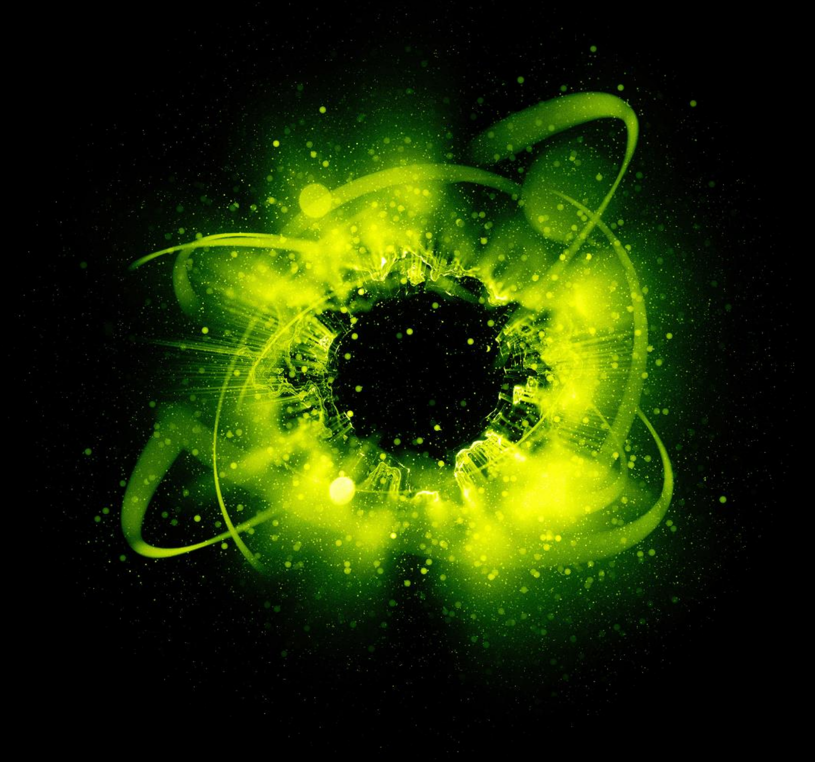
Carbon Capture and Storage in Europe

Unlocking deployment at-scale
2025



Deloitte.

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Executive summary

Current state of CCS

Industry players are dealing with increasing efforts towards decarbonisation. According to the International Energy Agency (IEA), **carbon capture and storage (CCS) will be essential** to achieve the goal of **Net-Zero emissions**. CC(U)S projects are gaining momentum globally with more than 800 projects and use-cases under consideration, of which nearly 40% are in Europe. Along with an increase in number of announced CCS projects, the design of the CCS value chain is also evolving. While **1st generation value chains were designed for captive use**, **recent 3rd generation FIDs,** such as the 2nd phase of Northern Lights in Norway**, are a stepping-stone to an open and mature market**. Transition to 2nd and 3rd generation value chains **faces two key challenges: value gap** due to high and uncertain costs; and **value chain barriers** due to delayed availability of infrastructure.

Overcoming the value gap

Costs across the CCS value chain in Europe **remain high**, resulting in an average value gap of ca. €150/t CO_2 compared to prevailing EU **Emissions Trading System (ETS)** price levels. The cost of transporting CO_2, ETS prices, and purity of CO_2 are three key variables that **add uncertainty to the already high costs**, which in turn is negatively impacting investor confidence. The high costs and uncertainties mean that **CCS subsidy intensity is typically higher** compared to that of other decarbonisation technologies.

Due to high cost-levels, there is a need to **prioritise low-hanging fruits** to scale-up the ecosystem (i.e., **high purity CO_2 streams** with lower levelized CCS cost). To derisk projects, governments should adopt a **hub-based approach for CO_2 transport**, put CO_2 **price hedging mechanisms** in place, and promote **dissemination of knowledge from the initial wave of large-scale projects** (e.g., impact of CO_2 purity on storage capacity). It is important for governments to acknowledge that **CCS subsidy intensity is high due to the nascent state of technology**; there is **no alternative but to invest and progress along the cost curve**. Use cases where emitters can **complement ETS revenues with strong local schemes** and alternate revenue mechanisms (such as voluntary carbon rights) are likely to lead deployment. Countries such as the Netherlands have created additional support mechanisms (e.g., SDE++) to bridge the gap. S**cale of success will depend on total fund size and speed of subsidy award**. So far, all leading CCS projects in the EU have relied on extensive government support, a trend which will continue in the short to medium term.

Overcoming value chain barriers

While there exists a structural gap between the available storage capacity and the increasing need for carbon capture, market uncertainty creates a climate of **hesitation among emitters** for **long-term contracts** with fixed dates. Governments should consider **financial support for essential first-stage infrastructure projects** to **reduce risks** and enable **future scale-up**. **Early adopters** should get **extra incentives**. Moreover, as the **CCS value chains evolve to become increasingly sophisticated** with an increasing number of players, the **cooperation model** for the value chain participants will need to rely on **standard market regulations** instead of tailored agreements between the participants.

The ecosystem has so far developed for point-to-point and often captive CCS, leading to a **gap in transport infrastructure and services required** by emitters **for a plug-and-play approach**. Therefore, initiatives to scale-up the ecosystem, such as a CO_2 market-place, also need to **focus on modular (and at times temporary) transport solutions** such as inland shipping. New business models in the onshore CCS value chain, in the form of **specialised 3rd party players**, are required to support **aggregation** from multiple emitters, and the subsequent CO_2 **transportation and transformation** solutions (e.g., liquefaction or purification).

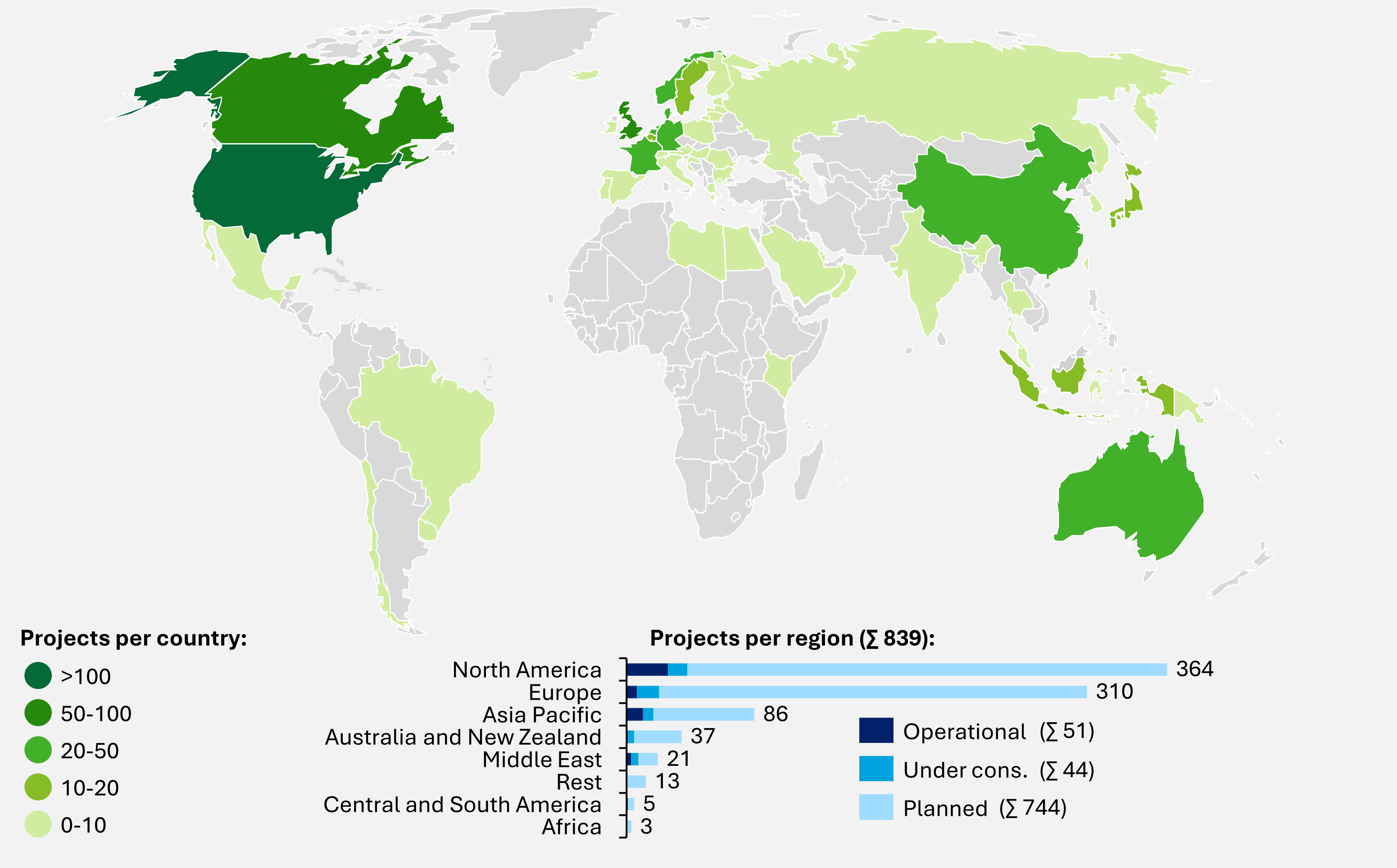
Due to high costs and uncertainty, **project developers** in the offshore part of the value chain are constantly **on the look-out** for **additional optimisation opportunities**. **Regulatory flexibility** is required for CO_2 **utilisation** and **cross-border movement**, especially in the initial years. Oil & gas (O&G) CCS players need an **option to exit developed projects** to derisk their portfolio.

To summarise, for CCS scale-up, **there is a need to demonstrate flexibility in funding and regulations to swiftly operationalise projects** and **recalibrate** the level of **support as the market matures**.

What is the current state of CCS, and how is it evolving?

CC(U)S projects are gaining momentum with more than 800 projects and use-cases across different stages of maturity, of which nearly 40% are in Europe

Global heatmap of CC(U)S projects[1]



CC(U)S is gaining momentum globally. As of Q2 2025, there are **more than 800** projects and use-cases across **different stages of maturity**: in operation (51), under construction (44) and planned (744). This also includes CO_2 utilisation projects related to enhanced oil recovery (EOR) and blue hydrogen projects in the oil & gas (O&G) industry. **Clear regional concentration** is observed, with **674 projects (80%) located in North America and Europe.**

In addition to the regional concentration, each **region** also has **unique characteristics**. In **North America**, the current market is relatively well-established and is primarily driven **by point-to-point EOR** application in the O&G industry. Notable projects in North America are Labarge Shute Creek, Petra Nova CC, Quest.

In **Europe, the hub model** is emerging, with **multiple emitters connected to the storage facilities**. Notable projects are Porthos, Orca and Northern Lights.

Given its large and mature O&G industry, the **Middle East** is focusing on production of **blue hydrogen with local carbon storage**. Project examples are Qatar LNG, Uthmaniyah and Abu Dhabi CCUS. Similarly, owning to its fossil fuel production, **Australia** also seeks to make use of its **abundant geological storage** potential.

In Asia Pacific, development in **China** is driven by **extensive government stimulus**. Japan has focus on blue hydrogen to move towards an optimal balance between energy security, cost, and emissions reduction. Key projects in Asia Pacific include Mikawa BECCUS, CNOOC Offshore CCUS and Jiling Petrochem CCUS.

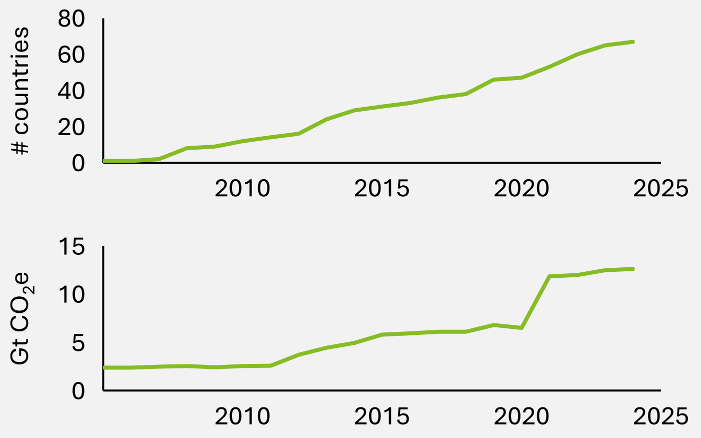
Note: [1] Sum of operational, under construction and planned projects; CCUS in this chart includes EOR; Suspended, cancelled or decommissioned projects have not been included in this overview; Data from March 2024
Sources: [1] IEA; Deloitte CCUS Database

With increasing adoption of carbon taxes in the EU, and expected decrease in allowances, companies in specific hard-to-abate sectors are looking into CCS

Adoption of carbon taxes is increasing globally

To reach the agreed climate goals, increasing number of countries are implementing carbon pricing mechanisms such as a carbon tax or an emissions trading system. As of 2025, **more than 50 countries have carbon pricing mechanisms**, covering a total of ca.13 Gt CO_2eq[1], which amounts to **approximately a quarter of the global greenhouse gas emissions[2]**. As the scope of these mechanisms steadily increases, industry players are pushed to decarbonise their operations.

Countries with carbon tax and associated emissions covered[1]



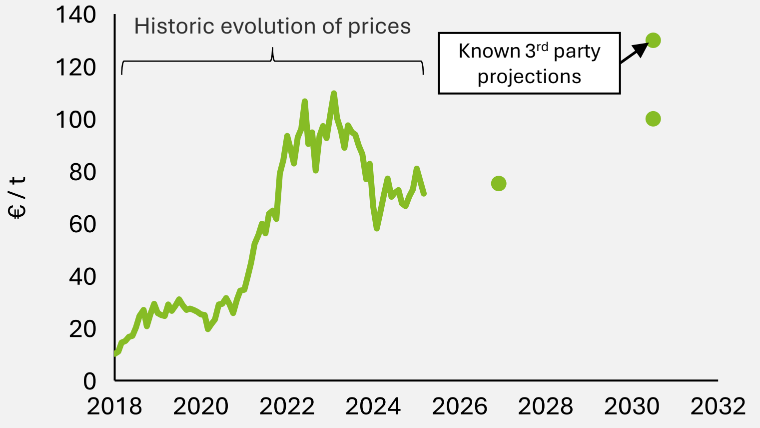
EU **CBAM** will also incentive **decarbonisation in country of origin** of products, even if there are no local taxes.

National oil company

Drop in EU ETS allowances will increase carbon tax burden

Within the EU, the **pressure to decarbonise is heightened by the set reduction in available ETS allowances** over the coming years to become a climate-neutral continent by 2050. Free allowances are being withdrawn, which will **require companies to integrate carbon price into their business model**. To navigate this tightening emissions landscape, low-carbon solutions such as CCS are needed to comply with regulations and to decouple economic growth from emissions.

EU ETS price evolution (€/t)[2]



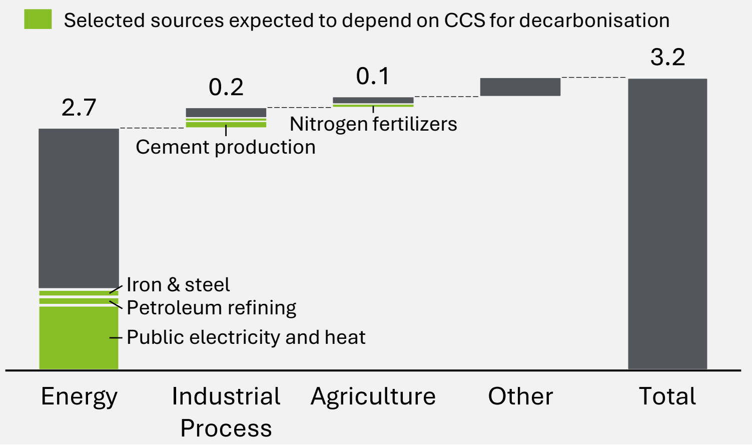
Our **free allocations** are **uncertain after 2030**; we need to **plan for and act on that now**.

Heavy manufacturing industry

CCS is an alternative for key hard-to-abate sectors

Irrespective of the possible pathways to Net-Zero, certain emissions in hard-to-abate sectors cannot be abated solely through electrification or use of clean molecules such as green hydrogen. For example, the CO_2 released during the calcination process of cement manufacturing. The **adoption of CCS will be pivotal in covering residual emissions**, ensuring that industry players can achieve their Net-Zero targets while maintaining operational integrity.

CO_2eq emissions in EU in 2021 ($GtCO_2e$)[3]



More risk in allocating big quantities of blue H_2, blue NH_3, but **CCS you will need in any case** for hard-to-abate sectors.

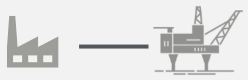
Low-carbon technology holding company

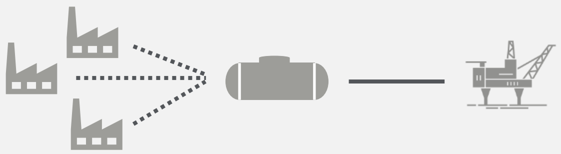
Source: [1] Carbon Pricing Dashboard World Bank; [2] Our World in Data, Intercontinental Exchange, and Deloitte (secondary) analysis; [3] UNFCC and Deloitte analysis

The CCS ecosystem is maturing, while 1st generation value chains were designed for captive use, recent 3rd generation FIDs are a stepping-stone to an open and mature market

CCS value chain evolution[1]

1st generation	2nd generation	3rd generation
Point-to-Point network (leading projects are **operational**)	**Multiple use dedicated network** (leading projects are **under construction**)	**Multiple use open network** (leading projects have **reached FID**)





CO_2 captured for premium in market or to meet product specifications → Industry specific incentive

CO_2 captured to meet Net-Zero mandates → Industry specific tax or penalty

CO_2 captured to meet Net-Zero mandates → Emission/tax penalty across multiple industries

Examples (1st generation)

Sleipner

Shute Creek

Quest CCS

Examples (2nd generation)

Porthos

Northern Endurance Partnership

Northern Lights Phase 1

GREEN SAND

Examples (3rd generation)

Northern Lights Phase 2

ARAMIS

EAST CO_2AST CLUSTER

HyNet North West

Originally CCS projects were driven by the business dynamics of individual projects to improve the financials. **CO_2 utilisation often went hand in hand** with the **capture**. These **1st generation CCS value chains, are point to point networks**. CO_2 is captured at a **single emission site** and often used to enhance O&G extraction.

The purpose of CCS has now evolved to be a tool for decarbonisation of industries, especially for hard-to-abate sectors such as cement. **The 2nd generation value chains** are **multiple use dedicated networks.** Government and a **selected set of emitters** come **together to facilitate a dedicated** CO_2 transport and storage **facility**. The focus is to jointly progress projects, typically using contracts between the involved parties.

We are also observing the evolution towards a **mature and liquid market characterised by the 3rd generation value chains** having **multiple use open networks**. In these value chains, **more emitters of varying sizes** and carbon storage needs can flexibly connect to the value chain. FID on Northern Lights Phase 2 is a key milestones in this regard.

Source: [1]Deloitte analysis

At-scale deployment of CCS faces two key challenges – value gap due to high costs and value chain barriers due to infrastructure readiness

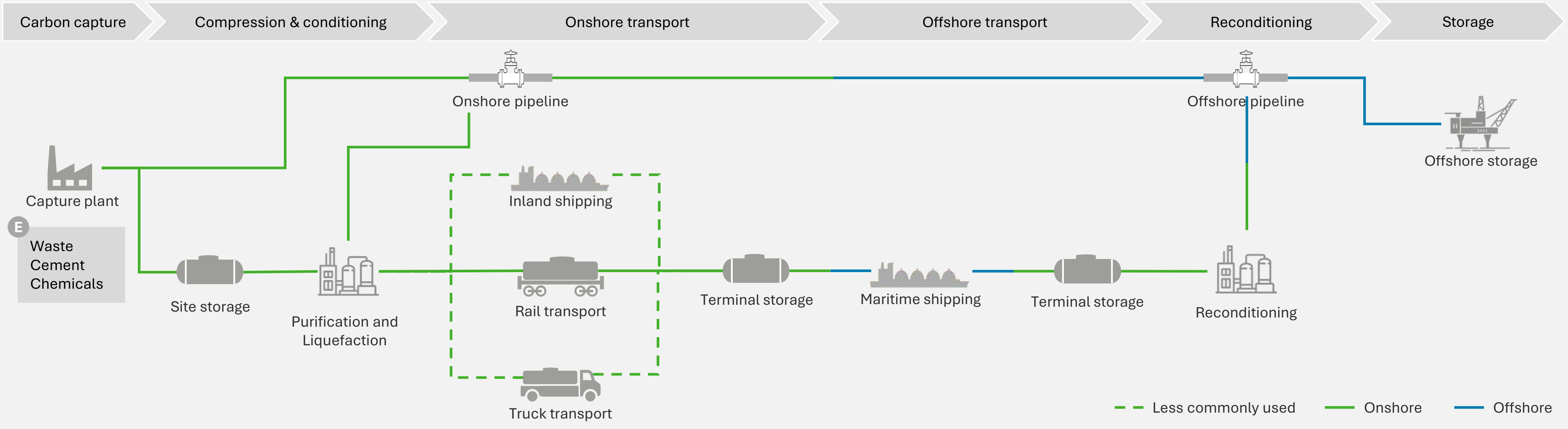
Value gap

A **significant value gap exists** in the deployment of CCS across the value chain, stemming from the difference **between low ETS revenues and high costs.** Additional challenges arise due to **risks and uncertainties** attributable to **nascent state of technology maturity, high cost of transport of CO_2, delayed readiness of infrastructure, high tariffs, and the variation in purity of the captured CO_2**. Furthermore, the **volatility of EU ETS prices**, along with **challenges in securing long-term contracts** is delaying project decisions.

Value chain barriers

For **many emitters**, **carbon capture is not their core business**. This means that they will require **3rd party transport and storage** infrastructure once their CO_2 capture projects go live. The **delay in establishing the necessary transport infrastructure**, particularly pipelines, introduces significant **uncertainty for emitters** regarding the **offloading of captured CO_2**. This uncertainty is compounded by a gap between the available supply of CO_2 transport and storage and the actual demand from emitters. **For infrastructure development**, the **involvement of multiple partners** with **varying priorities** creates challenges by **making the "buy-in" process long-drawn and complicated**. While some organisations seek to derisk the coordination complexities by participating in additional stages of the value chain, this can lead to a non-optimal model where organisations start to operate beyond their core competences.

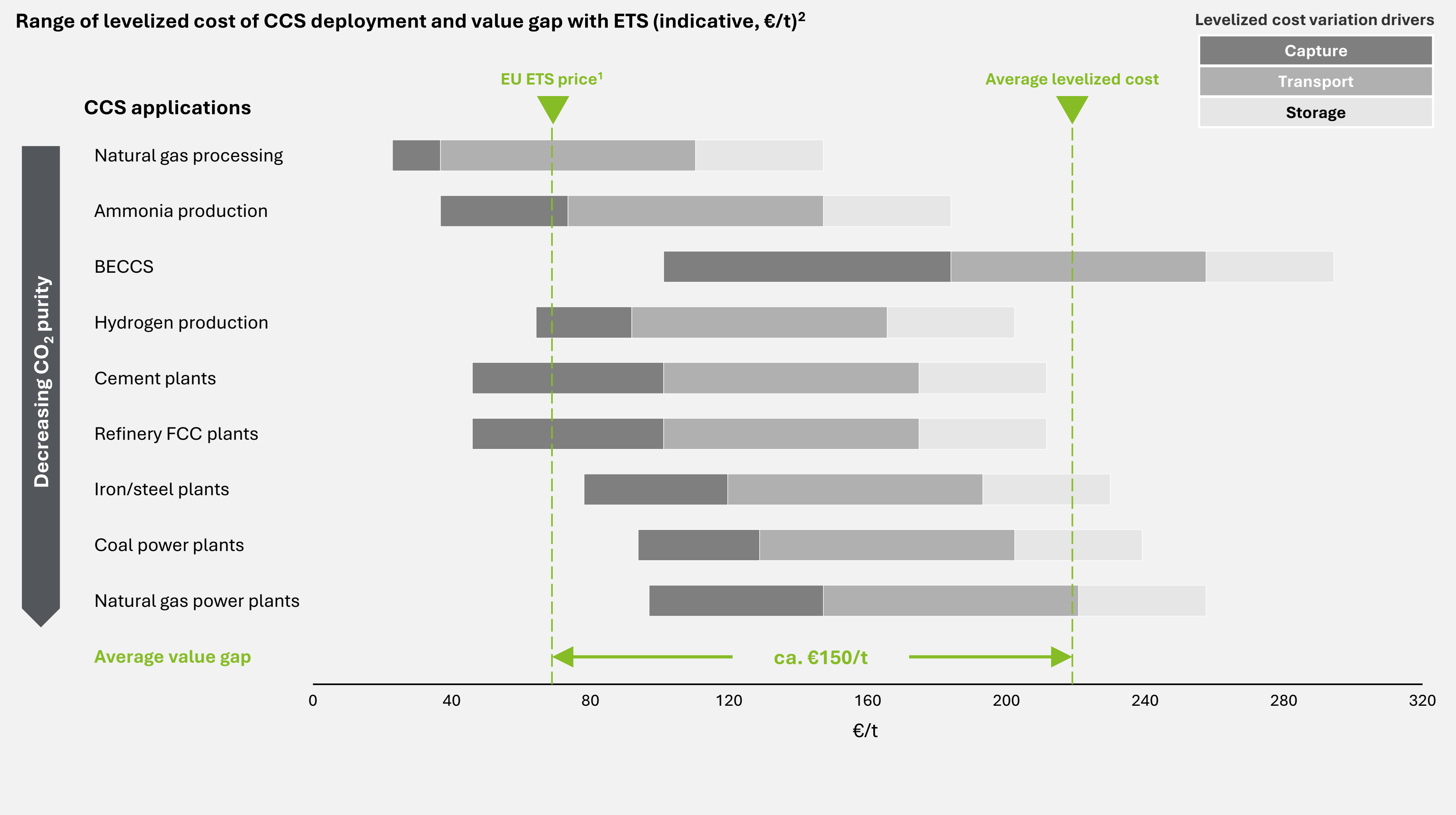
CCS value chain in Europe, with example players (illustrative)[1]



Source: [1]Deloitte analysis

Overcoming the value gap

Costs across the CCS value chain in Europe remain high, with an average value gap with the ETS price of ca. €150/t CO_2 captured, transported and stored



The financial incentive for an emitter to invest in CCS solutions is driven by the 'market price' of avoided CO_2 emission in Europe. For a **positive business case, the levelized cost of CCS** must be **lower than the EU ETS prices**. At present, the **ETS price** is structurally **below** the **cost** estimates for levelized cost of CCS. This indicates that in the foreseeable future, **CCS will require a significant level of investments** in the form of direct or indirect **government subsidies** (or corporate sponsorships to a certain extent).

While national 'sticks' in the form of CO_2 levies and 'carrots' in the form of reverse CO_2 auctions can help improve the business case, to maximise the effectiveness of limited public funds, there is a **need to consider the prioritisation easily attainable opportunities**, by channelling subsidies towards **emitters with lower levelized cost** (i.e., high purity CO_2 streams). This **targeted approach** will **facilitate a scale-up** for the industry. As the industry scales up, we can anticipate an increase in the number of viable CCS applications.

> Not all use cases have numerous reference projects, and as we gain **more experience** with these projects, **costs** are likely to **decrease.**
>
> EPC player with strong CCS involvement

Sources: [1] Price gathered from Trading Economics in March 2025, [2] Global CCUS Institute, National Petroleum Council, Oxford Institute for Energy Studies, Deloitte analysis (including expert interviews)
Note: [2] Original values in ($/t), converted on 11-03-2025 utilising $1 = €0.92

The cost of transporting CO_2, ETS prices, and impact of CO_2 purity on storage capacity add uncertainties to the cost of a CCS business case

Emitters far away from sinks face high CO_2 transport costs

Increased **distance to receiving terminals**, whether transportation occurs via ship or pipeline, has a considerable **impact on the overall unit cost** of transporting CO_2. Emitting companies are thus confronted with the need to assess their **capacity for scaling operations**, the **level of investment** required for infrastructure development, and the associated **risks of ensuring efficient utilisation** of their CO_2 transport systems. A **hub-based approach** with **common transport infrastructure** and **short offloading distance** may prove beneficial for early adopters. With time, as transport and storage infrastructure expands, additional emitters will come within a viable offloading distance.

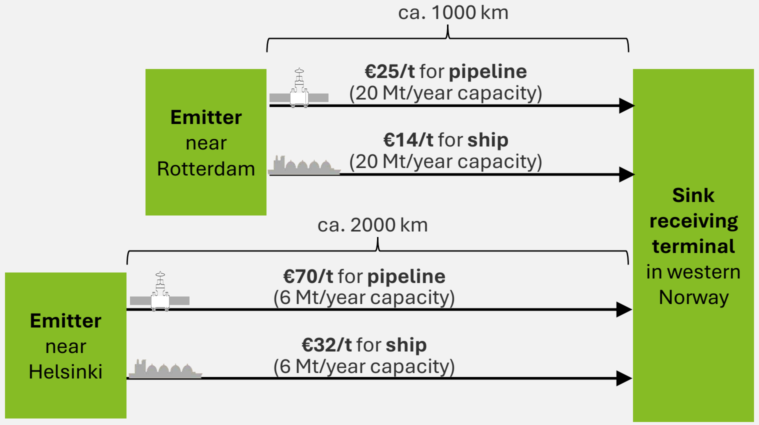
Emitters unsure of ETS price evolution, and delaying investment

As the quantity of allowances available under the EU ETS diminishes, coupled with a potential rise in market prices, emitters find themselves **incentivised to postpone** the signing of **long-term fixed-price contracts**. This strategy allows emitters to maintain **flexibility in their operations** and potentially capitalise on **favourable future market conditions**. **Hedging mechanisms**, such as a suitable **Carbon Contracts for Difference (CCfD) scheme**, can help investors **reduce risk and incentivise** them to be **early movers**. Subsidy schemes can also offer additional incentives to early adopters, for example, in UK's Northern Endurance project, charges for connector or feeder pipelines are not levied on early users.

Sinks unclear on CO_2 purity's impact on storage capacity

The **purity of CO_2** is a critical factor that determines the **normalised capacity for storage**. High levels of impurities can significantly diminish the effective storage capacity available, and this reduction is influenced by varying factors such as pressure and temperature conditions. As the levels of **impurities increase**, the capacity for safe and efficient **storage of CO_2 decreases**, which may result in companies needing to invest more in purification processes. Consequently, the **interplay of CO_2 purity, pressure, and temperature must be carefully considered** to ensure optimal storage solutions are achieved. Thus, **learnings from early projects** should be **made widely available** to sink investors.

CO_2 transport cost comparison (indicative)[1]



Stakeholder perspectives on carbon tax and uncertainties

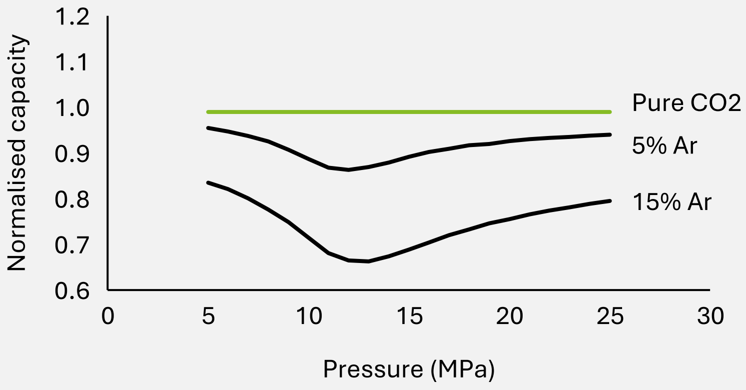
A few years ago, expectations were **ETS would exceed** €100/t by now; however, **fluctuations have hindered** decisions.

Engineering partner in CCS project consortium

Because of **political reasons**, there is **risk** that **high ETS prices** of more than €100/t may **not be sustainable.**

European energy transition expert

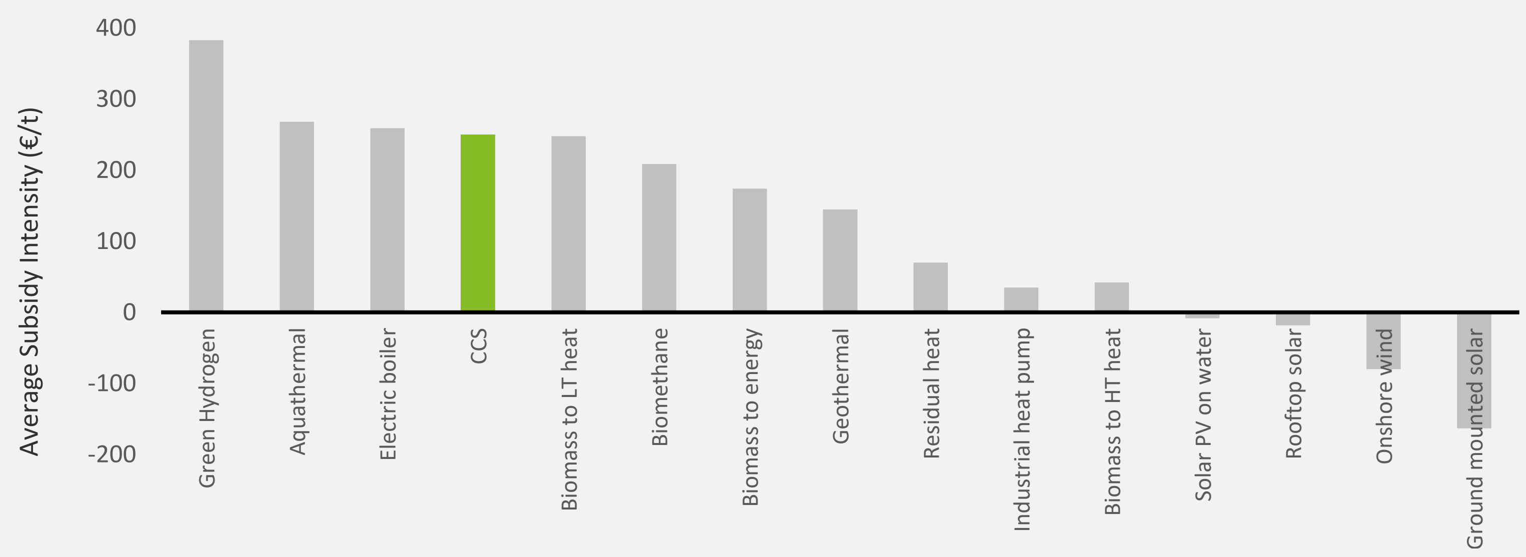
Normalised capacity for different CO_2 purity levels, per pressure level (MPa)[2]



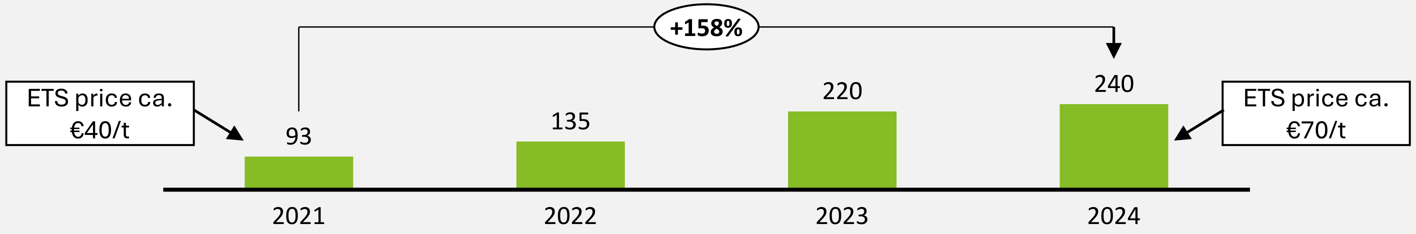
Source: [1] Expert interviews; [2] IEAGHG and Global CCS Institute

The high costs and uncertainties mean that CCS is one of the decarbonisation technologies with a higher subsidy intensity

Subsidy intensity of decarbonisation technologies as per SDE++ (€/t of CO_2 abated)[1]



Subsidy intensity of CCS over the years as per SDE++ (€/t of CO_2 abated)[1]



The Dutch SDE++ regime awards subsidy based on compensation sought in €/t for **shortfall in market revenue** compared to cost. The **SDE++ is an indication of subsidy intensity** in the market. While the subsidy intensity of CCS is competitive with green hydrogen, it is expensive compared to more widely deployed technologies such as solar power.

Over the past few years, **CCS subsidy intensity continued to rise** beyond what can be explained by inflation. The subsidy intensity continued to increase even when EU ETS prices have increased from around €40/t in the beginning of 2021 to €70/t by the end of 2024. An explanation for the increased subsidy need is the **increased risk perception** as the details of the value chain development and project-on-project risk become increasingly clear.

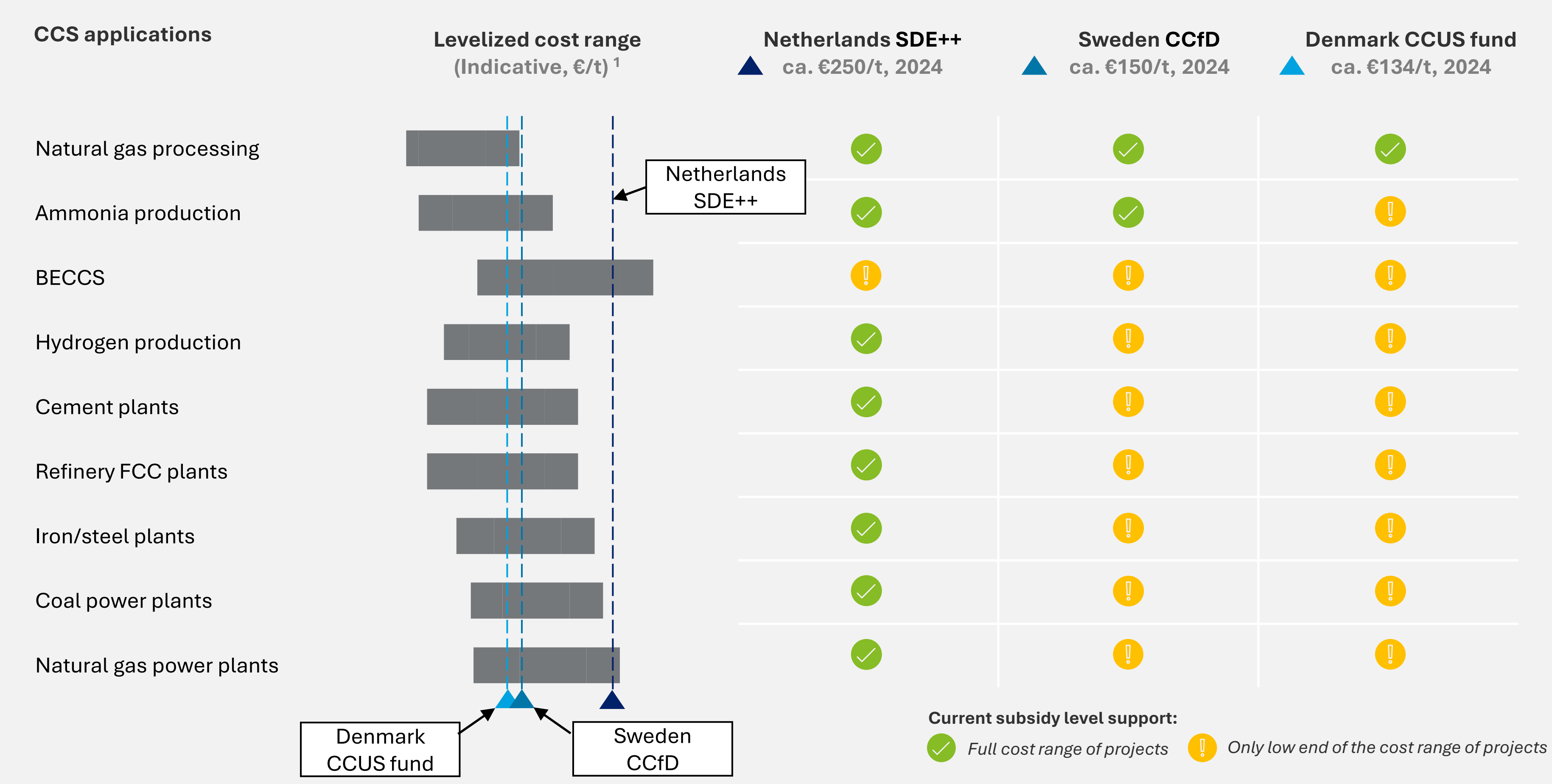
As a solution, governments should **explore adjusted risk allocation models** between private and public sector. An approach could be that governments accept certain (value chain or non-insurable) risks that the private sector is not well positioned to take and mitigate. Governments also need to be cognizant of the fact that while certain decarbonisation pathways may have alternatives (e.g., battery EV versus bio-fuels), **CCS does not have an alternative**.

> Unless mandate is introduced for low-carbon end products (e.g., green steel in new cars sold in Europe), **large subsidies are the only way forward to scale up** these technologies.
>
> European energy transition expert

Source: [1] SDE++ Results 2024

Use cases where emitters can complement ETS revenues with strong local schemes and alternate revenue mechanisms are likely to lead deployment

Extended support schemes for CCS (net of all support schemes, including ETS)



Since 2022, **EU ETS prices**[2] have ranged mostly between €70-90/t. However, price levels are too **low to cover the value gap.**

Recognizing the value gap, countries across Europe are contemplating the **implementation of additional support schemes** that are designed to cover the value gap, net of any other support scheme (like Innovation fund, etc.) and/or EU ETS. These schemes typically take form of one- or two-sided carbon contracts for differences. The **Netherlands, Sweden and Denmark** appear to be **at the forefront** of this trend.

The **support level is adequate to start** with **projects having lower levelized cost of CO_2** capture. **Scale of success** will be determined by **total fund size** and **speed of finalising deals** with developers. **Tailor-made agreements may be needed** to account for unique needs of individual business cases.

> **CCS FID** is a **mixture of CCfD and direct funding** via innovation fund or EU PCI.
>
> Large national oil company

Source: [1] Global CCUS Institute; National Petroleum Council; Oxford Institute for Energy Studies; Expert interviews; Deloitte Analysis; [2] Trading Economics
Note: [1] Original values in ($/t), converted on 11-03-2025 utilising 1 $ = 0.92 €

So far, leading CCS projects in Europe have relied on extensive government support, which will continue to be critical in the short to medium term

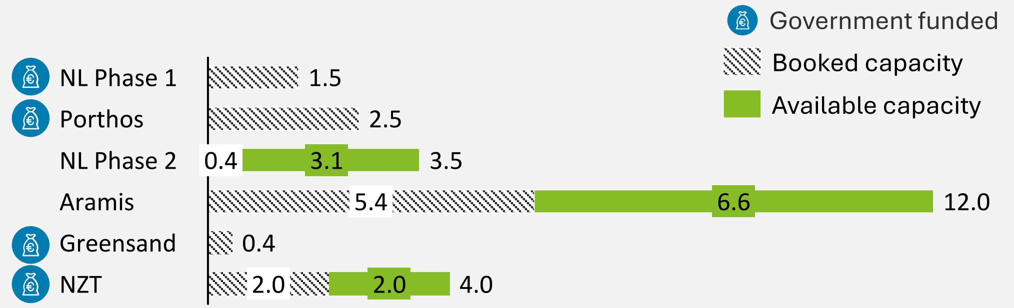
Projects	Porthos (NL)	Northern Endurance (UK)	Northern Lights (NO)	Greensand (DK)
Description	Project Porthos comprises 54 km of **pipeline** (33 km onshore, 21 km offshore), a **compressor station** and **offshore storage**. Porthos is developed by a consortium of government-owned Port of Rotterdam, EBN, and Gasunie.	The Northern Endurance Partnership is the first CCS project reaching FID linking a **gas-fired power plant** with carbon capture to **offshore storage**. Shareholders are private sector companies.	Northern Lights includes **comprehensive T&S infrastructure** for captured CO_2 from industrial emitters in Norway and other European countries. It is developed by a **consortium of public and private companies**, with support from the Norwegian government through policy frameworks, regulatory oversight, and financial backing.	Greensand aims to **permanently store** 8Mt of **biogenic and fossil CO_2** per annum. The project is developed by a consortium of 23 partners, including: INEOS Energy, Wintershall Dea, Maersk Drilling, GEUS and Nordsøfonden. Greensand Future (first phase) reached Final Investment Decision in December 2024.
Regulatory framework	Emitters can apply for Dutch **SDE++ subsidy.** However, they will compete for funding with other decarbonisation projects. There is no dedicated support for transport and storage providers. **Free market approach** is used whereby tariffs are negotiated bilaterally between network developers and users (i.e. unregulated tariffs).	The UK government decided on a **Regulated Asset Base (RAB) approach** for CCS. The Government set up an external subsidy mechanism to ensure 'reasonable' tariffs for network users.	The network is regulated by the Norwegian Ministry of Petroleum and Energy, which follows the Carbon Dioxide Transportation Infrastructure Finance and Innovation (CIFIA) program. A **collaborative framework** is proposed to determine the revenue requirement for the Northern Lights network.	Companies (CO_2 emitters, transporters and CCS developers/operators) can compete for **state subsidies in CCS tenders** for up to €4.9B. For every CO_2 storage license, Nordsøfonden (state-owned) participates with 20%. Currently, there is no dedicated support for T&S providers.
Tariff allocation	Porthos and its customers signed a Transport Capacity and Storage Agreement (TSA) to agree on the relevant fees that the **customers will pay Porthos**: a fixed Transport Capacity Fee, a Storage Space Fee and a Transferable Transport Capacity Fee.	Transport and Storage companies charge tariffs verified by the Energy regulator. These charges include a **connection charge** and **use of system charge**. T&S connection charges for connector or feeder pipelines are **not levied on early users**, with costs included instead in the use of system charge.	The tariffs for the Northern Lights network are regulated by the Norwegian Ministry of Petroleum and Energy and consist of a **fixed charge per tonne of CO_2 stored** – covering the cost of providing storage services; and a **variable charge based on the distance the carbon dioxide is transported** – covering the cost of transporting the CO_2 from the source to the storage site.	Tariffs are **negotiated bilaterally** between CCS developers/operators and the remaining value chain players (i.e. unregulated tariffs). The tariff offered by Greensand Future includes **CO_2 pick-up** at the Port of Esbjerg, **transportation** to the injection point by a specially designed CO_2 carrier vessel, and **storage**.
Financing	The **Dutch government** has awarded **grants** of up to €2.1B, which come from the "SDE++" scheme. Additionally, The **European Commission** has awarded €102M funding for the Porthos project.	The integrated CCS value chains qualified as 'Track 1 clusters' under the UK government's CCS Cluster Sequencing Process resulting in substantial **subsidies**. The subsidies allow for **lower tariffs** to be charged to the users in **initial years**.	**State aid** provided to the developers and certain users of the Northern Lights (also referred to as Longship) program amounting to ca. €1.5B (NOK 16.8B)	Greensand was awarded €26M in **public funding** from the Energy Technology Development Program (EUDP), which is led by the Danish Energy Agency. After reaching FID, the consortium is taking the next step, investing $150M in **commercial agreements** across the entire value chain.
Government approach	**Focusing on financial subsidies for emitters, commercial entities lead the implementation.**	**Proactive stance providing a regulatory framework and facilitating partnerships, creating a conducive environment for commercial companies to invest.**	**Strong commitment through significant financial backing, positioning itself as a leader in developing CCS.**	**Collaborative strategy by investing in research and development, financing the first CCS project, and fostering a supportive regulatory environment.**

Source: Individual project websites and Deloitte analysis

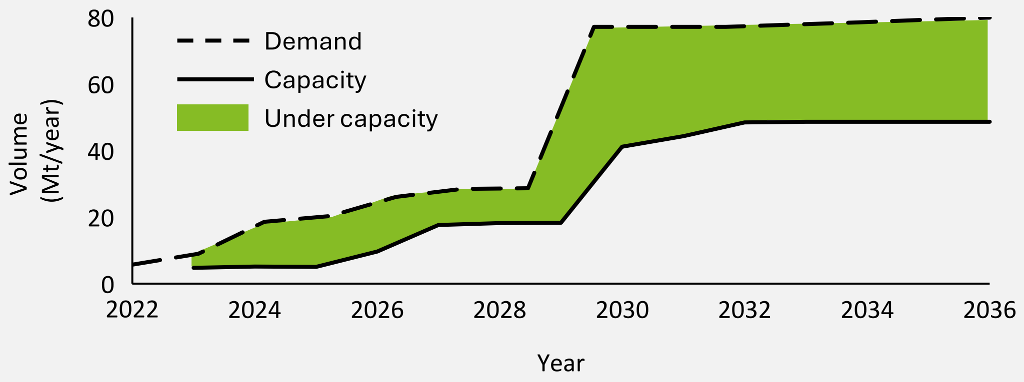
Overcoming value chain barriers

Available CCS storage is limited compared to demand from emitters, at the same time emitters are hesitant to enter long-term contracts

CO_2 storage capacity overview per project (Mt/year)[1]



Capture volume demand and capacity forecast (Mt/year)[2]



Source: [1] Deloitte analysis; [2] Clean Air Task Force
Note: [1] As of February 2025

Government-supported transport and storage systems for CO_2 have **limited capacity for emitters** that seek to **secure new contracts**. This restricted access presents a considerable challenge for non-contracted emitters seeking to manage their emissions effectively. Without established agreements in place, these emitters may find themselves at a disadvantage, as they are **unable to tap into the government-backed infrastructure.** This situation may compel them to seek **alternative solutions** or **invest in their own transport and storage technologies**, which could be both costly and time-consuming. As the landscape of carbon management evolves, the limited availability of these supportive systems highlight the need for policy changes that could **expand access for all emitters**, enabling broader participation.

Ironically, while there exists a structural **gap between the available storage capacity and the increasing need for carbon capture**, the pervasive market uncertainty creates a climate of **hesitation among emitters** regarding their **commitment to long-term contracts** with fixed dates. This uncertainty stems from fluctuating carbon prices, evolving regulatory frameworks, and concerns about future technological developments. Addressing these uncertainties through **clearer policies** and more **stable market conditions** will be crucial for driving commitment and investment in long-term carbon capture strategies.

As a solution, there is a narrative on the **socialisation of costs** to consider the **allocation of tax money to support essential first-stage infrastructure projects**, such as the Northern Lights initiative. The scale-up and actualisation of this narrative will be crucial to meet the emerging demand.

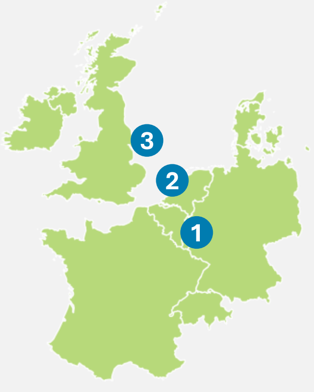
> Government should play an **initial foundation** role, where later **scale-ups** can be **left to the market**. Overcapacity creation in Northern Lights phase 1 has been a critical component to enable FID for phase 2.
>
> CCS commercial model expert

> We are seeing a chicken and egg problem. **Sinks need fixed contracts** to progress projects and eventually **lower their costs**, and **emitters are waiting till costs come down**. The way forward is to give **extra incentives to early adopters**.
>
> European energy transition expert

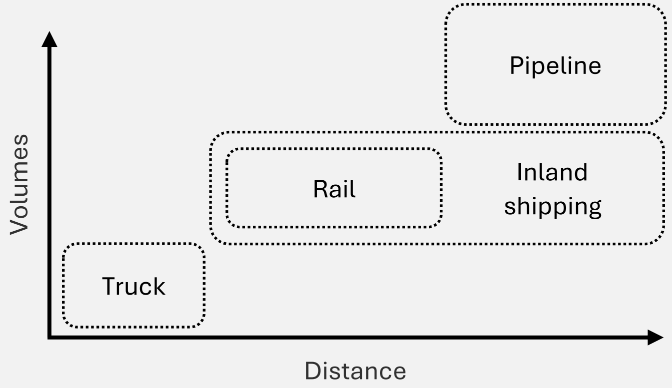
The ecosystem had so far developed for point-to-point CCS, therefore, delay in deployment of common transport infrastructure and services is a barrier to a plug-and-play approach

European CO_2 transport infrastructure[1]

1. **Delta Rhine Corridor**
   2032 operational (4 years delay)
2. **Aramis Project**
   2028 operational (2 years delay)
3. **Northern Endurance Partnership**
   2028 operational (2 years delay)



Optimal mode of CO_2 transport per volume and distance travelled[1]



For longer distances, availability of CO_2 pipelines is critical for project viability. However, the development of European **CO_2 transport infrastructure has experienced significant delays**, which have had a detrimental effect on the readiness of CCS initiatives across the continent. The delay is making it increasingly **difficult for emitters to incorporate carbon management strategies into their operational frameworks.** The bottlenecks in infrastructure development mean that emitters may **struggle to transport the captured CO_2 efficiently**, which could lead to increased costs and a longer timeline for achieving carbon neutrality. These delays not only hinder the timely implementation of essential projects but also pose significant challenges to meeting the climate targets.

Therefore, emitters **located further away from storage sites or coastal areas** must carefully consider the connectivity of their existing assets when planning for carbon capture and storage operations. The geographical distance to these sites can **significantly influence the logistics and economics of CO_2 transport**. While deployment of a well-planned pipeline network will have to be the long-term solution for transporting captured CO_2 to appropriate storage facilities, emitters may need to explore **alternative solutions** to address their immediate transport needs, which could include temporary transport methods that allow for more flexible arrangements. The sub-optimal transport infrastructure also **impacts sinks** by **reducing the extent of their viable catchment area**.

Therefore, **emitters and sinks will need to work together with aggregators, logistics players, and service providers**. In terms of solutions, while **inland shipping is currently the most modular option**, it will also require the establishment of inland hubs.

The European Union is actively initiating a tender for a **CO_2 market-place**, with the government serving as an intermediary to facilitate risk aggregation among multiple emitters. It would be advisable for the initiative to increase focus on **3rd party modular (and temporary) logistics and transport services**.

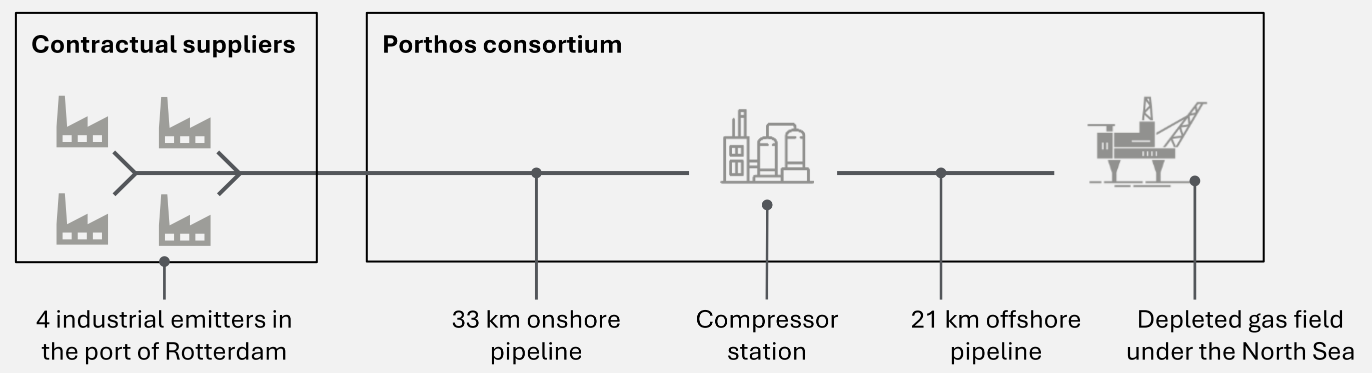
> The good news is that we are seeing **new 3rd party CO_2 transporters** enter the **value chain**.
>
> International development aid agency

> We see interest from some geographically **scattered small-scale emitters**. The solution, at least for now, must be **shipping**.
>
> CCS asset management for energy super major

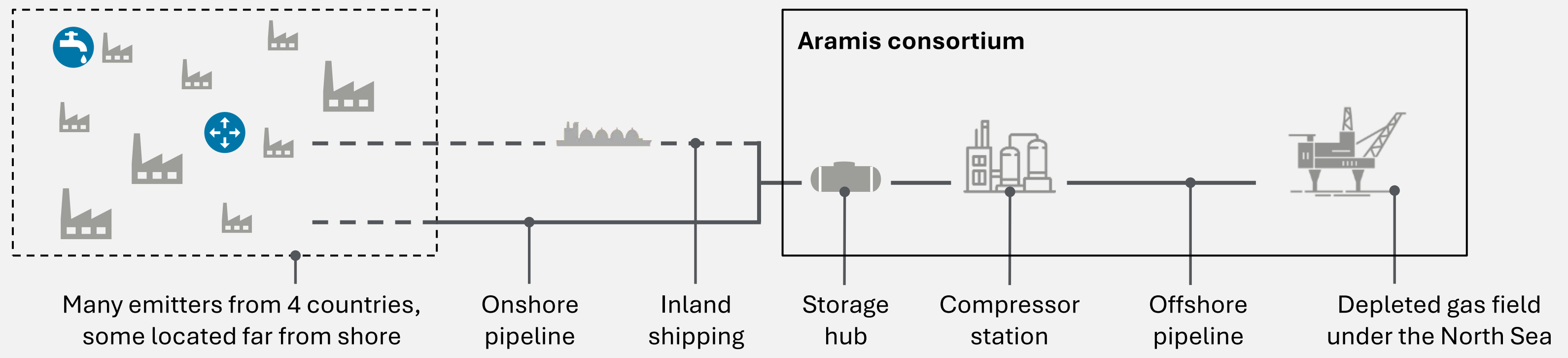
Source: [1] Deloitte analysis

As 3rd generation value chains become more sophisticated, the partnership models will shift from agreement driven to regulation and market driven

Multiple use dedicated network (2nd generation) – Porthos example[1]



Multiple use open network (3rd generation) – Aramis example[1]



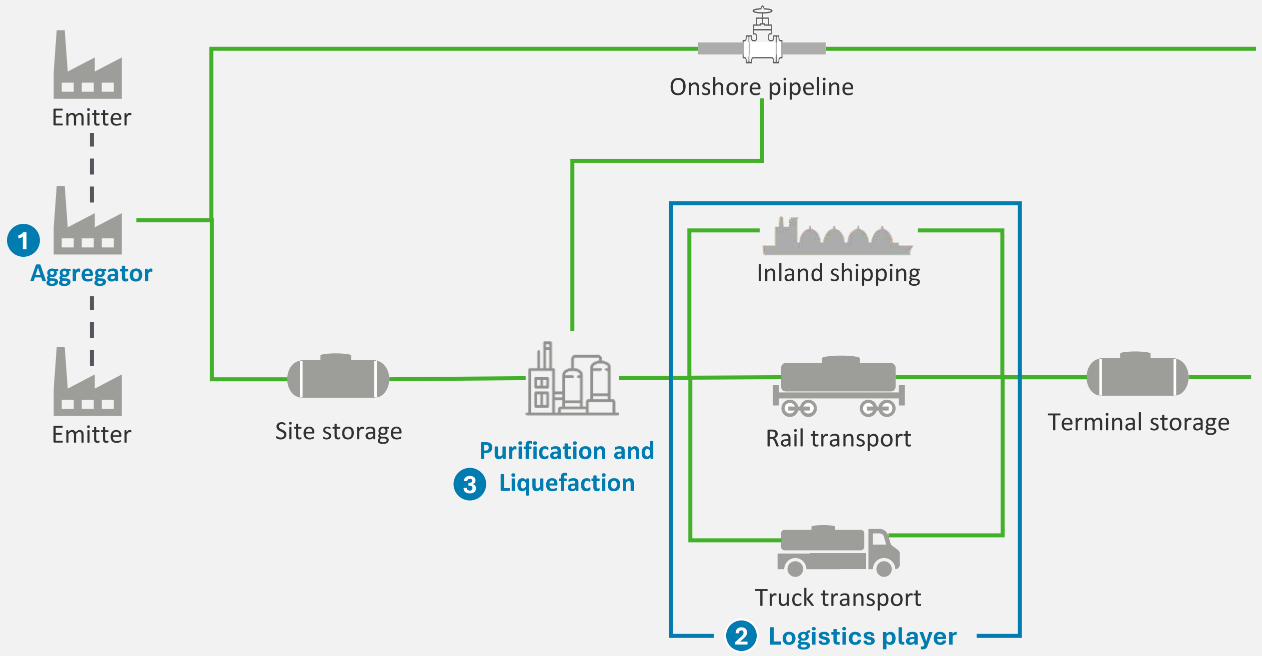
While 2nd generation value chains primarily serve power and chemical industries, 3rd generation value chains will aim to integrate a broader spectrum of industries, including waste management, cement production, and smaller chemical enterprises. Unlike 2nd generation, where frameworks like Porthos were minimally regulated and driven by agreements between the partners, **3rd generation value chains** will require increasing **reliance on government regulation**. The key drivers of this trend are:

- **Increased number of emitters:** The transition to 3rd generation value chains will see a significant rise in the number of emitters integrated into the network, complicating coordination efforts and operational management.
- **Extended distances between emitters:** Emitters in the 3rd generation network will be dispersed over larger distances, presenting challenges in connecting them to a cohesive CO_2 transport system that feeds into the aggregator.
- **Greater transport distances to coastal facilities:** With many emitters situated inland, the logistics of connecting them to coastal facilities for storage become more complex and costly. This necessitates the exploration of alternative transportation methods, such as inland shipping, rather than relying solely on pipeline infrastructure.
- **Smaller CO_2 volumes:** Many 3rd generation emitters are smaller in scale, generating relatively modest volumes of CO_2. This variability poses a challenge in ensuring that sufficient CO_2 is fed to storage providers, which is critical for maintaining an efficient and long-term network operation.

Source: [1]Project websites and Deloitte analysis

Emitters, especially small-scale ones, will need flexible options in the onshore part of the value chain to hand-over CO_2 in a flexible and cost-effective manner

Routes to onshore storage (not exhaustive)



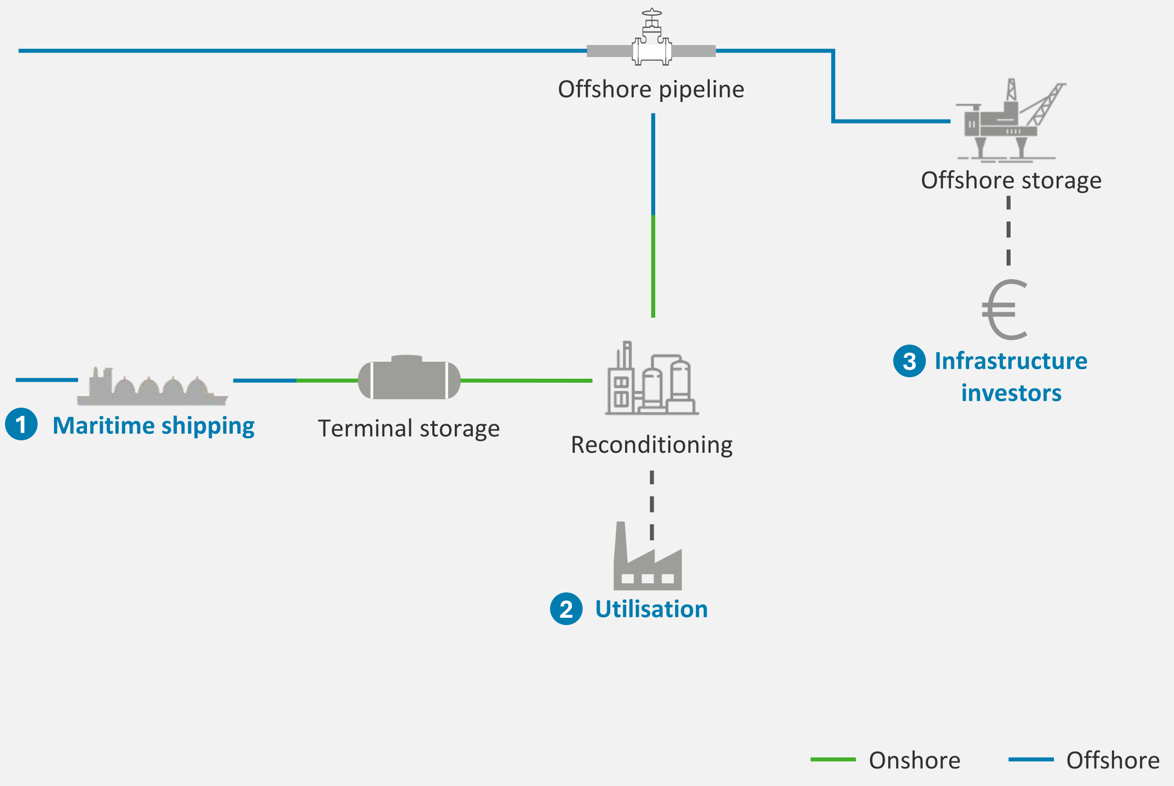
New business models and value chain players in the onshore CCS value chain are required to support aggregation from multiple emitters, transportation and transformation solutions. This will ensure that emitters can focus on their core business and are not distracted by CO_2 transportation complexities that lie beyond their core competence.

1. **Flue gas aggregator:** Most current capture projects are dedicated installations for specific use cases. As smaller emitters enter the value chain, a dedicated capture facility becomes increasingly cost-prohibitive. An **aggregator** can collect flue gas from multiple emission sources and then extract CO_2 in a capture facility. This would be most applicable in industrial hubs or parks. Transport providers are perhaps well positioned to provide these services as an integrated add-on service offering.
2. **Last mile CO_2 logistics player:** As capture projects emerge further away from shore, transportation solution are needed to get the CO_2 to the export terminal. Onshore pipelines are the preferred solution considering cost but are often delayed and unavailable for first movers. **Trains, trucks and inland shipping** (where applicable) are the only alternatives, but there is a lack of sufficient providers so far who can offer flexible logistics solutions at-scale.
3. **Liquefaction and purification services:** 3rd generation emitters will often have lower CO_2 content and pay significant cost penalty to meet export specifications for most transport and storage projects (which require high specifications). Current offshore transport is dominated by liquid CO_2 carriers as offshore pipelines remain immature. Therefore, liquefaction is adding to the emitters cost stack. Service providers connecting with multiple emitters to aggregate, **purify and liquify** the captured CO_2 will help in enabling wider adoption and in lowering costs for emitters.

> When dealing with industrial-scale **projects located far from coastal terminals** (for example, steel factories 400 km inland), **liquefaction** is typically **required**.
>
> Engineering advisory firm active in CCS

Regulatory support is needed for new business models in the offshore value chain to help further derisk projects

Routes to offshore storage (not exhaustive)



Due to high costs and uncertainty, project developers are constantly on the look-out for additional cost and revenue optimisation opportunities. Industry representatives believe that allowing flexibility to transport CO_2 across borders and allowing utilisation of captured CO_2 could give a much-needed incremental boost to projects' business cases, especially in the initial years.

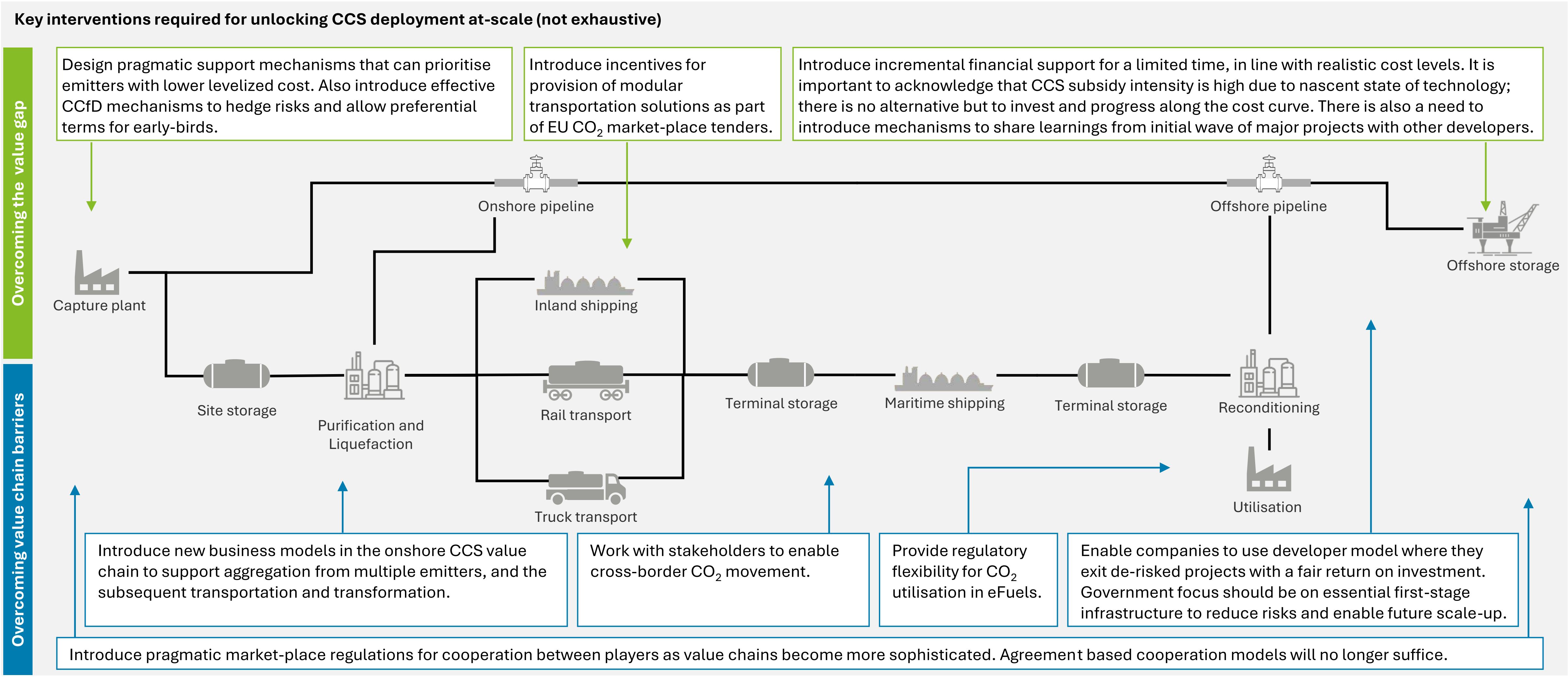
1. **Cross-border flexible CO_2 transport:** While offshore pipelines are the most cost-efficient solution in the long-term for transport of large volumes of CO_2, their business case is heavily dependent on utilisation and subject to long lead times. In addition, demand uncertainty on CO_2 volumes captured and where they originate from increases stranded asset risk for pipelines. **Ship based transport** solutions, catering **for cross border CO_2 shipments** are well suited for scalable and flexible deployment of infrastructure to meet demand wherever it originates. There is a growing discussion on amendments to London Protocol to facilitate such solutions.
2. **Carbon utilisation for eFuels:** As the energy transition progresses, decarbonising heavy industry remains a significant challenge, with different carriers (Hydrogen, Ammonia, etc.) being championed by different stakeholders. However, SAF and eMethane are starting to gain increasing preference due to the low inherent infrastructure risk associated with them. **Utilising the captured CO_2** for making eFuels such as eMethane can be an attractive business case for O&G companies.
3. **Developer model:** Given the inherent value of CO_2 as a "waste commodity", the margins in the storage value chain are likely to stagnate to single digits, making it unattractive to incumbent O&G companies. Provided adequate regulatory support, O&G companies can adopt a **developer model**, wherein they **exit the projects after de-risking at a suitable multiple to infrastructure investors**.

Trans-border regulation need not be a big issue; we have seen **solutions** with **bilateral MoU**. That is what Belgium and Denmark did.

CCS asset manager

Conclusion

For CCS scale-up, there is a need for flexibility in funding and regulations to swiftly operationalise major projects, and recalibrate level of support as the market matures



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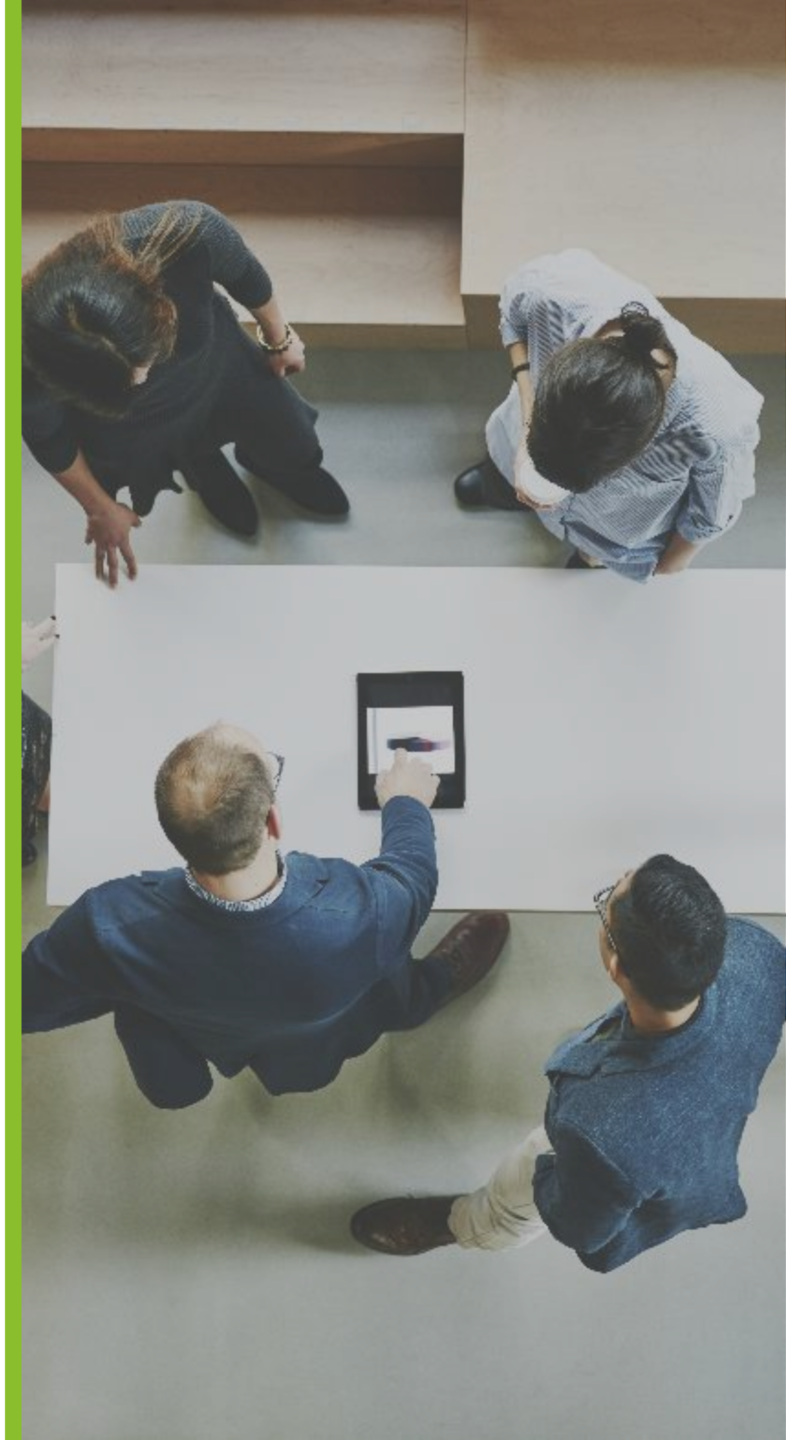

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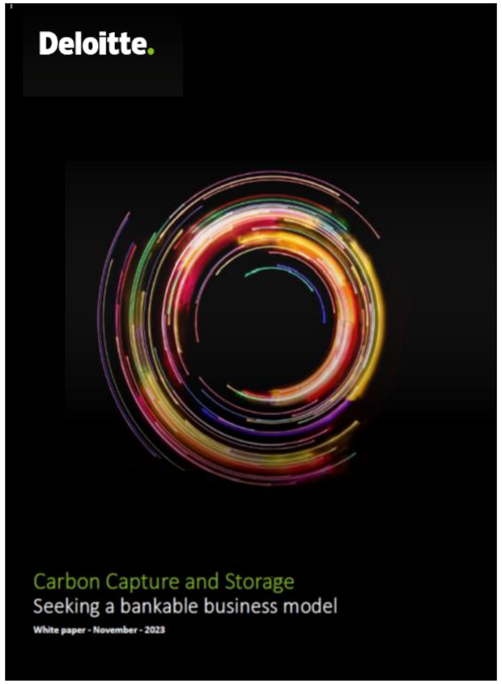
Also read: Our publication on bankable CCS business models
(click on link below)



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