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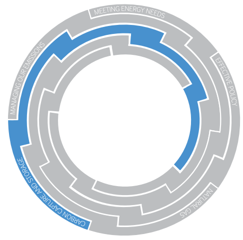


CCS: A key technology for delivering a low-emissions world

THE PARIS PUZZLE

Carbon Capture and Storage

This document is one piece of the Paris Puzzle – a series of papers intended to address what we see as key components of efforts to address climate change, and demonstrate our commitment to meeting the challenge. Find the other pieces at www.ipieca.org

Carbon capture and storage (CCS) is the only known technology that can enable the use of fossil fuels as a primary source of energy in a world seeking significant emission reductions of CO_2. CCS can use existing processes and technologies to collect and compress CO_2 generated by fossil fuel production, conversion and combustion, and is primarily intended for use with power plants. Compressed CO_2 is then sequestered at depths beyond one kilometre below the earth's surface, within geological formations suitable for permanent storage.

However, practical and economic limitations mean CCS cannot be applied to all relevant emission sources, and to be deployed at scale the barriers to CCS deployment must be overcome. This will take continued technological research and development, geological research and analysis on storage availability, demonstration projects to gain experience and reduce costs, public-private partnerships, and transitional governmental support. IPIECA believes that the barriers to widespread CCS deployment can be overcome.

The Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report attaches considerable importance to CCS deployment[1] with costs for delivering atmospheric CO_2 stabilisation pathways without CCS shown to be much higher than when it is utilised[2]. According to the IPCC, the mitigation cost increase for a theoretical 450ppm CO_2 – equivalent stabilisation would be approximately 2.5 times greater than a base case with all technologies available.

	Increase in total discounted mitigation costs in scenarios with limited availability of technologies			
2100 Concentration (ppm CO_2 eq)	No CCS	Nuclear phase out	Limited Solar/ Wind	Limited Bioenergy
450 (430-480)	138% (29-297%)	7% (4-18%)	6% (2-29%)	64% (44-78%)
550 (530-580)	39% (18-78%)	13% (2-23%)	8% (5-15%)	18% (4-66%)

Uncertainty ranges shown in brackets

THE TECHNOLOGY

CCS comprises three different processes:

- **Capture:** Isolating the CO_2 produced from combustion of hydrocarbons before it is emitted to the atmosphere.
- **Transportation:** Moving the captured CO_2 by pipeline, ship or land transportation to a secure storage site – processes for which the oil and gas industry already have substantial experience.
- **CO_2 injection/storage:** Injecting CO_2 into carefully selected and managed deep geological formations (e.g. saline formations, depleted oil and gas reservoirs, enhanced oil recovery operations or enhanced coal-bed methane deposits), some of which previously contained hydrocarbons for millions of years.

Each process is widely used in the oil and gas industry and available from a range of suppliers and service providers. CO_2 captured from a variety of industry sources for Enhanced Oil Recovery (EOR) has demonstrated the capture, transportation and injection processes in some applications. Several gas processing projects have also demonstrated CCS technology, including some with dedicated long-term storage.

THE ECONOMICS

CCS is only economical today in a limited number of situations. In addition to capital costs, currently available technologies for CCS on power plants impose an energy penalty by requiring additional energy to operate the CO_2 capture and compression equipment. In some cases a relatively pure stream of CO_2 in a natural gas feed or conversion process can be captured and used economically in CO_2 EOR, if in close proximity to existing transportation infrastructure (e.g. onshore US) or stored in other geological formations in close proximity to the source, provided the carbon price is high enough (e.g. Norway). Otherwise, large scale demonstration projects have not been economic and have depended on public funding to move forward (e.g. Alberta, US coal-fired power plants).

Currently, incentives to drive development and deployment of CCS are modest. Explicit carbon pricing systems have operated over the range \$5-\$25 per tonne, and CO_2 EOR prices do not exceed this range either.

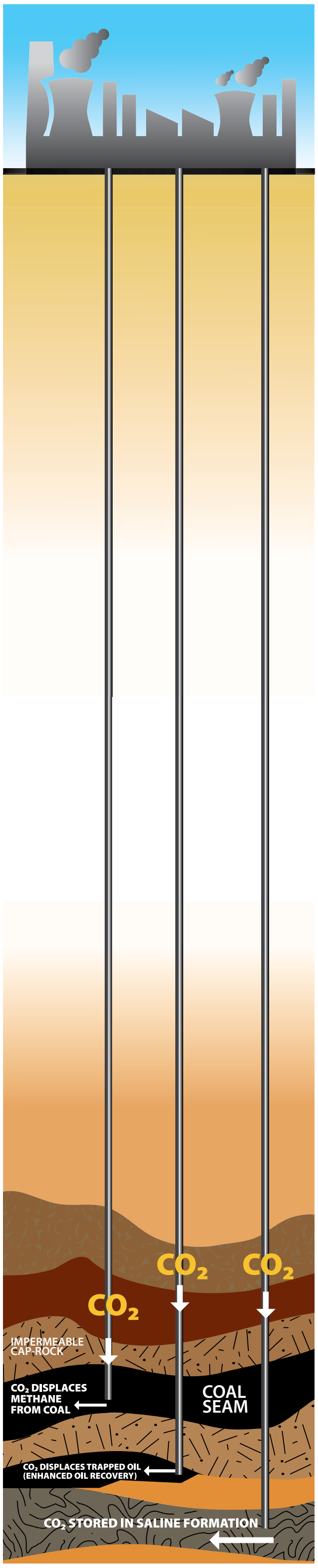
KEY MESSAGES

- Carbon capture and storage (CCS) is a key technology for delivering significant emission reductions during this century. Without it, deep cuts in emissions are likely to be more costly and, at worst, unachievable.
- CCS comprises a number of technologies that are widely used in the oil and gas industry and are readily available from a range of suppliers, companies and service providers.
- Deployment of CCS on a scale that makes a material contribution to reducing CO_2 emissions requires addressing current barriers, which include: cost, complexity along the value chain, regulatory/policy uncertainty, public acceptance, large-scale storage sites and long-term liability issues.

Footnotes

[1] Notably, many models could not prevent warming above 2°C if bioenergy, CCS and their combination (BECCS) are limited (high confidence).

[2] Edenhofer, O. *et al* (2014) Climate Change 2014: Mitigation of Climate Change. *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. [Online] Available at: http://bit.ly/1CDEg1e



CCS PROJECTS WORLDWIDE: OPERATIONAL AND IN EXECUTION[3]

A number of early large-scale demonstration projects are now in operation or under construction globally. The Global Carbon Capture and Storage Institute (GCCSI) state there are 22 large-scale CCS projects in operation or construction with capacity to capture up to 40 million tonnes of CO_2 annually with another 14 large-scale CCS projects in advanced planning stages.

INDUSTRY KEY

SNG	Synthetic Natural Gas
PG	Power Generation
NGP	Natural Gas Processing
FP	Fertiliser Production
HP	Hydrogen Production
ISP	Iron and Steel Production
OR	Oil Refining
CP	Chemical Production

PRIMARY STORAGE TYPE KEY

- Enhanced oil recovery
- Dedicated Geological Storage

OPERATIONAL PROJECTS

	Project	Industry	Storage
1	Great Plains & Weyburn-Midale	SNG	Enhanced oil recovery
2	Boundary Dam	PG	Enhanced oil recovery
3	Shute Creek	NGP	Enhanced oil recovery
4	Lost Cabin	NGP	Enhanced oil recovery
5	Century	NGP	Enhanced oil recovery
6	Val Verde	NGP	Enhanced oil recovery
7	Enid Fertilizer	FP	Enhanced oil recovery
8	Coffeyville	FP	Enhanced oil recovery
9	Air Products	HP	Enhanced oil recovery
10	Lula	NGP	Enhanced oil recovery
11	In Salah	NGP	Dedicated Geological Storage
12	Sleipner	NGP	Dedicated Geological Storage
13	Snøhvit	NGP	Dedicated Geological Storage

EXECUTE PROJECTS

	Project	Industry	Storage
1	Abu Dhabi	ISP	Enhanced oil recovery
2	Alberta Carbon Trunk Line – Agrium	FP	Enhanced oil recovery
3	ACTL – NorthWest Sturgeon	OR	Enhanced oil recovery
4	Gorgon	NGP	Dedicated Geological Storage
5	Illinois	CP	Dedicated Geological Storage
6	Kemper County	PG	Enhanced oil recovery
7	Petra Nova	PG	Enhanced oil recovery
8	Quest	HP	Dedicated Geological Storage
9	Uthmaniyah	NGP	Enhanced oil recovery

By contrast, first generation CCS costs[4] for power generation applications are many times current carbon pricing levels. For this reason, almost all of the CCS facilities that are currently operational or under construction have required specific fiscal support from government.

Broader demonstration of CCS at scale will likely reduce implementation costs. As common infrastructure is installed and process configuration is optimized, cost reductions of around 30-50% may be possible[5]. Continued research and development should further lower costs and energy use, particularly in the capture stage. For CCS technology to progress and play a significant role, economic support and a strong, long-term price signal for CO_2 emissions will likely be needed to trigger projects at the scale and duration necessary.

As such, CCS deployment will be triggered by:

- A high enough cost for emitting CO_2 (through legislation and market-based mechanisms)
- A high enough value of CO_2 as a product (e.g. for EOR) to offset the CCS cost
- A high enough price premium (i.e. willing to be paid by the consumer) on a lower carbon product (e.g. electricity, oil, steam, LNG, steel, cement or any other product)
- A mandated requirement

DEPLOYMENT AND SCALABILITY

Many areas across the US, Western Europe, the Middle East and Central Canada have favourable geology for CO_2 storage. By contrast, inland China, mainland India, and Central Africa appear less attractive. As current assessments of total global storage potential vary widely, more exhaustive studies are needed.

CCS requires an underpinning clear and simple regulatory framework that, amongst other things, addresses long-term storage site risk and liability. As an example of best practice, the province of Alberta in Canada has made significant steps forward in this area[6]. To deploy CCS at scale will also mean cross border transport between emissions source countries and those with large-scale storage opportunities. Additional legislative and regulatory modifications between countries will be needed in such cases.

Nevertheless, as seen from the list of 22 projects, CCS is beginning to be demonstrated across the world on a variety of sources and scales. Since late 2014, the application of CCS for power generation is being demonstrated on a full-scale coal-fired power station in Saskatchewan, Canada. Initial performance data indicate lower than expected energy penalties and that the one million tonnes per annum (Mtpa) capture rate will be met.

For large-scale cost-effective mitigation and stabilization of atmospheric CO_2, CCS is a critical technology. The oil and gas industry is continuing to develop CCS technologies and projects, as well as address barriers and explore opportunities to enable its uptake.

Footnotes

[3] GCCSI (2015) *Large Scale CCS Projects*. [Online]. Available from: http://bit.ly/1yt2y8V

[4] Amortised capital expenditure and ongoing operational costs

[5] UK CCS Cost Reduction TF (2013) *Final Report*. [Online] Available at: http://bit.ly/1Dl6iRj

[6] Alberta Energy (2013) *CCS Regulatory Framework Assessment*. [Online] Available at: http://bit.ly/1yt2pCu

IPIECA is the global oil and gas industry association for environmental and social issues. It develops, shares and promotes good practices and knowledge to help the industry improve its environmental and social performance.

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