Current Status of Carbon Capture and Storage: challenges and future prospects

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Summary

The relative abundance and energy content of fossil-fuels coupled with a rising global demand for energy pose significant challenges for carbon management and utilization. Carbon capture and storage (CCS) can offer a partial solution to CO_2 emission abatement particularly from energy-intensive manufacturing processes such as steel and cement that lack alternative solutions.

As a technology CCS has made significant advances in the last 10 years. Within the last two years two significant full-scale integrated capture and storage projects on coal-fired power stations have come on stream: Kemper and SaskPower's Boundary Dam both linked to Enhanced Oil Recovery (EOR) applications. There are already nine CCS projects that supply CO_2 for EOR from oil refining and other industrial sites mostly in the US but with at least 10 others are at varying stages of development in Norway, the Middle Easy and China.

Boundary Dam is the first power sector demonstration site that utilizes post-combustion capture (PCC). This is a technology which has made significant progress in development of new solvents/solvent based processes as well as improvements in absorber design/modelling and simulation. The solvent PCC technology is capable of storing 1 M tonnes CO_2/year. After teething problems in 2015 the system is now fully operational. With improved performance over 1 M tonnes has already stored since it began operating. 90% of the CO_2 is destined for the Weyburn Field via a 66 km pipeline. The remainder is injected into basal sandstone formations 2 km away at the Aquistore site.

There have also been significant advances in other capture technologies notably oxy-fuel which can be applied to steel, cement and high purity silica production. Integrated gasification Combine Cycle also offers scope for CO_2 capture alongside other gases which have commercial value. The Kemper County plant, for example, produces sulphuric acid and ammonia as well as CO_2 via the gasification of lignite. Other CO_2 capture technologies including calcium looping, solid sorbents and polymeric membranes are at a less advanced stage and require technical proofing at pilot scale.

CO2 storage has benefitted from over 40 plus years' of experience with CO2-EOR and the applicability of oil industry exploration and production technology. Many of the target first generation storage sites are former depleted oil and gas fields, for example Goldeneye and Snøhvit. In the longer term deep saline formations (DSFs) offer significantly greater storage capacity but will still require conventional seismic and formation characterisation from wellbore logging and coring. One of the best known DSF demonstration sites, Sleipner, has been successfully operated since 1996. Over 16 million tonnes have been stored. The high permeability and overburden has enabled good seismic imaging of the CO2

which has been tracked since the inception of injection. The ability to track CO2 with high resolution has also enhanced numerical simulations and therefore the ability to predict how CO2 behaves in this reservoir. Conditions elsewhere have been more challenging. For example in the Snøhvit Field an alternative formation was selected when it was discovered that the original fault-bound reservoir was causing the pressure level to reach the threshold limit for the reservoir.
Large-scale demonstration over the last decade has improved pressure management and plume imaging. Monitoring concepts are also under development, and for new sites a variety of techniques are used to track CO2. For example at Aquistore 3-D surface seismic surveys have been combined with, VSP surveys, Distributed Acoustic Surveys (DAS), pulsed neutron logging and InSAR.

As CCS is a relatively recent technology there has been a concomitant research effort to understand the environmental effects caused by unplanned leaks into the overburden and ultimately into shallow aquifers or the sea. Natural CO_2 seeps have been studied to observe the tolerance levels of ecosystems to varying concentrations of CO_2. These studies have been complemented by a large number of controlled release experiments that have shown that the surface expression of CO_2 in the environment may be some distance from the source. One implication of this pattern of migration is the difficulty in locating potential leaks. The evidence to date shows that environmental impacts are usually in the form of small isolated areas. Advances are also currently in progress to improve storage capacity estimates through dynamic modelling.

New storage projects are subject to rigorous risk appraisal to identify potential leakage and ensure long term storage security. One key area that does require attention are legacy wellbores, especially where depleted oil and gas fields are prospective storage candidates. Induced seismicity caused by elevated reservoir pressures acting on faults and fractures also remains a possibility.

The over-riding evidence from the last 10 years shows that the scientific and technological advances in CCS are significant. These advances have improved confidence and demonstrate that CCS is ready for large-scale deployment. Cost reduction remains a key objective which greater experience should bring. It is also clear that CO_2 storage is safe provided storage sites are properly selected, characterised and managed. Moreover, CCS specific laws have now been drafted in the EU, USA and Australia and the technology is included in the UNFCCC's Clean Development Mechanism.