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Brief

CCS: Applications and Opportunities for the Oil and Gas Industry

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Contents

1. Introduction 2

2. Applications of CCS in the oil and gas industry 2

3. Conclusion 4

1. Introduction

Production and consumption of oil and gas currently account for over half of global greenhouse gas emissions associated with energy use[1] and so it is imperative that the oil and gas industry reduces its emissions to meet the net-zero ambition. At the same time, the industry has also been the source and catalyst of the leading innovations in clean energy, which includes carbon capture and storage (CCS). Indeed, as oil and gas companies are evolving their business models in the context of the energy transition, CCS has started to feature more prominently in their strategies and investments.

CCS is versatile technology that can support the oil and gas industry's low-carbon transition in several ways. Firstly, CCS is a key enabler of emission reductions in the industries' operations, whether for compliance reasons, to meet self-imposed performance targets or to benefit from CO_2 markets. Secondly, spurred by investor and ESG community sentiment, the industry is looking to reduce the carbon footprint of its products when used in industry, since about 90% of emissions associated with oil and gas come from the ultimate combustion of hydrocarbons – their scope 3 emissions. Finally, CCS can be a driver of new business lines, such as clean power generation and clean hydrogen production.

From the perspective of the Paris Agreement, however, the deployment of CCS globally remains off track. To meet climate mitigation targets, an estimated 2,000-plus large-scale CCS facilities must be deployed by 2050, requiring hundreds of billions of investments and a one-hundred fold increase in the number of CCS facilities in operation relative to today[2]. For the private sector, including the oil and gas industry, to scale up its investments in CCS supportive policy frameworks are urgently needed to underpin a robust business case.

2. Applications of CCS in the oil and gas industry

The oil and gas industry is one the earliest adopters of CCS, having been deploying the technology since the 1970s in North America. This is no coincidence as the industry originally developed and used many of the techniques integral to CCS: separating CO_2 from natural gas is required before it can be transported by pipelines, and separated CO_2 is occasionally pumped back into geological formations to reduce the emissions intensity of operations or into reservoirs to enhance oil production.

There are several oil and gas processes that produce highly concentrated streams of CO_2 that are relatively easy and cost effective to capture and store. Indeed, IEA estimates that more than 700mt %) of operational CO_2 emissions from oil and gas operations can be avoided by using CCS and over 250mt could be captured at a cost of less than \$50/tonne[3].

Most of these lower-cost opportunities are in **gas processing**. Natural gas reservoirs can contain impurities such as CO_2 or sulphur dioxide which need to be separated before the gas can be transported by pipelines or liquefied into LNG because of user specifications and as impurities may lead to corrosion. The separation process results in a very concentrated stream of CO_2 which is easy to transport and store, thereby making this one of the easiest and lowest cost applications of CCS. As a result, up until the 2000s, nearly all the CO_2 captured globally at large-scale facilities came from gas processing, and today 10 of the 19 existing large-scale CCS facilities [4]in operation worldwide are associated with natural gas plants, capturing around 20 mtpa of CO_2.

Of these 10 CCS applications in natural gas processing facilities, two are at LNG plants that deploy CCS in their upstream operations to separate CO_2 from natural gas before it is cooled down: these are Snohvit LNG in Norway and Gorgon LNG in Australia. In addition, there are several emerging LNG based CCS opportunities, notably QP LNG expansion in Qatar, Browse LNG in Australia, G2 Net-Zero

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[1] CDP, Oil and Gas Report 2018
[2] Global CCS Institute, Global Status of CCS 2019
[3] IEA WEO 2018
[4] Global CCS Institute, Global Status of CCS 2019

LNG project in the US.

CCS can also help commercialize previously stranded high CO_2 gas fields where CO_2 concentration rates can be as high as 50%. To this end, Petronas, JOGMEG and JX Nippon announced an agreement earlier this year to explore using CCS to develop a number of high CO_2 gas fields in Malaysia.

Using CO_2 to increase oil production is a well-known **enhanced oil recovery** (EoR) technique and has been in use for decades. CO_2 that is reinjected into the reservoir leads to permanent storage of CO_2 underground. Currently 14 of the 19 operating large-scale CCS facilities use EoR as the means of permanently storing CO_2. Some academic studies have claimed that using CO_2 for EoR can lead to emissions reductions from oil on a life-cycle basis if the CO_2 used comes from man-made (anthropogenic) sources. Using a consequential life cycle assessment[5] methodology, oil that is produced by EoR could show a life cycle carbon footprint that is up to 50% less than conventionally produced oil.

Perhaps what is not widely known is that the majority of CO_2 that is currently used for EoR (up to 70%)[6] comes from naturally occurring CO_2 deposits underground, and so , there is significant potential to replace naturally occurring CO_2 used in EoR with CO_2 that is captured from large emissions sources or from the atmosphere.

Ethanol production is another lower cost application of CCS. Currently the only commercial scale ethanol plant with CCS is the Illinois Industrial CCS facility , but there is increased interest from both project developers and finance community due to smaller scale and ease of replicability of ethanol applications coupled with supportive policies in the US, including the 45Q tax credit and CCS Protocol in California's Low-Carbon Fuel Standard. In 2018, White Energy and Oxy announced plans to capture CO_2 from White Energy's two ethanol facilities in the Midwest US.

Refining is a part of the oil value chain that provides an opportunity to apply CCS. Refineries have several units that emit CO_2, including steam methane reformers that produce hydrogen, catalytic crackers and Combined Heat and Power (CHP) units. Currently there are 2 refineries (Shell's Quest Refinery and Air Products' Steam Methane Reformer at the Port Arthur refinery) that capture and store CO_2 from their steam methane reformers (SMRs), whilst a third (Sturgeon Refinery) is scheduled to come online in 2020. Other notable CCS refining projects under development include Preem's Lysekil refinery, and Porthos which plans to capture CO_2 from several refineries in the Port of Rotterdam. In the future, it may be possible to capture CO_2 from cracking and combined heat and power units in a refinery as well as SMR units.

Low-carbon hydrogen (H2) is emerging as a promising energy carrier which, when combusted, only produces heat and water and no CO_2. Touted by many as the "next LNG" due to the growth potential of the hydrogen market[7] as well as transportation of H2 by tankers catalyzing international trade, hydrogen can be used to decarbonize home heating, transportation and can provide high heat to hard-to-abate sectors such as steel production. Currently around 50% of hydrogen is produced globally through SMR of natural gas. SMRs can be coupled with CCS to enable a near-emissions free hydrogen production and is currently being employed at industrial scale at two facilities as mentioned above (Quest and Air Products).

Whilst there are expectations for electrolysis costs to come down, SMR with CCS is a scalable and lower cost method of producing low-carbon hydrogen with costs in the range of \$1.5 to \$2.5 /kg H2 as

[5] In contrast to attributional methods, that directly relate emissions to a functional unit, consequential methodologies model an entire product system and estimate the extent to which that is expected to change *as a consequence of a change in demand* for one functional unit.

[6] IEA WEO 2018

[7] From 70 Mtpa today to potentially up to 530 Mtpa by 2050 according to the briefing paper on Australia's National Hydrogen Strategy.

opposed to electrolysis, which costs around $4 to $6/kg H2 and makes up only 2% of current H2 production[8]. Blending hydrogen into existing natural gas networks, at concentrations of 10 to 15%, is technically possible today, and could both significantly reduce emissions and potentially facilitate hydrogen infrastructure build out. This could be a win-win strategy, beneficial for scaling up the hydrogen market regardless of its method of production.

Many oil and gas companies have started to factor in hydrogen into their decarbonization strategies and investments. Shell, one of the first movers in clean hydrogen with its Quest facility, is rolling out hydrogen fueling stations in North America and Europe. Another early mover, Equinor, is investing in H21 North of England, Zero Carbon Humber UK and Magnum project in the Netherlands all of which involve clean hydrogen production.

Gas-fired power generation offers another emerging application for CCS. NetPower's 50 MW first-of-a-kind natural gas-fired demonstration power plant in the US employs Allam cycle technology, which uses CO_2 as a working fluid in a supercritical CO_2 power cycle. The plant, first operated in 2018, aims to demonstrate it can produce zero-carbon electricity at costs competitive to conventional power generation. Whilst there are no commercial scale post-combustion gas power plants with CCS in operation today, a consortium of oil and gas companies, led by BP, is developing a post-combustion natural gas plant with CCS as part of the Net Zero Teesside project in the UK. Another consortium including Equinor and Gasunie is exploring the conversion of Vattenfall's Magnum natural gas fired power plant in Netherlands to run on hydrogen.

A nascent but promising technology is **Direct Air Capture (DAC)**, which enables 'sucking' CO_2 from the atmosphere as opposed to large emission sources. Whilst it is not directly linked to the operations of oil and gas companies, DAC could enable capturing and storing residual atmospheric emissions. As several oil and gas majors have started to aim for and commit to emission reduction targets, including from the end-use of their products, utilizing DAC is likely to emerge as a possible option to meet these targets. Indeed, several majors have announced taking equity stake in DAC technology providers, including Exxon's investment in Global Thermostat and Chevron and Occidental Petroleum's investment in Carbon Engineering. In 2019 Oxy and Carbon Engineering announcement commencement of work to build the world's first commercial scale (1 mtpa) DAC facility in the US.

3. Conclusion

Whether as a driver of growth and business development or as a means of lowering carbon footprint of operations and products, CCS offers numerous synergies to the oil and gas industry. It is a versatile and well understood tool in the oil and gas companies' energy transition toolkit. Notwithstanding the currently challenging economic times, the deployment of CCS is forecast to increase significantly to help meet clean growth and decarbonization goals, with oil and gas companies continuing to take a leading role.

[8] IEA WEO 2018

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