White Paper

Carbon Capture, Use and Storage (CCUS)

Opportunities and Implications for the AIEN

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INTRODUCTION

In the 1700's Voltaire famously coined the phrase "Perfect is the enemy of the Good", which reflects the sentiments that go back centuries, such as "Better a diamond with a flaw than a pebble without one." Whatever the provenance of the saying, carbon capture, use and storage, or CCUS, has sparked debate, most recently at the COP 28 gathering in the UAE, about whether carbon capture and storage technology, in association with fossil fuel development, is an appropriate means to achieving "net zero".

While carbon removal, or "net negative" technologies that rely on CCUS, such as Direct Air Capture (DAC) are also under development, at the moment these are at an earlier stage in their evolution, and at much higher cost compared to the abatement of CO2 allied to fossil fuel usage. However, they remain a potentially important future development as costs reduce and carbon pricing mechanisms evolve.

The Association of International Energy Negotiators, AIEN, is no stranger to the trade offs and compromises that have to be made in seeking ways to provide the global economy with energy sources that address today's trilemma of *sustainability, security* and *affordability*. As the nascent CCUS industry emerges from the world of academic research and pilot scale testing and embarks on a process of growth and industrialization, AIEN can apply its decades long experience in commercialization of energy concepts to good effect.

Some of the most notable advantages of CCUS as a carbon mitigation technology rely on the century or more of developments in oil and gas. Expertise in engineering and technology, understanding of complex geological structures and well completion techniques, safe and reliable operation of complex and potentially hazardous processes, and cost-effective supply chain management are all essential elements of successful CCUS deployment.

Furthermore, as the world counts the cost of zero carbon energy solutions, and the implications for developing economies, affordability plays a significant part in determining a suitable compromise between expensive but fully sustainable energy sources, and those that are cost effective and deliverable with today's technology. CCUS is one of the few avenues along the path to net zero that can claim to be both cost effective, at least for certain industrial and power generation applications, and without significant technology risk.

Aside from the more philosophical arguments for and against CCUS as a climate solution, its significance in CO2 management in the medium term appears assured. In fact, most of the models cited in the Intergovernmental Panel on Climate Change's Fifth Assessment Report[1] required CCUS for the goal of staying within 2 degrees Celsius of warming from pre-industrial days. As time progresses and developments on carbon free energy alternatives appears to be slower than planned, the role of CCUS as a mitigation tool appears likely to grow.

In fact, with 32 Mtpa CO2 in construction, 280 Mtpa CO2 in development and a total project pipeline capacity of 361 Mtpa CO2 (November 2023[2]), it is clear that pragmatism and need are driving the CCUS industry forward. There is an immediate need for commercial and contractual

[1] https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_full.pdf

[2] https://www.globalccsinstitute.com/wp-content/uploads/2023/11/GSR23-Executive-Summary_PDF.pdf

mechanisms, regulatory and policy approaches and mechanisms for financing and enabling. This is where the AIEN's decades of experience can pay dividends for this emerging industry.

What is CCUS?

Carbon Capture, Use and Storage (CCUS) covers a host of technologies which together create a pathway to capture CO2, for example from an industrial process or power generation plant, and either use it in a way that keeps the CO2 from being emitted into the atmosphere, or enables it to be sequestered in geological formations deep underground, where it will be permanently stored.

While uses of CO2 in the food industry and other non-energy sectors are growing, the main use of captured CO2 to date is for enhanced oil recovery (EOR). This is where the CO2 is used as a way to flood an oil-bearing reservoir both to pressurize and improve flow characteristics and has been an established way to improve the economics of oil production for many decades. While the vast majority of the CO2 remains trapped underground, CO2 for EOR technology has been criticized due to the oil production increases that it can facilitate, and the carbon emissions associated with them. The counter argument is that geological permanent sequestration of CO2, typically in a deep saline aquifer or in a depleted gas reservoir, provides for carbon removal, thereby reducing the carbon intensity of energy production using fossil fuels such as coal, oil or natural gas.

Permanent sequestration of CO2 also plays a role in other technologies unrelated to fossil fuels, such as those involving Direct Air Capture, where air is processed using complex solvents and heat exchangers such that CO2 is removed and then injected into storage. Another emerging technology which, like DAC, is a "carbon negative" solution that removes the amount of CO2 in the atmosphere, as opposed to simply neutralizing it, is the use of biofuels for power generation. Bioenergy with Carbon Capture and Storage, or BECCS, is similar to the use of CCUS alongside coal or gas fired power generation, but since the fuel is carbon neutral, the overall effect is one of net carbon removal.

In addition to carbon capture alongside a conventional power generation cycle, such as the use of steam or gas turbines with carbon removal process plants treating the exhaust gases, there are other ways to decarbonize the use of natural gas. These include pre-combustion CO2 separation, whereby an air separation plant carries out CO2 removal, and oxygen is combined with natural gas to produce pure water and high-pressure CO2 which can be more easily and cost effectively stored. Furthermore, gas reforming plants, such as Steam Methane Reforming (SMR) or Auto-Thermal Reforming (ATR) can be used to manufacture hydrogen, which can further be processed into ammonia for easier long-distance transportation.

Why CCUS?

Every day, we see reports in the media about various renewable technologies, sustainable fuels, and in particular, the considerable benefits of a hydrogen economy, based on green hydrogen that originates from electrolysers powered by renewable power sources. For many sectors, such as transport which accounts for about one fifth or all CO2 emissions, this form of liquid fuel offers flexibility and a zero-carbon footprint.

For the power sector, renewable sources such as wind and solar can provide cost competitive sources of generation, but when grid stability and intermittency are taken into account, today's battery technology is not yet at a stage of maturity or cost effectiveness to provide a solution. Often, gas turbines have to be used to ensure uninterrupted power supplies, and the additional capital burden needed to do this is passed on to the consumer. Fossil fuels continue, therefore, to be required to maintain stable and cost-effective energy supply across the globe.

For CCUS, therefore, providing a low carbon source of energy at a cost that compares favourably with true zero carbon technologies is the compromise that is offered. The key features that support this proposition are as follows:

- Considerable low-cost fossil fuel resources, especially natural gas, are available globally and some of these exist in countries which could benefit economically from resource development.
- Carbon capture process technology is well proven, and while there are potential improvements under development, performance, costs and design basis can all be assessed with confidence.
- The engineering and execution of CCUS projects relies heavily on the proven core skills of the oil and gas industry, thus enabling cost competitive and on-time project development.
- The supply chain involved in CCUS, including processing plant, pipelines, compressors and well drilling and completion are already in existence and can be leveraged for this new segment of the energy industry.
- Finally, and of significance to the AIEN is that the contractual frameworks involved in CCUS contain strong similarities to oil and gas, including framework agreements along the following lines:
    - Joint Venture Agreements
    - Gas transportation / pipeline tariff agreements
    - Marine transportation / ship charters
    - Pore space lease agreement
    - EPC agreement / operating agreement
    - Financing agreements
    - Sequestration services agreement / CO_2 offtake agreement (containing many similar provisions to e.g. an LNG Sale and Purchase Agreement)

CCUS Funding Models

With these complex regulatory mechanisms emerging, funding models for CCUS typically involve one or more of five mechanisms:

1. A direct capital subsidy, which reduces the capital burden on the developer, but still leaves development risk and cost escalation, and can take time to negotiate, for example with government agencies.
2. A tariff subsidy which can reduce the risk/cost of financing for a project but does not address development and cost uncertainties.
3. A preferential loan, which can reduce project WACC and provides some mitigation around development and capex risk but can take time to negotiate and manage.
4. Government equity investment including an IRR threshold mechanism, which has the advantages of limiting the downside risk for project sponsors and providing a mechanism for government to share in upside, but can set up a conflict of interest between regulatory agencies and the project.

Examples of all 4 of these mechanisms exist within the emerging CCUS industry as governments and stakeholders seek to establish an investment framework that results in cost effective project selection and FID. These mechanisms translate into a range of business models which are further described below.

CCUS Business Model

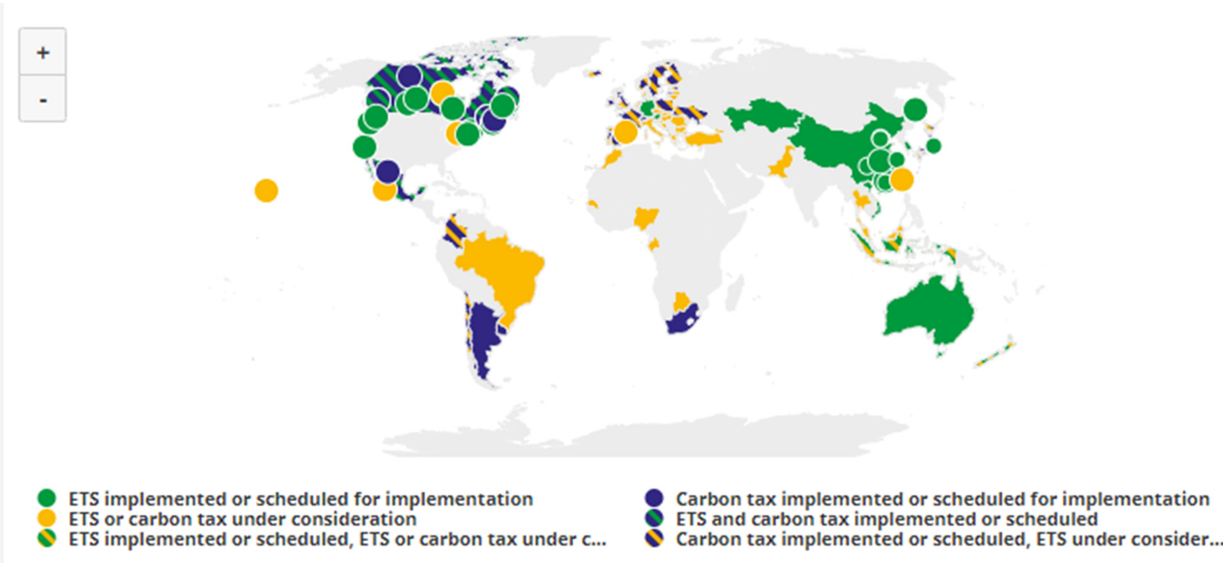
Setting aside EOR, which can result in an economic value placed on injected CO_2 linked with the incremental oil produced, captured CO_2 has limited commercial value as a commodity. Instead, the value that is derived from carbon capture is the result of regulatory constructs that allow an emitter to capture monetary value to recover the costs of installing and operating capture equipment and pay for storage.

This can be created in a number of ways, but the key driver for the majority of CCUS projects arises from:

- A carbon tax, imposed on the emitter, which results in a financial incentive, by way of tax avoidance, for the emitter
- A "cap and trade" market-based mechanism which places limits on the amounts of CO_2 that can be emitted, either through a national or regional scheme, and requires the purchase of "credits" for emitters who would otherwise exceed the cap.
- A tax credit, which can be in the form of an investment tax credit (ITC) or a production tax credit (PTC).
- A subsidy or grant intended to fully or partially compensate the emitter for installing appropriate carbon capture systems. This can be on a $/tonne basis, or an agreed capital amount, or a combination.

The mechanisms above are typically part of what is termed the "compliance" carbon market, where a legislated mechanism for carbon management has been established. The areas of the world where an ETS or carbon tax exists, or is being introduced or contemplated, is shown below[3]:

Figure 1 Summary map of regional, national and sub-national carbon pricing initiatives



There is another mechanism which can also create potential revenue from carbon capture, which is usually termed the "voluntary" carbon market or VCM, whereby a party wishing to offset their carbon emissions can contract with a party able to capture CO_2, for example through CCUS. To date, CCUS projects have not typically been able to benefit from the VCM, where most of the so-called "offsets" arise from nature-based projects such as afforestation. However, a protocol is under development to enable CCUS to participate in the VCM, which may make it possible for CCUS projects in countries outside the compliance mechanisms, to benefit from revenues to support carbon capture projects.

The most noteworthy of these mechanisms, in the context of CCUS, are the provisions of the 45Q tax credits operated by the Inland Revenue Service (IRS) [4]an agency of the US federal government. 45Q credits are a flat rate tax credit, which can sometimes be treated as a tax refund, even if the entity responsible does not have taxable revenues to offset. The level of tax credit available was increased as part of the so-called

[3] https://carbonpricingdashboard.worldbank.org/
[4] https://home.treasury.gov/news/press-releases/jy1830

Inflation Reduction Act, in October 2022. With a tax credit[5] of $60/tonne for EOR, $85/tonne for geologically sequestered CO_2 from an industrial process and up to $180/tonne for direct air capture, permanently sequestered, these levels of financial incentive have spurred dozens of carbon capture related project in the US. In particular, Texas and Louisiana are the focus for much of this activity, as the regional geology is well suited to CO_2 storage in deep aquifers, but other parts of the US, particularly where ethanol production from biomass is widespread, are also benefitting.

The frameworks being used to incentivize CCUS investment in Europe typically have a greater degree of government involvement, including, in some cases the sharing of investment costs and therefore risk. For example, in the case of the UK, the government has developed a regulatory framework approach to CCUS that governs the CCUS network and users separately and has introduced different business model arrangements for the different emitters (e.g. industry, waste-to-energy, power sector). The emitters are selected through a competitive tender and granted a contract. For instance, the contract for the industrial sector is referred to as the Industrial Capture Contract (ICC). The contract runs for a period of 10 years with the option for up to five one-year extensions. It provides emitters with subsidies in the form of capital grants from the Carbon Capture and Storage Infrastructure Fund and ongoing revenue support scheme with payment covering the CAPEX (including a return), OPEX, T&S fees. The revenue stream is based on the price difference between a reference price (based on the UK-ETS) and a strike price (the cost of abatement). Through these contracts, emitters are also protected against some cross-chain risks.

The transport and storage segment is regulated separately and is funded through the Transport & Storage Regulatory Investment (TRI) business model. The business model establishes an economic regulatory regime (ERR) linked to a user-pays revenue model plus a government support package (GSP) and mandates open access networks. Under this business model, a private company is established (the T&S company or T&SCO) which will be responsible for construction, financing, operation, maintenance, and decommissioning of the T&S network. Within the context of the ERR, the regulator, who in this case is Ofgem, provides a license to the T&SCO based on key parameters including allowed revenue. The users of the network will pay fees for T&SCO, and through these fees, the company will recover its allowed revenues. The T&S fees will be set by a methodology that allows the company to recover its costs plus an allowed return. A Government Support Package (GSP) is in place to protect the company from some events, such as CO_2 leakage, if commercial insurance schemes are not available.

The UK has a target to capture and store 20-30 mtpa of CO_2 (including removals) by 2030 and following a 'cluster sequence' approach. Hynet and East Coast clusters were selected for initial government support (Track 1) and planned to enter operation by the mid-2020s, with two further clusters selected, Acorn and Viking as Track 2, due to come online by 2030. The North Sea Transition Authority (NSTA) regulates the CO_2 storage licensing rounds. In September 2023, it awarded 21 licences to 14 companies in the UK's first ever carbon storage licensing round

In Denmark, the approach is different with the state being a co-investor in the project. What is fascinating to note about Denmark is that pre-2020, injection of CO_2 into the Danish subsoil was prohibited under legislation, and all previous attempts at launching CCUS had been publicly opposed. The change happened in 2020 when the Danish government passed the Danish Climate Agreement for Energy and Industry, committing

[5] The tax credit requires a range of conditions to be met, applies only to projects commencing operations within a certain period, and continues for a limited time period, currently 12 years.

the country to a 70% reduction in GHG emissions relative to 1990 levels by 2030. The agreement acknowledged CCUS as a critical component to achieve the target and a CCUS target was set at 4-9 mtpa of CO_2 storage by 2030. In addition, the Danish government has allocated over €3 billion of support to projects across the CCUS value chain. Danish CCUS projects are also eligible to apply for funding from the EU Innovation Fund, which aims to allocate over €38 billion towards low-carbon technologies by 2030. The state company Nordsøfonden will have a 20% interest in all future CO_2 storage licences. The state will receive a share of future profits and also invest in the project (sharing the risk) with investors.

Since then, a series of successive changes to update the country's subsoil and marine laws have taken place. In January 2022, the Danish Marine Act was amended to exclude geological storage of CO_2 under the seabed from the prohibition and carriage of materials and substances for dumping. In October 2022, a bilateral agreement was signed under the London Protocol between Belgium and Denmark, which allowed for cross-border transportation of CO_2 between the two countries. In January 2023, the EU commission approved a €1.1 billion Danish scheme to support the role out of CCS technologies.

The staggering and rapid change in Denmark's CCUS journey culminated in the initiation of CO_2 injection at the Project Greensand pilot in March 2023. This was the first cross-border CO_2 to be stored in the North Sea, and the first CO_2 to be stored in a depleted North Sea reservoir. The Greensand pilot received funding of 197 million DKK (€26 million) from the Danish Energy Agency.

In Denmark, storage licences are obtained by applying to the Danish Energy Agency (DEA), including a technical description of the proposed storage project, an environmental impact assessment, and a financial plan. The DEA reviews the application and makes a recommendation to the Ministry of Climate, Energy and Utilities, who then decide whether to grant the license or not.

Norway's approach to CCUS is also through government participation in the project. The country has a relatively long history with CCUS where the Sleipner project has been in operation since 1996, followed by Snohvit in 2008 and CO_2 Test Center (TCM) opening in 2012. As such, Norway has over 28 years of operational CCUS experience with around 22 million tonnes of CO_2 stored so far. There is high-level and consistent political support for policies that have helped achieve this. This began with legislating a carbon tax in 1991, which effectively led to the Sleipner and Snohvit CCUS projects. The tax currently sits at NOK 952/tonne (US$91). Proposals are in place for it to rise steadily, reaching NOK 2000/tonne (US$220) by 2030. The tax applies to EU Emissions Trading System and non-EU ETS emissions. The government also established Gassnova, a state entity responsible for all CO_2 activities in Norway.

In addition, regulations for transport and storage of CO_2 are mature and have been in place since 2014. Following completion of CO_2 injection, the storage licence will be transferred to the state government no less than 20 years later. The operator will be liable for funding 30 years of MMV costs post-closure. This must be paid into a fund upfront.

The Northern Lights is a CCUS project that has passed FID and is under construction. It is a partnership between Equinor (majority owned by the Norwegian government), Shell and Total, and will be the first ever cross-border, open-source CO_2 transport and storage infrastructure network, offering companies across Europe the opportunity to store their CO_2 under the Norwegian seabed. It consists of two dedicated CO_2 carriers and will ship captured CO_2 to an onshore terminal on the Norwegian west coast and, from there, transport it by pipeline to an offshore subsurface storage location in the North Sea. Phase one of the project will be completed mid-2024 with a capacity of up to 1.5 mtpa of CO_2. The ambition is to expand capacity by an additional 3.5 mtpa, to a total of 5 mtpa, dependent on market demand. The onshore receiving terminal will need to be expanded, while the pipeline to the offshore subsurface storage location can already accommodate the additional volumes. Both phases will offer flexibility to receive CO_2 from European sources

Northern Lights was a first of a kind full chain CCUS commercial project based on industrial emissions. In the absence of a market for CCUS, the project required a public-private partnership to kickstart the industry in order to assist and bridge the financing gap. Also posing a challenge was the use of phases. It was difficult for the project to get commitment from industrial emitters to build capture plants without having storage, but the project required commitment from emitters to justify building the storage. State support was therefore critical during the market development phase. The Norwegian government provided funding of US$1.8 billion, covering 80%[6] of the Northern Lights' cost.

While Asia is still looking at a range of regulatory structures, Indonesia became one of the first countries in the Asia-Pacific region to introduce regulations on CCUS, when it issued MEMR Regulation 2/2023 in March 2023. The regulation aims to support upstream oil and gas activities and help decarbonise the extraction industry in Indonesia, on top of being a step towards Indonesia's net-zero emissions target by 2060. The regulation sets out ways that carbon can be captured, how carbon is to be used (including EOR), how carbon is to be stored in accordance with various technologies, and how carbon is to be transported. Even before the processes can begin, interested parties must seek approval from MEMR, which will then evaluate whether the proposed CCUS activities take into account the technical, economical, operational, environment and safety considerations.

CCUS activities can be monetised by carbon trading in accordance with the applicable laws and/or through reimbursement of operational costs. For carbon emissions not from upstream oil and gas activities, CCS facilities can profit from storage services. Following these rules, Indonesia is also looking at introducing a "cap and trade" and a "cap and tax" mechanism, along with tax incentives. Indonesia's state-owned Pertamina has signed preliminary agreements with ExxonMobil and Chevron to develop its own CCUS hubs, which will rely heavily on the new regulation to proceed smoothly.

In Malaysia, the government has acknowledged the critical importance of CCUS in delivering significant emission cuts in fossil fuel-based emissions. It has partnered with the Global CCS Institute to develop and implement the Malaysian CCS Capacity Development Program.

The Malaysian government has said they would always support any initiative that can reduce carbon emissions to become a carbon-neutral nation as early as 2050. The Budget 2023 proposes new tax incentives for companies working on CCUS activities as a new source of economic growth and in achieving net-zero greenhouse gas emission. Currently, CCUS projects in Malaysia will be regulated using the existing national legislation. Malaysia is also developing a carbon pricing mechanism, but has no carbon price yet.

[6] https://ccushub.ogci.com/focus_hubs/northern-lights/

In addition, Petronas recently signed a Memorandum of Cooperation (MoC) with Japan's Ministry of Economy, Trade and Industry (METI) and Japan Organization for Metals and Energy Security (JOGMEC) to strengthen collaboration on cross-border CO_2 transportation from business to business for CCUS projects.

Malaysia's Petronas took FID to develop the Kasawari CCS project off the coast of Sarawak, Malaysia, in November 2022. The facility will be able to capture around 3.3 mtpa of CO_2. The other project in development is also offshore, where the operator will be Thailand's PTT Exploration and Production Public (PTTEP). This will capture CO_2 from the Lang Lebah field, offshore Sarawak, and then transport it to the Golok field. The company hopes to reach FID this year and start commercial production in 2026. State-owned Petroleum Sarawak Bhd (Petros) has also received their first licence for carbon storage to begin its strategic role as resource manager for CCUS in Sarawak.

China's CCUS projects are state-led and controlled through the multitude of state-owned companies. For example, the first integrated 1 mtpa Qilu Petrochemical - Shengli Oilfield CCUS Project came into operation in 2022. Furthermore, Baogang Steel Group plans to build an integrated 2 mtpa scale CCUS demonstration project for the steel industry, and a first phase of the 500,000 tpa demonstration project has already started construction. Meanwhile, CNOOC, Guangdong Development and Reform Commission, Shell China and ExxonMobil China signed an MoU to jointly study a large-scale CCUS hub in Daya Bay. However, the development of CCUS in China still faces challenges such as the lack of market mechanism or sufficient policy incentives.

Since the introduction of China's "1+N" policy system for emission peaking and carbon neutrality, more CCUS-related policies have been released. By May 2023, China had issued about 80 CCUS-related policies at the national level, including plans, standards, roadmaps, and technology catalogues accumulatively. CCUS has been included for the first time in China's national Five-Year Plan (2021-2025).

In general, the current policies issued for CCUS are at the guidance stage, with the aim of setting out initial incentives. There is currently no specific legislation to regulate in detail the access, construction, operation, regulation and termination of CCUS. China has also implemented its own ETS in 2021 and is the world's largest in terms of covered emissions, however, the carbon price is set at only \$8/tCO_2e.

At this stage in the evolution of the CCUS sector, considerable variations exist in the extent to which the regulatory and economic conditions exist to facilitate or encourage investments.

In Japan, the Japanese Government "set a goal in 2020 to achieve zero greenhouse gas emissions for realizing carbon neutrality by 2050, and in 2021 declared that it aims to reduce greenhouse gas emissions by 46% compared to FY2013 by FY2030. In addition, in the 'Basic Policy for Realization of GX' the Japanese Government states that it will support advanced projects that would become role models for developing the business environment toward the start of CCS."[7] Japan's CCS policy is further underpinned by the Government's "Japan's CCS Long Term Roadmap" for developing the said business environment to achieve "operation ready" status for several commercial scale "Advanced CCS

[7] JOGMEC (2023) "First Step to Launch Japanese CCS Project - JOGMEC selected 7 projects, starting CO2 storage by FY2030." Available at https://www.jogmec.go.jp/english/news/release/news_10_00036.html

Projects" for a total CCS capacity of 6-12 mtpa by 2030, and to further enable the delivery of 6-12 mtpa of CCS capacity annually to hit its 2050 target of 120-240 MTPA[8]. In 2023, JOGMEC announced its "selection of 7 role model projects (5 for domestic storage and 2 for overseas storage) for Japanese Advanced CCS Projects. JOGMEC provides (funding) support (to these 7 role model projects) for the first time in Japan toward the initiation of CCS that is to capture and store CO_2 underground[9]" for delivering on the "Japan's CCS Long Term Roadmap."

The CCUS Value Chain

For most carbon capture applications, the emissions arise from an industrial process such as gas processing, power generation, or some other sort of petrochemical or industrial plant. The appropriate form of carbon capture process is highly varied and depends largely on both the CO_2 concentration and its pressure. In general, high pressure, high concentration CO_2, such as one might find in the sort of natural gas processing plant that sits within an LNG liquefaction plant, represents an ideal source of CO_2 which requires minimal additional treatment prior to transport and storage. Conversely, gas fired power generation, or cogeneration facilities that might be found in a refinery represent low pressure, low concentration applications that require considerable additional treatment and compression. Examples of carbon capture candidates, and where they sit in the purity/pressure hierarchy are shown below:

Figure 2 Carbon Capture candidates sorted by purity and pressure characteristics

	High Pressure	High Purity	Dilute	Very Dilute	Extremely Dilute
CO_2 Concentration	Variable	40-100%	10-25%	3-8%	0.04-1%
Sources	Gas processing Synthesis gas	Ethanol Ammonia Ethylene Oxide Hydrogen	Coal Cement Crackers Steel & Iron	Gas Turbines Furnaces	Confined Spaces Air

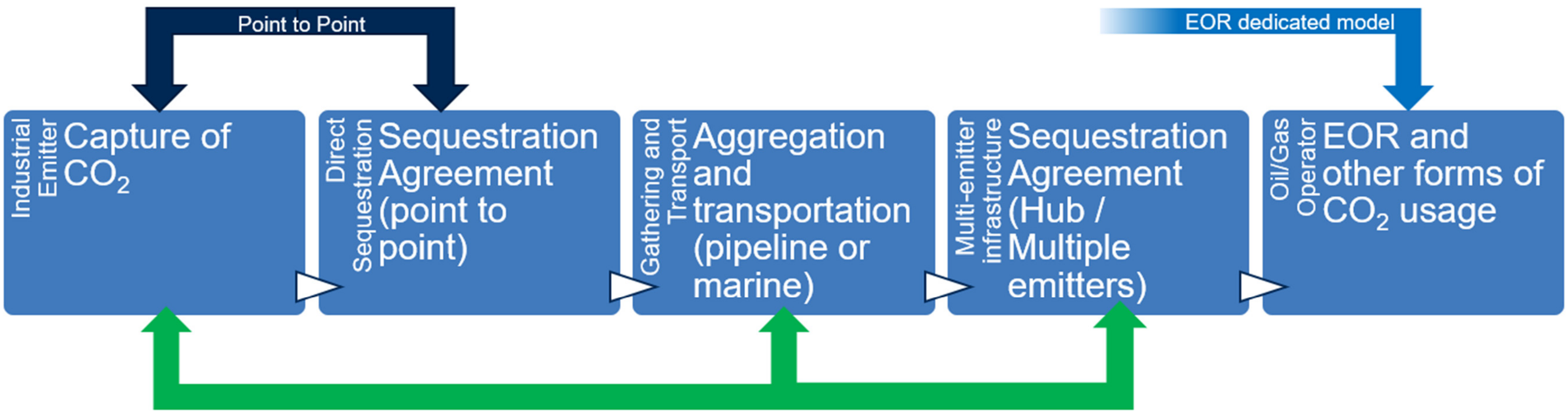
[8] METI (2022) "Japan's CCUS policy" presentation at GCCI's Japan CCS forum 2022, pg 14. Available at https://jp.globalccsinstitute.com/japan-ccs-forum_en/

[9] JOGMEC (2023) "First Step to Launch Japanese CCS Project - JOGMEC selected 7 projects, starting CO2 storage by FY2030." Available at https://www.jogmec.go.jp/english/news/release/news_10_00036.html

Due to the unique characteristics of each carbon capture candidate plant, a generic carbon capture offering by a company specializing in this type of plant has yet to emerge. The effect a carbon capture plant has on its host can be wide ranging in terms of efficiency, reliability, availability and maintenance requirements and as such, few large industrial or power entities are ready to outsource these services. As a result, carbon capture design, construction and operation are typically handled by the owners of the emitting plant, such as an LNG facility or a power station.

However, the remaining features of the value chain, including aggregation, transport, compression, injection and storage are such that dedicated entities are emerging which are focused on carrying out these tasks efficiently, and profitably.

CO_2 Value Chain – Alternative Concepts



A number of different models are being applied to CCUS, which are summarized graphically above. These comprise, in general, the following approaches:

1 Point to Point

A single emitter teams up with a single sequestration agent, typically close to the emitting source, and contracts to take the CO_2 emissions from the emitter and sequester them usually through permanent geological storage.

Key Characteristics

- Limited development and coordination risks
- In general emitter, transport and capture single owner, operator
- Bespoke T&S infrastructure with limited flexibility for expansion of T&S
- In general 'First of a Kind' projects to prove concept with capture ready emitter
- Direct government subsidy of project (in many cases) to bridge funding gap

Examples

Project name	Country
Gorgon CCS	Australia
Illinois Industrial Carbon Capture and Storage (IL)	United States
Qatar LNG	Qatar
Quest (ALB)	Canada
Sleipner	Norway
Snohvit CO_2 capture and storage	Norway

2 National CO_2 T&S Cluster (Government sponsor)

A number of CO_2 emitters contract with a sequestration agent to take and store CO_2 emissions. The transportation element of the chain can be handled by the same entity as the storage operator, or a different entity that contracts only to take the CO_2 from the emissions source to the storage location, including compression of the CO_2 up to super-critical pressures if required. In the case of large-scale aggregation coupled with marine transport to a storage location, the T&S agent is typically different to the storage entity.

Key Characteristics

- Significant coordination risk, from commercial and financing complexity of multiple emitters
- Transport and storage regulated to avoid monopolization of infrastructure and overcharging for CO_2 disposal services, inherent flexibility for expansion

- Direct government subsidy of emitter CAPEX to bridge investment case for capture plant and OPEX to bridge funding for T&S charges
- Government subsidy or equity investment in T&S infrastructure to reduce capital burden or share project risk
- Government may take equity in return for capital contribution in T&S infrastructure to gain insight and control of development.
- T&S agreement negotiated between operator and each individual emitter

Examples

Project name	Country
Aramis CCS phase 1	Netherlands
Errai storage project	Norway
L10 CCS	Netherlands
Northern Lights Phase 1	Norway
Northern Lights Phase 2	Norway
Porthos phase 1	Netherlands
Project Greensand phase 1	Denmark

3 Open Market CO_2 T&S Utility

Currently almost exclusively focused on the US, the commercial model, typically supported by 45Q tax credits, is run as a typical energy infrastructure project, with aggregated emitters paying a tariff for a service which typically includes the T&S hub taking on title and all risks and liabilities associated with the CO_2 as soon as it enters the transmission system allied to the sequestration asset or assets.

Key Characteristics

- Significant coordination risk, from commercial and financing complexity of multiple emitters
- Emitter negotiates with Storage operator for T&S services
- Storage owner operator negotiates transportation agreement with pipeline operator
- Limited Government subsidy of infrastructure
- Subsidy provided to emitter via tax credit and dispersed to storage and transportation entities via T&S tariff

- T&S infrastructure regulated for environmental compliance, but owner, operators have full commercial freedom to offer assets or capacity as required
- Potential for monopolization of existing pipeline or corridors

Examples

Project name	Country
Midwest Carbon Express (NE, SD, ND, MI, IA)	United States
Denbury Ascension Parish sequestration (LA)	United States
ExxonMobil Vermilion parish storage (LA)	United States
Central Louisiana Regional Carbon Storage (CENLA) Hub (LA)	United States
Gulf Coast Sequestration Hub Lake Charles (LA)	United States

Risks and Opportunities along the CCUS Value Chain

Each segment of the CCUS value chain (carbon capture, transportation, and storage) carries key risks and opportunities which have to be addressed through suitable risk allocation to parties best positioned to manage the risks, contractual arrangements to clarify the terms and conditions of the risk allocation agreed among the parties across the value chain, and risk mitigations and remedies to be addressed by the parties who will manage the risks. While each project is unique, key risks that tend to me common among all projects are summarised below.

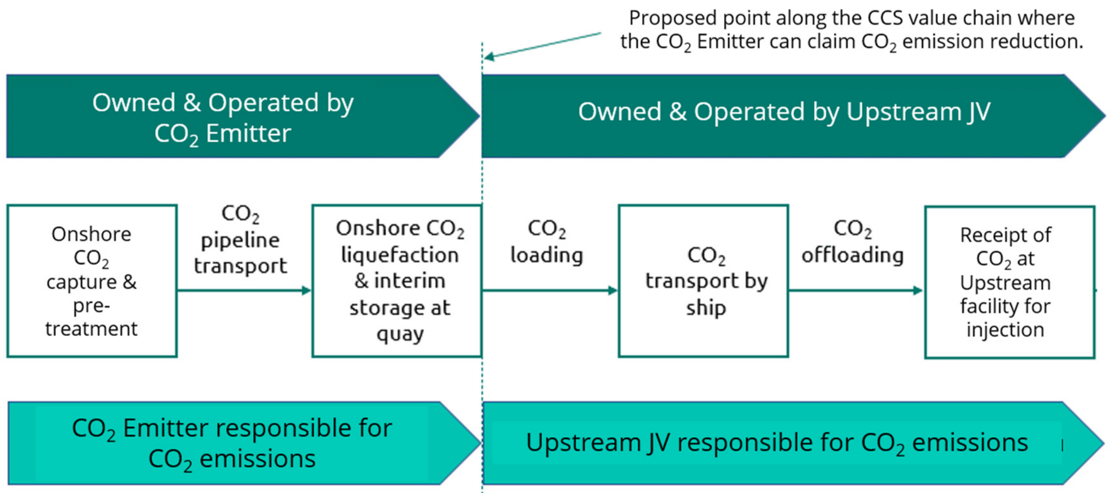
Key Risks and Opportunities		Description
Risks	**Cost / Schedule Overrun and Performance Risks**	• Risk of overrun of EPC schedule and/or cost • Risk of achieving guaranteed performance threshold within the warranty period from EPC handover • Risk of achieving guaranteed performance threshold (post warranty period)
	Delivery / Offtake Risks	• Risk of fulfilling annual CCS volume • Risk of meeting agreed CO_2 specification
	Asset Damage / Loss Risks	• Risks of asset damage or loss due to Force Majeure (FM) event during EPC ad operation • Risks of asset damage or loss due to non- FM event during EPC ad operation
	Payment Risks	• Failure of counterparties to pay agreed fees • Failure of carbon credits to be obtained for conducting CCS (where relevant)
	CO_2 Price Risk	Risk of carbon credit market price fluctuation relative to CCS price
	Environmental Liabilities	Remediation & 3rd party liability obligation for CO_2 leakage / release
	Decommissioning Liabilities	Obligation to decommission facilities after completion of operation
	Long Term Sequestration Liability	• Obligation to monitor and ensure sequestration after completion of operation • Risk for being able to transfer long term liability to government
Opportunities	**Under-run of EPC Schedule and/or Cost**	Opportunity of under-run of EPC schedule and/or cost
	Excess CCS Volume / Capacity	Availability to manage more CCS volume relative to annual contract volume
	CO_2 Price Upside	Opportunity of CCS price relative to carbon credit market price
	Residual Value of Facilities After Initial Contract Duration	Opportunity to extend CCS duration post initial contract duration, leveraging amortised facilities

Systematic Project Risks and Opportunities Allocation (Example)

As a project evolves and the Front-End Loading (FEL) stages are completed, a sufficiently well defined set of CO_2 handing requirements, technical features, and responsibilities along the value chain are defined, a commercial framework can be developed. Depending on the project, different entities or corporate bodies are likely to be accountable for carrying out certain tasks, ranging from capturing the CO_2, moving it, and sequestering it. Equally, other interfaces will start to be defined, such as the Engineering Procurement and Construction (EPC) arrangements, where such things as technical performance guarantees, volumetric specifications, and reliability will be relevant.

As with any major project, a framework of contractual mechanisms will evolve which assign risk to a potentially large number of different entities involved in some aspect of the CCUS operation. The commercial arrangement set out below is one such summary and is shown by way of an example of how a CCUS project can be structured. The example below involves the following commercial arrangement, noting that this example is a ship transportation based CCS project:

- CO_2 Emitter enters into a CO_2 Offtake Agreement with the Upstream JV, under which the ownership of CO_2 and the associated legal responsibility of CO_2 emission will transfer from the CO_2 Emitter to the Upstream JV. CO_2 Emitter is assumed to be the attributable party for carbon credits.
- Upstream JV is the titleholder of CO_2 storage acreage, owns the upstream facilities and wells to sequestrate CO_2, and enters into a CO_2 Ship lease arrangement with the CO_2 Ship JV (owner of the CO_2 Ship) for transportation.
- This commercial arrangement is subject to confirmation of compatibility with the jurisdiction(s) that the CCS project will be situated.



Based on the commercial arrangement as outlined above, the matrix below summarises an example of how the key risks can be allocated among the parties across the value chain (noting the following terms used to represent each party across the value chain).

- CO_2 Emitter - The supplier of CO_2 to the CCS ship transportation based CCS project.
- CO_2 Ship JV - The entity that owns the CO_2 ship.
- Upstream JV - The entity that owns the upstream facilities and wells to sequestrate CO_2, and is titleholder of CO_2 storage acreage.
- CO_2 Ship EPC Contractor - The entity that EPCs the CO_2 ship.
- Upstream EPC Contractor(s) - The entity that EPCs the upstream facilities and D&Cs the wells.
- CO_2 Ship O&M Provider - The entity that provides O&M services for the CO_2 ship.
- Upstream O&M Provider(s) - The entity that provides O&M services for the upstream facilities and the wells.

		CO2 Emitter	CO2 Ship JV	Upstream JV	CO2 Ship EPC Contractor	Upstream EPC Contractor(s)	CO2 Ship O&M Provider	Upstream O&M Provider(s)	Notes
Cost / Schedule Overrun and Performance Risks	Overrun of EPC schedule and/or cost	Ultimate risk owner for CO2 capture scope	Ultimate risk owner for CO2 Ship scope	Ultimate risk owner for upstream scope	Risk owner for CO2 Ship scope	Risk owner for upstream scope	n/a	n/a	Subject to negotiation of liability cap. Compensation mechanism for schedule and/or cost impact that affects the operation start of the integrated CCS project needs consideration.
	Facility fails to meet guaranteed performance threshold within the warranty period from EPC handover						n/a	n/a	
	Facilities fails to meet guaranteed performance threshold (post warranty period)				n/a	n/a	Potential risk owner for CO2 Ship scope	Potential risk owner for upstream scope	Risk Ownership depends on the cause of failure
Delivery / Offtake Risks	Failure to deliver annual CO2 volume	Risk owner to deliver to CO2 Ship scope	Risk owner to deliver CO2 to upstream scope	Risk owner post receipt from CO2 ship	n/a	n/a	n/a	n/a	Supply or pay provisions to be negotiated
	Failure to deliver CO2 within agreed entry specification				n/a	n/a	n/a	n/a	Provisions of off-spec CO2 and compensation mechanism to be negotiated
Asset Damage / Loss Risks	Force Majeure (FM) event causing asset damage or loss during EPC	Ultimate risk owner for CO2 capture & liquefaction scope	Ultimate risk owner for CO2 ship scope	Ultimate risk owner for upstream scope	n/a	n/a	n/a	n/a	Risk Owner to enter into suitable CAR insurance and comprehensive general liability insurance
	FM event causing asset damage or loss during operations				n/a	n/a	n/a	n/a	Risk Owner for bank debt repayment obligations Risk Owner to enter into suitable insurance
	Non-FM event causing asset damage or loss during EPC				Potential risk owner for CO2 Ship scope	Potential risk owner for upstream scope	n/a	n/a	Risk Ownership depends on the cause of failure. Risk Owner to enter into suitable CAR insurance and comprehensive general liability insurance
	Non-FM event causing asset damage or loss during Operations				n/a	n/a	Potential risk owner for CO2 Ship scope	Potential risk owner for upstream scope	Risk Ownership depends on the cause of failure. Risk Owner to enter into suitable insurance
Payment Risks	Failure to pay fees	n/a	Risk owner to receive fee for CO2 ship scope	Risk owner to receive fee for CO2 offtake	n/a	n/a	n/a	n/a	
	Failure of carbon credits to be obtained for conducting CCS	Risk Owner	n/a	n/a	n/a	n/a	n/a	n/a	Assumes that carbon credits (for net CO2 emission reduced from CCS) resides with CO2 emitter, which is subject to negotiation.
Environmental Liabilities	Remediation & 3rd party liability obligation for CO2 leakage / release	Ultimate risk owner until CO2 delivered to CO2 Ship scope	Ultimate risk owner until CO2 delivered to upstream scope	Ultimate risk owner post receipt from CO2 ship	n/a	n/a	Potential risk owner for CO2 Ship scope	Potential risk owner for upstream scope	Risk Ownership depends on the cause of failure. Risk Owner to enter into suitable insurance for remediation & 3rd party liability obligations
Decom m	Decommissioning obligation	Risk owner for CO2 capture scope	Risk owner for CO2 ship scope	Risk owner for upstream scope	n/a	n/a	n/a	n/a	
Opportunities	Under-run of EPC schedule and/or cost	n/a	n/a	n/a	Beneficiary for CO2 Ship scope	Beneficiary for upstream scope	n/a	n/a	
	Excess CO2 offtake volumes	Beneficiary	Beneficiary	Beneficiary	n/a	n/a	Beneficiary	Beneficiary	Ensure that contractual incentives are in place to align the interest of the Parties
	CO2 price upside	Beneficiary	n/a	Beneficiary	n/a	n/a	n/a	n/a	Assumes that carbon credits (for net CO2 emission reduced from CCS) resides with CO2 emitter, which is subject to negotiation. Beneficiary of this opportunity also subject to price mechanism of CO2 offtake.
	Residual value of the facilities after initial contract duration	n/a	Beneficiary for CO2 Ship scope	Beneficiary for upstream scope	n/a	n/a	n/a	n/a	

As mentioned in the section "Why CCUS," the key risks and opportunities highlighted above are similar to those that are addressed for oil and gas projects. The table below outlines an example of the framework agreements that can be used to clarify the terms and conditions of the risk allocation agreed among the parties across the value chain (as per the matrix above).

		CO2 Emitter	CO2 Ship JV	Upstream JV	CO2 Ship EPC Contractor	Upstream EPC Contractor(s)	CO2 Ship O&M Provider	Upstream O&M Provider(s)	Notes
Agreements and Contracting Parties	CO2 Offtake Agreement	Contracting Party	-	Contracting Paty	-	-	-	-	CO2 for offtake assumed to be pre-treated & liquefied. Delivery point of CO2 assumed to be at the jetty where the CO2 ships are loaded.
	CO2 Ship Lease Agreement	-	Contracting Party	Contracting Party	-	-	-	-	Assumed that the Upstream JV is the leasee of CO2 ship, based on the CO2 delivery point being at the jetty.
	Construction Tie-In Agreement	Contracting Party	Contracting Party	Contracting Party	-	-	-	-	Need to agree compensation mechanism for scenario when EPC delay of a certain CCS scope affects operation start of the integrated CCS project
	CO2 Ship EPC Agreement	-	Contracting Party	-	Contracting Party	-	-	-	
	Upstream EPC Agreement	-	-	Contracting Party	-	Contracting Party	-	-	
	CO2 Ship O&M Agreement	-	Contracting Party	-	-	-	Contracting Party	-	
	Upstream O&M Agreement	-	-	Contracting Party	-	-	-	Contracting Party	

how the key risks can be allocated among the parties across the value chain (noting the following terms used to represent each party across the value chain).

Summary and Conclusions

The emerging CCUS industry is based on a fundamentally different form of revenue generation, compared with the more traditional oil and gas industry which involves selling a commodity at a price based largely on global supply and demand. As such, the investment case for CCUS currently relies almost entirely on regulatory and policy measures which are quite diverse and variable. Furthermore, while most of the projects in the US are largely commercially driven based on anticipated tax credits which create a revenue model, in the rest of the world there is often a much greater government involvement, through subsidies and/or equity participation in a project.

However, at the heart of all these models lies the offtake or sequestration services agreement, which governs the terms under which captured CO_2 is processed, moved, and place into permanent storage (or potentially put to an alternative use based on removing the CO_2 from the ecosystem). An agreement of this type has many similarities with those already well adapted for the oil and gas industry. The similarities with the LNG industry, with its focus on revenue assurance through take or pay mechanisms, and the commodity obligations that each counterparty (seller or buyer) undertakes, with the corresponding credit and financial support. For CCUS, take or pay is substituted by a "send or pay" arrangement, and it is the emitter who undertakes to supply a minimum quantity of CO_2 and the sequestration entity who undertakes to take delivery and sequester the CO_2 appropriately.

As with the gas industry, larger scale projects or hubs, of the sort that are emerging in both the US and Europe, also involve significant transportation infrastructure, with strong similarities to natural gas pipeline arrangements. Increasingly, this extends to the growing role of marine transportation of CO_2, particularly in Asia, where an analogy can be drawn to the well-established LNG marine sector, involving a series of agreements from charter arrangements, to scheduling loading and unloading, and transfer of title and responsibility.

Finally, as the CO_2 reaches its destination, typically in a depleted reservoir or saline aquifer, there are parallels with how mineral rights, pore space access, and ownership are handled, which provides for another family of existing agreements that can be modified for CO_2 use.

As the AIEN approaches the next phase of its work in model contract development for CCUS, the findings above will be used to selectively rank the existing range of model contracts, identify those with (a) a high relevance and applicability for CCS and (b) relatively simple requirements for adaptation, and a list of model agreements for amendment will be identified and pursued.

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