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INSIGHTS

CCS and the Role of Project Finance

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The UN Climate Change Conference in 2021, known as "COP26", highlighted the scale of global carbon emissions and the speed with which they must be addressed in order to meet net zero targets by 2050. Carbon capture and storage ("**CCS**") technologies form part of the measures that must be implemented to meet those targets and are therefore seen as integral to the energy transition and beyond.

CCS is a suite of technologies that captures carbon dioxide ("**CO_2**") primarily from large point sources (like biomass or fossil-fuelled power generation or industrial facilities) or, to a lesser extent, the atmosphere. The captured CO_2 can either be used in a range of industrial applications, within the broader field of carbon capture, *utilisation* and storage ("**CCUS**"), or injected into underground geological formations (including appropriate depleted oil and gas reservoirs and saline or basalt rock formations) for permanent storage.

This article explores the main CCS technologies that exist today, their advantages, the challenges to be overcome for their commercial viability at the scale required to constitute a meaningful part in the energy transition, and the role that project finance can play in this journey.

CCS today

Three main types of CCS technologies – post-combustion, oxyfuel and pre-combustion – focus on capturing CO_2 at its source, which is generally regarded to be more effective than atmospheric CO_2 removal.[1]

Post-combustion

Post-combustion CO_2 capture occurs after the combustion process takes place, separating CO_2 from the mixture of combustion exhaust gases (or flue gases) produced after fuel is burnt in power stations and industrial plants. Materials that selectively absorb or react only with CO_2 (such as amine, an ammonia-derived solvent) are used to filter out CO_2 from the other gases for liquefaction and transport for other uses or underground storage in a suitable geological formation. Amine solvent technology is decades old and extensively used in the oil and gas industry, particularly for separating CO_2 from natural gas to produce purified natural gas for sale. It is also used in generating CO_2 for sparkling drinks. The last decade has seen its adaptation for use on combustion gases.

Given the very high energy intensity and costs of capturing and liquefying 100% of the CO_2, typical capture levels have been around 80-90%. Recent studies indicate that more advanced amine solvents can improve capture to around 99% with lower energy requirements and little cost increase. It is anticipated that further effectiveness studies will improve the design of future CCS plants.[2]

Post-combustion technologies can also be applied to work directly with current industrial processes and power plants without any adaptation to the plant's design.[3] This allows for retrofitting to existing plants by being added at their "back end" and is cost-effective as it leverages the existing power plant, supporting infrastructure, and technical know-how.[4] Such retrofitting can help address emissions from existing fossil fuelled power plants in the near and medium term without having to shut them down.[5]

There are, however, some challenges with retrofitting post-combustion technology to a conventional power plant. These include cost and efficiency penalties (i.e. the power generation loss) from installing the technology as well as an initial increase in carbon emissions at the energy input stage due to the increased fuel consumption and increased freshwater consumption required by the application of CCS technologies.[6] Impact assessment methodologies are still being refined in order to improve the reliability of quantitative assessments of the net environmental impact of using CCS technologies,[7] but CCS technologies are likely to become more efficient as they advance from being the emerging technologies they are today to more mature technologies.

Oxyfuel

Oxyfuel carbon capture operates by using pure oxygen in power station boilers rather than normal air. Fuel combustion that occurs in pure oxygen rather than normal air (which contains a large proportion of nitrogen) generates waste gas that contains predominantly CO_2 (around 90%) and water vapour. In contrast, fuel combustion in normal air produces a mix of waste gases, of which CO_2 comprises only 3-15%.[8]

A pre-combustion process separates air into its two major components of nitrogen and oxygen, with highly purified oxygen entering the power station boiler with the fuel to be burnt. The relative ease in separation of CO_2 and water vapour (by condensing out the water vapour) leaves 95-99% of CO_2 to be piped or transported to a storage facility.

Although this is an efficient process for capturing CO_2, separating large volumes of air into its constituent gases can use a significant percentage[9] of the power produced at a power plant, resulting in increased energy consumption. A power station's conventional base design also needs to be adapted by adding equipment and processes at the "front end", prior to combustion taking place in the boiler. The boiler design must additionally change to accommodate the air separation process and input of oxygen. Burning fuel in pure oxygen (in the absence of nitrogen to dilute the flames and gases) results in extremely high temperatures that the combustion chamber may not be able to withstand. Some of the combustion gases therefore need to be diverted back into the combustion chamber to provide the dilution effect that limits temperature rises to acceptable levels.

These design requirements make oxyfuel technology more suited for incorporation into the design of new-build power plants from the outset, rather than being retrofitted to a conventional power plant.

Pre-combustion capture

Pre-combustion carbon capture requires conversion of the fuel pre-combustion to separate out the carbon for capture, in a process known as gasification. Air is channelled through an air separation unit to generate a high level of very pure oxygen, which is used with steam to convert the fuel into a synthesis gas (or “syngas”) of carbon monoxide and hydrogen – this differs slightly from the dominant method of producing hydrogen, known as steam methane reforming, which involves the use of steam alone.

A water shift reaction process follows, in which the carbon monoxide in the syngas reacts with water to produce CO_2 and more hydrogen. CO_2 can then be captured via a chemical solvent process, while the hydrogen can go on to be burnt as a carbon-free fuel.

Pre-combustion capture benefits from a long industrial history with decades of cumulative expertise and know-how for the gasification of fuel into syngas. Some power stations in the USA and Europe, for example, already use gasification to produce syngas that is sent directly to gas turbines to generate electricity, albeit without the carbon capture elements.

The energy input required for the gasification and water shift reaction processes, however, result in a less efficient power station. Particularly for natural gas power stations where all the gaseous fuel needs to react with steam and oxygen to produce CO_2 and hydrogen, the economic advantage of pre-combustion carbon capture over post-combustion carbon capture has yet to be established.

The electricity generation process, where hydrogen is produced from the fuel to generate electricity in a gas turbine, also requires a significantly different design from that of conventional combustion processes.***[10]*** This limits the application of pre-combustion technology to new-build power stations, and excludes the ability to retrofit older coal power plants, which currently comprise much of the world's installed base of fossil fuel power.

Transport

Captured CO_2 needs to be safely and efficiently transported, either for onward industrial use or to a permanent underground storage site in a suitable geological formation (often depleted oil and gas reservoirs). It is typically compressed under high pressure into a liquid, as dense liquid is easier to transport than gas and allows transportation of greater volumes.

Compared with other transport options, pipelines are often seen as the most cost-efficient and viable long-term option for transporting large quantities of CO_2 to be captured from industrial sources such as power stations and hydrocarbon production, despite the cost associated with pipeline construction. CO_2 is already widely transported today via pipelines, in accordance with established industrial safety standards and regulations. For example, the US has seen pipeline transportation of liquid CO_2 for oil recovery for almost four decades.***[11]*** However, depending on the location of the CO_2 capture and the geological formation used for storage as well as availability of land and pipeline construction and operation regulatory regimes, other forms of transportation (such as shipping or trucking) may also be appropriate. For example, in the absence of a UK-wide network of CO_2 transportation pipelines, it may be more economical to transport any CO_2 captured in the south of the UK and destined for storage in geological formations in the North Sea by ship than by building a dedicated pipeline.

Moreover, the use of pipelines for mass transportation of CO_2 would require a dramatic expansion of existing pipeline networks. An estimated 40 million tonnes of CO_2 is captured and stored annually today,*[12]* compared with projections by the International Energy Agency that climate change abatement scenarios would require up to 1.6 billion tonnes (Gt) of CO_2 annually to be safely transported and stored underground from 2030, rising to 7.6 to 10 Gt of CO_2 annually from 2050.*[13]* Such vast volumes of CO_2 would require, in the case of the high-end estimate of 10 Gt of CO_2 annually, the construction of over 200,000 kilometres of pipelines,*[14]* significantly increasing the demand for carbon steel (the primary material used in constructing CO_2 transportation pipelines today).*[15]*

Pipelines also suffer from potential corrosion risk, because CO_2 dissolves in water to form carbonic acid, which is highly corrosive for carbon steel. Corrosion risk is increased by variables such as the presence of other chemicals or impurities, the composition of the carbon steel material, as well as conditions associated with the source of the CO_2. Flue gas, for example, which would be the source of CO_2 in post-combustion carbon capture processes, can introduce contaminants such as sulphur dioxide and nitrogen dioxide, which increase corrosion risk. The Gorgon LNG Project in Western Australia is a prominent example of CO_2's corrosive nature. The $54 billion project includes a significant carbon capture and storage element, and water entering the pipeline that injected the CO_2 underground resulted in corrosion that required equipment to be replaced, contributing to the three-year delay to the facility's operations.*[16]*

To mitigate this corrosion risk, pipelines for CO_2 transport need to operate at higher pressure, while requiring low levels of impurities,*[17]* in contrast to natural gas pipelines. Further, when variables such as impurities cannot be controlled, there may be a need to consider constructing pipelines from corrosion-resistant alloys, which can increase the cost of construction.*[18]*

The role of project finance

As with the CCS technologies themselves, financing of projects with a CCS element is not new. There is, however, an increasing focus on, and significance of, CCS to businesses in the context of the evolving regulatory and commercial landscape of the energy transition. The foundation for any successful project financing is appropriate mitigation and allocation of risk and that is no different with CCS projects.

For each category of CCS project, the mitigation and allocation of risk will be different, and will also change over time as the technologies mature. For example:

- **CCS as a key element of a project:** Mitigating environmental risks and pollution are not new to the project financing world. For example, the Equator Principles, which include various requirements in relation to environmental and social impact assessment and mitigation, apply to the vast majority of projects financed by westerns banks and institutions in recent years. However, the implementation of a material CCS element in a project has the potential to raise additional challenges. This is especially so where emission mitigation involves an absolute contractual or regulatory obligation (for example, a condition of the environmental or other permits granted to the project) to either capture a specified quantity of CO_2 from the project or not emit more than a specified quantity of CO_2. Given the nascent nature of CCS technology, lenders may require an enhanced diligence process in order to get comfortable with the risk of the proposed CCS technology not being able to meet those targets. Accordingly, detailed negotiations are likely to take place between the lenders, sponsors and contractors/providers of the CCS technology regarding the appropriate allocation of risk if the project fails to meet its targets. While projects that fail to fully discharge their CCS obligations are likely to still be able to generate revenues and repay their debts, lenders may also be concerned with the potential reputational harm of being associated with a project that fails to meet its environmental obligations and are likely to impose strict requirements regarding these matters.

- **Retrofit projects:** Unlike new projects, retrofit projects are less likely to involve concerns of reputational harm if the CCS technology does not fully meet expectations, since they would be acting to reduce existing emissions. However, the revenues of such projects are likely to be fully (or at least largely) tied to the CO_2 that is captured by the project. For example, in absence of additional government grants or incentives (which many jurisdictions are considering, but few have implemented), any revenues are likely to be based on the carbon credits generated and/or related savings received by the retrofit CCS project or underlying infrastructure (e.g., a gas-fired power plant) as a result of the CCS technology. A key concern will therefore be whether the technology proves sufficiently successful to capture the necessary quantity of CO_2, as well as the price or cost of those emissions to the project had they not been abated. In many cases, there would be reasonable expectation on the owner of the underlying infrastructure (to which the CCS technology is retrofitted) to assume some of the risks associated with the retrofit project and to help ensure a steady flow of revenue to service the project's debt.

- **CCS networks and hubs:** CCS networks and hubs are very appealing for the future of CCS because they can capitalise on economies of scale and support a wide array of CCS activities. However, in the early days of the development of CCS networks and hubs, the structure of any project financing is likely to be heavily reliant on the applicable regulatory regime and government incentives or strong commitments from "anchor" users of these networks and hubs. This issue is not unique to the CCS industry as, historically, government support and direct investment have been pivotal in de-risking and initiating infrastructure-heavy industries such as rail, telecommunications and electricity generation and distribution.[19] The historic experience of these industries will be instructive in guiding project finance structuring in the CCS sector as support regimes are rolled out across various jurisdictions.

- **Project-on-project risk:** Where a CSS project requires the use of a facility or infrastructure that does not yet exist, any project financing will have to address the inherent project-on-project risk. For example, a CCS retrofit project on a gas-fired power plant may require the use of a CCS hub that is under development at the same time for the transport and/or storage of the captured emissions. If the CCS retrofit project is complete before the CCS hub is ready to receive the emissions, the CCS retrofit project will not be able to operate and generate revenues in the absence of an operational CCS hub. Addressing this risk may be difficult as the sponsors of the CCS retrofit project will be reluctant to assume the risk of delays to the CCS hub and the sponsors of the CCS hub will equally be reluctant to assume additional liabilities to future users (in this case the CCS retrofit project) resulting from delays to the CCS hub. In order to avoid a 'chicken and egg'-type situation, Governments may need to step in and guarantee or assume a degree of such project-on-project risk to mitigate some of the key perceived risks in order to accelerate the development of CCS projects, networks and hubs.

In conclusion, existing CCS technologies appear very promising in emissions reduction and abatement, and can therefore play an important role in the energy transition and combating climate change. Project finance has a critical role to play in accelerating the deployment of those CCS technologies, particularly upon effectively addressing the key challenges of minimising technology risk and allocating the residual technology risk appropriately between the project participants. Government support and the underlying regulatory landscape, in contributing to addressing the key associated risks and challenges, will have a significant impact on the incentivisation of future project financings in relation to CCS technologies and how they are structured.

Footnotes

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