Carbon capture and storage and the oil and gas sector

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Often overlooked has been the petroleum industry's own important role in developing carbon capture and storage, and deploying CCS in the future in order to stabilise carbon emissions in the atmosphere. The need for stabilisation of emissions has been starkly underlined by the Intergovernmental Panel on Climate Change's (IPCC) Fourth Technical Assessment Report (2007). This contained three important findings about global warming:

- warming of the climate system is unequivocal;
- most of the observed increase in global average temperatures is very likely due to human-induced greenhouse gas (GHG) emission concentrations in the atmosphere and
- it is likely that there has been significant human-induced warming in the past 50 years.

The IPCC estimates the global temperature increase in the coming century could be between 1.8-4.0°C, which is much more rapid than any temperature changes known to have occurred during the past 10,000 years .

To limit climate change, GHG emissions need to be reduced significantly.

In 2010, the United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties 16 (COP16) adopted a non-legally binding goal to limit global temperature increases from pre-industrial levels to 2°C. This is equivalent to stabilising greenhouse gas concentrations in the atmosphere to about 450 parts per million of CO2 equivalent by 2050 (with CO_2 concentrations stabilised at less than 400 parts per million). This compares to an estimated concentration of CO_2 in the atmosphere of around 395 parts per million in June 2011.

Achieving the degree of decarbonisation implied by the above statistics – no further growth in the concentration of CO2 in the atmosphere over the course of a generation – is a challenge that can only be met by using a number of technologies in parallel.

Scenarios by the International Energy Agency (IEA) indicate that CCS could account for some 19 per cent of energy-related GHG emission reductions, on a par with the contribution from renewable energy and other efforts, if greenhouse gas concentrations in the atmosphere are to be stabilised by 2050. CCS is particularly important if this stabilisation is to be achieved at least cost.

CCS involves capturing bulk CO_2 from large stationary sources, transporting the CO_2 often via pipeline or other means (e.g. barge or tanker) and storing the CO_2 in a geological formation (for example, a depleted oil and gas reservoir, deep saline formation or an oil field suitable for enhanced oil recovery).

Much of the public policy discussion surrounding CCS in recent years has focussed on the power generation sector. This focus is understandable. It is prudent that governments take action to improve the costs and demonstrate the performance of CCS in the power generation sector, where future emissions will eclipse all other industrial sectors and where the application of capture technologies is considered to be immature and in need of "demonstration". This is also the case in other high emitting industries such as iron and steel and cement.

The origins of CCS are found in the oil and gas sector

The same capture technologies considered not yet mature in power and many industrial applications have been commercially deployed by the gas processing and chemical industries for decades.

Substantial pipeline networks already exist for transporting CO_2. Most are in North America and are used to supply CO_2 for Enhanced Oil Recovery (EOR), with more than 5,900km of operating pipeline infrastructure.

In terms of storage applications, CO_2 use in EOR has a long history and represents an area of significant experience and expertise as well as an annual injection in the US of over 50 million tonnes per annum (Mtpa) of both natural and anthropogenic CO_2.

Through its annual survey of large-scale integrated CCS projects in 2010, the Global CCS Institute has identified eight operational projects. All of these projects have direct links to the oil and gas sector although the drivers for each are diverse.

One of the first operational projects was ExxonMobil's Shute Creek Facility in 1986 in Wyoming. Using natural gas separation, today, this facility separates around 7 Mtpa of CO_2 and pipes it over 120 miles to a number of purchasers, including Chevron and Anadarko for EOR. The need to separate the CO_2 from the methane to create a marketable product, use of commercially available natural gas separation technology and significant EOR potential has made this project viable.

The same model applies to Occidental's Century Plant and the Val Verde Gas Plants in Texas, both of which use CO_2 from natural gas separation to provide millions of tonnes of CO_2 each year for EOR. In addition, the Great Plains Synfuel Plant and the Enid Fertiliser plant both have similar models

Large-scale integrated carbon capture and storage projects in operation and construction

Name	Location	Capture type	Volume CO_2 (Mtpa)	Storage type	Key proponents
Operation stage					
Sleipner CO_2 Injection	Norway	Gas processing	1 Mtpa	Deep saline formation	Statoil ASA
Snøhvit CO_2 Injection	Norway	Gas processing	0.7 Mtpa	Deep saline formation	Statoil ASA
In Salah CO_2 Injection	Algeria	Gas processing	1 Mtpa	Deep saline formation	BP, Sonatrach, Statoil ASA
Great Plains Synfuel Plant and Weyburn-Midale Project	United States/Canada	Pre-combustion (synfuels)	3 Mtpa	EOR	Dakota Gasification, Cenovus Energy, Apache Canada
Shute Creek Gas Processing Faiclity	United States	Gas processing	7 Mtpa	EOR	ExxonMobil, Chevron, Anadarko
Enid Fertilizer Plant	United States	Pre-combustion (fertiliser)	0.68 Mtpa	EOR	Koch Industries, Chaparral, Anadarko
Occidental Gas Processing Plant	United States	Gas processing	5 Mtpa (and 3.5 Mtpa in construction)	EOR	Occidental Petroleum
Val Verde Natural Gas Plants	United States	Gas processing	1.3 Mtpa	EOR	Blue Source, PetroSource Energy
Construction stage					
Enhance Energy EOR Project	Canada	Pre-combustion (fertiliser and oil refing)	1.8 Mtpa	EOR	Agrium Fertiliser, North West Upgrading, Enhance Energy
Gorgon Carbon Dioxide Injection Project	Australia	Gas processing	3.4 - 4 Mtpa	Deep slaine formation	Chevron, ExxonMobil, Shell
Plant Ratcliffe	United States	Pre-combustion (power)	2.5 Mtpa	EOR	Mississippi Power, Denbury Resources
Saskpower Boundary Dam 3 CCS Project	Canada	Post-combustion (power)	1 Mtpa	EOR	Saskpower

using CO_2 separated by commercially available technology (synfuel and fertiliser production respectively) for EOR.

In Norway, there are another two operational projects but the motivation for storing CO_2 is quite different to enhanced oil production. In 1991, the Norwegian government established a tax on GHG emissions. In response to the US$51 per tonne of CO_2 tax, the Sleipner and the Snohvit projects have been injecting around 1 Mtpa and 0.7 Mtpa of CO_2 into offshore deep saline formations since 1996 and 2007 respectively. While they both use natural gas separation technology, the storage of CO_2 into deep saline formations has been prompted by having an adequate price on carbon.

Another operating project is In Salah in Algeria, which separates and injects around 1 Mtpa of CO_2 into a deep saline formation.. This project has no external financial incentive driving the CO_2 storage component of the gas field operation. While there are subsurface lessons that can be transferred to other CCS projects), there is an expectation that this project could receive carbon credits through the UNFCCC's Clean Development Mechanism (CDM). This is an important point for many potential CCS projects in developing countries. The CDM is meant to allow emission-reduction projects in developing countries to earn certified emission reduction (CER) credits. These CERs can be traded and sold, and used by industrialised countries to meet a part of their emission reduction targets under the Kyoto Protocol. While no CERs have been received to date for any CCS project, in 2010 at COP16 the Meeting of Parties agreed (subject to general recommendations from the Subsidiary Body for Scientific and Technological Advice which is advising the UN) to include CCS as an eligible project activity under the CDM. This may eventually provide a financial incentive for CCS projects in developing nations.

In addition, the four CCS projects currently in construction also have direct links to the oil and gas sector. Over the past year an important development has occurred in that →

the inclusion of captured CO_2 from power facilities is now a factor. The two projects of note are Mississippi Power's Plant Ratcliffe and Saskpower's Boundary Dam project in Saskatchewan. In both projects CO_2 captured from power plants will be injected for EOR.

These 12 projects, as well as the broader CO_2 EOR experience, highlight the extensive contribution of the oil and gas sector. This contribution includes:

- the commercial scale separation of bulk CO_2 to near purity;
- the compression, safe handling and transport of CO_2 over long distances at high pressure and extreme temperatures;
- the exploration and appraisal of suitable EOR injection sites and suitable storage sites in deep saline formations;
- CO_2 injection well design and development and
- reservoir management practices, including measurement, monitoring and validation.

All of these activities are central to the oil and gas sector and all of these will be required in demonstrating CCS today and deploying CCS into the future.

The future of CCS and the oil and gas sector

The above analysis of projects also provides a valuable stock of information that can be drawn upon to support the current demonstration of CCS. While this knowledge needs to be applied to a broad range of industries (power, cement, iron and steel, fertiliser production, refining, gas separation, ethanol production, etc), much of the effort, skills and expertise of developing CCS projects resides in the foundations of the oil and gas sector. By sharing this knowledge, the oil and gas sector can support accelerated technology diffusion, improved public understanding of CCS, cost and risk reduction and accelerated innovation. Overall, these active projects provide knowledge, insight, and lessons into developing CCS projects that can assist others to do so more effectively.

These projects also show that the drivers for CCS are diverse and growing. In some limited instances the application of CCS was commercial. In others, a price on carbon was sufficient and indicates that CCS can be more cost effective than paying to emit. Current studies similarly show that in some industries, for example, natural gas processing, fertiliser production and ethanol production, the cost of applying CCS could be as low as US$20 per tonne CO_2 according to a 2011 report by Worley Parsons, commissioned by my institute. This cost represents the cost of adding compression, transport and storage where a pure stream of CO_2 already exists.

Building on this, the CDM provides promise for the arrival of CCS projects in developing countries, especially in industries where the costs of applying CCS are lower and only a modest incentive is required. Ultimately a significant price on carbon will be required to see CCS deployed in future high emitting industries and countries. As governments move towards this, it is likely that new CCS projects will be developed, greater innovation will emerge and that the oil and gas sector will be heavily involved.

Since the beginning, the oil and gas sector has responded to incentives that apply to CCS. This has been shown through developing the first set of operational CCS projects and through the current suite of projects being developed to demonstrate CCS in industries such as the power sector. All of the current demonstration projects and those in the future that arise in response to new incentives will require a number of the core skills (individual and work practices) contained in the oil and gas sector. The past, present and future of CCS and the oil and gas sector are intertwined. Perhaps this combination can make significant inroads into the mountainous task of decarbonising the energy sector and reducing global warming. ■

Great Plains Gasification and CO_2 Capture Plant