Abstract

The CO₂ Capture Project (CCP) is an award-winning partnership of seven major energy companies working to advance the technologies that will underpin the deployment of industrial-scale CO₂ capture and storage (CCS).

Harnessing the unique expertise of its members, the CCP has worked in collaboration with government bodies and more than 60 academic institutions, industry and leading environmental groups. Initiated in 2000, the overall objective of CCP is to deliver major cost reductions for CO₂ capture and demonstrate that geological storage is efficient, verifiable and secure. Phase 3 of The CO₂ Capture Project (CCP3) is being undertaken during 2009-2013.

Capture technologies for application in oil refineries, extraction of heavy oils and in power production from natural gas are included in the portfolio of CCP3. Demonstration of the next generation technologies is a key aspect of this phase. Two demos are currently planned. One such demonstration is currently in the advanced stages of construction, oxyfiring on a FCC Prototype unit located at the Petrobras’ research complex in São Mateus, Paraná state, Brazil and a second demonstration is planned for 2011, oxyfiring on a Once-Through Steam Generator (OTSG) in Alberta, Canada.

The storage monitoring and verification (SMV) program is focusing on key assurance issues and the field trialing of emerging and integrated technologies. Major projects include approaches to assessing and predicting long-term well integrity, understanding subsurface physico-chemical phenomena and monitoring technology cost-effectiveness and optimization. The SMV program continues its commitment to rapid provision of technical findings and their implications to stakeholders.

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1. General

CCP3 began in late 2009 and is scheduled to run until 2013. This phase of work is absolutely critical in preparing the ground for widespread deployment of the next generation of CCS technologies. Thus much of CCP’s work will be focused upon moving from theory to commercial application.
The capture programme will further develop those technologies identified as having high potential, with at least one full scale demonstration. CCP has to date two demonstrations planned. One such demonstration is currently in the advanced stages of construction, oxyfiring on a FCC Prototype unit located at the Petrobras’ research complex in São Mateus, Parana state, Brazil and a second demonstration is planned for 2011, oxyfiring on a Once-Through Steam Generator (OTSG) in Alberta, Canada.

Storage activity will focus upon R&D and field trials of monitoring, well integrity and subsurface technologies to further improve understanding around the security of long term storage. And there will also be an increased effort to share this knowledge with a broader range of thought leaders and stakeholder groups, to further their understanding and provide them with the information they need.

During the life of the CCP, a number of external factors have changed, and learnings accrued, which have shaped and re-shaped the programme. These include:

- Political and industry interest in CCS has grown exponentially, from almost zero in 2000. As other industry sectors have become involved, notably the coal-fired power sector, the CCP decided to avoid duplication by focusing its capture activities on the oil, gas and natural gas-fired power sectors.
- The initial four capture implementation scenarios used in CCP1 (refinery, natural gas power station, distributed turbines and gasification) were reduced to three (refinery, heavy oil development and natural gas power station) in order to represent realistic, relevant and challenging environments.
- Early enthusiasm for the so-called Hydrogen Economy, which led to an initial natural tendency towards pre-combustion as a favored capture technology, has abated somewhat. Although other capture technologies have also emerged as options for retrofits at existing plants, hydrogen firing remains an option suitable for existing industrial plants, including refineries. Nevertheless, pre-combustion technology still represents the technology with the least scale-up risk, given that the component parts are already in use at the size typically needed for commercial scale application for carbon capture.
- The focus of CO2 storage has shifted from characterization and modeling towards specific containment issues (e.g., well integrity, CO2-water-rock interactions) and specialized simulation to improve flood efficiency and avoid complications (e.g., pressure management).

Possibly the most significant alteration has been the sea change in scientific, political and public opinion in recognizing the need for swift, decisive action to reduce anthropogenic CO2 emissions. CCS is now recognized as being an appropriate set of technologies to reduce emissions from fossil fuels that will give society time to develop alternative energy sources and embrace energy conservation techniques. The IEA CCS Roadmap, published in 2009, assessed strategies for reducing greenhouse gas emissions by 50% by 2050 and concluded that CCS will need to contribute one-fifth of the necessary emissions reductions to stabilize GHG concentrations in the most cost-effective manner. To achieve this, an initial 100 projects would be needed by 2020, rising to 3400 projects by 2050. With some 60% of IEA’s proposed CCS applications outside the power sector, the need for oil and gas industry involvement is clear.

2. Capture

Demonstration of next generation capture technologies is a key aspect of the third phase of the CCP3. Two demonstration runs are planned in the 2010-2011 timeframe, as detailed below. A second task in the CCP3 capture program is the development of technologies in the CCP1/CCP2 portfolio to “ready for demo”, subsequently promoting their demonstration among member companies. Identification through a screening process of technologies with high economic potential and well-defined technical risk for development, at least to the “ready for pilot” level, is the third task of the CCP3.

Technologies in the CCP3 portfolio must be applicable to the following scenarios, considered of primary interest by CCP members:

- Steam production for SAGD (steam assisted gravity drainage) extraction of heavy oils and oil sands.
- Oil refinery (process heaters, fluid catalytic cracking, hydrogen production).
- Natural gas power stations.

For each scenario, technologies under development will be evaluated relative to state-of-the-art post-combustion baselines. The baseline cases are currently in preparation.

2.1 The SAGD scenario and technologies

Extraction of heavy oils or oil sands requires considerably more energy than conventional fossil fuels. SAGD is the most advanced extraction technique for heavy and ultra-heavy oils [1] injecting steam into the reservoir to soften and displace hydrocarbons. Steam is typically produced in once-through-steam-generators (OTSG) fired with natural gas.
and using oily water from the reservoir as the water source. The CCP scenario considers a set of large OTSGs (4 x 250 MMBTU/hr), causing emissions of about 500,000 metric tons per year of CO₂. For this scenario a second baseline will be prepared, using a pre-combustion technology (auto-thermal reforming) to supply hydrogen fuel to the burners. Evaluations performed in the previous phases of the CCP point to oxy-firing as a promising option for this scenario. The CCP, in collaboration with other companies and with co-financing by the government of the province of Alberta (Climate Change and Emissions Management Corporation Program), has organized the retrofit to oxy-firing and demonstration of a commercial OTSG boiler used in oil sands operation in Canada. Praxair performed the feasibility study to establish the design basis and costs for retrofitting both a large scale boiler (duty of 250 MMBTU/hr) and a test boiler for the demonstration (duty of 50 MMBTU/hr). The retrofit of the test boiler, including installation of different types of oxy-fuel burners and the necessary piping for oxygen supply, as well as a demonstration testing three different burners, will take place in 2011.

The CCP has been supporting the development of chemical looping combustion (CLC) technology since 2001. This technology could be well-suited for application to the SAGD scenario, since the larger footprint compared to conventional boilers should not be a limitation, and pure oxygen generation is not needed, simplifying its deployment. The CCP will evaluate application of CLC for SAGD, possibly contributing to the speed-up of the development of this technology.

2.2 The oil refinery scenario and technologies

Oil refineries are large CO₂ emitters (about 4% of total emissions [2]), but these emissions come from a number of dispersed sources. The CCP scenario considers capture from the following sources, representing a major share of total emissions:

- Process heaters fired with refinery fuel gas (4 x 150 MMBTU/hr duty)
- Regenerator of a fluid catalytic cracking (FCC) unit, processing 60,000 bpd of feedstock
- Steam methane reformer (SMR) producing 50,000 Nm³/hr of hydrogen from natural gas.

Differently from the SAGD scenario, this is mainly considered as a retrofit of existing equipment. Considering pre-combustion options, a centralized production of hydrogen by auto-thermal or gas heated reforming, feeding the process heaters and optionally replacing the steam reformer is being considered. Novel technologies may be included in the pre-combustion scheme such as membrane water gas shift (MWGS), where plans are under way to support further development to the design of a field pilot unit by 2013.

Oxy-firing is also a promising option, although it may incur footprint problems when considering the reduced space available in existing refineries. For process heaters the CCP will study options for modification of existing burners to oxy-firing.

The regenerator of the FCC unit is the single most significant emitter in a refinery, accounting for more than 30% of total emissions. A study in CCP2 showed that oxy-firing may result in lower costs than post-combustion processing. Based on this, the CCP joined Petrobras in the organization of a demonstration in a large FCC pilot unit located in the Petrobras research complex of Sao Mateus, Parana, Brazil. The unit is capable of processing up to 33 bpd of feedstock, emitting about 1 ton per day of CO₂. The unit will be modified, adding a CO₂ recycle system and an oxygen supply system. The plant will then be run in oxy-firing mode for two months testing two different feedstocks in a range of operating conditions.

2.3 The NGCC scenario and technologies

The development of technologies for CO₂ capture from natural gas fired power plants was one of the main topics in CCP1 and CCP2. Demonstration of technical feasibility of exhaust gas recycle to the combustion chamber and scale-up by order of magnitudes of several pre-combustion technologies in R&D programs co-funded by CCP are among the major achievements of the programme. A screening process is now under way to identify technologies with high potential for cost reduction in this specific scenario. Technologies emerging from the screening will be considered by the CCP for financial support of R&D programs to develop them, at least to the “ready for field pilot” level by 2013.

3. Storage Monitoring and Verification (SMV)

CCP3’s storage monitoring and verification (SMV) program is organized along three themes: 1) storage assurance – technical studies aimed at addressing remaining acknowledged or perceived risks, 2) field trialing – deployment of
emerging and integrated monitoring technologies, and 3) stakeholder issues – provision of technical findings in a form useful to the general public and regulatory groups. Project topics are selected by the SMV team and contracted to third party commercial and research organizations.

3.1 Storage Assurance

Considerable progress has been made by CCP and other organizations over the past decade to identify, qualify, and in some cases quantify risks associated with CO2 storage. Commonly cited storage risks include well material alteration, pressure induced fracturing/fault reactivation and CO2-fluid-rock interactions. Whereas these processes are often seen as threats to containment they are in reality manageable through characterization, operational planning, and intervention, if they are well understood.

An approach to assessing the integrity of wells through logging, testing, and sampling of fluids and solids was pioneered by CCP. The initial comprehensive survey in a 30 year old CO2 production well revealed variable alteration (carbonation) but continued barrier performance, illustrating that conventional cements provide suitable barriers if good cementing practices are followed [3]. An ongoing experimental program seeks to duplicate rock/cement dissolution and precipitations reactions observed in the well and simulate their long-term impact on well integrity. Initial experimental results show that carbonation is observable and that stable carbon isotopes may also be useful in tracing such reactions [4]. The CCP3 well integrity program is currently conducting a global search for additional CO2-experience wells to survey.

CCP subsurface processes studies encompass physio-chemical phenomena that may impact CO2 movement within reservoirs or through barriers. CCP3 projects in this area are diverse. A field-based fault study in the Paradox Basin of Utah seeks to document diagenetic processes, involving CO2, that serve to seal faults over time. Protocols have been developed for determination of relative permeability (Krel) and capillary entry pressure (Pe). The impact of CO2 impurities (highest expected values of N2, CH4, Ar, O2, SNO3 from the three major capture approaches) on plume migration and reservoir mineralogy will be assessed through simulation and experimental studies. Simulations, using new binary pressure-volume-temperature (PVT) data, will be performed on generalized Gulf of Mexico siliciclastics and Western Canadian carbonates. Rock samples from these areas will be used in static experiments to compare pre- and post-reacted rock mineralogy and fluid chemistry.

The CCP3 monitoring and verification program includes a retrospective of the cost-effectiveness of monitoring systems deployed in previous field projects (collaborative with Texas Bureau of Economic Geology and the Earth Technologies Institute) with the aim of developing a process to identify optimal monitoring tool selections. An integrated modular borehole design including monitoring, suitable for most field sites, is also under development.

Storage optimization as a study area is based on the “certification framework”, which is a platform for organizing data, simulating CO2 migration and trapping, and calculating leakage risk [5], but also includes development of analytical or numerical solutions to specific problems. Included among these are the effect of gravity number, pressure elevation risk, and fault leakage potential (density, connectivity and transmissivity). The approach has been applied to a hypothetical Gulf Coast Texas site, a proposed San Joaquin Valley, California pilot site and to BP’s In Salah project (using pre-injection and then late 2008 data). The future focus of the storage optimization program will be the technical-economic considerations of maximizing injection rate, storage capacity, and maintaining containment security.

3.2 Field Trialing

Given the demonstration mandate of CCP3, the SMV program includes deployment of promising monitoring technologies at third party sites. Deployments in progress include borehole gravity at Denbury Resources’ Cranfield CO2 EOR project, through casing resistivity and 3D VSP at CO2CRC’s Otway Basin Piloting site and an InSAR feasibility study at MGSC’s Decatur, Illinois site. Upcoming deployments include seismic (micro-, crosswell and walkaway VSP) and fiber optic pressure/temperature, likely at a single site.

3.3 Stakeholder Issues

The CCP SMV, Policies and Communications teams will continue to interact to produce and release timely technical information on CO2 storage assurance to stakeholders.
List of References


Acknowledgments

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