



Market Models for CCUS/CDR - A Global Screening

Technical Report 2025-06
September 2025

IEAGHG

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Leading the way to net zero with advanced CCS research. IEAGHG are at the forefront of cutting-edge carbon, capture and storage (CCS) research. We advance technology that reduces carbon emissions and accelerates the deployment of CCS projects by improving processes, reducing costs, and overcoming barriers. Our authoritative research is peer-reviewed and widely used by governments and industry worldwide. As CCS technology specialists, we regularly input to organisations such as the IPCC and UNFCCC, contributing to the global net-zero transition.

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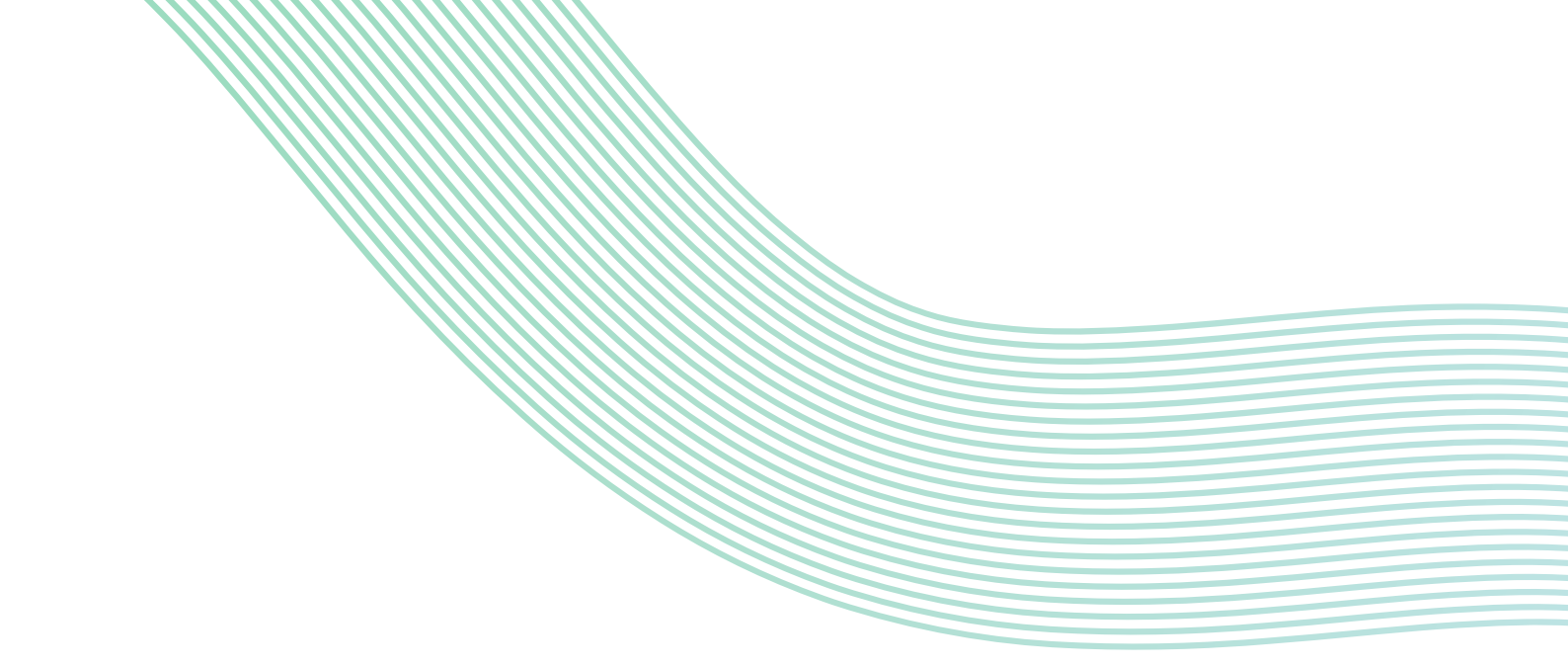
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CONTACT DETAILS

Tel:	+44 (0) 1242 802911	Address:	IEAGHG, Pure Offices,
E-mail:	mail@ieaghg.org		Cheltenham Office Park, Hatherley Lane,
Internet:	www.ieaghg.org		Cheltenham, GL51 6SH, UK



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- Silvian Baltac
- Amelia Mitchell
- Hannah Galbraith-Olive

To ensure the quality and technical integrity of the research undertaken by IEAGHG each study is managed by an appointed IEAGHG manager. The report is also reviewed by a panel of independent technical experts before its release.

The IEAGHG manager for this report was Jasmin Kemper and the expert reviewers were:

- Cameron Henderson (UK DESNZ)
- Carl Greenfield (IEA)
- Carly Leighton (UK DESNZ)
- Catriona Reynolds (Drax)
- Chris Manson-Whitton (Progressive Energy)
- Gunter Siddiqi (Conim)
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- Joel Flitton (Aker Carbon Capture)
- Jonathan Lindsell (UK DESNZ)
- Mathilde Fajardy (IEA)
- Paulien Veen (Perspectives Climate)
- Richard Deutsch (UK DESNZ)
- Sarju Patel (UK DESNZ)



Report Overview:

Market models for CCUS/CDR – A global screening

Introduction

This report provides a key pillar to interested parties including policy makers, regulators, and the technical carbon capture, utilisation and storage (CCUS) / carbon dioxide removal (CDR) community on potential successful market strategies, including their pros and cons and their suitability for different economic and political realities, which may lead to the fast development of an efficient, safe, and accepted CCUS/CDR market sector.

Key Messages

- The potential market strategies identified in this report offer a roadmap for accelerating CCUS/CDR deployment.
- These market strategies can be used by CCUS/CDR project developers as well as policymakers, trade bodies and other interested parties, to support rapid deployment of CCUS/CDR technologies.
- Adopting flexible ownership models, ensuring stable revenue mechanisms, and securing sustainable capital financing, can all drive the deployment of CCUS/CDR technologies and facilitating the roll-out of infrastructure.

- However, market strategies will vary depending on the sector (e.g. industry, power) and region so market strategies must be adaptable to address the unique economic, regulatory, and technological contexts of different markets.
- Collaboration among governments, industry leaders, and investors will be essential in overcoming challenges and driving widespread deployment of CCUS/CDR infrastructure to achieve net zero emissions.

Scope

The goal of the study is to globally screen and describe current (and planned) market models for CCUS/CDR considering the variable economic and political contexts of different countries. The study considers regulatory frameworks, policies and incentives across the world and identify how these have assisted with the process chain development.

These market models are also compared to market models in other fields that have proven to be successful in the past. The outcome of the study is a suite of best-practices and a presentation of potential successful future market order strategies, including their pros and cons (and their suitability for different economic and political realities), which may lead to the fast development of an efficient, safe, and accepted CCUS/CDR market sector. This is a necessary development to help reach the goals of the Paris Agreement.

The scope of the study consists of the following tasks:

1. Background
2. Literature review
 - a. Screening of current CCUS/CDR market models and designs, including but not limited to the following criteria:
 - i. Geographic location (incl. cross-border transport)
 - ii. Project type (e.g. full chain, part chain)
 - iii. Ownership (e.g. public (federal/national/decentralised), private, public-private-partnership (PPP))
 - iv. Source of funding (e.g. grants, loans, tax credits, public procurement, emissions trading system (ETS), contract for difference (CfD), voluntary carbon market (VCM))
 - v. Source and fate of the CO₂
 - vi. Risk management approach
 - b. Screening of future/proposed market models and designs
 - c. Analogous market models
 - d. Comparison with analogous market models, including lessons learnt that are transferable to CCUS/CDR market models

3. Survey of industry stakeholders on current and future/proposed CCUS/CDR market models and designs
4. Best practices for CCUS/CDR market models
5. Outlook on potential future market strategies
6. Recommendations/Gap analysis

IEAGHG commissioned ERM, UK, to undertake the assessment according to the above scope.

Conclusions

This study identified potential market strategies from undertaking analysis on operational and planned CCUS/CDR projects, analogous markets and engaging with stakeholders working in the CCUS/CDR space. In this study, a market model is defined as the combination of policies, regulatory frameworks, revenue generation methods and the business case that underpin a CCUS/CDR project, and CDR was limited to CCUS-enabled CDR, i.e. biomass with CCS (BECCS) and direct air capture with CCS (DACCS).

A screening of 12 operational and 14 planned CCUS/CDR projects was undertaken to analyze their supporting market model and identify similarities and differences between projects.

Five analogous markets (waste generation, renewable electricity, low-carbon fuels, liquefied natural gas (LNG) transport, and hydrogen) were investigated for similarities/differences between these markets and the CCUS/CDR market.

17 CCUS/CDR industry stakeholders joined 4 workshops in July 2024 to discuss best practices for the CCUS/CDR market based on their own market experiences.

Insights from each of these sources were divided into potential market strategies which relate to (i) ownership structure of a CCUS/CDR project, (ii) revenue generation opportunities available for the project and (iii) capital financing sources which can be leveraged to cover initial upfront costs of undertaking a CCUS/CDR project.

There are a wide variety of potential market strategies which could help the CCUS/CDR market to develop to the scales required to meet net zero.

Future market strategies associated with the ownership of different parts of the CCUS/CDR value chain include having different owners for the operational and construction phases of a CCUS/CDR project, government coordination of part-chain ownership structures, standardisation of CO₂ transport infrastructure, partnering with entities with pre-existing expertise (or those offering CCS-as-a-service) as well as flexibility in CCS incentives to allow for a range of emerging ownership structures.

Potential market strategies to generate revenue from CCUS/CDR projects include robust, traceable low-carbon certification, defining clear market segments on mandated markets, enabling the evolution of government revenue support through time as well as implementation of regulations to drive a compliance market for CDR projects, which are likely to become increasingly important in the future, especially as current demand in the voluntary carbon markets (VCM) is limited to a few off-takers, potentially limiting CDR scale up.

Targeting capital financing sources appropriate for the CCUS/CDR project, obtaining stable revenue generation, using buffer pools to reduce investment risk and using revenue support schemes rather than public grants to raise capital finance are potential market strategies associated with raising capital financing.

Best practices associated with these potential market strategies are likely to vary in different regions, sectors and different market maturities.

Some potential market strategies identified in this report are likely to be most effective in the scale-up phase of the CCUS/CDR market (e.g. government coordination of part-chain ownership structures, robust traceable certification), whereas other market strategies identified may endure in a widespread CCUS/CDR market (e.g. standardisation of CO₂ transport infrastructure, regulations to support the compliance market).

Deployment of carbon capture is likely to vary between sectors due to differences in existing expertise between sectors and in costs of capture due to variations in CO₂ purities in different sectors.

Governance structures are likely to impact the deployment of potential market strategies through differing revenue incentives for CCUS/CDRs and differing levels of ownership and coordination of CCUS/CDR projects.

Expert Review

Ten experts were invited to review the draft report, of which eight agreed and provided comments within the deadline. Most comments were minor, requiring simple responses, clarifications and/or additions. The more substantive comments included:

- The need to more clearly define a market model, how this differs from the current carbon markets and the differences in driving forces between CCS and CDR projects.
- The need to highlight parallels between the waste management analogous market and the CCUS/CDR market as a “waste disposal service” in terms of how revenue can be generated.

- Case studies for the ownership structure market strategy on different owners for development, construction and operational project phases were not directed towards different market phases.
- Suggestion to include reference to government procurement mandates as a key driver of green premiums for low-carbon products. This would also require robust tracking systems for the carbon intensity (CI) of those products.
- Highlighting the need of integration of CDR into compliance markets, including reference to mechanisms on how this might be carried out (e.g., EU CRCF).

All the above have been addressed in the final version of the report.

Recommendations

- The potential market strategies identified in this report can be used by CCUS/CDR project developers as well as policymakers, trade bodies and other interested parties, to support rapid deployment of CCUS/CDR technologies.
- Future work could include the following:
 - Evaluation of liberalised carbon market designs;
 - Investigating the implementation of different CCUS/CDR deployment rates in market models;
 - Evaluating how additionality, permanence, leakage, and baselines are dealt with;
 - Analysing what implications system security and stability have for market models;
 - Extend the CDR project base to include non-CCUS methods;
 - Periodic re-screening to see which market models are being used, how they have evolved and what further changes might be needed.



Market Models for CCUS/CDR - A Global Screening

Final Report

PREPARED FOR



DATE
7th February 2025

For more information, please contact:

Silvian.Baltac@erm.com



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Authors

This report has been prepared by ERM.

As the largest global pure play sustainability consultancy, ERM partners with the world's leading organizations, creating innovative solutions to sustainability challenges, and unlocking commercial opportunities that meet the needs of today while preserving opportunity for future generations.



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The authors of this report sit within ERM's Sustainable Energy Solutions team which provides a wide range of services in industrial decarbonisation, including a profound understanding of techno-economic drivers of CCUS/CDR adoption. Close collaboration with a wide range of industrial sites on their decarbonisation strategies has given ERM invaluable insight into the drivers and barriers to CCUS/CDR uptake in heavy industry.

This report was authored by:

Silvian Baltac	Partner
Amelia Mitchell	Managing Consultant
Hannah Galbraith-Olive	Consultant

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Disclaimer

This final report was developed for the IEAGHG. The conclusions and recommendations do not necessarily represent the view of the IEAGHG. Whilst every effort has been made to ensure the accuracy of this report, neither the IEAGHG nor ERM warrant its accuracy or will, regardless of its or their negligence, assume liability for any foreseeable or unforeseeable use made of this report which liability is hereby excluded.

EXECUTIVE SUMMARY

Scaling Carbon Capture, Utilisation and Storage (CCUS) and CCS-enabled Carbon Dioxide Removal (CDR) technologies is key to achieving global net zero goals.¹ This is because CCUS and CCS-enabled CDR (CCUS/CDR) projects will play a critical role in deep decarbonisation across multiple hard-to-abate sectors. These types of projects can help to reduce emissions in industries like power generation, cement, steel, and hydrogen production, necessary to meet Paris Agreement targets.^{2,3}

Currently CCUS/CDR deployment remains limited, often reliant on proactive policies and incentives such as the USA's 45Q tax credit⁴; the UK's CCS Business Models⁵ and the Netherlands's SDE++⁶. However, scaling CCUS/CDR deployment to reach net zero is likely to require robust market models that can facilitate investment, ensure stable revenue generation, and align with regulatory frameworks.

The objectives of this study were to explore potential market strategies for scaling CCUS/CDR infrastructure deployment by:

- Globally screening and describing market models for operational and planned CCUS/CDR projects with reference to their supporting market model and how this varies based on geographic location, project type, ownership structure, source of funding, source and fate of the CO₂, to provide an evidence-based approach how these projects have developed.
- Comparing these market models to analogous markets (e.g., waste management, electricity) that have proven successful in the past, drawing on lessons learnt that are transferable to evaluate their adaptability to the CCUS/CDR projects.
- Surveying stakeholders working in the CCUS/CDR sector on current and future CCUS/CDR market models and designs.
- Providing a presentation of potential successful market strategies, including their pros and cons, which may lead to the fast development of an efficient, safe, and accepted CCUS/CDR market sector.

Methodology

This study drew insights from:

- **Operational and planned projects** - A screening of 12 operational and 14 planned CCUS/CDR projects was undertaken to analyze their supporting market model and identify similarities and differences between projects.
- **Analogous market models** - Five analogous markets (waste management, renewable electricity, low-carbon fuels, Liquefied Natural Gas (LNG) transport and

¹ In this study, carbon dioxide removal (CDR) projects are limited specifically to bioenergy with CCS (BECCS) and direct air carbon capture and storage (DACCS).

² [How can carbon capture help us meet climate change goals? | World Economic Forum](#)

³ <https://research.american.edu/carbonremoval/2022/04/04/ipcc-wgiii-report-affirms-the-necessity-for-cdr-to-meet-goals-of-the-paris-agreement/>

⁴ [The Tax Credit for Carbon Sequestration \(Section 45Q\)](#)

⁵ [Carbon capture, usage and storage \(CCUS\): business models - GOV.UK](#)

⁶ [Stimulation of sustainable energy production and climate transition \(SDE++\) | RVO.nl](#)

low-carbon hydrogen) were investigated for similarities/differences between these markets and the CCUS/CDR market.

- **Stakeholder Engagement** – IEAGHG and ERM hosted 4 international roundtables in July 2024, with 17 leading experts across the CCUS/CDR value chain to gather stakeholder views based on their own experiences.

Key insights were drawn from the evidence gathered and for each of these, learnings were drawn in terms of three key components of a CCUS/CDR market model:

- **Ownership Structure** - who owns the CCUS/CDR infrastructure and the relationship of that owner with the rest of the value chain (e.g., full-chain ownership or part-chain ownership).
- **Revenue Generation** - method by which income can be generated by a CCUS/CDR project. An effective CCUS/CDR revenue generation model will provide a value proposition that incentivizes low-carbon production methods and ensures that low-carbon products are competitive alongside carbon-intensive products.
- **Capital Financing** - source of the money needed to fund the development, construction and operation of assets and infrastructure required for a CCUS/CDR project (e.g., capture plant facilities, CO₂ pipelines) as well as any external support that a project can get for capital funding.

These insights were then used to develop potential market strategies for ownership structure, revenue generation and capital financing of CCUS/CDR market models. These are summarized below.

Many of the potential market strategies investigated in this report are likely to evolve through time as the CCUS/CDR market matures from the current small-scale, nascent market to widespread CCUS/CDR deployment needed to reach net zero. The tables below also detail how these market strategies are likely to evolve from these first-of-a-kind (FOAK) to nth-of-a-kind (NOAK) projects.

However, the evolution of these market strategies is likely to significantly depend on the location and the sector of the CCUS/CDR project, as well as the maturity of the CCUS/CDR market. Not all market strategies identified will be suitable for every situation as regional and sectoral differences are likely to impact how suitable a potential market strategy will be.

Ownership Structure Market Strategies

Successful market models require robust ownership structures in terms of both, who owns the CCUS/CDR infrastructure (entity ownership), and the relationship of the entity owner with the rest of the value chain (value chain ownership). Potential market strategies, the barriers they are designed to overcome and their evolution from first-of-a-kind (FOAK) to nth-of-a-kind (NOAK) are outlined in the table below.

Potential market strategy	Barrier which the market strategy is designed to overcome	Description of the market strategy	Current development stage*	Evolution from FOAK to NOAK projects
Regulating CO₂ pipeline infrastructure	Potential monopolization of pipeline infrastructure (in places where this is a risk)	By unbundling services, mandating open access, and regulating rates, regulations are likely to be able to foster a competitive CO ₂ transport market.	Current practice	Regulation of CO ₂ pipeline infrastructure is likely to remain a best practice for NOAK projects except in regions (e.g., US Gulf Coast) where multiple and competing CO ₂ pipelines may develop in parallel.
Clear contractual arrangements for commercial risk allocation	High commercial risks associated with undertaking a full-value chain CCUS/CDR project (e.g., long-term storage liabilities)	Clear contractual arrangements are needed to reduce commercial risks to entities which are not directly responsible for specific risks. These entities may be willing to take on these commercial risks if its within their control and they know how to quantify and mitigate it and can price it into their risk/reward assessment.	Current practice	Contractual arrangements may become more standardized from FOAK to NOAK projects.
Different owners for development, construction and operational project phases	Different expertise, risk appetites and expected return on investment between different phases of the project	A change in ownership can be beneficial in terms of different expertise required, risk appetites and expected return on investment between different phases of the project	Emerging practice	Transfer of ownership is likely to become increasingly commonplace as entities develop specific skills or decide their strategic interests lie in or out of the CCUS/CDR space.

Government coordination of part-chain ownership structures	The “chicken-and-egg” problem in first-of-a-kind (FOAK) projects due to the interdependency of the capture, transport and storage components of the value chain.	Governments (local, regional or national) can take on an orchestrating role in developing CCUS/CDR value chains, as they are in a unique position to provide central oversight, long-term planning, and integration with national/regional development goals to the development of a CCUS/CDR project.	Emerging practice	Likely to become less significant for NOAK projects as multiple configurations for the CCUS/CDR value chain reduce the risk associated with the “chicken-and-egg” problem. Also, may be less common in jurisdictions such as the US where a lot of the CCUS/CDR projects are commercially driven.
Partnering with entities with pre-existing expertise	Limited expertise in deploying CCUS/CDR-like infrastructure in certain sectors	Collaboration with entities with pre-existing expertise (e.g., from the oil and gas sector), could leverage previous learnings from similar projects and therefore, should reduce both deployment and operational risks.	Emerging practice	Partnering with existing entities is likely to become more prevalent in NOAK projects as certain entities refine their CCUS/CDR expertise.
Capture-as-a-service solutions	High CAPEX associated with deploying a full-value chain CCUS/CDR project	Carbon capture provided as-a-service can offer flexibility and scalability, whilst also potentially providing standardized systems that can be easily upgraded or expanded as technology improves or as carbon capture needs increase. This should improve the economic viability of undertaking carbon capture for some emitters.	Emerging practice	Capture-as-a-service solutions are likely to become increasingly widespread in a mature CCUS/CDR market to enable the flexibility to respond to market conditions.

Flexibility in government incentives to allow a range of emerging ownership structures	Design of CCUS/CDR incentives that dictate a certain ownership structure	Flexibility in government incentives is likely to be important to allow a range of emerging ownership structures to evolve.	Emerging practice	Government incentives are likely to become increasingly flexible to enable a widespread, market-driven CCUS/CDR market.
Standardization of CO₂ transport and storage infrastructure	Captured CO ₂ with certain technical specifications can only be stored in certain CO ₂ storage sites	By developing clear standardisation of requirements for transportation and storage (e.g., CO ₂ purity requirements), flexible CO ₂ transportation infrastructure using multiple modes (e.g., pipelines, shipping and trucking) can be developed.	Future strategy	Standardisation is likely to become increasingly important for NOAK projects to allow flexibility in transport and storage options.

*Current practice = some operational CCUS/CDR projects screened are currently employing this market strategy; Emerging practice = some planned CCUS/CDR projects screened are currently employing this market strategy; Future strategy = no operational/planned projects screened are currently employing this market strategy, but it could potentially be significant in the future.

Revenue Generation Market Strategies

Revenue generation refers to the method by which income can be generated by a CCUS/CDR project. Ensuring financial viability and certainty is critical for achieving final investment decisions and scaling-up CCUS/CDR infrastructure deployment.

Potential market strategy	Barrier which the market strategy is designed to overcome	Description of the market strategy	Current development stage*	Evolution from FOAK to NOAK projects
Implementation of regulations to drive a compliance market for CDR projects	The current demand for CDR credits on the Voluntary Carbon Market (VCM) is limited to just a few offtakers (e.g., Shell, Microsoft), meaning revenue generation from CDR projects may face problems with scaling-up.	Implementing regulations can encourage the creation of compliance markets, and therefore increased demand for CDR credits, by establishing clear regulatory frameworks that incentivize or require entities to decarbonise. Therefore, compliance markets are likely to become increasingly important in driving revenue generation, particularly for DACCS and BECCS projects, as entities seek to purchase CDR credits.	Emerging practice	Compliance markets are likely to become increasingly important to sustain a widespread CCUS/CDR market.
Defining clear market segments to implement mandated markets	Implementing a mandated market on a dispersed market segment is likely to be difficult due to the wide range of players in complex product value chains.	It could be beneficial for the CCUS/CDR market to define low-carbon mandated markets only on specific products. By defining a specific mandated market on a clear market segment, this could drive the development of fully decarbonised products.	Emerging practice	Mandated markets are likely to become less important in NOAK projects as most products available to buy are decarbonised.

Evolution of government revenue support through time	Different amounts of revenue support will be needed as the market evolves from first-of-a-kind (FOAK) to n th -of-a-kind (NOAK) projects	As the CCUS/CDR market grows, government revenue support should transition from direct subsidies to long-term market-driven incentives.	Future strategy	Government revenue support is likely to evolve through time as the market matures as CCUS/CDR projects become increasingly commercially feasible.
Robust, traceable certification to enable green premiums	Conscious consumers are not willing to pay a green premium if they are not certain a product is decarbonised	Revenue could be generated by charging a green premium on the low-carbon product to a conscious consumer (e.g., through government procurement mandates). However, a system needs to be devised to track the carbon intensity of the product through (often very complex) value chains. Transparent certification that can follow the product/material along the value chain can help to prove that the product is decarbonised to the consumer.	Future strategy	Low-carbon certification will likely become increasingly important in enabling green premiums to be charged.

*Current practice = some operational CCUS/CDR projects screened are currently employing this market strategy; Emerging practice = some planned CCUS/CDR projects screened are currently employing this market strategy; Future strategy = no operational/planned projects screened are currently employing this market strategy, but it could potentially be significant in the future.

Capital Financing Market Strategies

Securing investment is a major challenge for CCUS/CDR. Capital financing refers to process of obtaining money from investors and lenders to meet the CCUS/CDR project's needs.

Potential market strategy	Barrier which the market strategy is designed to overcome	Description of the market strategy	Current development stage*	Evolution from FOAK to NOAK projects
Targeting capital financing sources appropriate for the CCUS/CDR project	CCUS/CDR projects are often currently a high-risk, low-return investment opportunity, which can hinder the range of investors willing to supply capital to these projects	It is likely to be important for a CCUS/CDR project to use an appropriate source of capital depending on the project's specifics, including its size, location, and stage of development. For instance, early-stage or innovative projects/technologies might benefit more from government grants or venture capital, while large-scale, established projects might find corporate investment or debt financing more suitable. However, this assumes that capital exists in the market and that investors are willing to deploy it for CCS. Other market strategies discussed in this report, such as enabling stable revenue generation, will also shift the type of capital required for the projects.	Current practice	Appropriate capital financing will remain important for NOAK projects. Specialised CCUS/CDR financiers may emerge in the long-term.

Using collaborative funding pots to reduce financial risk	Risks associated with a CCUS/CDR project underperforming and/or failing can deter investors	Buffer pools, or other multi-stakeholder financing structures, can be used as an insurance mechanism to safeguard against financial risks associated with underperformance or failure of a CCUS/CDR project.	Current practice	Buffer pools and other risk management techniques are likely to remain important, even in a widespread CCUS/CDR market, to mitigate against technological risks.
Using revenue support schemes rather than public grants to raise capital finance	Uncertainty in expected rate of return may limit the willingness of private investors to provide capital	To attract private investors to CCUS/CDR projects, having government incentives that support a guaranteed revenue generation is likely to be more effective in raising private capital than a public grant.	Current practice	Public grants and government subsidies are very unlikely to scale to support a widespread CCUS/CDR market. Other revenue incentives are more likely to be widespread for NOAK projects.
Obtaining stable revenue generation	Unclear expected rate of return on investments (e.g., due to volatility in costs, energy prices, carbon prices) means investors may not be willing to invest	If the CCUS/CDR project can provide certainty to investors on the potential for stable, long-term revenue generation, then this is likely to encourage investment from a wider range of sources.	Emerging practice	Stability of revenue generation is likely to remain important even in a widespread CCUS/CDR market to leverage a wide range of capital funding sources.

*Current practice = some operational CCUS/CDR projects screened are currently employing this market strategy; Emerging practice = some planned CCUS/CDR projects screened are currently employing this market strategy; Future strategy = no operational/planned projects screened are currently employing this market strategy, but it could potentially be significant in the future.

Conclusions

- The potential market strategies identified in this report offer a roadmap for accelerating CCUS/CDR deployment.
- These market strategies can be used by CCUS/CDR project developers as well as policymakers, trade bodies and other interested parties, to support rapid deployment of CCUS/CDR technologies.
- Adopting flexible ownership models, ensuring stable revenue mechanisms, and securing sustainable capital financing, can all drive the deployment of CCUS/CDR technologies and facilitating the roll-out of infrastructure.
- However, market strategies will vary depending on the sector (e.g., industry, power) and region so market strategies must be adaptable to address the unique economic, regulatory, and technological contexts of different markets.
- Collaboration among governments, industry leaders, and investors will be essential in overcoming challenges and driving widespread deployment of CCUS/CDR infrastructure to achieve net zero emissions.

1. BACKGROUND TO THE PROJECT

Deploying carbon capture, utilisation and storage (CCUS) and CCS-enabled carbon dioxide removal⁷ (CDR) projects is a key lever that entities (e.g., industrial sites, governments) will likely use to realize their greenhouse gas (GHG) reduction targets and ensure the global aims of the Paris Agreement are met.^{8,9}

These types of projects should enable decarbonisation across multiple sectors such as power generation, energy intensive industries (e.g., cement, iron and steel etc.) as well as the production of clean hydrogen.¹⁰ The ramp up required in both CCUS for hard-to-abate fossil and process emissions, as well as CDR projects involving CCS, such as bioenergy with CCS (BECCS) and direct air carbon capture with CO₂ storage (DACCS), requires new infrastructure for CO₂ transport and storage (CO₂ T&S) at regional, national and international level (i.e., cross-border transport).¹¹

However, to date, climate-targeted CCUS/CDR deployment globally is limited.¹² CCUS/CDR projects that have already been developed have often benefited from proactive policy, regulation or incentives. Supportive policies and linked incentives such as the USA's 45Q¹³ and Inflation Reduction Act (IRA)¹⁴; the development of UK's CCS Business Models¹⁵; the Netherlands' SDE++¹⁶; and others, have been crucial for infrastructure deployment to date.

Accelerating deployment of CCUS/CDR projects to achieve the Paris Agreement goals will require a massive ramp-up in scale.¹⁷ Key to this is governments, industry, and stakeholders collaborating to further develop broad-scale market models which ensure the financial viability of projects deploying CCUS/CDR technologies, in terms of securing revenue streams that underpin commercially viable projects and providing returns to shareholders, whilst navigating any imposed regulatory frameworks and policies.¹⁸

As such, the objectives of this study were to:

- Globally screen and describe market models for operational and planned CCUS/CDR projects with reference to their supporting market model and how this varies based on geographic location, project type, ownership structure, source of funding, source and fate of the CO₂, to provide an evidence-based approach how these projects have developed.

⁷ In this study, carbon dioxide removal (CDR) projects are limited specifically to bioenergy with CCS (BECCS) and direct air carbon capture and storage (DACCS).

⁸ [How can carbon capture help us meet climate change goals? | World Economic Forum](#)

⁹ <https://research.american.edu/carbonremoval/2022/04/04/ipcc-wgiii-report-affirms-the-necessity-for-cdr-to-meet-goals-of-the-paris-agreement/>

¹⁰ [CCUS in Clean Energy Transitions – Analysis - IEA](#)

¹¹ [CO₂ Transport and Storage - Energy System - IEA](#)

¹² [Global Status Report 2024 - Global CCS Institute](#)

¹³ [The Tax Credit for Carbon Sequestration \(Section 45Q\)](#)

¹⁴ [8.18 InflationReductionAct Factsheet Final.pdf](#)

¹⁵ [Carbon capture, usage and storage \(CCUS\): business models - GOV.UK](#)

¹⁶ [Stimulation of sustainable energy production and climate transition \(SDE++\) | RVO.nl](#)

¹⁷ [Thought-Leadership-Scaling-up-the-CCS-Market-to-Deliver-Net-Zero-Emissions-Digital-6.pdf](#)

¹⁸ [TL-Report-Policy-priorities-to-incentivise-the-large-scale-deployment-of-CCS-digital-final-2019-1.pdf](#)

- Compare these market models to analogous markets (e.g., waste management, electricity) that have proven successful in the past, drawing on lessons learnt that are transferable to evaluate their adaptability to the CCUS/CDR projects.
- Survey stakeholders working in the CCUS/CDR sector on current and future CCUS/CDR market models and designs.
- Provide a presentation of potential successful market order strategies, including their pros and cons, which may lead to the fast development of an efficient, safe, and accepted CCUS/CDR market sector.

In this study, a market model is defined as **the combination of policies, regulatory frameworks, revenue generation methods and the business case that underpin a CCUS/CDR project**. Successful market models should enable the deployment of enough CCUS/CDR projects and infrastructure, which together can achieve widespread CO₂ emissions reductions necessary to reach net zero.¹⁹ While the current carbon permit markets (e.g., the EU's Emissions Trading System) and carbon credit markets (e.g., the Voluntary Carbon Markets) do encourage some CO₂ emissions reductions, the current scale of CCUS/CDR infrastructure deployment in these markets is not yet sufficient to reach net zero.²⁰ This study is therefore focused on potential market strategies which can support the scale-up of CO₂ emission reductions through supporting the development of CCUS/CDR projects, and their associated infrastructure.

The market model underpinning individual CCUS/CDR projects is likely to vary significantly depending on (i) jurisdiction, (ii) the type of CCUS/CDR project (e.g. fossil fuel emissions, negative emissions), (iii) technical capability/maturity (iv) geological and geographical aspects, (v) part of the value chain (e.g. capture, transport, shipping or storage etc.), (vi) the market maturity for the final decarbonized product(s) and (vii) the perceived risk/reward trade-off by investors and shareholders. The market forces driving these models will also likely vary, in particular between CCS and CCS-enabled CDR (i.e., BECCS and DACCS) projects. Whilst CCS focuses on capturing CO₂ from industrial sources, it often faces public skepticism as a fossil fuel enabler and currently requires government incentives (e.g., tax credits) to be deployed.^{21,22} On the other hand, CCS-enabled CDR projects, which remove CO₂ from the atmosphere, are currently driven by voluntary carbon markets and corporate net zero goals (e.g., through the Science Based Targets Initiative, SBTi).^{23,24,25}

This report therefore provides a key pillar to interested parties including policy makers, regulators, and the technical CCUS/CDR community on potential successful market strategies, including their pros and cons and their suitability for different economic and political realities, which may lead to the fast development of an efficient, safe, and accepted CCUS/CDR market sector.

¹⁹ [CCUS Policies and Business Models: Building a Commercial Market – Analysis - IEA](#)

²⁰ [How credit markets are evolving in climate and nature finance | World Economic Forum](#)

²¹ [Public perception of carbon capture and storage: A state-of-the-art overview](#)

²² [TG1 Briefing-Report-Public-Perception-of-CCS.pdf](#)

²³ [Ambitious corporate climate action - Science Based Targets Initiative](#)

²⁴ [2025 CDR Outlook: Policy Drivers Shaping the Carbon Removal Market](#)

²⁵ [Why the voluntary carbon market is key to carbon dioxide removal | World Economic Forum](#)

2. METHODOLOGY OF STUDY

The methodology of the study revolved around identifying potential market strategies from undertaking analysis on:

- **Operational and planned projects** - A screening of 12 operational and 14 planned CCUS/CDR projects was undertaken to analyze their supporting market model and identify similarities and differences between projects.
- **Analogous market models** – Five analogous markets (waste management, renewable electricity, low-carbon fuels, Liquefied Natural Gas (LNG) transport and low-carbon hydrogen) were investigated for similarities/differences between these markets and the CCUS/CDR market.
- **Stakeholder Engagement** – IEAGHG and ERM hosted 4 international roundtables in July 2024, with 17 leading experts across the CCUS/CDR value chain to gather stakeholder views based on their own experiences.

In the next chapter (Chapter 3), learnings from each of these sources were then divided into potential market strategies which relate to (i) ownership structure of a CCUS/CDR project, (ii) revenue generation opportunities available for the project and (iii) capital financing sources which can be leveraged to cover initial upfront costs of undertaking a CCUS/CDR project.

Operational and Planned Projects

Operational and planned CCUS/CDR projects were screened to give insight into their supporting market model. Each planned and operational CCUS/CDR project will be operating on a market model, and these may differ based on factors such as geographic context, regulatory environment, market sector, and project type. By identifying similarities and differences between operational and planned projects, insights into best practices and therefore potential market strategies for the CCUS/CDR market can be drawn.

In this study, a subset of operational (12) and planned (14) projects were screened and the CCUS / CDR market models that they use were characterised by a review of public sources.

Selecting a representative subset of operational and planned projects

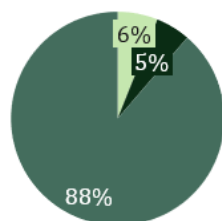
To determine the subset of projects that were screened in this study, the International Energy Agency's (IEA) CCUS projects database was used.²⁶ The IEA database contains >800 planned and operational projects from across the world.²⁷ These projects cover capture, transport, utilisation and storage components of the CO₂ value chain. As shown in Figure 1, most of these projects are planned (i.e., pre-final investment decision), rather than operational or under construction. Most projects (82% of projects) contained within the database are located in North America and Europe.

²⁶ [CCUS Projects Database - Data product - IEA](#)

²⁷ It is important to note that "projects" listed in the IEA database may cover different phases of the same overall project.

Project status

- Operational
- Under Construction
- Planned

**Project region**

- North America
- Europe
- Middle East
- Asia-Pacific
- Rest of World

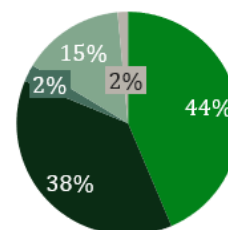


Figure 1: Summary of Projects in the IEA CCUS Projects Database (by number of projects)

The subset of projects screened were carefully selected (Figures 2 and 4) to be internationally representative and to include a spectrum of CCUS and CDR applications, as illustrated in Figures 3 and 5. The subset of projects selected for screening cover variations such as:

- **Geographies:** Broad coverage across categories of Europe, North America, Asia-Pacific, and Middle East, with further consideration of specific projects in the rest of the world (e.g., Brazil)
- **Applications:** Fuel supply (e.g., natural gas processing, hydrogen production, refining, biofuels), industry (e.g., iron & steel, cement), Power (e.g., coal, natural gas, biomass, and waste-fired generation), Direct Air Capture
- **Value Chain Components:** Carbon capture, CO₂ transport (pipeline, shipping, hubs), CO₂ storage (onshore, offshore), CO₂ utilisation.

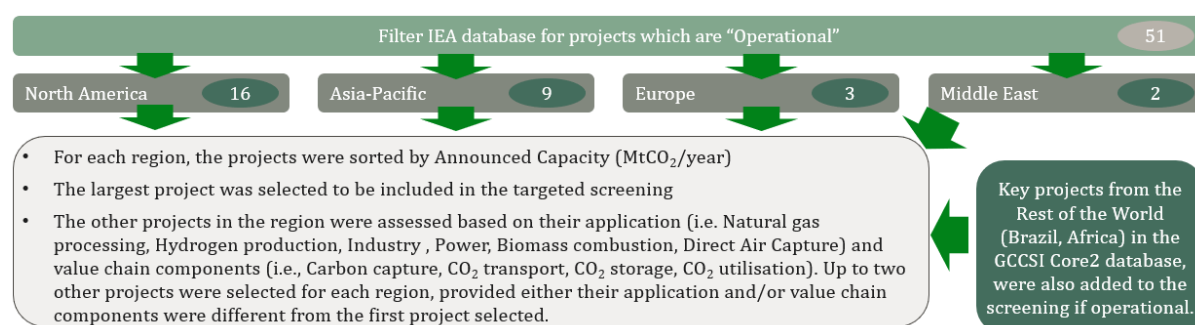
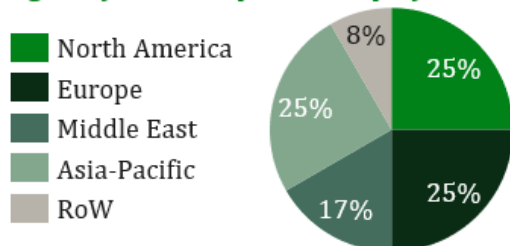


Figure 2: Methodology for Screening Operational Projects²⁸

²⁸ The projects within the IEA database cover both capture, transport and storage projects.

Region of selected operational projects



Sector of CO₂ capture for selected operational projects

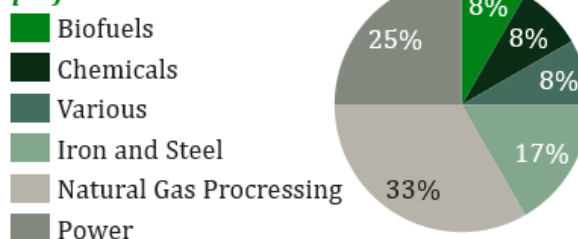


Figure 3: Overview of selected operational projects (statistic by number of projects)

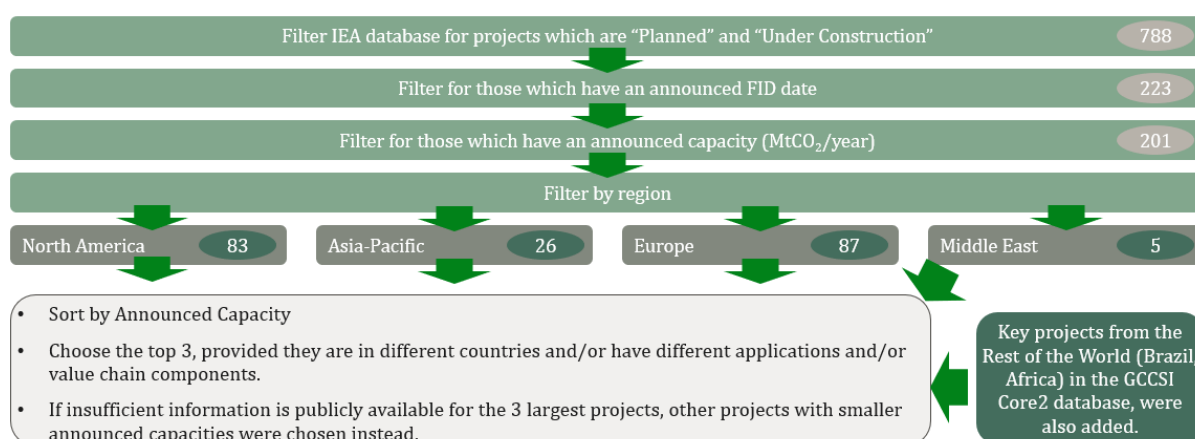
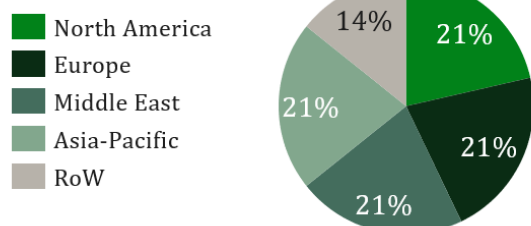


Figure 4: Methodology for screening planned projects

Project region



Application

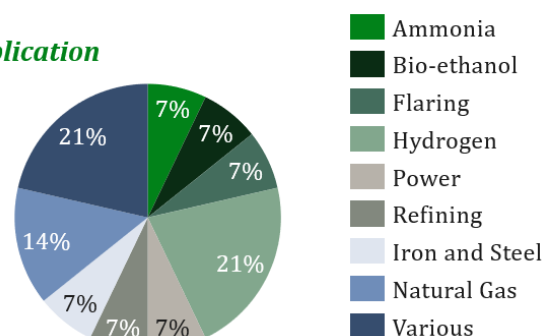


Figure 5: Overview of selected planned projects (statistics by number of projects)

The full list of selected operational and planned CCUS/CDR projects considered are listed in the Appendix.

It is important to note that there is a difference in the size of projects between operational and planned projects selected. Compared to the operational projects where only 33% of projects are >1 MtCO₂/year; the planned projects have larger capacities, with 92% having capacities >1 MtCO₂/year. All planned projects are expecting to store their CO₂ in the subsurface for the purpose of emissions reduction, whereas 42% of the selected operational projects undertake Enhanced Oil Recovery (EOR). Furthermore, all

planned projects are expected to take FID before 2025 and are targeting the start of operations between 2025 and 2030.

Screening of selected operational and planned CCUS/CDR projects

To undertake the screening of current and future CCUS/CDR projects, prominent components of CCUS/CDR market models were identified to compare these projects across geographic locations, project types, ownership structures, sources of funding and the source/fate of the CO₂.

The prominent components were defined following extensive literature review of relevant market model literature, including the IEA's 'CCUS Policies and Business Models'²⁹ and 'Legal and Regulatory Frameworks for CCUS'³⁰ reports and the Oxford Institute for Energy Studies 'Capture Carbon, Capture Value'³¹ report alongside consulting ERM's internal studies on CCUS business models (e.g., for the C4U project) and CCUS policies (e.g., for Oil and Gas Climate Initiative).

The prominent components of CCUS/CDR market models, along with the possible model within these components, are summarized in the table below. Please see the Appendix for full details on the definition of each model option.

Type	Model Component	Model Options (not mutually exclusive)
CCUS/CDR project identifiers	Project capital assets (principal)	• Capture • Transport • Storage
	Type of project	• CCS • CCU • CDR
	Project stage	• Feasibility/pre-FEED • FEED • Construction • Operating • Decommissioning
	Source of the CO₂	• Fossil vs biogenic vs direct air capture • Purity of CO₂ source (i.e. industrial sector/power/direct air source)
	End Destination of CO₂	• Permanent storage, same country as capture • Permanent storage, cross-border

²⁹ CCUS Policies and Business Models: Building a Commercial Market – Analysis - IEA

³⁰ Legal and Regulatory Frameworks for CCUS – Analysis - IEA

³¹ CM08-Capture-Carbon-Capture-Value_Final.pdf (oxfordenergy.org)

		Non-permanent removal/utilisation (conventional or emerging)
Ownership Structure	Value Chain Integration	- Full chain - Part-chain - Hub/cluster
	Entity Ownership Structure	- Public, direct - State-owned enterprise (public, indirect) - Joint public-private ownership, through a Public-Private Partnership (PPP) or Joint Venture. - Private (Single Entity/Joint Venture/Special Purpose Vehicle (SPV))
Revenue Generation	Low-Carbon Product Revenue Model	- Product GHG intensity tax - Regulated market for low-carbon products - Public procurement - Green premium/conscious consumer
	CO₂ Revenue Model	- Tax credits or avoidance of carbon taxes - Permit markets (e.g., Emissions trading systems ETSs) - Carbon Contracts for Difference (CCfD) - Credit markets (e.g., VCM, CDRs only) - Enhanced Oil Recovery (EOR) - Utilisation (excluding EOR)
Capital financing	Capital funding sources	- Public - Private - Mixture of public and private
	Capital financing support	- Investment tax credit - Tax exemptions/special depreciation allowances - Concessional finance (capital grants or direct loans/debt capital at favourable rates)

Analogous Markets

Analogous markets were investigated for similarities/differences between these markets and the CCUS/CDR market.

The value chains for analogous markets were mapped to focus on the key relationships between stakeholders within the analogous market. Our focus was on the following markets:

- Waste Management
- Renewable Electricity

- Low-carbon fuels
- LNG Transport
- Low-carbon hydrogen

These examples were used to identify existing successful market mechanisms that can exist between different players (e.g., consumers-distributors, distributors-suppliers), to draw parallels with the CCUS/CDR markets and to extract lessons learned.

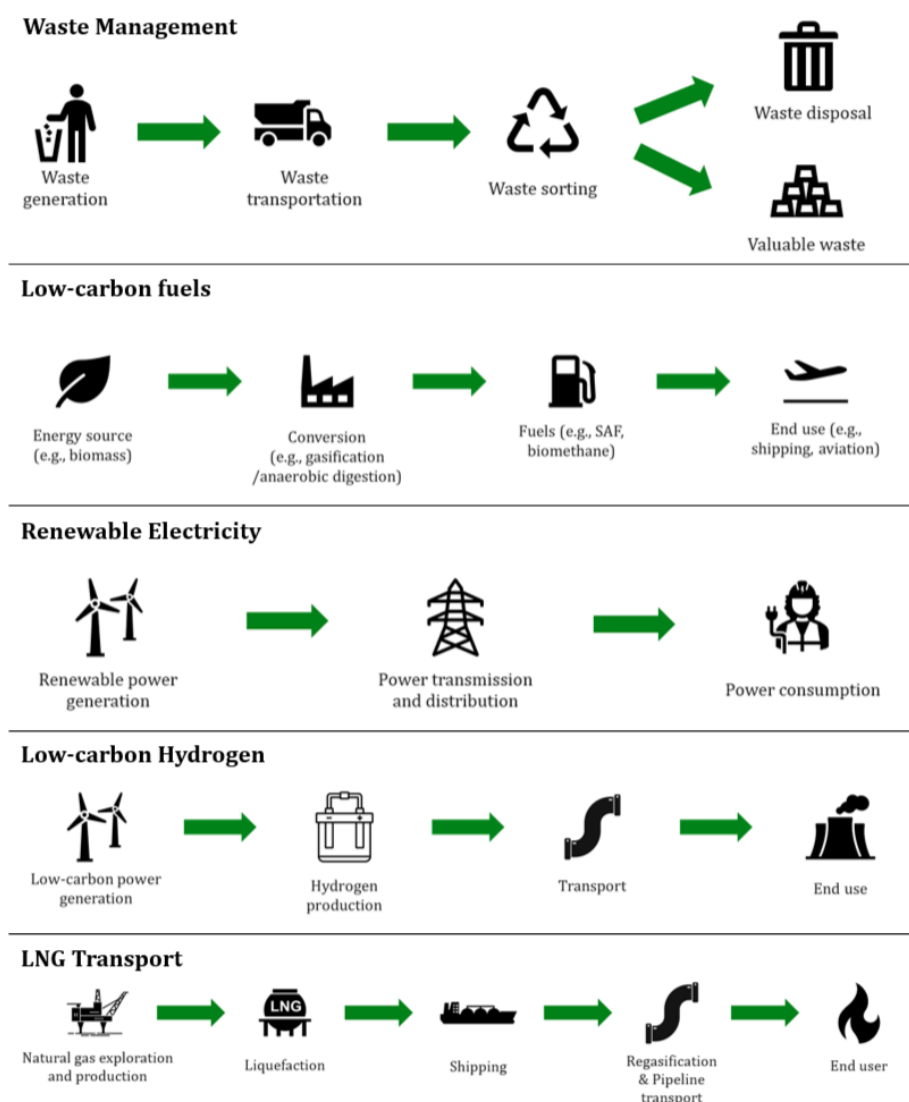


Figure 6: Value chains of the analogous markets considered in this study

Stakeholder Consultation

Objectives

Four roundtables were held, with the aim to gather industry and market perspectives on the prominent existing, emerging, and analogous market models identified in the study so far.

Stakeholders attending these roundtables were encouraged to share their views on the relative strengths and weaknesses of different ownership structures, capital financing and revenue generation models available for CCUS/CDR projects, considering their own

CCUS/CDR market experiences and applicability to specific sectors regarding their deployment of CCUS/CDR technologies, geography, and projects.

Attendees

43 individuals expressed interest in attending the roundtables with most respondents located in Europe, with a large amount of interest from the UK, with other respondents from the Middle East (Oman, UAE), Asia-Pacific (Australia, Japan), and North America (United States, Canada). Most respondents expressed interest in a range of global regions with greatest interest in Europe (35) and North America (23).

Respondents identified themselves as a mix of CCUS developers, CDR developers, policy makers, carbon market players, and investors. In selecting stakeholders for invitation to roundtables, prioritization was given to those with senior roles in companies with clear links to CCUS/CDR project development, policy or investment.

Representative candidates were selected and grouped into 4 diverse groups. Each group was selected to contain:

- European CCUS/CDR developer
- Non-European CCUS/CDR developer
- Policy maker/researchers
- If possible, representatives from each region of Europe, Middle East, Asia-Pacific and North America

A total of 17 stakeholders from across the CCUS/CDR value chain attended 4 roundtables held in mid-July 2024. Most of these were invited directly by ERM/IEAGHG to participate and came from a wide variety of backgrounds (see Figures 7-9).

Outputs

Minutes from each stakeholder roundtable were collated under three key themes – ownership structure, revenue generation and capital financing. These minutes were consolidated into themes associated with different best practices identified by the stakeholders to form the basis of potential market strategies identified in this study.

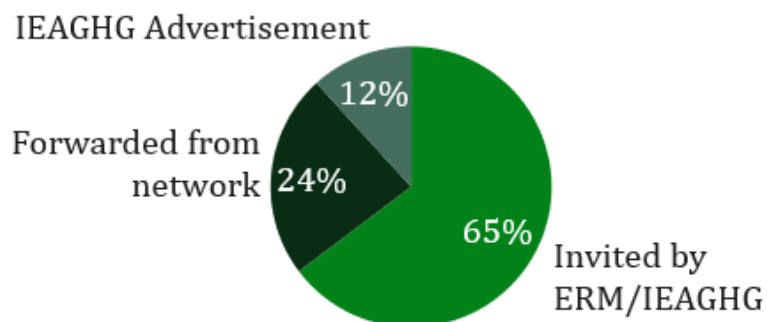


Figure 7: How attendees found out about the roundtable

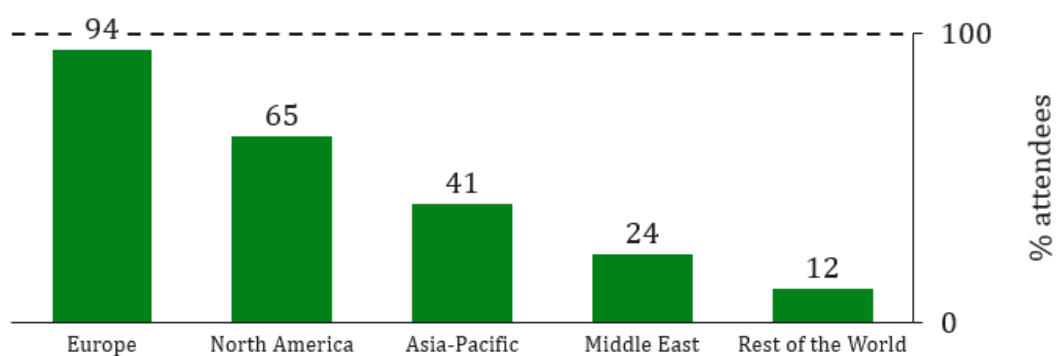


Figure 8: Percentage of attendees interested in each region of the world

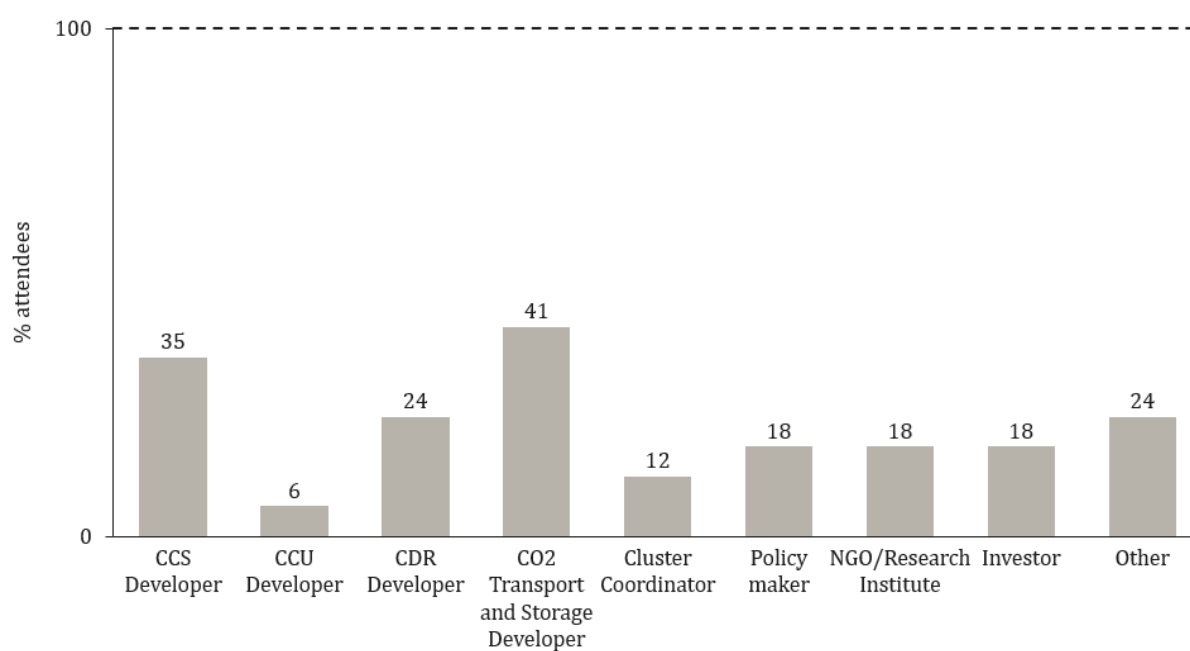


Figure 9: Percentage of attendees that operate in each part of the CCUS/CDR value chain

3. SUMMARY OF INSIGHTS FROM PLANNED/OPERATIONAL CCUS/CDR PROJECTS, ANALOGOUS MARKETS AND STAKEHOLDER ENGAGEMENT

In this Chapter, key insights are drawn from the evidence gathered in Chapter 2 on planned/operational CCUS/CDR projects, analogous markets and stakeholder engagement. For each of these, learnings were drawn in terms of three key components of a CCUS/CDR market model:

- **Ownership Structure** - who owns the CCUS/CDR infrastructure and the relationship of that owner with the rest of the value chain (e.g., full-chain ownership or part-chain ownership).
- **Revenue Generation** - method by which income can be generated by a CCUS/CDR project. An effective CCUS/CDR revenue generation model will provide a value proposition that incentivizes low-carbon production methods and ensures that low-carbon products are competitive alongside carbon-intensive products.
- **Capital Financing** - source of the money needed to fund the development, construction and operation of assets and infrastructure required for a CCUS/CDR project (e.g., capture plant facilities, CO₂ pipelines) as well as any external support that a project can get for capital funding.

These insights were then used to develop potential market strategies for ownership structure, revenue generation and capital financing of CCUS/CDR market models. Potential market strategies are detailed in Chapters 4-6.

Key insights from planned/operational projects

Ownership Structure

- Around half of planned projects considered will operate only part of the value chain, whereas most operational projects operate along the full value chain. Furthermore, 4 planned projects plan to transport the captured CO₂ across international borders.
- Both operational and planned projects in North America/Europe tend to be privately owned, whereas projects in Asia-Pacific and the Middle East tend to be publicly owned via state-owned enterprises.

Revenue Generation

- 42% of the selected operational projects undertake EOR as a key driver of revenue generation.
- On the other hand, most planned projects are relying on the European ETS/Carbon Border Adjustment Mechanism (CBAM) to generate revenue from their CO₂, except for:
 - CDR projects which target VCMs and/or;
 - Projects in the USA which will receive tax credits for CCS under section 45Q of the US-American Internal Revenue Code.
- Most planned projects expect to sell their low-carbon product (e.g., cement, steel) at a competitive rate compared to an equivalent unabated product, some supported by

carbon leakage policies such as CBAM (when sold internationally), and some through anticipated market demand for low-carbon products. However, at the 7 Blue Ammonia Facility in Qatar, low-carbon ammonia will be procured by QAFCO, a fully owned subsidiary of a publicly listed company (Industries Qatar) which itself is majority owned by state-owned Qatar Energy.

- However, in several planned projects, particularly in Asia-Pacific and the Middle East, it is unclear how revenue will be generated in the future.

Capital Financing

- All operational and planned projects have received, or expect to receive, some degree of upfront public capital financing, whether that be through state-owned enterprises or capital grants.
- One planned project screened has also used a green loan, supplied by the private sector, to support raising of capital financing.

Key insights from analogous markets

Ownership Structure

The ownership structure of analogous markets depends on the respective value chain configurations and market designs. Parallels can be drawn with the CCUS/CDR market, particularly from typical ownership structures in the LNG market, but also from how the renewable electricity generation market manages natural monopolies which arise from the transmission and distribution of electricity. In both these markets, a range of different ownership structures exist. However, there is an increasing trend towards breaking up integrated companies (e.g., in the LNG sector) and regulating natural monopolies (e.g., electricity transmission grids) to avoid excessive charges for the users of the infrastructure

The LNG market is shaped by global supply-demand imbalances, with major exporters like Qatar, Australia, and the U.S., supplying high-demand regions such as Asia and Europe. Geopolitical factors, such as energy security and trade policies, heavily influence the market. In the LNG market there are three typical ownership structures which operate³²:

1. **Integrated company** – same company operates the upstream production, liquefaction and export terminal
2. **Merchant** – one company owns the liquefaction plant and can source the natural gas from one, or several producers.
3. **Tolling** – the liquefier does not own the natural gas or LNG but is paid a fee to operate their liquefaction services (common in the US).

It is likely that integrated company ownership structure would only operate in a non-liberalised market, that is not open to competition and is controlled by a single supplier (i.e., the integrated company). In general, globally there is a trend towards ownership unbundling (i.e., separating generation, transmission, distribution and retail services)

³² [Economics of the LNG Value Chain \(econnectenergy.com\)](https://econnectenergy.com)

within the LNG market.³³ This has been driven by deregulation efforts in natural monopolies, such as gas transmission networks, as well as market forces at play when it comes to fair and transparent access to LNG terminals.^{34,35}

In the CCUS/CDR market, similar ownership structures may be present. It could also be the case that different parts of the value chain are operated by different entities, for example:

1. **Integrated company** – one company owns the capture, transport and utilisation/storage components.
2. **Merchant** – the CCUS/CDR project operates some of the value chain and owns the CO₂ in that part of the value chain.
3. **Tolling** – the CO₂ emitter pays a fee to another company to provide capture, transport and/or storage as a service.

However, to encourage competition within the CCUS/CDR market and avoid the formation of monopolies, particularly in CO₂ transport and storage infrastructure, a trend towards ownership unbundling may occur as the market grows, similar to that which has occurred in the LNG market.

Similarly, in the renewable electricity generation market, different parts of the value chain tend to have different configurations of their ownership. In the generation portion of the value chain, these renewable generation assets are often owned by multiple different entities, competing with fossil fuel generators, to sell the electricity generated into a transmission grid.

However, transmission of this electricity is a natural monopoly, and in many jurisdictions is often under public ownership.³⁶ The role of regulators (e.g., Ofgem in the UK) in preventing market participants from charging excessive fees is also likely to be important in preventing monopolies from forming. This value chain structure is analogous to a CCUS/CDR value chain where CO₂ capture is undertaken by multiple different entities which then transport their CO₂ via a pipeline. These CO₂ pipelines are also likely to be natural monopolies, akin to electricity transmission grids, particularly if a country's emissions profile is highly clustered. Expansion of alternative modes of transport (e.g. CO₂ shipping) may reduce the dependence of the CCUS/CDR market on any emerging pipeline monopolies and encourage a merchant-like model to emerge.

Revenue Generation

Analogous markets studied generate revenue by leveraging a variety of mechanisms including the polluter-pays principle, participating in mandated markets, using contracts for difference schemes, and through state-supported purchasing.

Parallels can be drawn between the CCUS/CDR market and the waste management market in terms of their options for revenue generation. Revenue generation methods from the waste management market, such as the polluter pays principle, could be

³³ [Gas Market Liberalisation Reform – Analysis - IEA](#)

³⁴ [The Complete Guide of Natural Gas Deregulation | Diversegy](#)

³⁵ [An Overview of LNG Import Terminals in Europe - King & Spalding.pdf](#)

³⁶ [Electricity networks: how 'natural' is the monopoly? - ScienceDirect](#)

applied to the CCUS/CDR market. The polluter pays principle holds waste producers responsible for the costs of waste disposal and treatment. This encourages waste reduction and sustainable practices through mechanisms like landfill taxes, Extended Producer Responsibility, and Pay-as-You-Throw systems.³⁷ In the CCUS/CDR market, the polluter pays principle would require industries emitting CO₂ to fund the capture, transport, and storage of their emissions, thus generating revenue for CCUS/CDR project deployment. However, a key difference is that conventional waste can have significant local impact, whilst the impact of CO₂ emission is global. This may lead to challenges in implementing the polluter pays principle in the CCUS/CDR market because it could be difficult to ensure that individual polluters are held accountable for their emissions when the impacts of their actions are global.

In the sustainable aviation fuel (SAF) market, mandated markets can be leveraged to generate revenue. For example, in the EU, the ReFuelEU Aviation initiative states the minimum shares of SAF that must be supplied within the EU.³⁸ This mandate applies in 5-year steps from 2% in 2025, to 63% by 2050 to gradually increase the share of SAF used in the aviation sector. In the CCUS/CDR market, mandates for low-carbon products produced using CCUS/CDR technologies could provide a dedicated market in which the only competition is with other low-carbon products. This would allow pass on of costs to consumers and generate revenue within the CCUS/CDR market.

In the renewable electricity market, Contract for Difference (CfD) schemes can be used by generators to stabilize their revenues at a pre-agreed level (the Strike Price) for the duration of the contract. For example, in the UK CfDs incentivise investment in renewable energy by providing developers of projects with high upfront costs and long lifetimes with direct protection from volatile wholesale prices, and they protect consumers from paying increased support costs when electricity prices are high.³⁹ Similar schemes in the CCUS/CDR market (e.g., Carbon Contracts for Difference (CCfDs) through the UK's Cluster Sequencing programme) could operate to enable CCUS/CDR project developers to have certainty in revenue generation. However, in the long-term this scheme may have significant implications for taxpayers and/or consumers, depending on the level of the strike price and on the performance of the selected reference price (e.g., the ETS price).

State supported purchasing can also help to generate revenue in analogous markets. For example, in Germany, buyers of hydrogen are supported by the state through the H2Global scheme.⁴⁰ H2Global is based on a double auction model in which federal grants offset the difference between the buying and the selling price for a certain period. Similarly, in the CCUS/CDR market, state supported buyers of low-carbon products (e.g. ammonia) or the CO₂ itself could allow certainty in revenue generation for CCUS/CDR project developers but may also have significant implications for taxpayers. For example, the U.S. Department of Energy's CDR Purchase Pilot Prize allocates \$35 million to incentivize the development of carbon dioxide removal solutions by purchasing verified

³⁷ [Ensuring that polluters pay - European Commission](#)

³⁸ [ReFuelEU Aviation - European Commission \(europa.eu\)](#)

³⁹ [Contracts for Difference - GOV.UK \(www.gov.uk\)](#)

⁴⁰ [One-Stop-Shop - Hydrogen - H2Global \(bmwk.de\)](#)

CDR credits from domestic providers.⁴¹ However, this initiative may have significant implications for taxpayers if scaled up to the number of CDR projects necessary to achieve net zero.

Capital Financing

In many analogous markets studied, private debt is used to leverage capital funding.

In the waste management sector public-private partnerships (PPPs) are often leveraged to help raise capital. For example, the Bristol Waste Company (in the UK) leveraged PPP ownership to upgrade its waste processing facilities and secured £250 million in funding.⁴² Public-private partnerships could also be used to raise capital finance in the CCUS/CDR industry. This type of investment can be used to finance the infrastructure through a long-term agreement whereby returns are paid through taxes and/or users of the CCUS/CDR project.

In the LNG market, project finance is used in the LNG market to raise debt, particularly from commercial banks, export credit agencies and, less often, debt capital markets and multilateral agencies.⁴³ Long-term offtake contracts, creditworthy LNG purchases and/or take-or-pay clauses all help to reduce risks associated with the project and thus aid debt raising. Similarly, in the CCUS/CDR market debt could be raised via project finance to support projects. However, the CCUS/CDR market faces higher risk premiums because it is still emerging, with uncertain revenue generation mechanisms and evolving regulatory frameworks. This higher risk premium may limit financing options for a CCUS/CDR project.

Key insights from Stakeholder Engagement

Stakeholders attending the roundtables brought ideas around best practices for CCUS/CDR market models. These insights originated from a wide range of stakeholders operating across the CCUS/CDR value chain, from a variety of different sectors and located across the world. Minutes from stakeholder engagement were compiled into a list of best practices for future CCUS/CDR market models which included ownership structure, revenue generation and capital financing best practices. Ideas raised by stakeholders are outlined in terms of ownership structure, revenue generation and capital financing below. The interpretation of these ideas and how these relate to potential market strategies are discussed in Chapters 4-6.

Stakeholder ideas on Ownership Structure

- Stakeholders see carbon capture, transport and storage-as-a-service as a developing trend whose uptake is likely to depend on the sector and region of the industrial emitter. Small, niche sectors are more likely to explore CCS-as-a-service, potentially on a lease structure. There may also be more opportunities for CCS-as-a-service in markets (e.g., the US) where CCS incentives (e.g., 45Q) do not dictate ownership structure.

⁴¹ <https://www.energy.gov/fecm/funding-notice-carbon-dioxide-removal-purchase-pilot-prize>

⁴² [Funding for large scale waste management infrastructure projects - Service by FasterCapital](#)

⁴³ [Insight-78-LNG-Finance-will-lenders-accommodate-the-changing-environment.pdf \(oxfordenergy.org\)](#)

- Stakeholders thought that industrial sectors which currently operate large-scale chemical plants and regularly handle industrial gases are more likely to have the in-house expertise needed to operate a carbon capture plant. On the other hand, sectors (e.g., cement, paper & pulp) which may not have expertise similar to operating a carbon capture plant, may prefer to use carbon-capture-as-a-service from a specialised technology developer.
- Stakeholders mentioned that industrial sites may not want a third-party carbon capture-as-a-service operator closely integrated into their main process activity. Therefore, stakeholders suggested that industrial sites may prefer to operate the carbon capture facility themselves, or at least manage an expert contractor to do it rather than fully outsource.
- Stakeholders suggested that it makes sense to limit pipelines per region to avoid duplication and capitalise on economies of scale, but this requires continued regulation of these pipelines and strategic planning. However, by limiting the number of pipelines, cross-chain risks (between capture, pipeline and storage project developers as well as between multiple capture projects accessing the same pipeline) may increase.
- Stakeholders saw governments taking on an orchestrating role in coordinating CCUS/CDR hubs/clusters, where they take on counterparty risks to alleviate the “chicken-and-egg” issue.
- Due to differences in government structures (e.g., unitary vs federal, monarchy vs republic) and the availability of state aid, stakeholders anticipated that different regions are likely to have different levels of government involvement in owning and operating the CCUS/CDR infrastructure.
 - For example, in the Middle East, governments may be more likely to own and operate CCUS/CDR infrastructure through state-owned companies, alongside the operation of other utilities and oil and gas infrastructure.
 - On the other hand, Europe has a lot of private players in CCUS/CDR project development. Some first-of-a-kind (FOAK) projects in Europe may be done with government involvement but as the market develops, the expectation is for greater private involvement.

Stakeholder ideas on Revenue Generation

- Stakeholders noted that some customers are willing to pay premiums on e.g., non-GMO food in the US, or organic food products. They also noted that customers may also be willing to pay for decarbonized products, but a structure (i.e., certification) needs to be enabled to account for the decarbonisation of a product and to pass it down the value chain to the consumer.
- Compliance markets were seen as likely to become increasingly important in the future for CCUS/CDR revenue generation.
- It was suggested that local entities (e.g. public entities, city councils) with net zero commitments may become leaders in buying credits from emerging CDR projects, such as is already happening in countries like Denmark or cities like Zurich.

- The EU ETS price was seen as currently being too low/unstable to encourage long-term offtake agreements based on the current observable project costs for CCUS projects. Some EU countries currently try to address volatility through Contract for Difference mechanisms (e.g., SDE++ in the Netherlands, and the UK's ICC business model).
- Stakeholders suggested that utilisation is unlikely to scale as a revenue generation model because the captured CO₂ use case is too small. In certain circumstances, such as to meet the ReFuelEU aviation e-fuel sub-mandates, there may be revenue generation opportunities, but this is unlikely to be scalable to provide revenue for the volume of CO₂ which needs to be captured in order to meet any net zero goals. Additionally, EOR could be a driver as part of a wider decarbonisation plan (e.g., 45Q EOR specific incentives) but may impact the project's social license to operate in certain regions (e.g., the EU).
- Stakeholders highlighted that CCUS/CDR revenue generation is context dependent and is likely to vary by region:
 - In Europe, government incentives revolving around carbon pricing may be an effective way of generating revenue, as the social cost of emitting CO₂ is widely recognised.
 - However, this may be more challenging in markets such as the US and Middle East who may be more opposed to carbon taxation. Incentives such as tax credits (e.g., 45Q) may be more politically acceptable in these jurisdictions.
 - In regions where much of the economy is based on exporting projects (e.g., Asia), mechanisms such as the EU's Carbon Border Adjustment Mechanism (CBAM) will impact the competitiveness of exported products and may therefore be an effective decarbonisation lever.
- It was suggested that variations are also likely to occur between different industrial sectors and primary interest in the value chain as the cost of capture will be different.
 - For example, in the cement sector, currently amine-based carbon capture is likely to be most appropriate for the large-scale, medium purity CO₂ stream emitted from a cement kiln. Amine-based capture is likely to be more expensive than membrane-based technologies used for capture of CO₂ from higher purity CO₂ streams emitted from other sectors (e.g., ethanol production, biogas upgrading).
 - However, incentives, such as 45Q, give a similar level of incentive for capture across all industrial sectors (although the incentive is higher for Direct Air Capture (DAC)), assuming the CO₂ is stored in dedicated storage and defined wage and apprenticeship requirements are met. This type of incentive is likely to encourage carbon capture only in the cheapest industrial sectors.
 - On the other hand, incentives which vary depending on the sector which CCS is undertaken in (e.g., the UK's Business Models) should incentivise CCS deployment across a wider variety of sectors.

Stakeholder ideas on Capital Financing

- Stakeholders currently see CCS as a high-risk, low return solution. However, they emphasised that CCUS/CDR project returns are difficult to estimate, particularly due to uncertainty in future carbon price. Long term offtake agreements can pass this volatility risk onto offtakers for greater stability in returns over the long-term.
- It was suggested that that pension funds traditionally invest in stable, low risk, low return projects which have long term life whereas traditional O&G-type investors are used to ~20% returns, rather than <10% expected with CCS (although CDRs could provide greater returns). Some pension funds are interested in providing funds for CCS if some of it can be used for CCU as well and others are recognising that investing in CCUS/CDR technologies may be necessary as part of their wider decarbonisation strategy.
- Stakeholders suggested that for first-of-a-kind (FOAK) projects, heavy equity financing may be likely, but this will evolve over time.
- It was highlighted that in developing countries, multi-lateral development banks and finance institutes can help support the raising of capital. However, there may be limitations, for example, the World Bank does not finance coal-CCS.
- The certainty of the business case was seen as key to unlocking capital financing; increased investor confidence in the CCUS/CDR market should make it easier to raise capital finance for projects.
- Stakeholders emphasized that often the issue in raising finance is not usually the amount of capital required, but more a clear idea of what the risks associated with returns are, and therefore the expected rate of return on the investment, and crucially, the risk allocation. Support such as the UK Business Models for Industrial Carbon Capture are designed to also reduce certain specific risks for investors.
- It was suggested that many current projects have only emerged thanks to heavy subsidies (e.g., from the EU Innovation Fund). However, for future projects, stakeholders thought that obtaining public grants may become less attractive because investment decision towards business entry is taken with a view towards commercially sustainable business models. Such models cannot rely on long-term availability of subsidies because boards decide investment decisions based on risks, and capital grants do not change the risks, rather they just limit the amount investors can invest.

Compiling insights into potential market strategies

In Chapters 4-6, best practices identified from stakeholder engagement were brought together, alongside insights from planned/operational projects and analogous markets. Additional literature review was also incorporated where required. Together these were used to identify potential market strategies for the scale-up CCUS/CDR technology deployment necessary to reach global climate goals.

The potential market strategies presented in this study should be interpreted as actions that the CCUS/CDR industry (e.g., project developers) and supporting entities (e.g., governments, financial institutions) could take in order to scale-up the deployment of CCUS/CDR technologies such that global climate goals/targets can be met. These

potential market strategies are discussed in terms of ownership structure, revenue generation and capital financing.

It is important to note that not all market strategies identified will be suitable for every situation. Regional and sectoral differences are likely to impact how suitable a potential market strategy will be.

4. OWNERSHIP STRUCTURE MARKET STRATEGIES

Ownership structure covers both who owns the CCUS/CDR infrastructure (entity ownership) and the relationship of the entity owner with the rest of the value chain (value chain ownership).

The following section includes concepts identified in planned/operational CCUS/CDR projects, in analogous markets and raised by stakeholders on suggested best practices of how to overcome ownership structure barriers to CCUS/CDR project deployment. These suggested best practices have been developed into potential market strategies for the CCUS/CDR market. The relevant barriers which the market strategy is designed to overcome are summarized in the table below.

Potential market strategy	Barrier which the market strategy is designed to overcome
Different owners for development, construction and operational project phases	Different expertise, risk appetites and expected return on investment between different phases of the project
Government coordination of part-chain ownership structures	The “chicken-and-egg” problem in first-of-a-kind (FOAK) projects due to the interdependency of the capture, transport and storage components of the value chain.
Clear contractual arrangements for commercial risk allocation	High commercial risks associated with undertaking a full-value chain CCUS/CDR project (e.g., long-term storage liabilities)
Standardization of CO₂ transport and storage infrastructure	Captured CO ₂ with certain technical specifications can only be stored in certain CO ₂ storage sites
Regulating CO₂ pipeline infrastructure	Potential monopolization of pipeline infrastructure (in places where this is a risk)
Partnering with entities with pre-existing expertise	Limited expertise in deploying CCUS/CDR-like infrastructure in certain sectors
Capture-as-a-service solutions	High CAPEX associated with deploying a full-value chain CCUS/CDR project
Flexibility in government incentives to allow a range of emerging ownership structures	Design of CCUS/CDR incentives that dictate a certain ownership structure

Ownership Structure Market Strategy #1: Different owners for development, construction and operational project phases

One potential best practice for a CCUS/CDR project highlighted by stakeholders is a change in infrastructure ownership between the construction and operational phases of a project. There may also potentially be different developers between the initial development and construction phases.

The construction phase requires expertise in design, engineering, construction management and procurement, whereas in the operational phase the focus shifts to maintaining, managing, and optimizing the operational performance of the asset. Similarly, during the development stage, smaller developers may be able to move quicker than larger corporations in the early stages of development and work with a wider range of through chain stakeholders more readily compared to entities focused on one part of the chain. These different project stages require different skill sets so a transfer in ownership can be beneficial for optimizing this expertise, particularly in first-of-a-kind (FOAK) projects.

The nature of the risks also changes between phases of a project. In the construction phase, delays, cost overruns and other construction-related risks may require a different risk appetite compared to risks associated with the operational phase (e.g., maintenance risks, market conditions). An entity may not be willing to take on construction risk but may have a risk appetite which is more appropriate for the longer-term operational phase of the project. Entities expecting a stable but low return on their investment may also be more suited to the operational phase of the project (e.g., institutional investors, pension funds), compared to entities with a relatively higher risk appetite hoping for larger returns on investment during the construction phase of the project (e.g., venture capitalists, private equity firms).

Case study – HyNet, UK: Changing ownership between initial development and construction phases

- HyNet is one of the UK's leading decarbonisation projects, focused on unlocking a low-carbon future across the northwest of the UK.⁴⁴
- The project combines hydrogen production, carbon capture, and CO₂ transport infrastructure to reduce emissions at industrial sites across the region.⁴⁵
- By utilizing repurposed pipelines and offshore storage in the Liverpool Bay gas fields, the project aims to deliver 10 million tonnes of CO₂ emissions savings annually by 2030.
- As the project developer, Progressive Energy spearheaded the initial development of the HyNet project.⁴⁶
 - The company led efforts to conceptualize and coordinate the integration of low-carbon infrastructure.

⁴⁴ [HyNet North West](#)

⁴⁵ [About HyNet - HyNet](#)

⁴⁶ [Eni & Progressive Energy join forces on UK CCS development - Industry Europe](#)

- They collaborated with industrial partners to identify hydrogen demand and CO₂ captures sources as well as led funding applications and stakeholder engagement to secure government and private sector support for the project.
- In the construction phase of the project, Eni will take the lead in developing the CO₂ transport and storage infrastructure.⁴⁷
 - This leverages Eni's expertise in offshore operations to repurpose the Liverpool Bay gas fields for long-term CO₂ storage.
 - Eni will also lead the delivery of the CO₂ pipelines, both onshore and offshore.
- This collaboration highlights the partnership between an innovative developer like Progressive Energy and a major energy company like Eni, leveraging their respective strengths in project development and offshore expertise during different project phases.

Ownership Structure Market Strategy #2: Government coordination of part-chain ownership structures

For a part-chain ownership structure, one of the key risks highlighted by stakeholders is the “chicken-and-egg” problem. This problem lies in the interdependency of the capture, transport and storage components of the value chain: entities hesitate to invest in CO₂ capture technologies without a reliable and extensive transport and storage network, while downstream infrastructure developers are reluctant to build transport and storage facilities without sufficient captured CO₂ to make the investment viable. Without centralised coordination, there is a risk of stranded assets.

Governments (local, regional or national) can take on an orchestrating role in developing CCUS/CDR value chains, as they are in a unique position to provide central oversight, long-term planning, and integration with national/regional development goals to the development of a CCUS/CDR project. Governments are also likely to be able to help coordinate across various sectors, municipalities, and regions. However, much of the practical coordination may be done by private entities, with oversight from the government, such as in the case of Progressive Energy and the initial establishment of the HyNet cluster in the UK. Care should also be taken to ensure coordination does not result in monopolization of the full-value chain by any one entity.

Case study – UK Cluster Sequencing

In the UK's Carbon Capture and Storage Cluster Sequencing Process, the UK Government has taken a coordinating role in identifying and designating key industrial clusters that are suitable for CCS based on their potential for carbon emissions reduction and proximity to storage sites.

- The “chicken-and-egg” problem is solved through a phased approach whereby the UK Government is helping to align and sequence the timings of infrastructure deployment for various projects to overcome the risk of timing mismatch:
 - **Phase 1 (Cluster Selection):** The first phase focused on choosing clusters where long-term geological storage facilities and the infrastructure required to

⁴⁷ [HyNet North West: CO₂ storage and capture in the United Kingdom | Eni](#)

transport the CO₂ to the injection site will be developed. The UK Government is coordinating the timelines and organising collaboration between players to form these anchor transport and storage projects.

- **Phase 2 (Project Selection):** Following cluster selection, the UK Government is selecting capture projects to connect to the planned T&S facilities. Existing and future carbon capture projects were selected from certain sectors⁴⁸. These projects are selected based on their ability to contribute to the UK's net zero goals, financial viability, and readiness for deployment. The UK Government incentivizes the selected capture projects to connect to the T&S scheme through revenue support contracts, mainly based on a Contracts for Difference schemes but designed specifically for each sector, which help stabilize revenues and address key risks.
- **Ongoing Expansion:** As the clusters develop, there may be opportunities for new projects to be added in expansion phases. However, during the Market Transition period (i.e., beyond 2030), government intervention is likely to evolve so later projects may not necessarily benefit from the same revenue incentives.⁴⁹
- This Cluster Sequencing Process also uses a "track" approach to **stagger the deployment of CCS**, ensuring that the most ready and impactful clusters are developed first.
 - **Track-1** focuses on identifying and supporting CCS clusters that can be operational by the mid-2020s. The East Coast Cluster (Teesside/Humber) and HyNet North West were selected to receive UK Government support.
 - **Track-2** is designed to bring additional CCS clusters into operation by the end of the decade (by 2030). The Acorn and Viking Clusters were selected to form Track-2.

Ownership Structure Market Strategy #3: Clear contractual arrangements for commercial risk allocation

In many cases, commercial risks of undertaking CCUS/CDR projects are high, particularly for first-of-a-kind (FOAK) projects. An entity faces commercial risks when it is exposed to a situation which could reduce profits or lead to project failure. These entities may be willing to take on these commercial risks if its within their control and they know how to quantify and mitigate it and can price it into their risk/reward assessment.

Stakeholders highlighted the following key commercial risks as being particularly important in CCUS/CDR projects:

- Long-term liability of CO₂ storage.

⁴⁸ For the first two clusters, these are industry, waste management, power & hydrogen. In subsequent phases greenhouse gas removals plan to be added.

⁴⁹ Carbon Capture, Usage and Storage: a vision to establish a competitive market - GOV.UK

- Cross-border CO₂ transport – whether the liability for the CO₂ remains with the industrial emitter until it arrives at the storage site, or whether the liability is transferred to the transport operator.
- Carbon accounting - particularly where the CO₂ needs to be traced across an extensive value chain and/or CO₂ captured from the same point source ends up at different storage sites.

Clear contractual arrangements are needed to reduce commercial risks to entities which are not directly responsible for specific risks. For example, an industrial emitter is likely to require a clear contractual arrangement with the downstream CO₂ transport and storage provider to ensure that the industrial emitter is not liable for a failure in the transport and/or storage operations.

Transfer of liabilities between different entities in the value chain could be allocated by for example, flow-through liability clauses in offtake contracts, or joint liability clauses to share the responsibility of certain cross-value chain liabilities. There may also be a role for an external party (e.g., governments) to help mitigate commercial risks. This external party may evolve over time, with an increasing role for insurers as the CCUS/CDR market matures.

Case study – Transfer of long-term liability to governments

- Long term ownership risk and liability of sequestered CO₂ could be transferred to governments to reduce risks to the CO₂ storage provider.
- This transfer of liability to government is included in the CO₂ storage regulations in certain jurisdictions, for example:
 - In the UK, CO₂ storage liability can transfer to the UK Government after at least 20 years of post-closure monitoring and demonstration of the site's long-term stability.⁵⁰ Operators must meet strict regulatory conditions, including successful decommissioning, ongoing monitoring, and proving there is no significant risk of leakage. A financial contribution is also required to cover potential future monitoring or remediation costs.
 - Similarly in both Australia (15-years post-closure)⁵¹ and the EU (20-years post-closure)⁵², liability for the CO₂ storage site may be transferred to the relevant government, providing that ongoing monitoring does not identify any CO₂ leakage.
- These clear contractual arrangements, transfer risk between different players in the CCUS/CDR market and therefore reduce risks to CCUS/CDR project developers.

⁵⁰ [The Storage of Carbon Dioxide \(Termination of Licences\) Regulations 2011](#)

⁵¹ [Offshore Petroleum and Greenhouse Gas Storage Act 2006](#)

⁵² [Legislative framework - European Commission](#)

Ownership Structure Market Strategy #4: Standardisation of CO₂ transport and storage infrastructure

Without standardisation of CO₂ transport and storage infrastructure, captured CO₂ may only be accepted by specific CO₂ storage sites (those where it meets the required specifications) leading to limited flexibility in storage site selection. By developing clear standardisation of requirements for transportation and storage (e.g., CO₂ purity requirements), flexible CO₂ transportation infrastructure using multiple modes (e.g., pipelines, shipping and trucking) can be developed. This market strategy would benefit CO₂ transport and storage developers as it would enable them to accept CO₂ from a wide range of emitters.

Stakeholders also suggested that the private sector may also start to take up more of the commercial risks associated with CCUS/CDR project deployment under a scenario with standardised CO₂ transport infrastructure because they know that captured CO₂ can be diverted to other storage sites in the case of a temporary, or permanent shutdown. The storage sites could also receive other CO₂ from a variety of different capture point sources, thus reducing commercial risks associated with developing a part-chain CO₂ storage project.

Developing either regional, or even global, standardised CO₂ transportation and storage infrastructure would involve creating a unified framework to design, build, and operate systems for transporting, and safely storing carbon dioxide. This would include establishing common technical specifications to ensure compatibility across projects. The impact of differences in transport modes (i.e., pipeline, shipping, trucking) and storage sites (i.e., deep saline aquifers, depleted oil and gas reservoirs, rapid mineralisation sites etc.) will likely need to be considered when setting technical specifications. Developing standardised CO₂ transportation and storage infrastructure may also require developing regulatory guidelines to address safety, monitoring, and environmental impact, alongside protocols for measuring, monitoring and verification (MMV). Together these technical specifications and regulations could be used to govern how infrastructure is developed and operated.

Developing global standards for CO₂ transport and storage infrastructure would ensure global consistency to streamline projects but could come with high costs and complex implementation. On the other hand, standardization on a regional scale (e.g., North Sea) could offer tailored solutions that address local environmental and socio-economic conditions, potentially leading to more effective implementation of the agreed standards. Regional implementation could also reduce coordination complexity and costs compared to global standardisation, as there would be fewer regulatory and political differences to navigate. Additionally, regional standards could serve as testing grounds for best practices that could eventually inform global standards.

By developing standardised CO₂ transportation and storage infrastructure which connects multiple industrial emitters to multiple CO₂ storage sites, increased competition between the storage companies could potentially reduce overall CCUS/CDR costs as well as reducing risks associated with individual projects. Standardised transport and storage infrastructure can also allow phased scale-up of hubs/clusters as pre-determined pipeline volumes can be supplemented by for example shipping and trucking of CO₂.

Case study – Antwerp@C, Belgium⁵³

- The Port of Antwerp is one of Europe's largest industrial clusters, emitting approximately 18 million tons of CO₂ annually.
- The Antwerp@C project aims to capture, transport, and store up to 10 MtCO₂/year by 2030, utilizing both pipeline and non-pipeline transport methods.
- The industrial area is densely populated, limiting the feasibility of constructing new pipelines, whereas non-pipeline transport allows for phased scalability, where CO₂ capture can begin even before the full pipeline network is established.
- Non-pipeline transport will provide flexibility in transporting CO₂ to different storage locations, particularly as Belgium has limited opportunities for subsurface geological storage so will rely on international cooperation.
- In the first phase of Antwerp@C, the CO₂ will be shipped in liquid form to depleted gas fields in the North Sea area. The initial plan is to use the Northern Lights shipping and storage solution, while looking for other potential storage options such as depleted gas fields in the North Sea.
- In the second phase, Antwerp@C will also explore the possibility of transporting CO₂ by pipeline to the Netherlands.

Ownership Structure Market Strategy #5: Regulating CO₂ pipeline infrastructure

CO₂ pipelines are likely to be developed to link certain CO₂ capture projects with downstream CO₂ storage or utilisation projects. However, pipeline infrastructure can become a natural monopoly in some regions – it makes sense to limit pipelines per region to avoid duplication and capitalise on economies of scale.

Stakeholders highlighted that different countries have different proposed approaches to the development of CO₂ pipelines, for example:

- In the Middle East, most CO₂ pipeline development is likely to be done by state-owned infrastructure companies, in a similar manner to the development of natural gas transmission and other regional pipelines.
- Some Canadian provinces are also considering state-owned utilities as the owners of future CO₂ pipelines.
- Europe is likely to have a lot of private players in CO₂ pipeline development. For example, in Germany, Open Grid Europe (OGE), a private sector company is taking the lead.⁵⁴ However, the capacity for these pipelines is still under debate given that Germany will likely get CO₂ from other countries.

However, since pipeline infrastructure can be a natural monopoly, without regulation of CO₂ pipelines, any one company that controls a significant portion of the pipeline infrastructure could easily dominate the market, restricting access to competitors, manipulating prices, and reducing the overall efficiency of the CO₂ transport market. By unbundling services, mandating open access, and regulating rates, regulations are likely

⁵³ [Antwerp@C | Port of Antwerp-Bruges \(portofantwerpbruges.com\)](https://portofantwerpbruges.com)

⁵⁴ [CO₂ Overview | OGE](https://www.oqe.com)

to be able to foster a competitive CO₂ market while ensuring that the pipeline infrastructure remains efficient, reliable, and capable of meeting needs.

The risk of monopolisation from CO₂ pipelines may be lower in certain regions, where the scale of emissions within one geographic area (e.g. in the US, along the Gulf of Mexico coastline) means that multiple CO₂ pipelines will be required. Depending on the geographic distribution of the emission sources and pipeline corridors, emitters may be able to access multiple transportation routes. As a result, a more dynamic, commercially-driven, market, may emerge, requiring lower levels of regulation of the CO₂ pipelines.

Case study – Regulation of US natural gas interstate pipelines

- The U.S. natural gas industry was initially dominated by vertically integrated companies that controlled both the production and transportation of natural gas which exerted significant control over access to the infrastructure and drove up prices.⁵⁵
- Today, the Federal Energy Regulatory Commission (FERC) is responsible for regulating the interstate transportation of natural gas in the US, to ensure that the market remains competitive.⁵⁶
- FERC has implemented a series of regulatory measures:
 - **Unbundling of Services:** In the 1980s, FERC introduced regulations that required the unbundling of natural gas sales from transportation services. Prior to this, pipeline companies often bundled these services, making it difficult for independent producers to access the market.
 - **Order No. 436 (1985):** This requires pipeline companies to offer open-access transportation services on a non-discriminatory basis, effectively breaking the vertical integration that allowed pipeline operators to control the market.⁵⁷
 - **Order No. 636 (1992):** Known as the "Restructuring Rule," this order further enhances competition by mandating that pipeline operators separate their gas sales operations from their transportation services entirely, ensuring that all gas suppliers have equal access to the pipeline network.⁵⁸
 - **Open Access:** FERC mandate that pipeline operators must provide open and non-discriminatory access to their pipelines.
 - **Rate Regulation:** FERC regulate the rates that pipeline operators can charge for transportation. Rates are typically based on the cost of providing the service plus a reasonable return on investment.⁵⁹

⁵⁵ [Natural Gas Markets 101: How History Shaped Today's Infrastructure - OPIS, A Dow Jones Company \(opisnet.com\)](https://www.opisnet.com)

⁵⁶ [Natural Gas | Federal Energy Regulatory Commission \(ferc.gov\)](https://www.ferc.gov)

⁵⁷ [RCED-87-133BR Natural Gas Regulation: Pipeline Transportation Under FERC Order 436 \(gao.gov\)](https://www.gao.gov)

⁵⁸ [Order No. 636 - Restructuring of Pipeline Services | Federal Energy Regulatory Commission \(ferc.gov\)](https://www.ferc.gov)

⁵⁹ [Cost-of-Service Rate Filings | Federal Energy Regulatory Commission \(ferc.gov\)](https://www.ferc.gov)

- **Control on Pipeline Expansion:** FERC also requires pipeline operators to obtain a Certificate of Public Convenience and Necessity before constructing new pipelines or expanding existing ones, ensuring that new infrastructure is in the public interest and did not lead to anti-competitive outcomes.⁶⁰

Ownership Structure Market Strategy #6: Partnering with entities with pre-existing expertise

Many sectors (e.g., cement) reliant on CCUS/CDR projects as a decarbonisation option have limited expertise in deploying CCUS/CDR-like infrastructure (e.g., handling industrial gases, sub-surface expertise). A potential market strategy to overcome this barrier is for these entities to partner with other entities which may have more pre-existing expertise deploying CCUS/CDR-like infrastructure.

In particular, stakeholders highlighted that entities involved in oil and gas operations are more likely to have in-house knowledge from operating similar facilities which they are able to translate to the CCUS/CDR value chain. Stakeholders observed that current CCUS/CDR project ownership is often driven by whoever is the current owner of the existing oil and gas value chain. For example, ExxonMobil currently owns the largest CO₂ pipeline network in the USA.⁶¹ Similarly, Saudi Aramco owns and operates the Hawiyah-Uthmaniyah CO₂-EOR project in Saudi Arabia.⁶²

On the other hand, industrial sectors such as cement are less likely to have pre-existing knowledge from operating facilities similar to CO₂ capture, transport and storage facilities. Likewise oil and gas companies are unlikely to take on the risk of ensuring continuous cement plant operations.

Therefore, a potential market strategy could be for entities in sectors such as cement to collaborate with entities with pre-existing expertise (e.g., from the oil and gas sector), through a joint venture (JV), a special purpose vehicle (SPV) or potentially through a long-term service agreement. This market strategy would leverage previous learnings from similar projects and therefore, should reduce both deployment and operational risks, thus increasing investor confidence in the CCUS/CDR project. However, a potential challenge with this approach is the differences in working practices between different industries, therefore more robust project management and communication strategies may be needed.

Case study – Brevik cement plant carbon capture and the Longship project

- The Brevik cement plant, owned by Norcem (a HeidelbergCement subsidiary) plans to capture approximately 400 ktCO₂/year, equivalent to about 50% of the plant's emissions.⁶³
- However, the captured CO₂ will be transported by the Longship project (part of the Northern Lights JV DA, a collaboration between Equinor, Shell and TotalEnergies).⁶⁴

⁶⁰ [Understanding FERC's Natural Gas Certificate Policy Review | Steptoe](#)

⁶¹ [Carbon capture and storage | ExxonMobil](#)

⁶² [Launching the Kingdom's first carbon capture project | Aramco Japan](#)

⁶³ [Brevik CCS – World's first CO₂-capture facility in the cement industry | Brevik CSS](#)

⁶⁴ [Northern Lights \(norlights.com\)](#)

- The entities operating the Longship project have significantly more experience operating facilities similar to CO₂ shipping and storage (e.g., LNG shipping, natural gas extraction), compared to Norcem (a cement company).
- By leveraging this previous experience through an ownership structure appropriate for the sectoral expertise, deployment and operational risks are likely to be reduced, thus increasing investor confidence.

Ownership Structure Market Strategy #7: Capture-as-a-service solutions

Deploying a full-value chain CCUS/CDR project has a high upfront CAPEX. By leveraging capture-as-a-service solutions, the economic viability of undertaking a CCUS/CDR project may improve for some industrial emitters, particularly in terms of upfront capital expenditure. This potential market strategy is similar to the previous ownership market strategy on partnering with entities with pre-existing expertise.

Carbon capture providing as-a-service can offer flexibility and scalability, whilst also reducing the upfront capital costs to the emitter. Additionally, if systems are standardized, they can be easily upgraded or expanded as technology improves or as carbon capture needs increase, making them a versatile solution. Standardization could enable as-a-service models to be increasingly viable, as the underlying asset can be relocated from site to site if required and retains a level of residual value (at least in theory). Expertise developed within the capture-as-a-service company, as well as competition between capture-as-a-service providers, could reduce costs of deploying and operating carbon capture equipment. This reduction in costs may broaden the appeal of CCUS/CDR technologies, particularly to sectors with smaller-scale of emissions.

However, in certain sectors (e.g., refining, chemicals) the capture process is likely to be more integrated with the emitter than in other sectors (e.g., cement) due to technical factors associated with the number of flue gas streams. This level of integration may be a barrier to capture-as-a-service if a complex integration of the carbon capture plant with the existing industrial emitter is required. As a result, stakeholders suggested that sectors such as refining, and petrochemicals are more likely to own and operate their own capture plant because of the high levels of integration needed to the host plant.

On the other hand, sectors such as the cement and paper & pulp industries, may have lower complexity when integrating a capture facility to an existing industrial emitter. Therefore, these sectors may favour technology developers providing capture-as-a-service to operate the capture plant. For example, they might have a pay-per-tonne service agreement to cover their needs which could potentially scale-up as the original industrial operations expand. This type of service agreement could reduce upfront capital costs for the emitter, thus enabling increased deployment of CCUS/CDR projects.

Case study – SLB Capturi

- SLB Capturi is offering a comprehensive carbon capture and storage-as-a-service, including capture, transportation, injection and long-term CO₂ storage.⁶⁵
- Their standard capture solution aims to cover a range of flue gases, with CO₂ transport and storage embedded through strategic partnerships and CO₂ emitters would pay-per-tonne of CO₂ captured.
- SLB Capturi also offer standardized, modular capture plants named “Just Catch” which may be used to facilitate their as-a-service operating models.⁶⁶
- By leveraging SLB Capturi’s capture-as-a-service solution, this could increase the economic viability of deploying carbon capture, particularly in sectors which have a lower complexity in terms of capture integration.

Ownership Structure Market Strategy #8: Flexibility in government incentives to allow a range of emerging ownership structures

The design of CCUS/CDR incentives can dictate a certain ownership structure, and these may become a barrier to more novel value-chain ownership structure options. Flexibility in government incentives is likely to be important to allow a range of emerging ownership structures to evolve.

For example, stakeholders emphasised CCS-as-a-service (CCS-aaS) as a developing trend that may influence future CCUS/CDR value chain ownership structures. Currently, most opportunities for CCS-aaS are in the US market, because the design of CCS incentives (e.g., 45Q) is such that there is more opportunity to explore different ownership structures through well-structured service agreements. As highlighted in previous ownership structure market strategies, CCS-aaS can be beneficial in industrial sectors with limited expertise in CCUS/CDR-like infrastructure and those which may struggle to overcome high upfront capital costs.

However, the design of incentives may limit the viability of a CCUS/CDR project in industrial sectors with low complexity and limited expertise. An emerging market strategy is to design incentives that are flexible to a range of ownership structures.

⁶⁵ [Carbon Capture as a Service | SLB Capturi](#)

⁶⁶ [Just Catch™ | SLB Capturi](#)

5. REVENUE GENERATION MARKET STRATEGIES

Revenue generation refers to the method by which income can be generated by a CCUS/CDR project. An effective CCUS/CDR revenue generation model for an industrial emitter will provide a value proposition that incentivizes low-carbon production methods through the permanent storage of CO₂ and ensures that low-carbon products are competitive alongside carbon-intensive products. Similarly, CO₂ storage providers could generate revenue through methods such as storage capacity payments, monetizing carbon credits or charging injection fees through long-term contracts.

Two key criteria for generating sufficient revenue to cover the costs of deploying a CCUS/CDR project are outlined below:⁶⁷

- **Cost neutrality** – the entity should not be worse off for having implemented a CCUS/CDR project relative to equivalent entities who have not yet implemented decarbonisation measures.
- **Continuous decarbonised operations** – continuous revenue generation across the whole project lifetime should be enabled. There should also be a desire by the entity to operate efficiently, driving costs of decarbonisation down.

The following section includes concepts identified in planned/operational CCUS/CDR projects, in analogous markets and raised by stakeholders on suggested best practices of how to overcome revenue generation barriers to CCUS/CDR project deployment. These suggested best practices have been developed into potential market strategies for the CCUS/CDR market. The relevant barriers which the market strategy is designed to overcome are summarized in the table below.

Potential market strategy	Barrier which the market strategy is designed to overcome
Robust, traceable certification to enable green premiums	Conscious consumers are not willing to pay a green premium if they are not certain a product is decarbonised
Defining clear market segments to implement mandated markets	Implementing a mandated market on a dispersed market segment is likely to be difficult due to the wide range of players in complex product value chains.
Evolution of government revenue support through time	Different amounts of revenue support will be needed as the market evolves from first-of-a-kind (FOAK) to n th -of-a-kind (NOAK) projects

⁶⁷https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/759286/BEIS_CCS_business_models.pdf

Implementation of regulations to drive a compliance market for CDR projects

The current demand for CDR credits on the Voluntary Carbon Market (VCM) is limited to just a few offtakers (e.g., Shell, Microsoft), meaning revenue generation from CDR projects may face problems with scaling-up.

Revenue Generation Market Strategy #1: Robust, traceable certification to enable green premiums

Revenue for CCUS/CDR projects could be generated by charging a green premium on the low-carbon product to a conscious consumer. This means that an individual consumer pays more for the low-carbon product (which has been independently certified as such) in a competitively priced, open market. Customers may be willing to pay a 5-25% premium, depending on the region and the product.⁶⁸

Case study – Fairtrade minimum price and premium

Fairtrade requires companies to pay above market prices so that better prices, decent working conditions, local sustainability and fair terms for trade are provided for farmers and workers.

A combination of the Fairtrade minimum price and the Fairtrade premium accounts for the increased price of goods carrying the Fairtrade label.⁶⁹

- The Fairtrade minimum price defines the lowest possible price that a buyer of Fairtrade products must pay the producer.
- The Fairtrade premium is calculated as a percentage of the volume of produce sold. The premium that farmers receive differs from product to product and across regions.

In 2021, **59% of Fairtrade shoppers said they were willing to pay more for a product** to ensure farmers and workers were paid a fair price.⁷⁰

Low-carbon products could demand a significant “green” premium compared to traditional alternatives. Government procurement mandates which require public sector entities to prioritize purchasing specific goods or services, such as low-carbon products, are likely to be crucial in driving the green premium market. For example, HeidelbergMaterials has entered a Memorandum of Understanding to supply its evoZero⁷¹ net zero concrete for the construction of the new Nobel Center in Stockholm, scheduled to begin in 2027.⁷²

However, for many low-carbon products, green premiums are not currently feasible as a revenue generation stream. Stakeholders highlighted that the key barrier to revenue

⁶⁸ [How much will consumers pay to go green? | McKinsey](#)

⁶⁹ [Fairtrade Premium - Fairtrade Foundation](#)

⁷⁰ [Fairtrade sales boom by 14% as consumers demand sustainably sourced products and businesses ramp up ethical commitments - Fairtrade Foundation](#)

⁷¹ [The world's first carbon captured net-zero cement](#)

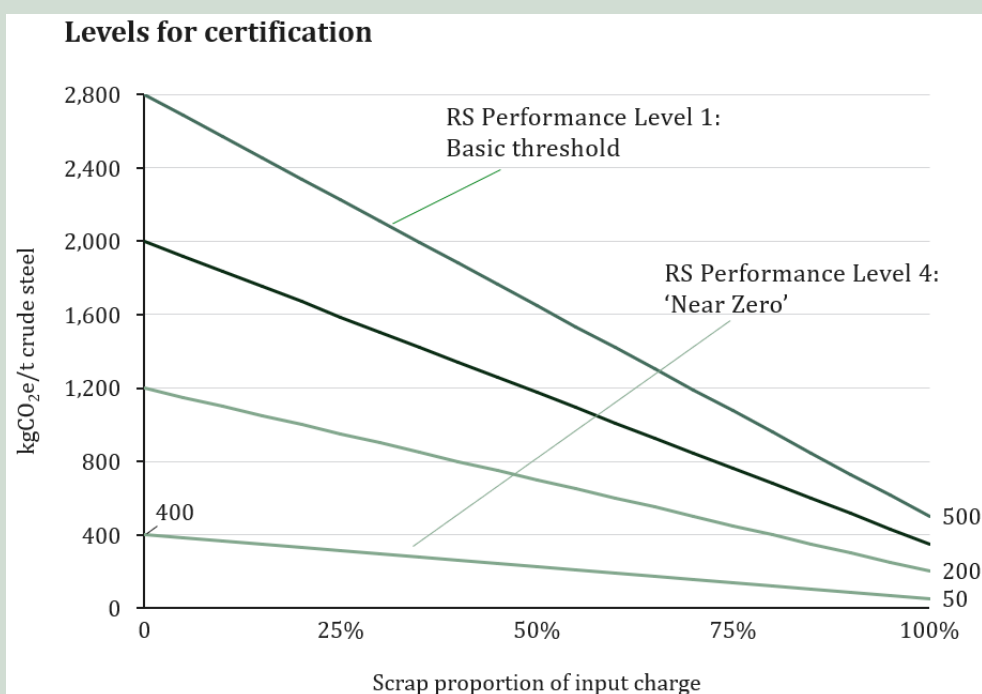
⁷² [New Nobel Center: net-zero concrete | Heidelberg Materials](#)

generation through green premiums is devising a system to track the carbon intensity of the product through (often very complex) value chains. They emphasized that there needs to be transparent certification that can follow the product/material along the value chain to ensure the product is decarbonised. For example, it has been reported that in the case of cars, decarbonising the steel used within the car would introduce <\$100 of additional cost to the final product.⁷³ Most end users would be willing to pay this green premium since it is <1% of the final product. However, stakeholders highlighted that there are often issues with the intermediate steps in the value chain being willing to pay, as well as the traceability of the decarbonisation benefits through these complex supply chains.

Therefore, to enable a conscious consumer to pay a green premium for low-carbon products, robust, traceable certification needs to be enabled to account for the decarbonisation of a product, where the certification is passed down the product value chain to the final consumer. Similarly, in the voluntary carbon market, stakeholders emphasised that buyers want high quality credits, so it is important to develop robust mechanisms to address these needs through carbon crediting programmes (e.g. Verra).

Case study – ResponsibleSteel's Green Steel Standards⁷⁴

- ResponsibleSteel (RS) certifies sites that operate 'in a responsible manner'. The sites are assessed against 13 principles that cover environmental, social and governance issues. If met, the site can gain a "Certified Site" certificate.
- Under the ResponsibleSteel standard V2.1, a "Certified Steel" certification is also available providing GHG emissions intensity of crude steel ($\text{kg CO}_2\text{e/t}_{\text{crude}}$) produced at the site falls below a certain threshold. Different levels are available:



⁷³ [Cleaning up steel in cars: why and how? | Transport & Environment](#)

⁷⁴ [Standards | ResponsibleSteel](#)

- Level 1 (RS's basic threshold) was set at the industry average plus 0.4 standard deviations, so all but the worst performers have the potential to gain this certification.
- Level 2 can be met by primary steel producers using gas-based direct iron reduction or secondary steel producers using a high share of renewable electricity.
- Level 3 and Level 4 require significant decarbonisation measures in place for both primary and secondary steel production but are likely to become a robust certification standard for decarbonised crude steel.

Revenue Generation Market Strategy#2: Defining clear market segments to implement mandated markets

Implementing a mandated market on a dispersed market segment is likely to be difficult due to the wide range of players in complex product value chains. To address this barrier, it could be beneficial for the CCUS/CDR market to define low-carbon mandated markets only on specific products. By defining a specific mandated market on a clear market segment, this could drive the development of fully decarbonised products, rather than incremental decarbonisation of several products.

A mandated market refers to a market where participation or certain activities are required by law or regulation. This means that entities are legally obligated to engage in the market, either by participating directly or by adhering to specific rules or guidelines set by governments or a regulatory authority. This intervention can enable revenue generation for low-carbon products by creating or sustaining the demand and/or supply through legal requirements. In the case of low-carbon products, manufacturers of certain products could be legally required to sell their products with a certain (low) carbon intensity.

Mandated markets can be beneficial in enabling revenue generation from CCUS/CDR projects by limiting competition of low-carbon products with their unabated equivalents. Entities looking to deploy a CCUS/CDR project to manufacture low-carbon products are likely to have increased confidence to invest in the project, knowing that there will be sustained demand.

However, implementing a mandated market on a dispersed market segment is likely to be difficult due to the wide range of players in complex product value chains. Some mandated markets (e.g., the EU's ReFuelEU SAF mandate) may require a certain percentage of product sold to be decarbonised to a particular standard. It may be difficult for certain sectors to produce a fully decarbonised product so this may be a barrier to entry, depending on the requirements of the mandated market. Therefore, it is important to make sure mandating is on a market segment which has the potential for this step-change in product decarbonisation. For products which are highly localised, implementing a regional or global mandate may be more challenging.

Given these limitations, stakeholders suggested that it could be beneficial for the CCUS/CDR market to define mandated markets on specific products, or mandates in relation to CO₂ storage (e.g., carbon takeback obligations). A mandated market for a

specific product would need to be defined based on a clear market segment to be easily implemented. This specific mandated market could then drive the development of fully decarbonised products, rather than incremental decarbonisation of certain products which may be the result from other revenue generation mechanisms (e.g., carbon pricing).

Case study - Sustainable Aviation Fuels (SAF) mandates⁷⁵

- Under the EU's ReFuelEU Aviation mandate, there are minimum shares of SAF that must be supplied within the EU.
- This mandate applies in 5-year steps from 2% in 2025, to 70% by 2050 to gradually increase the share of SAF used in the aviation sector.
- This mandate provides a dedicated market for SAF producers in which their products only compete with other SAF suppliers' products, allowing them to pass on costs to consumers and generate revenue within the SAF market.
- The implementation of the SAF mandate is made easier as the airline and aviation fuel supply industry is extremely consolidated, with few major players, which often have alliances at senior level. This means that decision making may be easier, compared to other low-carbon products markets, as well as meaning deciding and implementing a mandate is easier and faster.

Revenue Generation Market Strategy #3: Evolution of government revenue support through time

It is likely that a collection of measures will be initially needed to enable revenue generation in the CCUS/CDR markets depending on the sector and region of the project. However, as the CCUS/CDR market grows from the current small-scale market with first-of-a-kind (FOAK) projects to a mature CCUS/CDR market where projects are deployed globally, government revenue support should adapt and evolve.

In the current nascent market, stakeholders suggested that revenue generation needs to be combination of carrots (rewards) and sticks (penalties) which balance incentives and economic pressures to give the CCUS/CDR market certainty in the long-term. These should be sensitive to the structure of the industrial sectors they are targeting.

In the current CCUS/CDR market the combination of multiple revenue support schemes may needed to encourage initial revenue generation. In the USA, the 45Q tax credit scheme is an example of a carrot which can help drive revenue generation for CCUS/CDR projects.⁷⁶

In Europe, the combination of an Emissions Trading Scheme (ETS), Carbon Contracts for Difference (CCfD) and related schemes (e.g., (reversed) auctions or carbon pricing for captured CO₂), and a Carbon Border Adjustment Mechanism (CBAM) can help ensure stable revenue generation from CCUS/CDR projects. An ETS works because it forces decarbonisation by applying a carbon price. The addition of a CBAM is designed to mitigate carbon leakage from the region with an ETS. However, the volatility of these ETS prices may also increase risk associated with revenue generation from CCUS/CDR

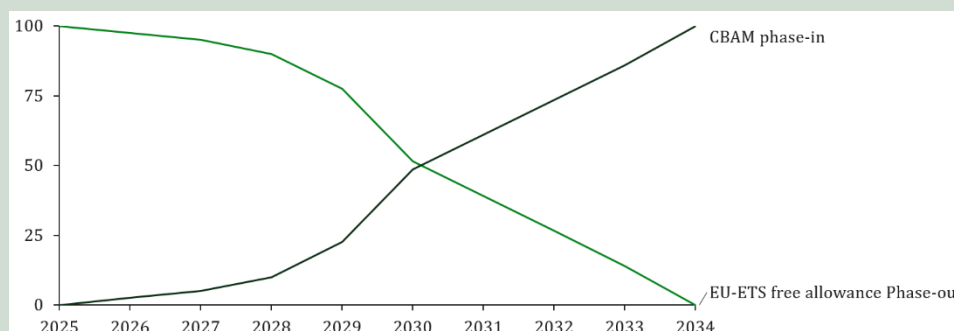
⁷⁵ ReFuelEU Aviation - European Commission ([europa.eu](https://european-council.europa.eu/media/en/press-summaries/default/11455.pdf))

⁷⁶ [IF11455 \(congress.gov\)](https://www.congress.gov/bills/114/1455)

projects. Therefore, Contracts for Difference schemes which are grounded on a revenue basis can help to give revenue stability for CCUS/CDR projects.

Case study – EU's Emission Trading System⁷⁷ and Carbon Border Adjustment Mechanism⁷⁸

- The EU ETS is a “cap and trade” system designed to gradually increase the cost of emitting CO₂ and incentivise cost-effective emissions reductions.
- An upper limit (cap) is specified for the annual CO₂ emissions of industrial emitters, in the form of “emission allowances” (one allowance = 1 tonne CO₂e).
- Emitters that exceed their allotted allowances must face a fine, or purchase allowances from another emitter. Conversely, emitters below their allowance cap can sell allowances to others.
- The cap is set to decrease every year (linearly at 2.2% for 2021-2030) such that the total number of emissions allowances, and therefore overall emissions, falls over time (see graph below)⁷⁹.
- This cap reduction is likely to drive up the price of allowances (and therefore the cost of emitting) due to reduced supply of allowances and increased demand.
- Furthermore, reductions in the number of free allowances automatically allocated to emitters should also make the ETS more competitive.
- To avoid carbon leakage, the Carbon Border Adjustment Mechanism (CBAM) is being gradually introduced (it started in 2023), with a transitional phase during which reporting obligations are enforced without financial penalties. Full implementation, including the payment of carbon costs on imports, is expected by 2026.



In the future, as the CCUS/CDR market matures and evolves from FOAK to nth-of-a-kind (NOAK) projects, government revenue support schemes should also be designed to evolve. For example, as the market matures the cost of emitting CO₂ under an ETS scheme could increase such that the prices of unabated products rise to match (or exceed) those of low-carbon products. At this stage, a Carbon Contract for Difference (CCfD) will likely no longer be needed to stabilize revenue although CBAMs will still be required to minimize carbon leakage to economies with lower (or absent) CO₂ prices. In

⁷⁷ EU Emissions Trading System (EU ETS) - European Commission ([europa.eu](https://european-council.europa.eu/media/1000000/1/related_content/eu-ets-2021-2023.pdf))

⁷⁸ Carbon Border Adjustment Mechanism - European Commission ([europa.eu](https://european-council.europa.eu/media/1000000/1/related_content/cbam-2023-2024.pdf))

⁷⁹ EU adopts landmark ETS reforms and new policies to meet 2030 target | International Carbon Action Partnership (icapcarbonaction.com)

a mature, developed CCUS/CDR market, where CO₂ prices are widespread, revenue generation could come purely from the CO₂ price associated with an emissions trading scheme.

Under an incentives scheme which relies on tax credits (e.g., 45Q in the US), as the market matures, these tax credits could be maintained to provide an ongoing revenue stream, although this is likely to be burdensome on taxpayers. Alternatively, these tax credits could gradually be reduced or withdrawn through time, perhaps alongside a transition into a compliance market with the introduction of certain low-carbon standards.

In a mature, developed CCUS/CDR market, other revenue generation mechanisms such as green premiums may become less important as low-carbon products become the default. In this situation, the cost of emitting CO₂ (both commercially and socially) may be high enough that unabated production is no longer competitive.

Revenue Generation Market Strategy #4: Implementation of regulations to drive a compliance market for CDR projects

The current voluntary carbon market has been critical in enabling many CDR projects to take a final investment decision (FID).⁸⁰ The current demand for CDR credits on the Voluntary Carbon Market (VCM) is limited to just a few offtakers (e.g., Shell, Microsoft⁸¹), meaning revenue generation from CDR projects may face problems with scaling-up. Implementing regulations can encourage the creation of compliance markets, and therefore increased demand for CDR credits, by establishing clear regulatory frameworks that incentivize or require entities to decarbonise. This is because for some entities, decarbonisation may include offsetting their emissions through purchasing carbon credits if emission reductions cannot be met. Therefore, compliance markets are likely to become increasingly important in driving revenue generation, particularly for DACCS and BECCS projects, as entities seek to purchase engineered carbon removal credits.

By establishing a compliance market, stakeholders suggested that entities, including public entities (e.g., local governments, city councils), with ambitious net zero commitments, may become leaders in buying credits from, or directly funding, emerging CDR projects. The establishment of a compliance market may encourage the development of CDR projects by giving clear signals that there is future demand for carbon credits and therefore drive CDR revenue generation in the future.

Stakeholders suggested that compliance markets could be the biggest CDR demand driver. By integrating CDR into compliance markets, there is the potential to ensure direct equivalency of future compliance market CO₂ prices with CDR price. This direct equivalency could provide revenue certainty for project developers, and fungibility between allowances and approved CDR. Certainty would also need to be provided to purchasers with regards to what they can and cannot use the removals for. If fully integrated, in principle it should facilitate the transaction of CDR credits via existing ETS

⁸⁰ Ørsted begins construction of Denmark's first carbon capture project; Ørsted enters into new major agreement on carbon removal with Microsoft

⁸¹ Shell and Microsoft lead the carbon credit market in 2024

allowance trading systems, which would fast track standardization of the transaction process, enabling increasing numbers of potential CDR purchasers to engage and therefore scale-up CDR infrastructure deployment. However, if CDRs were integrated into compliance markets, it will be important to ensure these are not favoured over direct emission reductions from industrial sites. For example, integration could be set to align with initiatives such as the Science-Based Targets initiative (SBTi) Corporate Net Zero Standard⁸², where CDRs can only be used to counterbalance the final 10% of residual emissions once emissions have already been cut by more than 90%.

Case Study – EU Carbon Removals and Carbon Farming Regulation (EU-CRCF)

- The EU's Carbon Removals and Carbon Farming Regulation is designed to establish a robust framework to promote carbon removal activities and incentivize sustainable land use practices.⁸³
- It establishes clear criteria and certification methodologies for quantifying, monitoring, and verifying CDRs.
- By certifying CDRs, the regulation could be used to create tradable carbon credits that may be used by entities to meet their obligations under the EU Emissions Trading System (EU ETS), although there are a range of risks and benefits which could come alongside integrating CDRs into the EU-ETS.⁸⁴
- If extensions to the CRCF regulation enable companies to offset emissions by purchasing certified CDR credits, this could provide significant incentives to scale-up the CDR market across the EU.

⁸² [The Corporate Net-Zero Standard - Science Based Targets Initiative](#)

⁸³ [Carbon Removals and Carbon Farming - European Commission](#)

⁸⁴ [CONCITO & CATF 2024 Emissions trading and permanent carbon removals.pdf](#)

6. CAPITAL FINANCING MARKET STRATEGIES

Capital financing in a market model refers to both funding of the infrastructure required for a CCUS/CDR project (e.g., capture plant facilities, CO₂ pipelines) as well as any external support that a project can get for capital funding.

The following section includes concepts identified in planned/operational CCUS/CDR projects, in analogous markets and raised by stakeholders on suggested best practices of how to overcome capital financing barriers to CCUS/CDR project deployment. These suggested best practices have been developed into potential market strategies for the CCUS/CDR market. The relevant barriers which the market strategy is designed to overcome are summarized in the table below.

Potential market strategy	Barrier which the market strategy is designed to overcome
Targeting capital financing sources appropriate for the CCUS/CDR project	CCUS/CDR projects are often currently a high-risk, low-return investment opportunity, which can hinder the range of investors willing to supply capital to these projects
Obtaining stable revenue generation	Unclear expected rate of return on investments (e.g., due to volatility in costs, energy prices, carbon prices) means investors may not be willing to invest
Using collaborative funding pots to reduce financial risk	Risks associated with a CCUS/CDR project underperforming and/or failing can deter investors
Using revenue support schemes rather than public grants to raise capital finance	Uncertainty in expected rate of return may limit the willingness of private investors to provide capital

Capital Financing Market Strategy #1: Targeting capital financing sources appropriate for the CCUS/CDR project

There are multiple potential sources of capital for CCUS/CDR projects. However, the expected rate of return and risk appetite is likely to vary between different investors. Since CCUS/CDR projects are often currently a high-risk-low-return investment opportunity, this can hinder the range of investors willing to supply capital to these projects. Therefore, it is important for a CCUS/CDR project to use an appropriate source of capital depending on the project's specifics, including its size, location, and stage of development. However, this assumes that capital exists in the market and that investors are willing to deploy it for CCS. Other market strategies discussed in this report, such as enabling stable revenue generation, will also shift the type of capital required for the projects. The potential sources of capital are linked to their appropriate CCUS/CDR projects in the table below.

Source of capital	Description of financing method	Appropriate projects	Example project
Government Grants	Governments may provide grants, subsidies, or tax incentives to encourage CCUS/CDR projects aligned with national or regional climate goals.	Early-stage projects, pilot programs, and projects aligned with national or regional climate goals.	EU Innovation Fund (funded by the EU-ETS) providing funding for a range of low-carbon technologies. ⁸⁵
Equity stakes of state-owned companies	Governments may be required to take a certain equity stake in CCUS/CDR projects through state-owned enterprises.	Large-scale projects aligned with national or regional climate goals, particularly where the state-owned enterprise has unique experience in the project infrastructure (e.g., pipeline operation).	EBN, the Dutch state-owned pipeline, is required to take up to a 40% equity stake in infrastructure joint ventures for CO ₂ storage in the Netherlands, such as Porthos. ⁸⁶
Private Equity / Venture Capital	Private equity firms and venture capitalists are often interested in funding innovative technologies with the potential for high returns.	Projects using breakthrough technologies that need funding to scale up.	Decarbonisation Partners funding scale-up of neustark's CDR technology. ⁸⁷
Corporate Investment	Large corporations, particularly those in the energy or industrial sectors, may invest in CCUS/CDR projects to reduce and/or offset their own emissions and/or comply with regulations.	Projects that are directly related to the core business of large entities.	The Gorgon Project is a Joint Venture (JV) funded by Chevron and its JV partners who have invested over AUD \$2 billion. ⁸⁸
Pre-sales to offtakers	Pre-sales allow CCUS/CDR project developers to secure funding while giving buyers an opportunity	Projects where the captured CO ₂ has an intrinsic value or final product is more	1PointFive and Trafigura entered into a significant pre-sales agreement for DAC

⁸⁵ [Innovation Fund - European Commission \(europa.eu\)](https://ec.europa.eu/innovation/fund/)

⁸⁶ [Carbon Capture and Storage - EBN](https://ebn.nl/en/carbon-capture-and-storage)

⁸⁷ [neustark | Neustark secures \\$69 million in funding to expand carbon...](https://neustark.com/news/neustark-secures-69-million-in-funding-to-expand-carbon-capture-capacity)

⁸⁸ [Gorgon Project Business Overview — Chevron](https://www.chevron.com/energy-transition/gorgon-project)

	to lock in future offtake, for example, carbon removal credits.	valuable than the unabated alternative.	carbon removal credits. ⁸⁹
Institutional Investors (e.g., pension funds)	Institutional investors seek low to moderate risk investments over long time frames.	Mature projects with proven technology and stable, but relatively low, returns.	Canada Pension Plan Investment Board's \$145m investment into Power2X, a Netherlands-based technology developer. ⁹⁰
Debt Financing	Banks and financial institutions may provide loans or other debt instruments, particularly if the project has a strong business case and a clear revenue stream.	Projects with predictable returns.	The Petra Nova project in Texas, USA, was given a \$250 million loan from the Japan Bank for International Cooperation (JBIC). ^{91,92}
Export Credit Agencies (ECAs)	ECAs often provide loans with lower interest rates and longer repayment terms, with the support of national governments.	Projects that involve cross-border technology transfer, equipment export, or multinational collaboration.	Export Finance Norway provided guarantees for €200 million to support the deployment of SLB Capturi's JustCatch at Ørsted's Danish power stations. ⁹³
Multilateral Development Banks	Offer financing for sustainable development, particularly in developing countries.	Projects in emerging markets or those with a strong emphasis on sustainable development.	World Bank supporting the development of a CCS Programme in South Africa. ⁹⁴

⁸⁹ [1PointFive and Trafigura Announce Direct Air Capture Carbon Removal Credit Agreement | Trafigura](#)

⁹⁰ [Canadian pension fund puts \\$145m towards 'green molecules' - Net Zero Investor](#)

⁹¹ [Project Financing for Post-Combustion Carbon Capture-Enhanced Oil Recovery Project in the United States | JBIC Japan Bank for International Cooperation](#)

⁹² It is important to note that the Petra Nova project generates revenue from Enhanced Oil Recovery

⁹³ [Export Finance Norway to provide guarantees for EUR 200m Aker Carbon Capture export contract | Eksfin](#)

⁹⁴ [World Bank CCS program activities in South Africa : results and lessons learned](#)

Green Bonds	Issuing green bonds allows companies to raise capital specifically for environmental projects.	Projects with clear environmental benefits that can be easily communicated to investors.	Up to ¥2tn available in green bonds from Japan's transition bond framework for sustainable technologies including carbon capture. ⁹⁵
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A combination of these capital financial sources will likely provide the most robust financial foundation. However, it will be important for CCUS/CDR to focus on raising capital from the most appropriate source. For instance, early-stage or innovative projects/technologies might benefit more from government grants or venture capital, while large-scale, established projects might find corporate investment or debt financing more suitable. Since CCUS/CDR projects are often a low-return investment opportunity, engaging with certain investors (e.g., institutional investors) which tend to invest in projects with relatively low, but stable returns, may be a potential market strategy.

Different requirements will be needed to unlock different capital financing sources. For example, for institutional investors (e.g., pension funds) and debt financing, obtaining stable revenue generation (see the following capital financing market strategy), is likely to be crucial in unlocking these sources. On the other hand, to raise capital from government grants or equity stakes of state-owned companies, the CCUS/CDR project likely needs to align with wider policy objectives, as well as demonstrating clear societal benefits.

Capital Financing Market Strategy #2: Obtaining stable revenue generation

An unclear expected rate of return on their investment is likely to deter private investors from providing capital financing to a CCUS/CDR project. If the CCUS/CDR project can provide certainty to investors on the potential for stable, long-term revenue generation, then this is likely to encourage investment into their project.

There are various options for potential revenue generation for CCUS/CDR projects (e.g., government support, green premiums) outlined in Chapter 5, and obtaining stable revenue generation is likely to be key to unlocking private capital finance. Stakeholders suggested that often the issue in raising finance is not usually the amount of capital required, but more a clear idea of what the expected rate of return is over the project lifetime, so an investor is confident that a return will be generated on their investment.

The business case for CCUS/CDR projects is currently relatively uncertain, with unclear expected rates of return driven by market or regulatory factors. Stakeholders highlighted the below factors as being particular areas of uncertainty:

⁹⁵ [Japan's green transition bond includes controversial tech like carbon capture - Green Central Banking](#)

- Uncertainty in future carbon prices (i.e., as determined by Emissions Trading Schemes).
- The time limitation of revenue support schemes (e.g., 45Q credits).
- Uncertainty in future regulations (e.g., future eligibility criteria) and the impacts this may have on accessing revenue support.
- Volatility in costs and energy prices, particularly for first-of-a-kind (FOAK) costs which are likely to have large errors in estimated infrastructure costs.

To prioritise a stable return on investment, strong market signals (e.g., long-term offtake agreements, contracts for difference schemes) which demonstrate the potential for long-term revenue generation over a CCUS/CDR project lifetime (>20 years) are needed.

These should be supported by clear national and regional decarbonisation ambitions as well as, consistent regulations around what is/is not eligible for certain revenue support schemes. By providing clarity on the potential for long-term revenue generation through strong market signals and clear decarbonisation ambitions, this should give confidence to private investors on the expected rate of return from CCUS/CDR projects.

Case study – UK Regulated Asset Base for CO₂ pipelines⁹⁶

- A Regulated Asset Base (RAB) model is one in which regulators allow the company to earn a specific return on their physical infrastructure assets, ensuring a stable revenue stream.
- The UK's RAB model for CO₂ pipelines is a financial framework aimed at supporting the development of CO₂ pipeline infrastructure.
- The RAB model has been used in the UK for other large infrastructure projects, such as gas and electricity networks as well as nuclear projects.⁹⁷
- Applying a RAB to CO₂ pipelines is intended to attract private investment by providing a stable and predictable return on investment, thereby reducing the financial risks associated with these long-term projects as well as addressing issues associated with monopolies and providing certainty for the users (i.e., capture projects) of the CO₂ pipelines.

Capital Financing Market Strategy #3: Using collaborative funding pots to reduce financial risk

Risks associated with a CCUS/CDR project underperforming and/or failing can deter investors. Reducing financial risk is important to encourage a wider variety of investors to invest. Financial risks may arise in a CCUS/CDR project if the project underperforms or fails to remove carbon, and thus is unable to generate revenue through carbon credits. Collaborative funding pots can be used as an insurance mechanism to safeguard against financial risks associated with underperformance or failure of a CCUS/CDR project.

⁹⁶ [Carbon Capture, Usage and Storage: an update on the business model for transport and storage \(publishing.service.gov.uk\)](https://publishing.service.gov.uk)

⁹⁷ [Nuclear Regulated Asset Base \(RAB\) model | Ofgem](#)

For example, buffer pools are a reserve of carbon credits set aside as a safeguard against the risk of project underperformance or failure.⁹⁸ They are created by withholding a percentage of credits from individual carbon offset projects and pooling them together. These reserved credits act as insurance, covering potential losses due to unforeseen events like natural disasters or inaccuracies in carbon sequestration estimates. If a CCUS/CDR project underperforms or is unsuccessful, credits from the buffer pool are used to compensate for the shortfall, ensuring that the overall carbon reductions or removals are maintained. Projects with a higher risk of reversal have a correspondingly larger buffer pool. These pools act as a risk management tool, providing insurance against non-permanence in carbon sequestration projects and thus reducing counterparty risk to the investor.

However, a key issue with buffer pools is setting the percentage of credits that are withheld. For forestry projects, ~10% is common where the risk of reversal (e.g., due to forest fire or change of use) is high.⁹⁹ However, since the likelihood of reversals for CCS-enabled CDRs considered in this report (BECCS, DACCS) is lower than for forestry projects, the percentage of credits withheld is also likely to be lower. For a buffer pool to operate effectively and minimize financial risk, setting the right percentage for the buffer pool will likely be crucial.

Special insurance products for CCUS/CDR projects (e.g., from Kita¹⁰⁰ or Carbonpool¹⁰¹) could also be used to reduce financial risk, although stakeholders suggested that a cost-benefit analysis of the premium charged compared to the revenue generated from the CCUS/CDR project should be undertaken.

Case study – Buffer pools in California’s forest carbon offsetting programme¹⁰²

- The California forest offset protocol addresses permanence concerns using buffer pools.
- Each forest offset project must contribute a share of its offset credits to the buffer pool, which is available to compensate for any unintentional “reversal,” or forest carbon loss, across all forest projects in the offset program over projects’ 100-year commitments.
- Forest offset projects typically contribute between 15% to 20% of their total credits to the buffer pool.
- The entire buffer pool is available to cover comprehensive carbon loss from unintentional reversals, no matter the share of the buffer pool associated with that specific risk and no matter the contribution an individual project has made to the collective buffer pool.

⁹⁸ [Guide to Carbon Credit Buffer Pools \(sylvra.com\)](https://sylvra.com/guide-to-carbon-credit-buffer-pools)

⁹⁹ [Frontiers | California’s forest carbon offsets buffer pool is severely undercapitalized](#)

¹⁰⁰ [Kita](#)

¹⁰¹ [Home | CarbonPool](#)

¹⁰² [Carbon offsets burning – CarbonPlan](#)

Case study – Swiss negative emissions fund¹⁰³

- The Swiss negative emissions fund is a public fund, starting in 2025 and reaching full scale in 2030, with an obligation for all Swiss territorial emitters to pay into the fund for removal of “their” CO₂.
 - The fund would then invest in a portfolio of carbon removal projects, building essential knowledge, monitoring, governance, infrastructure, public awareness and acceptance.
 - Alternatively, emitters could implement their own decarbonisation technology, thus avoiding the need to pay into the fund.
 - As a collaborative funding pot, this fund should help reduce financial risks associated with developing new CCUS/CDR infrastructure.
- In particular, waste incineration plants in Switzerland are calling for the development of such a fund due to the requirement of at least one CO₂ capture plant of 100,000 tonnes per year being in operation by 2030.¹⁰⁴ The creation of such a fund could be used to maintain competitiveness in the sector as well as reducing financial risk for the first waste incineration plant to install CO₂ capture.
 - There is also reluctance from the sector to be a first mover in developing transport and storage, owing to the lack of CO₂ transport and storage infrastructure so the creation of the negative emissions fund could also support development of this infrastructure.¹⁰⁵

Capital Financing Market Strategy #4: Using revenue support schemes rather than public grants to raise capital finance

Many current planned and operational CCUS/CDR projects have relied on public grants (e.g., from the EU Innovation Fund). However, for future projects, stakeholders emphasised that obtaining public grants is becoming less attractive because investors decide project investments based on risks. If a government (or other public entity) were to provide a capital grant, this would not change the risks associated with the project, rather capital grants limit the amount investors can invest in a project. To attract private investors to CCUS/CDR projects, having guaranteed revenue generation, potentially supported by government revenue incentives, is likely to be more effective in raising private capital than a public grant.

¹⁰³ [Swiss Negative Emissions Fund – paying for Net Zero – E4S](#)

¹⁰⁴ [Agreement with managers of waste treatment installations \(admin.ch\)](#)

¹⁰⁵ [70634.pdf](#)

Case Study – Evolution of the UK Government support schemes for CCS projects

- Based on previous learnings and extensive engagement with the sector, the UK Government has revised and modified its package of financial support for CCS projects from being centered around the distribution of capital grants, to being focused on Carbon Contracts for Difference as a current revenue support mechanism.
- The UK's first CCS competition launched in 2007 but was cancelled in 2011 due to insufficient recognition of the commercial risks associated with CCS.¹⁰⁶
- The second UK CCS competition, the "CCS Commercialisation Programme" was launched in 2012 with £1 billion of capital funding available.¹⁰⁷
 - However, the competition was cancelled in 2015 due to failure by the UK Government's energy department to agree the long-term costs of the competition.¹⁰⁸
- In 2017, the UK Government launched a new CCS competition based around Industrial Clusters¹⁰⁹:
 - Most of the UK Government support within this competition is through Carbon Contracts for Difference mechanisms and through the Regulated Asset Base for transport and storage (TRI).
 - In terms of capital grants, only the Industrial Carbon Capture and Waste Carbon Capture Business Models can access capital grants (of up to 50%) and the Hydrogen projects which can access capital grants of up to 20% through the Net Zero Hydrogen Fund – Strand 3.
 - The competition aims to create the conditions to attract investment into CCUS/CDR projects by creating a de-risked rate of return which is acceptable to investors.

¹⁰⁶ [Carbon capture and storage: lessons from the competition for the first UK demonstration - NAO report](#)

¹⁰⁷ [CCS competition launched as government sets out long term plans - GOV.UK \(www.gov.uk\)](#)

¹⁰⁸ [UK government spent £100m on cancelled carbon capture project - BBC News](#)

¹⁰⁹ [Carbon capture, usage and storage \(CCUS\): business models - GOV.UK](#)

7. EVALUATION OF MARKET STRATEGIES

Each of the potential market strategies identified for CCUS/CDR ownership structure, revenue generation and capital financing are at different development stages. Some market strategies are already current practices in many CCUS/CDR projects globally. Others are emerging practice in certain jurisdictions or certain sectors. Some market strategies identified are not widespread and may develop into a future strategy for CCUS/CDR projects. The table below summarizes the current development stage of each market strategy identified, from a global perspective.

Many of the potential market strategies highlighted are likely to evolve through time as the CCUS/CDR market matures from the current small-scale, nascent market to widespread CCUS/CDR deployment needed to reach net zero. The table below also details how these market strategies are likely to evolve from these first-of-a-kind (FOAK) to n^{th} -of-a-kind (NOAK) projects.

However, the evolution of these market strategies is likely to significantly depend on the location and the sector of the CCUS/CDR project, as well as the maturity of the CCUS/CDR market. Not all market strategies identified will be suitable for every situation as regional and sectoral differences are likely to impact how suitable a potential market strategy will be.

	Potential market strategy	Current development stage*	Evolution from FOAK to NOAK projects
Ownership Structure	Different owners for construction and operational project phases	Emerging practice	Transfer of ownership is likely to become increasingly commonplace as entities develop specific skills associated with developing or operating CCUS/CDR projects or decide their strategic interests lie in or out of the CCUS/CDR space.
	Government coordination of part-chain ownership structures	Emerging practice	Likely to become less significant for NOAK projects as multiple configurations for the CCUS/CDR value chain reduce the risk associated with the “chicken-and-egg” problem. Also, may be less common in jurisdictions such as the US where a lot of the CCUS/CDR projects are commercially driven.
	Clear contractual arrangements for commercial risk allocation	Current practice	Contractual arrangements may become more standardized from FOAK to NOAK projects.

	Standardisation of CO ₂ transport infrastructure	Future strategy	Standardisation is likely to become increasingly important for NOAK projects to allow flexibility in transport and storage options.
	Regulating CO ₂ pipeline infrastructure	Current practice	Regulation of CO ₂ pipeline infrastructure is likely to remain a best practice for NOAK projects except in regions (e.g., US Gulf Coast) where multiple and competing CO ₂ pipelines may develop in parallel.
	Partnering with entities with pre-existing expertise	Emerging practice	Partnering with existing entities is likely to become more prevalent in NOAK projects as certain entities refine their CCUS/CDR expertise.
	Capture-as-a-service solutions	Emerging practice	Capture-as-a-service solutions are likely to become increasingly widespread in a mature CCUS/CDR market to enable the flexibility to respond to market conditions.
	Flexibility in government incentives to allow a range of emerging ownership structures	Emerging practice	Government incentives are likely to become increasingly flexible to enable a widespread, market-driven CCUS/CDR market.
Revenue Generation	Robust, traceable certification to enable green premiums	Future strategy	The role of low-carbon certification may evolve from enabling green premiums in the near-term to supporting compliance in the long-term.
	Defining clear market segments to implement mandated markets	Emerging practice	Mandated markets are likely to become less important in NOAK projects as most products available to buy are decarbonised.
	Evolution of government revenue support through time	Future strategy	Government revenue support is likely to evolve through time as the market matures as CCUS/CDR projects become increasingly commercially feasible.

	Implementation of regulations to drive a compliance market for CDR projects	Emerging practice	Compliance markets are likely to become increasingly important to sustain a widespread CCUS/CDR market.
Capital Financing	Targeting capital financing sources appropriate for the CCUS/CDR project	Current practice	Appropriate capital financing will remain important for NOAK projects. Specialised CCUS/CDR financiers may emerge in the long-term.
	Obtaining stable revenue generation	Emerging practice	Stability of revenue generation is likely to remain important even in a widespread CCUS/CDR market to leverage a wide range of capital funding sources.
	Using collaborative funding pots to reduce financial risk	Current practice	Buffer pools and other risk management techniques are likely to remain important, even in a widespread CCUS/CDR market, to mitigate against technological risks.
	Using revenue support schemes rather than public grants to raise capital finance	Current practice	Public grants and government subsidies are very unlikely to scale to support a widespread CCUS/CDR market. Other revenue incentives are more likely to be widespread for NOAK projects.

*Current practice = some operational CCUS/CDR projects screened are currently employing this market strategy; Emerging practice = some planned CCUS/CDR projects screened are currently employing this market strategy; Future strategy = no operational/planned projects screened are currently employing this market strategy, but it could potentially be significant in the future.

8. SUMMARY AND RECOMMENDATIONS FOR FUTURE WORK

This study identified potential market strategies from undertaking analysis on operational and planned CCUS/CDR projects, analogous markets and engaging with stakeholders working in the CCUS/CDR space.

- A screening of 12 operational and 14 planned CCUS/CDR projects was undertaken to analyze their supporting market model and identify similarities and differences between projects.
- Five analogous markets (Waste Generation, Renewable Electricity, Low-carbon Fuels, LNG Transport and Hydrogen) were investigated for similarities/differences between these markets and the CCUS/CDR market.
- 17 CCUS/CDR industry stakeholders joined 4 workshops in July 2024 to discuss best practices for the CCUS/CDR market based on their own market experiences.
- Insights from each of these sources were divided into potential market strategies which relate to (i) ownership structure of a CCUS/CDR project, (ii) revenue generation opportunities available for the project and (iii) capital financing sources which can be leveraged to cover initial upfront costs of undertaking a CCUS/CDR project.

There are a wide variety of potential market strategies which could help the CCUS/CDR market to develop to the scales required to meet net zero.

- Future market strategies associated with the ownership of different parts of the CCUS/CDR value chain include having different owners for the operational and construction phases of a CCUS/CDR project, government coordination of part-chain ownership structures, standardisation of CO₂ transport infrastructure, partnering with entities with pre-existing expertise (or those offering CCS-as-a-service) as well as flexibility in CCS incentives to allow for a range of emerging ownership structures.
- Potential market strategies to generate revenue from CCUS/CDR projects include robust, traceable low-carbon certification, defining clear market segments on mandated markets, enabling the evolution of government revenue support through time as well as implementation of regulations to drive a compliance market for CDR projects.
- Targeting capital financing sources appropriate for the CCUS/CDR project, obtaining stable revenue generation, using buffer pools to reduce investment risk and using revenue support schemes rather than public grants to raise capital finance are potential market strategies associated with raising capital financing.

Best practices associated with these potential market strategies are likely to vary in different regions, sectors and different market maturities.

- Some potential market strategies identified in this report are likely to be most effective in the scale-up phase of the CCUS/CDR market (e.g., government coordination of part-chain ownership structures, robust traceable certification), whereas other market strategies identified may endure in a widespread CCUS/CDR market (e.g., standardisation of CO₂ transport infrastructure, regulations to support the compliance market).

- Deployment of carbon capture is likely to vary between sectors due to differences in existing expertise between sectors and in costs of capture due to variations in CO₂ purities in different sectors.
- Governance structures are likely to impact the deployment of potential market strategies through differing revenue incentives for CCUS/CDRs and differing levels of ownership and coordination of CCUS/CDR projects.

Future work to enable widespread deployment of CCUS/CDR technologies should leverage the potential market strategies identified in this report.

- The potential market strategies identified in this report can be used by CCUS/CDR project developers as well as policymakers, trade bodies and other interested parties, to support rapid deployment of CCUS/CDR technologies.
- Ownership, revenue generation and capital financing market strategies will all have a role to play in reducing risks of deploying CCUS/CDR technologies and facilitating the roll-out of infrastructure.
- The impact and effectiveness of each of these market strategies in deploying CCUS/CDR projects is likely to vary depending on the specifics of the project, including its region, sector and market maturity at the time of deployment.

APPENDIX

Definition of market model component options

Ownership structure

Infrastructure Ownership Structures

- **Full chain** = captured CO₂ transported from capture to injection site which is owned and operated by a single entity. Typical for first of a kind (FOAK) projects but have high investment, cross-chain risks and liabilities born by a single developer (traditionally oil and gas developers). May fail to scale, provide open access to a network and/or incentivise competition.
- **Part-chain** = split-up value chain with the potential to share infrastructure but can have issues with coordination which may make investors more reluctant if there is no certainty (on e.g. where the CO₂ will eventually be stored) and have implications for technical specifications. May lead to a “chicken-and-egg” scenario where emitters are reluctant to invest in capture projects without T&S certainty.
 1. Self-capture with third party CO₂ offtake – emitter captures but then sells the captured CO₂ to generate revenue. But CO₂ price may not be competitive, especially if reliant on a single client/supplier relationship.
 2. CO₂ transport and/or storage as a service – emitter captures but independent companies transport and store it. A natural monopoly in a T&SCo. Low risk if the CO₂ is sufficiently priced and a long-term contract is in place but may have a long lead time in getting contracts/purchasing agreements signed.
 3. Capture as a service – a separate entity supplies capture equipment and may also act as project developers (both owning and operating the capture equipment). Expertise in standard capture but also potentially customisable solutions. Potential lack of demand of these companies for CCUS related projects and lack of established supply chains for components/consumables.
- **Hub/cluster** = multiple companies collaborating and sharing infrastructure, often centred around an anchor project which opens up to other emitters (e.g. Ravenna).
 1. Single hub – multiple capture projects feeding into a single T&S company.
 2. Offshore CO₂ transport – An aggregator (e.g. Altera Stella Maris) consolidates CO₂ captured from multiple emitters and owns and operates the aggregation infrastructure as well as negotiating offtake agreements with transport and storage operators. Significant coordination risks but inherent flexibility for expansion. Aggregator should be regulated to avoid monopolisation.
 3. Free market – Emitters negotiate disposal of CO₂ on a cargo-by-cargo basis, but this can lead to significant coordination risk and complexity in commercial and financing arrangements.

Entity ownership

- **Public** – either a government itself directly invests in CCS infrastructure, or a state-owned enterprise owns the CCS infrastructure.
- **Private**
 - Single entity
 - Joint venture
 - Multiple entities form a Special Purpose Vehicle to develop a single project.
- **Public-Private Partnership** – A JV/SPV which includes some form of public body or state-owned enterprise.

Revenue Generation

Low-carbon product revenue generation

- **Green premium/conscious consumer** – an individual consumer pays more for the low-carbon product (which has been independently certified as such, like Fairtrade) in a competitively priced, open market.
- **Product GHG intensity tax** – Government sets a tax that an emitter has to pay based on the carbon intensity of their product. Price increases through time to incentivise emissions reduction but does not guarantee them. Can easily be applied as different amounts to different products within the same production sector (e.g. cars vs steel rods from the I&S sector).
- **Regulated market for low-emission products** – Regulations are defined in certain sectors which mandate a particular fraction having a certain emissions intensity (e.g. EU SAF mandate).
- **Public procurement** – Governments lead the way as a conscious consumer, buying products below a certain carbon intensity to establish a market for low-carbon products.
- **Carbon Contracts for Difference** – where a subsidy is paid to the project based on the difference between the strike price (the cost of operating the project) and a reference price (the price of operating at business-as-usual conditions, expected to grow through time if combined with an emissions trading scheme). This subsidy should level the playing-field by accounting for the increased costs of manufacturing the low-carbon product. For example, the UK's Industrial Carbon Capture business model and the Netherlands SDE++.
- **Regulated Asset Bases** - Authorities institute a controlled pricing mechanism or “allowable revenue” for the project which allows a pre-determined return on investment for the project to ensure low-carbon product revenue generation. For example, in the UK for CCS T&S operators.

CO₂ revenue generation

- **Carbon tax** – Government sets a price per tonne of CO₂ that an emitter has to pay. Price increases through time to incentivise emissions reduction but does not guarantee them.

- **Tax credits** – reduction in the amount an entity has to pay in tax as they are undertaking CCS. For example, the 45Q tax credit in the USA (variable prices depends on EOR/CCU \$60/t, CCS \$85/t or DACS, \$180/t).
- **Emissions Trading Systems** – An emissions cap (defined threshold of tCO₂/year) is allocated to each entity with a certain number of per-tonne allowances within that cap. An entity can obtain allowances via “free allowances” (to reduce the initial cost impact of ETS establishment), public auctions (allowances released by the regulator to stabilise the market) or via the secondary market (facilities buying/selling allowances between themselves) at a certain price, often referred to as “carbon price”. Allowances can be bought and sold on the secondary market, but the cap decreases through time so overall emissions are reduced. Allows the market to determine the price on carbon and revenues can be used to fund/finance other emissions reduction activities.
- **Utilisation** – captured CO₂ is sold for long-term storage in products (e.g., concrete, cement aggregates), circular economy activities (e.g., making e-fuels/plastics) or other utilisation activities (e.g., EOR).
- **Carbon credits from the voluntary carbon markets** – carbon credits can be sold, which represent one tCO₂ avoided, reduced or removed.

Capital financing

Capital Financing Sources

- **Public** – for example state-owned enterprises, but also governments and Development Financial Institutions.
- **Private** – such as external private equity, intragroup equity (i.e. JV/SPV) or development or commercial Banks. Multi-lateral agencies or green bond providers may be able to provide capital funding at favorable rates.
- **Mixture of public and private**

Capital Financing Support

- **Investment tax credits** – Tax repayments to recover capital costs, or reduction in taxes of certain key pieces of equipment. For example, as planned in Canada – ITC rate depends on type of project: 60% for direct air capture (DAC) projects, 50% for post-combustion capture investments, and 37.5% for T&S.
- **Tax exemptions** – discount based on a percent of the value of items purchased for the CCS project. For example, as planned in the 2023 Malaysian National Budget, CCS companies will have full import duty and sales tax exemption on carbon capture equipment from 2023 to 2027, a tax deduction for pre-commencement expenses within 5 years from the start of operations, and a tax exemption of 70% on statutory income for 10 years.
- **Concessional finance** – below market rate finance (loans, grants or equity investment) provided by major financial institutions, such as development banks and multilateral funds, to accelerate development objectives. Concessional finance targets high-impact projects responding to globally significant development

challenges such as a climate change mitigation that otherwise could not go ahead without specialised financial support. Often targeted at developing countries.

- **Capital grants** – monetary contribution to capital required for the project. Likely not to cover the full cost of the project and many projects will require significant additional private capital; may be limited to specific project stages (e.g., technology development). For example, US CarbonSAFE, EU Innovation Fund, UK Cluster Sequencing.
- **Government direct loans/debt capital** –repayable monetary contribution to capital required for the project, but often at favourable interest rates.
- **Loan guarantees** – a government promises to purchase the debt from the private lending institution and take on responsibility for the loan in the event that the borrower defaults.

Database for operational CCUS/CDR projects

Name of Project	Region	Project scale (MtCO ₂ /year)	Low-carbon product revenue model	CO ₂ Revenue model	Source of CO ₂	End Destination of CO ₂	Value chain integration	Entity Ownership	Capital financing sources
Alberta Carbon Trunk Line	North America	14.6		EOR	Fossil - Industrial	Utilisation	Hub/cluster	Private	Public-Private mix
Petra Nova Carbon Capture	North America	1.4		EOR	Fossil - Power	Utilisation	Full chain	Private	Public-Private mix
Red Trail Energy BECCS Project	North America	0.18	Green premium	Carbon credits	Biogenic - Industrial	Permanent storage, same country	Full chain	Private	Public-Private mix
Gorgon CCS	Asia-Pacific	4			Fossil - Industrial	Permanent storage, same country	Full chain	Private	Public-Private mix
Sinopec Qilu Petrochemical	Asia-Pacific	1		EOR	Fossil - Industrial	Utilisation	Full chain	State-owned enterprise	Public
Mikawa Power Plant BECCS	Asia-Pacific	0.18		Carbon credits on the	Biogenic - Power	Under Evaluation	Part-chain	Public-private partnership	Public-Private mix

				voluntary carbon market					
Sleipner	Europe	1		Avoidance of carbon tax	Fossil - Industrial	Permanent storage, same country	Full chain	Public-private partnership	Public-Private mix
Steellanol	Europe	0.125		Utilisation (excluding EOR)	Fossil - Industrial	Utilisation	Full chain	Private	Public-Private mix
Hellisheidi - CarbFix	Europe	0.004			Fossil - Power	Permanent storage, same country	Full chain	Private	Public-Private mix
Emirates Steel - Al Reyadah	Middle East	0.8	Green premium	EOR	Fossil - Industrial	Utilisation	Full chain	State-owned enterprise	Public
Hawiyah-Uthmaniyah	Middle East	0.8		EOR	Fossil - Industrial	Utilisation	Full chain	State-owned enterprise	Public
Petrobras Santos	RoW	10.6		EOR	Fossil - Industrial	Utilisation	Full chain	State-owned enterprise	Public

Database for Planned CCUS/CDR projects

Name of Project	Region	Project scale (MtCO ₂ /year)	Low-carbon product revenue model	CO ₂ Revenue model	Source of CO ₂	End Destination of CO ₂	Value chain integration	Entity Ownership	Capital financing sources
Bayu-Undan field storage hub Timor-Leste	Asia-Pacific	10		Emissions Trading System	Fossil - Industrial	Permanent storage, cross-border	Hub/cluster	Public-private partnership	Public-Private mix
Petronas Kasawari gas field CCS project	Asia-Pacific	3.3			Fossil - Industrial	Permanent storage, same country	Full chain	State-owned enterprise	Public
Baotou Steel	Asia-Pacific	2		Emissions Trading System	Fossil - Industrial	Under Evaluation	Full chain	Private	Public-Private mix
7 Blue Ammonia Facility	Middle East	1.2	Public procurement		Fossil - Industrial	Under Evaluation	Full chain	State-owned enterprise	Public
Hail and Gasha CO₂ Management	Middle East	1.5			Fossil - Industrial	Permanent storage,	Hub/cluster	State-owned enterprise	Public

						same country			
Fluxys-Equinor Belgium-Norway Trunk Line	Europe	40		Emissions Trading System	Fossil - Industrial	Permanent storage, cross-border	Part-chain	State-owned enterprise	
bpH2Teesside	Europe	2		Emissions Trading System	Fossil - Industrial	Permanent storage, same country	Part-chain	Private	Public-Private mix
Project Greensand	Europe	8		Emissions Trading System	Fossil - Industrial	Permanent storage, cross-border	Part-chain	Private	Public-Private mix
ExxonMobil Baytown petrochemical site	North America	10		Tax credits for CCS	Fossil – Industrial	Permanent storage, same country	Part-chain	Private	Public-Private mix
Battle River Carbon Hub	North America	5		Emissions Trading System	Fossil - Industrial	Permanent storage, same country	Hub/cluster	Private	Public-Private mix

Eastern Louisiana Clean Hydrogen Complex	North America	5		Tax credits for CCS	Fossil - Industrial	Permanent storage, same country	Full chain	Private	Public-Private mix
ENI Structures A&E	RoW	2.5			Fossil - Industrial	Permanent storage, same country	Full chain	Public-private partnership	Public-Private mix
FS Lucas do Rio Verde BECCS	RoW	0.42		Carbon credits on the voluntary carbon market	Biogenic - Industrial	Permanent storage, same country	Full chain	Private	
Heidelberg Materials Slite plant	Europe	1.8		Emissions Trading System	Fossil - Industrial	Permanent storage, cross-border	Part-chain	Private	Public-Private mix

IEAGHG

ieaghg.org
+44 (0)1242 802911
mail@ieaghg.org

IEAGHG, Pure Offices, Cheltenham Office Park,
Hatherley Lane, Cheltenham, GL51 6SH, UK



IEAGHG