Carbon Capture and Storage
Seeking a bankable business model

White paper - November - 2023
Context

• The International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) recognizes Carbon Capture and Storage (CCS) as a critical technology to achieve the Net Zero target by 2050\(^1\)

• The IEA’s Sustainable Development Scenario suggests ~15% of the world’s emission reductions to be achieved using CCS\(^1\), which will require at least $1.5 trillion investment on an international scale\(^2\)

• Private-sector investments are needed to achieve this level of funding, including debt financing, capital markets and other sources of capital

• This report provides an overview of emerging CCS business models, specifically focusing on their bankability - financial viability and attractiveness for potential private-sector investors

• Although various CCS projects and models are emerging across the world, this report focuses on recent developments across advanced CCS domains - Europe and the US

• While licensing and permitting processes for CO\(_2\) transport and storage are very important elements in the investment decision process, the detailed analysis of those is left for the future study
Executive summary

**CCS overview**

- Carbon Capture and Storage (CCS) is considered as one of the pivotal solutions to decarbonize hard-to-abate industries as well as to achieve negative emissions through its application in bioenergy production.

- Since the 1970s, some elements of CCS technologies have been used in the oil & gas and chemical industries. However, to achieve the required scale CCS should develop into a comprehensive commercial solution for various emitters underpinned by massive infrastructure.

- Full-scale CCS clusters are actively developing in Europe and the US, with the first 1.5 Mtpa CO₂ storage project launching in Norway in 2024. Meanwhile, European governments are actively introducing push and pull regulations to grow the storage capacity by a factor of 100 by 2030.

**CCS investability**

- While the first CCS projects receive significant government subsidies, scaling up the next wave will require private investments. With current risk assumptions, investment in a mid-size CO₂ transport and storage project can yield medium to high single-digit returns.

- However, to become ‘bankable’ specific CCS investment hurdles should be addressed, first it should be economically attractive for emitters, but also various cross-chain risks and risks of long-term storage leaks should be mitigated.

- The analysis indicated that only the UK has implemented an investable CCS business model by taking an integrated cluster view on the infrastructure and implementing the regulated asset base approach, which although might limit the expected returns.

**CCS investment catalysts in Europe**

- Although emitters in the UK, Netherlands and Denmark can receive local subsidies to cover a gap between CO₂ capture costs and the EU ETS price, similar Contracts for Difference-like subsidies tailored to CCS should be introduced across Europe to support the emitter business case.

- To make CCS investable, a guarantee-type of risk protection (e.g. regulated asset-based models or EU ETS-baked fund) should be established to support in case of low-probability high-impact events (e.g., CO₂ leakage) until the insurance instruments for CCS are developed and affordable.

- Cross-border CO₂ transport and storage (i.e., London Protocol) should be enabled to allow emitters to access ideal storage locations, as well as to promote competition among developers and mitigate storage underutilisation risks through access to a wider pool of emitters.
1. CCS overview
Historically, CCS was used for EOR and gas processing. Rapid scale up of CCS for hard-to-abate industries and BECCS will be required in the next decade to reach the climate targets.

**Enhanced Oil Recovery (EOR)**
- Injection of CO₂ into oil reservoirs to extract hard-to-recover oil remaining in older fields

**Decarbonizing own operations**
- Capturing CO₂ from own projects (e.g., gas processing) to ensure license to operate

**Decarbonizing hard-to-abate industries**
- Storing of CO₂ from various industrial emitters (e.g., cement) to avoid CO₂ emissions

**Bioenergy with CCS (BECCS)**
- Generating electricity from bio-waste (e.g., waste-to-energy plant) and storing CO₂, thereby achieving negative emissions

**Direct Air Capture (DAC)**
- Removal of CO₂ from the air with a storage, thereby achieving negative emissions

Focus of this study

Historical adaptation since 1970s

To scale up in next 10 years

Low technical readiness

Sources: Deloitte analysis

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Commercial CCS-as-a-service using a true merchant approach will be needed to offer the solution to various emitters, as opposed to integration along own O&G operations.

**CCS value chains and business models**

**ILLUSTRATIVE**

- **High degree of integration across the value chain (CCS is integrated in own operations)**
  - Vertically integrated Oil & Gas company develops, owns and operates EOR / CO$_2$ storage
  - CO$_2$ is captured only from its own upstream and midstream operations
  - CO$_2$ transportation through its own onshore or offshore pipelines being a part of the integrated operations

- **Low degree of integration across the value chain (Commercial CCS-as-a-Service)**
  - Development, ownership and operatorship of CO$_2$ storage could be allocated to multiple parties
  - CO$_2$ is captured from multiple independent emitters to be stored in multiple CO$_2$ storages
  - CO$_2$ transportation could be provided through various modes (e.g. shipping) by multiple independent parties

**Sources:** Deloitte analysis

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The CCS-as-a-service market has the potential to be large, depending on the availability and costs of alternative decarbonization options for emitters.

### Comments
- Application of CCS depends on technical readiness, availability and cost of alternative decarbonisation solutions in specific sectors and regions:
  - **Cement, Lime and Waste-to-Energy sectors** will need to use CCS due to a lack of alternative decarbonisation solutions.
  - **Refineries, petrochemicals and ammonia sectors** may apply CCS as a part of a mix of solutions, including low-carbon hydrogen and electrification.
  - **Blue hydrogen** production from fossil gas with CCS has a significant potential in the US.
  - The **steel sector** may aim to use low-carbon hydrogen as a reducing agent, and electrification, with consideration of CCS for addressing residual emissions.
  - The **power sector** may consider CCS to provide a stable base load in networks with a high share of renewables. The solution is being considered in the UK and the US, but currently controversial in the EU.

### CCS potential in selected sectors (CO₂ Mtpa | 2021)

#### Europe

<table>
<thead>
<tr>
<th>Sector</th>
<th>CCS and other decarbonisation pathways</th>
<th>Limited alternatives to CCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement &amp; Lime</td>
<td>125</td>
<td>85</td>
</tr>
<tr>
<td>Waste-to-Energy</td>
<td>97</td>
<td>85</td>
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<tr>
<td>Refinery</td>
<td>14</td>
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<td>Petro-chemical</td>
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<td>Ammonia</td>
<td>6</td>
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<tr>
<td>Hydrogen</td>
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<td>112</td>
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<tr>
<td>Steel</td>
<td>201</td>
<td>201</td>
</tr>
<tr>
<td>NG-power plants</td>
<td>475</td>
<td>475</td>
</tr>
<tr>
<td>Coal-power plants</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### United States

<table>
<thead>
<tr>
<th>Sector</th>
<th>CCS and other decarbonisation pathways</th>
<th>Limited alternatives to CCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement &amp; Lime</td>
<td>86</td>
<td>86</td>
</tr>
<tr>
<td>Waste-to-Energy</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>Ethanol</td>
<td>10</td>
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<tr>
<td>Refinery</td>
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<td>148</td>
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<tr>
<td>Petro-chemical</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Ammonia</td>
<td>14</td>
<td>14</td>
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<tr>
<td>Hydrogen</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>Steel</td>
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<td>65</td>
</tr>
<tr>
<td>NG-power plants</td>
<td>626</td>
<td>626</td>
</tr>
<tr>
<td>Coal-power plants</td>
<td>827</td>
<td>827</td>
</tr>
</tbody>
</table>

Sources: EEA ETS³, CREA⁴, EPA GHGRP⁵, U.S. Energy Information Administration⁶, Deloitte analysis

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European policies push to expand CO₂ storage capacity from currently ~4 Mtpa, which has taken Final Investment Decisions, to operational ~100 Mtpa by 2030 to meet the demand

Overview of developing CO₂ storage projects in Europe\(^7\) (2023)

- Development of major CO₂ storages
- CO₂ storage taken FID\(^1\)

Comments

- The EU Net Zero Industry Act is contemplating obligating oil & gas producers in the EU to contribute to the CO₂-injection capacity (CO₂ storage) with the goal of achieving at least 50 Mtpa of CO₂ by 2030\(^8\)
- Announced CO₂ storage projects in the EU total 35 Mtpa\(^7\); however, the analysis of progress indicates a capacity ~20-25 Mtpa at the advanced development stage
- CO₂ storage projects are being actively developed in the North Sea, but development in the Mediterranean Sea is progressing slow, although being crucial to unlock the solution for emitters in Italy, as well as in the south of France and Spain
- Outside the EU, Norway has a significant storage potential and supportive environment; currently announced projects will count to ~20 Mtpa\(^7\)
- UK has an ambition to capture and store 20-30 Mtpa of CO₂ by 2030\(^9\) and has progressed with the selection of 2 clusters with total ~9 Mtpa CO₂ storage capacity for further development\(^14\)

Notes: 1) Final Investment Decision - the point in the capital project planning process when the decision to make major financial commitments is taken and the construction begins
Sources: International Association of Oil & Gas Producers\(^7\), Deloitte analysis

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European projects can benefit from cross-border CO₂ imports to reduce commercial risks and achieve economies of scale, though adaptation of the legal agreements is required.

**CO₂ cross-border transportation in Europe (2023)**

- Development of major CO₂ storages
- Countries adapted London Protocol (contracting parties)
- Countries ratified Article 6 amendment
- Countries signed bilateral agreements
- Allowed CO₂ shipping

**Comments**

- The objective of the London Protocol is to promote the effective control of all sources of marine pollution, including CO₂.
- Initially Article 6 of the London Protocol prohibits the cross-border transport of CO₂ with the purpose of permanent CO₂ storage.
- In 2009, Norway proposed an Article 6 amendment allowing CO₂ export for CCS. However, it has yet to enter into force.
- In 2019, an additional resolution was adopted allowing two or more countries to export CO₂ if certain conditions are met, including the requirement that those countries have ratified the Article 6 amendment and entered into a bilateral agreement.
- Currently only two bilateral agreements were signed between Belgium and Denmark, as well as Belgium and the Netherlands, allowing cross-border transportation of CO₂ with the purpose of permanent storage.
- Some other European countries are working closely together to establish bilateral agreements and fully kick off a European internal market for cross-border CO₂ transportation.

Sources: Columbia Law School, GE Gas Power, Deloitte analysis.
Although there is no a firm target for CO₂ storage in the US, DOE¹ funding and subsidies under the IRA² and IIJA³ are expected to boost CCS projects for industrial emitters

Overview of developing CO₂ storage projects in the US¹⁰ (2023)

Comments

• Since the 1970s, the practice of injecting CO₂ into nearly depleted oil fields to extract additional oil has been applied in the US, which represents the first case of CO₂ storage underground

• Introduction of a specific tax credit per ton of CO₂ captured and stored in 2018 along with additional revenues from EOR initiated the development for a first few industrial CCS projects at power plants

• The further extension of the tax credit in 2022 (IRA²) and other supporting legislations sparked announcements of a number of CCS projects across the US

• However, there is significant uncertainty in the project pipeline, making it difficult to differentiate between projects which are progressing with the development and those that are merely ambitions

Notes: 1) United States Department of Energy 2) Inflation Reduction Act 3) Infrastructure Investment and Jobs Act
Sources: Clean Air Task Force⁹, Deloitte analysis
2. Investability of CCS projects
CCS is a multi-billion capital project with perceived high risks. Financial return could be in a range of a medium to high single-digit figures based on current risk assumptions.

**Expected financial project return\(^1\) of mid-size CCS project**

**INDICATIVE**

- Tariff for CO\(_2\) transport and storage service
- Emitter 1
- Emitter #

Capex \(\sim\) €0.8b – €1.2b

Liability\(^2\) estimates €0.2b – €0.3b but potentially up to €0.7b

Onshore pipeline \(\sim\) 50km

Offshore pipeline \(\sim\) 50km

Offshore storage

(declined oil&gas reservoir)

Sea-front

\(\sim\) 2-3 Mtpa

Expected project return\(^1\)

medium to high single-digit figures

**Notes:**

1) Project Internal Rate of Return (IRR)
2) decommissioning liabilities and CO\(_2\) leakage liabilities

**Sources:** Deloitte analysis

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**Comments**

- **Commercial CCS business models** are emerging worldwide and there is **still significant uncertainty regarding some elements of the business case**, as well as expected returns.

- **Limited empirical data on CO\(_2\) capture, transport and storage technical performance**, with only a few operating projects leads to uncertainty surrounding technical risks and therefore decreases expected project returns.

- **Development of the first full CO\(_2\) storage and transport projects is primarily funded by** from the balance sheet of **major oil & gas companies with support of various government grants**, which allow for **the acceptance of higher risks and lower returns**.
However, to make CCS an attractive investment for the private sector, specific CCS risks must be mitigated to ensure projects are 'bankable' and meet financing criteria.

Overview of CCS business case and specific investment hurdles

**NOT EXHAUSTIVE**

**How to make CCS attractive for the emitter?**

- **CO₂ capture**
  - Compensation for CO₂ avoidance
  - Volume of CO₂ captured
  - CO₂ capture CAPEX
  - CO₂ capture OPEX

- **CO₂ transport**
  - Tariff for CO₂ transportation
  - Volume of CO₂ transported
  - CO₂ transport CAPEX
  - CO₂ transport OPEX

- **CO₂ storage**
  - Tariff for CO₂ storage
  - Volume of CO₂ stored
  - CO₂ storage CAPEX
  - CO₂ storage OPEX
  - Decommissioning liabilities
  - CO₂ storage liabilities

**How to account for long-term storage leaks?**

**How to mitigate cross-chain risks of co-dependent projects?**

Sources: Deloitte analysis
First, CCS should become economically attractive for an emitter. Various government and market instruments are being rolled out to cover CO₂ capture costs.

Compensating CO₂ capture costs for the emitter

- Carbon pricing (EU ETS) or Tax incentives (US 45Q)
- Government direct grants or subsidies
- Green product premium
- Voluntary carbon markets
- Capital market premium

Cash Inflow

CO₂ capture capex and opex
Tariff for CO₂ transport
Tariff for CO₂ storage
Interest costs
Lost emitter revenue

Cash Outflow

Comments

- Carbon capture is a costly and complex technology, which might account up to ~50% of the total costs of CCS for an emitter.
- Specific CCS solutions for some industrial facilities located close to a CO₂ storage is becoming economically viable under European emission trading schemes.
- However, in general various government subsidies and grants are still needed to support emitter’s business case.
- Emitters can seek other sources of additional revenue to make CCS business case viable, including voluntary carbon market and green product premiums.
- However, scale up of voluntary carbon market is slow and requires further compliance verification mechanisms.
- Although additional cost of CCS as a price premium on a product is insignificant, green premiums (e.g., ‘green steel’) cannot be yet factored in without further development of the green markets.

Sources: Deloitte analysis

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Second, specific CCS risks should be mitigated - the cross-chain risks of co-dependent projects across the value chain and risks of CO₂ leakage from the storage in the long-term.

**Specific CCS risks during the project life-cycle**

- **Feasibility & permitting**
  - Final Investment Decision: ~5-7 years
  - Construction: ~2-3 years

- **Inject CO₂ & monitoring**
  - Start of CO₂ injection: ~15 years
  - Closure of storage site: ~20 years

- **Post - closure**
  - Transfer of liabilities to the state: ~30 years
    - Risk and liabilities carried by storage operator

- **Post - transfer**
  - Storage operator to fund monitoring costs conducted by the State

**Cross-chain risks**
- Transport and storage commissioning delay
- CO₂ capture project delay
- Transport and storage outages
- Transport and storage underutilisation

**Liability risks**
- CO₂ leakage from storage facility

Sources: Deloitte analysis

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The Northern Lights CCS project in Norway recently faced a cross-chain risk when one emitter temporarily halted its CCS project, potentially leading to network underutilization.

**Northern Lights CCS project in Norway**

- **Emitters**
- **CO₂-terminal**
- **CO₂-storage site**
- **Offshore pipeline**
- **Maritime shipping**

**Comments**

- The Northern Lights project in Norway is constructing the world’s first open-source CO₂ transport and storage Infrastructure.
- The Phase I of the Northern Lights took Final Investment Decision in 2020 and plans to transport and store 1.5Mtpa of CO₂ as of 2025 (initially late 2024).
- The Northern Lights project and its first customers (cement and waste-to-energy plants) received significant capex and opex subsidies from the Norwegian government.
- In April 2023 one of two initial customers (waste-to-energy plant) decided to put the CO₂ capture project on hold due to a large increase in costs estimates.
- Northern Lights is actively securing new commercial customers (ammonia plant in the Netherlands and biomass-to-energy plant in Denmark) to fill in the uncontracted capacity.
- However, it is likely that the CO₂ transport and storage infrastructure will be underutilized during some initial period.
- Realization of such risks in a fully commercial project with only funding from private investors might result in an unfeasible business case.

Sources: Northern Lights Project, Deloitte analysis

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CCS business models are being developed in Europe and the US. However, only the UK is viewed to set a holistic and bankable CCS framework, though it has yet to be proven.

<table>
<thead>
<tr>
<th>Scope of scheme</th>
<th>UK</th>
<th>European Economic Area</th>
<th>Netherlands</th>
<th>Denmark</th>
<th>Norway</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dedicated to CCS projects</td>
<td></td>
<td>Broad range of technologies (renewables and other CO₂ reducing tech)</td>
<td>Dedicated to CCS projects</td>
<td></td>
<td></td>
<td>Dedicated to CCS projects</td>
</tr>
<tr>
<td>Support receiver</td>
<td>Emitter Transport &amp; Storage company</td>
<td>Emitter</td>
<td>Emitter</td>
<td></td>
<td>Not yet replicable approach implemented</td>
<td>Emitter</td>
</tr>
<tr>
<td>Duration</td>
<td>10 + 5 years</td>
<td>15 years</td>
<td>15 years</td>
<td></td>
<td>12 years</td>
<td>Not available</td>
</tr>
<tr>
<td>Specific CCS risks protection</td>
<td>Government provides protection against major risks</td>
<td>Not available</td>
<td>Not available</td>
<td></td>
<td>Not available</td>
<td></td>
</tr>
<tr>
<td>Additional considerations</td>
<td>✓ Comprehensive regulatory and commercial framework</td>
<td>✓ CFD-type subsidy for emitter</td>
<td>✓ Straightforward subsidy award criteria</td>
<td>✓ Adjustable CfD-type subsidy for emitter</td>
<td>✓ Government is perceived to support CCS and storing of imported CO₂ in Norway</td>
<td>✓ Straightforward tax credit structure</td>
</tr>
<tr>
<td></td>
<td>✓ Adjustable CfD-type subsidy</td>
<td></td>
<td>✓ CCS dedicated subsidy fund</td>
<td></td>
<td></td>
<td>✓ Sectors with high capture costs remain unprofitable</td>
</tr>
<tr>
<td></td>
<td>✓ Regulated return limits the interest of private investors</td>
<td></td>
<td>✓ Additional complexity of subsidy award criteria</td>
<td></td>
<td></td>
<td>✓ Uncertainty after the tax credit realization period</td>
</tr>
<tr>
<td></td>
<td>✓ Complex and lengthy process</td>
<td></td>
<td>✓ Lack of flexibility in subsidy adjustments</td>
<td></td>
<td></td>
<td>✓ Total tax credit budget might not be sufficient</td>
</tr>
</tbody>
</table>

Bankability

Sources: National CCS regulations 9,12,13,18,19, expert interviews, Deloitte analysis

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UK has developed a regulatory and commercial framework that offers financial and risk mitigation support to emitters and CO₂ transport & storage providers.

### Key risks

<table>
<thead>
<tr>
<th>Financials</th>
<th>Risk Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emitter (CO₂ capture)</td>
<td>CO₂ transport &amp; storage (T&amp;S) provider</td>
</tr>
<tr>
<td>• Capital Grant and Capex repayments</td>
<td>• Regulated revenue model where T&amp;S company (single owner and operator of both onshore and offshore infrastructure) is allowed to charge emitters a certain Transport &amp; Storage tariff</td>
</tr>
<tr>
<td>• Subsidy for Opex (Contract for Differences mechanism)</td>
<td></td>
</tr>
<tr>
<td>• Subsidy for Transport &amp; Storage tariff as a pass-through</td>
<td></td>
</tr>
</tbody>
</table>

### Government protection

<table>
<thead>
<tr>
<th>Key risks</th>
<th>Construction risk</th>
<th>T&amp;S commissioning delay</th>
<th>Commercial risk</th>
<th>Operating risk</th>
<th>T&amp;S outages and T&amp;S capacity constraints</th>
<th>User Stranded Asset</th>
<th>Decommissioning risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government protection</td>
<td>✓</td>
<td>✓</td>
<td>☒</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>☒</td>
</tr>
</tbody>
</table>

### Government protection

<table>
<thead>
<tr>
<th>Key risks</th>
<th>Construction risk</th>
<th>Stranded asset risk (demand risk faced by T&amp;S)</th>
<th>Underutilization risk</th>
<th>Leakage of CO₂</th>
<th>Outages risk</th>
<th>Decommissioning risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government protection</td>
<td>☒</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>☒</td>
<td>✓</td>
</tr>
</tbody>
</table>

Sources: UK government ICC and T&S business models[^12], Deloitte analysis

[^12]: Deloitte analysis
Financial support for emitters can be extended up to 15 years and includes potential capital grant, various repayments and Contract-for-Differences like subsidies.

Overview of the financial support for an industrial emitter

**ILLUSTRATIVE**

- **Transport & Storage charges** are funded for an emitter during the first 10 years and treated as a pass-through.
- **Emitter receives a subsidy** for a difference between OPEX and the effective reference price (e.g. UK ETS – free allowance).
- **Emitter can receive a capital grant** as well as CAPEX repayments as a fixed amount per ton of CO₂ captured and stored in first 10 years.

The total levelised costs of CCS for emitter:

- **~£125**
- **~£40**
- **~£50**
- **~£35**

**Payment components**

<table>
<thead>
<tr>
<th>Year</th>
<th>OPEX</th>
<th>T&amp;S</th>
<th>Reference Price</th>
<th>Subsidy</th>
</tr>
</thead>
<tbody>
<tr>
<td>2028</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>2030</td>
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<td>2040</td>
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<tr>
<td>2042</td>
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</tbody>
</table>

- **In the first 10 years**, Emitter is compensated if OPEX per ton of CO₂ stored is below the reference price.
- **Emitter can get an extension** for another 5 years if certain performance and market conditions are met.
- **In the additional 5 years**, the reference price is the UK ETS price, and the emitter must reimburse if UK ETS exceeds OPEX + T&S tariff.

Notes: 1) CAPEX shortfall period - If the capex has not been paid fully in the first 5 years due to lower CO₂ capture, it will continue to apply for up to a further 5 years. Sources: UK government ICE business model, Deloitte analysis.
The government provides comprehensive protection for emitters and T&S providers against major risks, which makes the CCS proposition investable.

<table>
<thead>
<tr>
<th>Risk</th>
<th>Description</th>
<th>Protection from the government</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CO₂ emitter</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction risk</td>
<td>Construction risk refers to the group of risks associated with construction phase, including cost overruns, delays, contractual issues, etc.</td>
<td>✓</td>
</tr>
<tr>
<td>T&amp;S commissioning delay</td>
<td>The risk of delay in the commission phase of T&amp;S project. A delay in this stage can impact the overall project timeline and may result in postponed operational commencement</td>
<td>✓</td>
</tr>
<tr>
<td>Commercial risk</td>
<td>Commercial risk refers to the risk associated with obtaining the finance, managing cashflows and continuing commercial industrial operations</td>
<td>×</td>
</tr>
<tr>
<td>Operating risk</td>
<td>Operating risk refers to the risk of the facility either overperforming or underperforming in capturing and storing CO₂ compared to the initially agreed-upon terms</td>
<td>✓</td>
</tr>
<tr>
<td>T&amp;S outages and T&amp;S capacity constraints</td>
<td>T&amp;S outages refer to the risk when T&amp;S systems are temporarily unavailable or not in operation. T&amp;S capacity constraints refer to the risk of capacity limitations of T&amp;S infrastructure</td>
<td>✓</td>
</tr>
<tr>
<td>User stranded asset</td>
<td>The term 'User Stranded Asset' refers to the risk that if the T&amp;S network is discontinued, and no alternative T&amp;S option is feasible, then the capture project is considered stranded</td>
<td>✓</td>
</tr>
<tr>
<td>Decommissioning risk</td>
<td>Decommissioning risk refers to the challenges associated with the safe and effective closure, dismantling, and remediation of CCS facilities at the end of their operational life</td>
<td>×</td>
</tr>
<tr>
<td><strong>Transport &amp; Storage provider</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction risk</td>
<td>Construction risk refers to the group of risks associated with construction phase, including cost overruns, delays, contractual issues, etc.</td>
<td>×</td>
</tr>
<tr>
<td>Stranded asset risk (demand risk faced by T&amp;S)</td>
<td>In this case stranded asset risk refers to the demand risk faced by T&amp;S, e.g., where users are late in connecting to the network</td>
<td>✓</td>
</tr>
<tr>
<td>Underutilization risk</td>
<td>Underutilization risk refers to the potential risk that T&amp;S system may not be fully utilized or may operate below its optimal capacity</td>
<td>✓</td>
</tr>
<tr>
<td>Leakage of CO₂</td>
<td>CO₂ leakage refers to the potential risk for CO₂ to leak from its intended storage location</td>
<td>✓</td>
</tr>
<tr>
<td>Outages risk</td>
<td>T&amp;S outages risk refers to the risk of T&amp;S assets not operating and being unable to transport and store the captured CO₂ from relevant projects</td>
<td>×</td>
</tr>
<tr>
<td>Decommissioning risk</td>
<td>Decommissioning risk refers to the challenges associated with the safe and effective closure, dismantling, and remediation of CCS facilities at the end of their operational life</td>
<td>✓</td>
</tr>
</tbody>
</table>

Sources: UK government ICC and T&S business models⁹,¹¹, Deloitte analysis
However, T&S provider operates under a regulated revenue scheme. While being transparent, it may deter private investors due to expected limited returns.

<table>
<thead>
<tr>
<th>Allowed revenue&lt;sup&gt;9&lt;/sup&gt;</th>
<th>Return on Capital</th>
<th>Depreciation</th>
<th>Opex</th>
<th>Decommissioning cost</th>
<th>Tax</th>
<th>Adjustments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Return on Capital = Regulated asset value (RAV) * WACC</td>
<td>• Depreciation – revenue collected from users to cover asset depreciation over the operational period and profiled to reduce payments in the early operational period to support the initial stages of the project</td>
<td>• Opex will be the allowed spend for efficient operational costs, which will have been agreed in the initial settlement</td>
<td>• Decommissioning – allowance to cover decommissioning costs of the T&amp;S network at the end of assets life</td>
<td>• Allowed revenue will include an allowance for expected tax costs</td>
<td>• Adjustments – adjustment for pass-through costs and any required true-ups and incentives (can be positive and negative), including availability incentive, leakage incentive, connections incentive, construction delay</td>
<td></td>
</tr>
<tr>
<td>• RAV = development spend (Devex) + construction spend and asset expansion (Capex) + rolled up cost of capital (i.e., WACC during the construction period) – depreciation and disposals</td>
<td>• WACC - will consider</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Will consider: Expected costs of financing, Risks borne by T&amp;S (e.g., construction risk, development risk, technology risk, operational risk, etc.), Initial WACC will be determined in dialogue with the T&amp;S</td>
</tr>
<tr>
<td>• WACC will consider</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Included in the allowed revenue: Expected tax costs</td>
</tr>
</tbody>
</table>

Sources: UK government T&S business models<sup>9</sup>, Deloitte analysis
The Netherlands is yet to establish a comprehensive commercial CCS framework. Emitters can receive subsidy, but there is no dedicated support for transport and storage providers.

- Emitters can apply for Dutch SDE++ subsidy, but will compete for funding with other decarbonization projects.
- Emitter can seek additional financial support from EU subsidy schemes (e.g., EU Innovation Fund).
- No specific mechanisms to protect emitters against major risks.

<table>
<thead>
<tr>
<th>Financials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emitter (CO₂ capture)</td>
</tr>
</tbody>
</table>
| - Emitters can apply for Dutch SDE++ subsidy, but will compete for funding with other decarbonization projects.
- Emitter can seek additional financial support from EU subsidy schemes (e.g., EU Innovation Fund). |

<table>
<thead>
<tr>
<th>Risk Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>- No specific mechanisms to protect transport and storage providers against major risks.</td>
</tr>
<tr>
<td>- Indirect government support is evident through the active involvement of state-owned companies in the development of CCS transport and storage infrastructure.</td>
</tr>
</tbody>
</table>

Notes: 1) since 2023 domain fences for certain technologies are implemented (e.g., heating and ‘molecules’), but not for CCUS. Sources: SDE++ scheme, Deloitte analysis.
Emitters can apply for Contract for Differences-like subsidies and receive a 15-year support covering the cost of CCS above the EU ETS price

Overview of financial support for an industrial emitter

ILLUSTRATIVE

- Storage tariff
- Transport tariff
- Opex per ton of CO₂ captured
- Capex per ton of CO₂ captured

Emitter receives a subsidy for a difference between EU ETS and total levelized costs of CCS (in contrast with split compensations in the UK)

Sources: SDE++ scheme, Deloitte analysis

- CCS projects compete with other sustainable technologies in SDE++
- There is a maximum amount of subsidies emitter can apply for (the base rate upper bound)
- In case of the tariff increase and additional subsidy is needed, emitter needs to re-apply and might have a risk to lose the subsidy
- Granted subsidy is not adjusted for inflation during the 15 years period
Denmark has recently introduced two dedicated CCS subsidy schemes for emitters, but there is no dedicated support for transport and storage providers.

**Financials**

- Emitters can apply for CCUS subsidy fund with fossil and biogenic CO₂ sources being eligible (total target to store 2.7Mtpa of CO₂ from 2029)
- Emitters can also apply for NECCS subsidy fund, dedicated to the negative emissions with only biogenic (including Direct Air Capture) sources being eligible (total target to store 0.5Mtpa of CO₂ from 2029)

**Risk Protection**

- No specific mechanisms to protect emitters against major risks

**CO₂ transport provider**

- Free market approach, unbundled CO₂ transport and storage providers can set tariffs based on its expected returns
- CO₂ transport and storage providers can seek additional financial support from EU subsidy schemes (e.g., Connecting Europe Fund via Project of Common Interest status)

- No specific mechanisms to protect transport and storage providers against major risks

Sources: Danish Energy Agency, Deloitte analysis

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IRA 45Q tax credit might be seen attractive. However, it is short for some emitters, has post-credit uncertainty and lacks support for low-probability high-impact events

<table>
<thead>
<tr>
<th>Source</th>
<th>IEA, expert interviews, Deloitte analysis</th>
</tr>
</thead>
</table>

### Tax credit (45Q) mechanism in US (USD per ton of CO₂)

- **Capture costs**
- **Transport**
- **Storage**

<table>
<thead>
<tr>
<th>Concentration of CO₂ in Emitter Flue Gas</th>
<th>Ethanol (SMR)</th>
<th>Ammonia (SMR)</th>
<th>Ethylene Oxide</th>
<th>Refinery (SMR)</th>
<th>Steel BF-BOF</th>
<th>Cement</th>
<th>NG-fired power plant</th>
<th>Coal-fired power plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>45</td>
<td>65</td>
<td>65</td>
<td>75</td>
<td>10</td>
<td>15</td>
<td>110</td>
<td>135</td>
</tr>
<tr>
<td>Low</td>
<td>10</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Low</td>
<td>20</td>
<td>40</td>
<td>40</td>
<td>50</td>
<td>65</td>
<td>85</td>
<td>80</td>
<td>110</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value to be distributed across CCS value chain participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>$85 Tax Credit</td>
</tr>
</tbody>
</table>

### Comments

- **The Inflation Reduction Act (IRA) provides $85 tax credit per ton of CO₂ stored** in saline geologic formations from carbon capture on industrial and power generation facilities.
- **The claim period is 12 years** and developers can receive a 45Q tax credit as a fully refundable direct payment as if it were an overpayment of taxes (during first 5 years).
- **$85 per ton of CO₂ stored is not sufficient to make a viable business case for emitters with a low concentration of CO₂ in the flue gas** (e.g., cement, power plants) considering additional costs of CO₂ transport and storage.
- **Emitters can seek additional financing from other sources**, including IIJA and DoE grants although being limited and for specific purpose (e.g., FEED study).
- **The lack of risk-sharing mechanisms and protections against low-probability high-impact events significantly limits the bankability of certain projects.**

---

**Sources:** IEA⁹, expert interviews, Deloitte analysis
3. CCS investment catalysts in Europe
Only the UK business model demonstrates a holistic investable CCS proposition. Private-sector investments in CCS in other regions should be assessed on a case-by-case basis.

### Assessment of CCS bankability parameters

<table>
<thead>
<tr>
<th>Supporting policies and regulations</th>
<th>UK</th>
<th>NL</th>
<th>DK</th>
<th>NO</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>National CCS targets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Signal acceptance of CCS as a viable technology contributing to climate targets achievement</td>
<td>20-30 Mtpa by 2030</td>
<td>Not mentioned but flagship projects are supported</td>
<td>Not mentioned but flagship projects are supported</td>
<td>No mentioned but importance of CCS is acknowledged</td>
<td></td>
</tr>
<tr>
<td>CCS legal and regulatory framework</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Establish a legal framework, including permitting and operation, closure and post-closure obligations</td>
<td>Adaptation of EU CCS Directive</td>
<td>Adaptation of EU CCS Directive</td>
<td>Adaptation of EU CCS Directive</td>
<td>Various federal and state legislation</td>
<td></td>
</tr>
<tr>
<td>CCS commercial framework</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Establishing a structured commercial framework, including economic incentives, legal structures and market mechanisms</td>
<td>CCS business models only subsidy for emitters</td>
<td>Only subsidy for emitters</td>
<td>Not available</td>
<td>Only tax credits for emitters</td>
<td></td>
</tr>
<tr>
<td>Cross-border CO₂ shipping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Enable a cross-border, single market approach on CO₂ transport and storage</td>
<td>Provisional application of LP Article 6</td>
<td>Bilateral agreement BE/NL</td>
<td>Bilateral agreement BE/DK</td>
<td>Provisional application of LP Article 6</td>
<td>Not relevant</td>
</tr>
<tr>
<td>Carbon pricing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Incentivize emitters to consider CCS solution</td>
<td>UK ETS</td>
<td>EU ETS and carbon tax</td>
<td>EU ETS and carbon tax</td>
<td>EU ETS and carbon tax</td>
<td>No carbon pricing mechanism</td>
</tr>
<tr>
<td>Emitter economics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Provide a stable support scheme to make CCS projects economically acceptable for emitters</td>
<td>National Budget CCS Infra fund</td>
<td>SDE++ scheme</td>
<td>CCUS support scheme</td>
<td>Not available</td>
<td>IRA 45Q tax credit</td>
</tr>
<tr>
<td>CCS subsidies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Give an opportunity for CCS projects to get an access for broader innovation and infrastructure funding</td>
<td>EU Innovation Fund Connecting Europe fund</td>
<td>EU Innovation Fund Connecting Europe fund</td>
<td>Enova</td>
<td>IIJA and DoE CCS funding and state-level support</td>
<td></td>
</tr>
<tr>
<td>Additional funding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross chain risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Support complex CCS value chains during the first phases of infrastructure development</td>
<td>CCS business models</td>
<td>Emitters and T&amp;S providers bear all risks</td>
<td>Emitters and T&amp;S providers bear all risks</td>
<td>Emitters and T&amp;S providers bear all risks</td>
<td>Emitters and T&amp;S providers bear all risks</td>
</tr>
<tr>
<td>CO₂ leakage risks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Protect project against low-probability high-impact events during the technical and operational maturity of the CCS solution</td>
<td>CCS business models</td>
<td>T&amp;S providers bear all risks</td>
<td>T&amp;S providers bear all risks</td>
<td>T&amp;S providers bear all risks</td>
<td>T&amp;S providers bear all risks</td>
</tr>
</tbody>
</table>

Sources: expert interviews, Deloitte analysis

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Several actions should be taken to make commercial CCS-as-a-service attractive for private investments in Europe and scale up the solution

- Europe has the most advanced carbon emission trading scheme, which is firmly established and incentivised emitters to reduce carbon emissions by setting a price per ton of CO₂ emitted.
- However, CCS is still too expensive. A Contract-for-Difference type subsidy would effectively allow emitter to bridge the gap between the total CCS costs and EU ETS prices and make the project economically viable.
- Tailoring the subsidy instrument specifically to CCS, e.g., allowing for certain recalculations of the required subsidy amount, would provide the necessary stability and predictability.

Provide dedicated financial support for emitters

- CCS applications are limited to a few operational projects in North America and Europe with majority using CO₂ for the enhanced oil recovery purpose. However, the empirical data of operational CCS performance is limited.
- The first full large-scale commercial CCS projects in Norway and the Netherlands received significant support from the European governments. However, a few projects will not be enough to de-risk the solution for private-sector investors.
- Guarantee-type of risk protection (e.g., regulated asset-based model or EU ETS-baked fund) could be established to support in case of low-probability high-impact events (e.g., CO₂ leakage) until the insurance instruments are developed and affordable.

Protect against low-probability high-impact events

- Europe has a potential to develop two large-scale CO₂ storage domains, one in the North Sea and another in the Mediterranean Sea. This would allow to build the optimal CO₂ transport and storage infrastructure.
- Recently, the first few bilateral agreements on cross-border CO₂ transport for permanent storage offshore were signed (e.g., Belgium and Denmark). If other European countries follow suit, this could open a common CO₂ transport and storage market.
- This will also allow emitters to connect to storages in the most economical way, and CO₂ storages to achieve the economies of scale while minimise commercial risks by gaining access to a broader set of emitters.

Ratify European cross-border CO₂ shipping

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