP
CCP Communications Manager

KNOWLEDGE SHARING TO ADVANCE CO_2 CAPTURE AND STORAGE (CCS)

During 2010, the number of CCS projects around the world under development has increased considerably and a number of countries have put in place schemes to encourage demonstration projects. As a result, the profile of CCS has grown, attracting more interest from the world's media and generating more online traffic than ever before.

Yet, with increased interest comes increased scrutiny. Many questions around the technology still exist - politicians have questions, as do regulators, NGOs and the general public. There is an urgent need to share knowledge and build assurance and credibility.

Since 2000, the CO_2 Capture Project's (CCP) Communications Team has focused on creating a voice for the organization, outreaching to key audiences, such as industry and NGOs and to the CCS community – academia, industry bodies, and governments – to share knowledge and add to understanding. We work closely with the technical teams to identify where resources can best be used to support the CCP's aim of advancing CCS as a practical and cost effective option for reducing or eliminating CO_2 emissions.

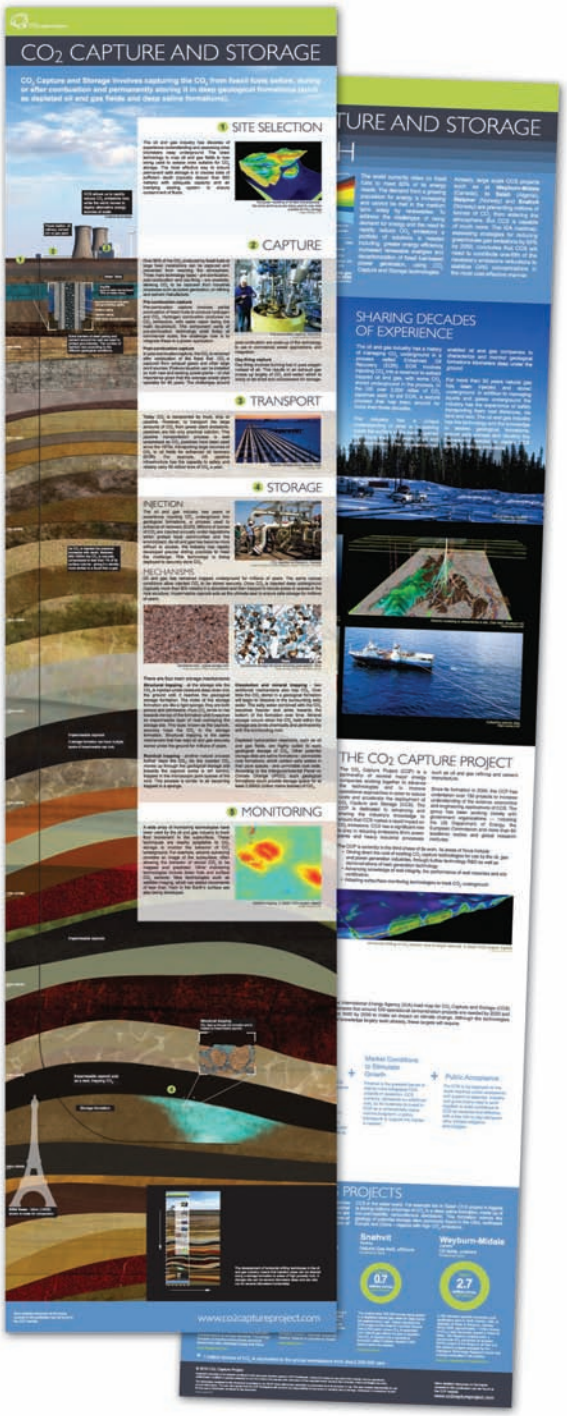
The challenge for the Communications Team continues to be to take the rich content from the ongoing work of the teams and deliver it in a relevant and understandable way to the increasingly diverse audiences that are critical to the advancement of CCS.

THE 2010 COMMUNICATIONS PROGRAM

The central thrust of our work during 2010 has been to prepare the ground for the field capture demonstrations which are due to take place in 2011 and early 2012, landmark studies and research in policy and storage arenas and the beginning of monitoring technology field trials.

To maximize efficiencies, our approach has been to combine a certain amount of direct audience communication with reaching out to others who are able to take the CCP story and use it with their own audiences.

In order to reflect changing information needs, a range of channels has been deployed to connect with our chief stakeholder groups – CCP members, industry, the CCS community, NGOs and policymakers.



THE 2010 COMMUNICATIONS PROGRAM

1. TECHNICAL CONFERENCES:

The CCP had a significant presence at the year's two most important CCS events – The US Department of Energy's National Energy Technology Laboratory conference (NETL 2010, Pittsburgh, May) and the international Greenhouse Gas Control Technologies conference (GHGT-10, Amsterdam). At both events, the CCP exhibition attracted visitors from a variety of backgrounds – industry, NGOs, policymakers and academia – and a selection of CCP publications were distributed. Poster sessions and presentations were given by CCP at both events.

2. LITERATURE

A range of communications material was produced and disseminated to key stakeholder groups throughout the year, and were also hosted online. This included:

- A revised and updated version of the CCP's highly popular CCS *In Depth leaflet.* This unique, meter-long leaflet provides a useful overview of the nature of subsurface characteristics and CO_2 storage. It is used by a range of audiences including NGOs, industry, media, schools and policymakers
- A CCP2 results update entitled CCP: *Preparing the Ground for Widespread Deployment*. This six page report summarizes the goals and results of the CCP2 technical program, looking at Capture, Storage and Policy activity. This report was made available at the GHGT-10 conference as well as being distributed to members for future use
- Two *Project Factsheets*, reporting on progress in two significant CCP capture technology demonstrations. The demonstration of oxy-fired CO_2 capture on the Fluid Catalytic Cracking (FCC) unit of an oil refinery and of oxy-firing on a once-through steam generator were covered in each of these papers, which were made available at conferences and online.

3. WEBSITE

The CCP website, www.co2captureproject.com, was reviewed and refreshed to improve usability. The front page was changed to make it more dynamic, better highlighting CCP news and developments. All literature has been made available on the website. To date, the website has attracted over 3,500 registered users who repeatedly access the site for information - the largest groups coming from education, energy, industry and research backgrounds.

4. MEDIA

The CCP has contributed expert articles in key industry media outlets to share the organization's work with industry leaders. Articles have been featured in: *Carbon Capture Journal, The IEA Greenhouse Gas Newsletter, Petroleum Economist and World Coal Magazine*. These in-depth expert articles have been on topics including CO_2 transportation and the CCP Storage Monitoring and Verification Program.

Media outreach

5. MEMBER COMMUNICATIONS

Member communications have been a key part of 2010's communication program, with materials prepared for management and communications teams to help them understand and communicate the work of the CCP.

THE CHALLENGE AHEAD

As we move into 2011 and the CCS technologies enter the full pilot and demonstration stage, the organization will enter a new phase of communication to address the need for education on the practical potential of CCS. The range of audiences with an interest in CCS is expected to grow, and it will become increasingly important to ensure their needs are met by the CCP.

CCP website

Sample of 2010 literature

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CAPTURE

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Ivano Miracca, eni

TEAM MEMBERS
Richard Beavis, BP
Jonathan Forsyth, BP
Karl Gerdes, Chevron
Raja Jadhav, Chevron
Cliff Lowe, Chevron
Julio Rincon, ConocoPhillips
George Parks (consultant)
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Mahesh Iyer, Shell
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Gerald Sprachmann, Shell
Evert Wesker, Shell
Mark Bohm, Suncor

STORAGE, MONITORING & VERIFICATION

TEAM LEAD
Scott Imbus,Chevron

TEAM MEMBERS
Walter Crow, BP
Kevin Dodds, BP
Craig Gardner, Chevron
Dan Kieke, Chevron
Marcos Briceno, ConocoPhillips
Marco Brignoli, eni
Richard Rhudy, EPRI
Robert Trautz, EPRI
Rodolfo Dino, Petrobras
Andreas Busch, Shell
Claus Otto, Shell
Alessandra Simone, Shell
Mark Bohm, Suncor

ECONOMIC MODELING

David Butler, David Butler & Associates

COMMUNICATIONS

TEAM LEAD
Mark Crombie, BP

TEAM MEMBERS
Lucy Almond, BP
Morgan Crinklaw, Chevron
Nancy Turner, ConocoPhillips
Renato De Filippo, eni
Leonardo da Silva Ribeiro, Petrobras
Kate Adlington, Pulse Brands
Simon Taylor, Pulse Brands
Rasmus Valanko, Shell
Michael Lawrence, Suncor

POLICY & INCENTIVES

TEAM LEAD
Arthur Lee, Chevron

TEAM MEMBERS
Lucy Almond, BP
Kevin Elm, ConocoPhillips
Renato De Filippo, eni
Richard Rhudy, EPRI
Leonardo da Silva Ribeiro, Petrobras
Rasmus Valanko, Shell
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