International Carbon Action Partnership

Emissions Trading Systems and Carbon Capture and Storage:

Mapping possible interactions, technical considerations, and existing provisions

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Executive Summary

The interaction between emissions trading systems (ETSs) and carbon capture and storage (CCS)[1] applications is likely to become an ever more relevant topic of regulatory attention. As a key tool in the response to climate change, CCS can deliver climate change mitigation within the scope of ETSs. Moreover, ETSs can support the development and deployment of CCS applications. At present there is limited literature on the interactions between ETSs and CCS. This report aims to contribute to filling this gap by understanding:

a) How ETSs could interact with CCS applications, and the attendant opportunities and risks;

b) The challenges faced when designing ETS regulation related to CCS; and

c) The specifics of how different ETSs implemented to date interact with CCS applications.

Key context and background

CCS applications capture and geologically store carbon dioxide (CO_2). They can deliver emissions reductions or, in very specific circumstances, CO_2 removals. For the purpose of this report, CCS applications are divided into two main categories:[2]

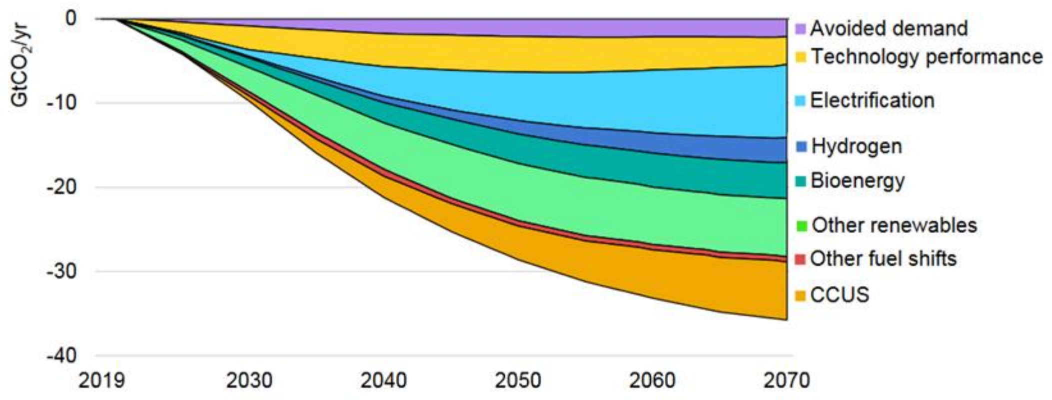
1. **Fossil energy and industrial point-source capture**: applications that *reduce CO_2 emissions* by capturing and storing CO_2 from the combustion of fossil fuels (e.g., for electricity generation), as well as from process emissions in the chemicals, cement, steel, and aluminum sectors, among others. These emission sources are typically covered by ETSs.
2. **Technological (or CCS-based) removals**: CCS applications that *remove*[3] *previously emitted CO_2 from the atmosphere.* These include direct air carbon capture and storage (DACCS), bioenergy with carbon capture and storage (BECCS) – if using renewable biomass –, as well as Waste-to-Energy (WtE) with CCS (to the extent that the waste contains biogenic fraction). These activities are typically not covered by ETSs.

CCS can be an important element in the decarbonization pathways of sectors covered by ETSs. Most jurisdictions with ETSs in force either already have policies on CCS in place or intend to make use of CCS applications. Moreover, there is an important overlap between the sectors covered by ETSs and those in which CCS shows the most promise: the International Energy Agency (IEA 2020b,

[1] While the focus of the report lies primarily on CCS applications, a few thoughts and considerations on carbon capture and utilization (CCU) are also provided.
[2] It is important to note that combined approaches may also exist. E.g., a power plant with CCS may combust both fossil fuels as well as renewable biomass.
[3] Carbon dioxide removal (CDR) refers to anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products, thus reducing the atmospheric concentration of CO_2. Many CDR methods, such as forestry and soil carbon, do not involve CCS technologies.

2022) and the Intergovernmental Panel on Climate Change (IPCC 2022d, Figure SPM.7) have identified an important role for CCS and CCU in achieving ambitious climate targets across the energy and industry sectors, the main sectors covered by ETS. In one of its scenarios, the IEA projects that CCS and CCU applications will be responsible for approximately 13% of energy sector CO_2 emissions reductions in 2050 (see Figure ES. 1). In the cement sector, which is regulated by most ETSs operational today, more than one third of the decarbonization effort by 2050 is forecast to rely on CCS and CCU applications (GCCA 2020).

Figure ES. 1 – Global energy sector CO_2 emissions reductions by measure in the Sustainable Development Scenario relative to the Stated Policies Scenario, 2019-2070

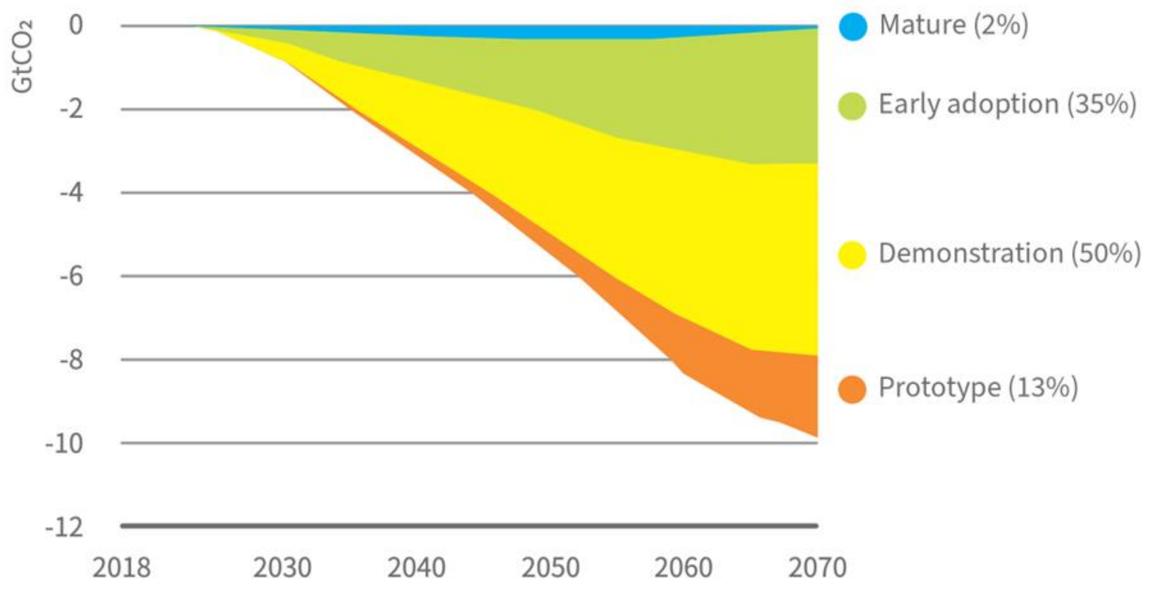


Source: IEA (2020b), Figure 2.1

Several new CCS projects are under development, but there remains a large gap between their potential capacity and projected decarbonization pathways. Current projects and those under development include the Alberta Carbon Trunk Line[4] in Canada, the Longship[5] project in Norway, the Porthos[6] project in the Netherlands, and the Northern Endurance Partnership[7] in the UK. Despite these initiatives, current efforts fall far short of the level of deployment outlined in decarbonization pathways. A further challenge is that only 2% of the decarbonization from CCS and CCU applications by 2070 is expected to come from applications considered to be "mature" today; nearly two thirds is expected to come from technologies that are still either in the "demonstration" or "protoype" stages (see Figure ES. 2).

[4] https://enhanceenergy.com/actl/
[5] https://norlights.com/about-the-longship-project/
[6] https://www.porthosco2.nl/en/
[7] https://www.netzeroteesside.co.uk/northern-endurance-partnership/

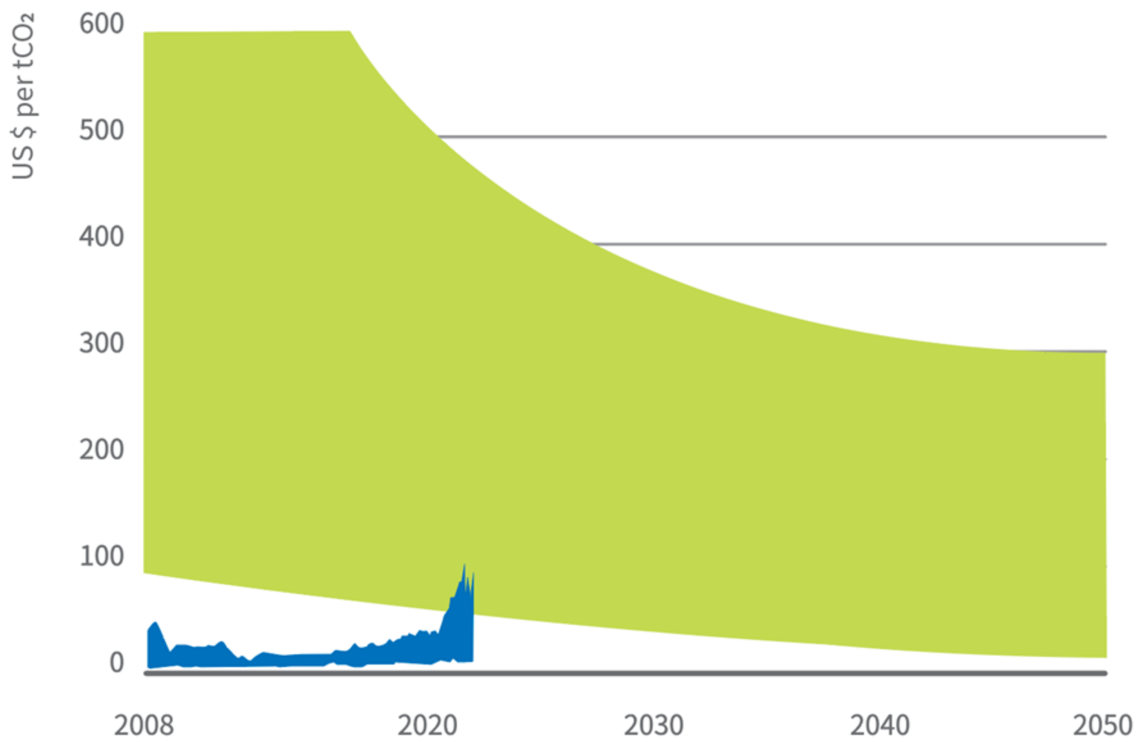
Figure ES. 2 – World CO_2 emissions reductions from CCS and CCU by technology readiness category in the IEA Sustainable Development Scenario relative to the Stated Policies Scenario



Source: Adapted from IEA (2020b), Figure 3.2.

A combination of policies and mechanisms will be necessary to support CCS development and deployment; carbon pricing can play an important role, but it is not sufficient on its own. Policies include capital grants, state-backed loans, tax credits, public procurement, and end product standards, among others. By establishing an explicit carbon price, ETSs support low-carbon production processes, products, and technologies such as CCS. As seen above, however, many CCS applications still require significant research and development (R&D) investments to reach technological maturity and deployment at scale. Even in their mature phase, they often involve significant capital expenditures and ongoing operating costs. Encouraging investment in such technologies requires sustained, long-term pricing support (Marcu et al. 2021). Many jurisdictions do not price carbon, and in most jurisdictions where carbon pricing is operational, emissions reductions from CCS are not taken into consideration or current and expected allowance prices are not high enough to incentivize emitters to capture CO_2 (see Figure ES. 3). Price volatility in carbon markets also presents a significant challenge (IEA 2020c). In the early deployment stages, CCS initiatives are likely to require additional support – e.g., in the form of “top ups” (such as contracts for difference) that complement the carbon price and provide a higher and more predictable price signal.

Figure ES. 3 – Economic Gap: Carbon price versus cost of carbon capture



Range of observed ETS allowance prices
Includes prices from the ETSs in California, China, European Union, Germany, Korea, New Zealand, Nova Scotia, Québec, RGGI, and the UK.

Range of values observed in studies estimating / forecasting cost of CO_2 capture.
Range of values for CO_2 capture (that is, excluding transportation and storage costs). Broadly speaking, direct air capture costs determine the upper end of the range, while fossil energy and industrial point-source capture costs determine the lower end.

Source: Authors' elaboration. Allowance prices based on data from ICAP (2022). Capture costs estimated based on data from Global CCS Institute (2020b); Fasihi et al. (2019); Evans (2017); Shayegh (2021); Fuss et al. (2018); IPCC (2022b).

Policy makers must balance the numerous risks and trade-offs associated with the use of CCS applications when considering their role in decarbonization pathways. The main concerns related to CCS applications include: legitimizing business-as-usual (notably fossil fuel) activities; the underperformance of the technology so far, alongside resulting doubts over its ability to deliver reductions and removals at scale; concerns about the magnitude of CDR deployment expected in many scenarios and the possibility that these predictions could dilute incentives to reduce emissions today; concerns over CO_2 leakage from storage sites; and concerns over the social and environmental impacts of the large-scale adoption of certain applications (e.g., impacts on land use from the large biomass needs of BECCS plants, including food security and biodiversity). Policy makers must weigh up these considerations in light of the local context and their own policy priorities, taking into account the importance of public acceptance in achieving mitigation goals and the large-scale commercialization of CCS (Whitmarsh et al. 2019).

Mechanics of the ETS-CCS interaction: Inside or outside ETS sectoral scope

ETSs can interact with CCS applications irrespective of whether the relevant sectors are covered by the ETS. Interactions between ETSs and CCS applications can be implemented in multiple sectoral coverage configurations. This is relevant because ETSs differ in how they cover e.g., fossil energy emissions. Most ETSs regulate emissions at source, at the point where the greenhouse gas (GHG) enters the atmosphere (e.g., a coal power plant). This is the case for the European Union ETS (EU ETS), the Regional Greenhouse Gas Initiative (RGGI), and the United Kingdom ETS (UK ETS), to name a few. Other ETSs regulate emissions upstream, meaning that ETS compliance obligations fall at the point at which the fossil fuel is first commercialized by extractors, refiners, or importers. The ETSs in Germany and Austria, for example, exclusively cover emissions upstream.

Interactions with fossil energy and industrial point-source capture are simplest in ETSs that regulate emissions at source. The point of emission of a GHG is where CO_2 capture takes place, making it easier for such ETSs to interact with fossil energy and industrial point-source capture. The ETS provides an incentive to adopt CCS applications by allowing regulated entities to reduce their compliance obligations by capturing their emissions (and to reduce their compliance costs). This is already the case in the EU ETS, the UK ETS, and the Québec Cap-and-Trade System.

Interactions with fossil energy and industrial point-source capture are also possible for ETSs that cover emissions upstream. ETSs with upstream coverage that wish to interact with industrial point-source capture could, for example, award a unit (e.g., an allowance or an offset credit) to entities performing capture from an industrial point-source, which could then be sold in the ETS market. Alternatively, the ETS could allow certain entities (e.g., a coal power plant) to voluntarily participate in the ETS. These entities would assume compliance obligations but also be incentivized to capture their emissions.

Interactions with technological removals within the ETS scope are possible, but the mechanics may vary by application. Technological removals that involve point-source capture – such as BECCS and WtE with CCS – could be covered directly under an ETS, as proposed by Rickels et al. (2021). Such applications could, for example, be allowed to voluntarily participate in the ETS, and receive free allowance allocations on the basis of renewable biomass used by the plant. In this case, the plant could subtract captured emissions from its emissions compliance obligations such that a surplus of allowances would be generated and could then be sold to the market.[8] Technological removals that do not involve point-source capture – such as DACCS – could not be reflected in the ETS through such a mechanism, but they could be included in the scope of the ETS through other means. For example, the ETS could allow for the voluntary participation of the DACCS plant in the ETS and then provide for this DACCS plant to receive an allowance for each tonne of CO_2 removed. This is similar to New Zealand's approach to removals from forestry activities in its ETS.

Interactions with technological removals outside the ETS scope can be akin to offsetting provisions. This could be done by awarding removal units (e.g., through a separate certification mechanism) and allowing such units to be used for compliance obligations within the ETS. In this case, two distinct "markets" would exist: a market for allowances (the ETS) and a market for removals.[9]

ETSs and CCS: Whether to interact, and with what

ETSs can interact with none, either or both CCS applications. We refer to these different configurations as "options"[10] (see Figure ES. 4).

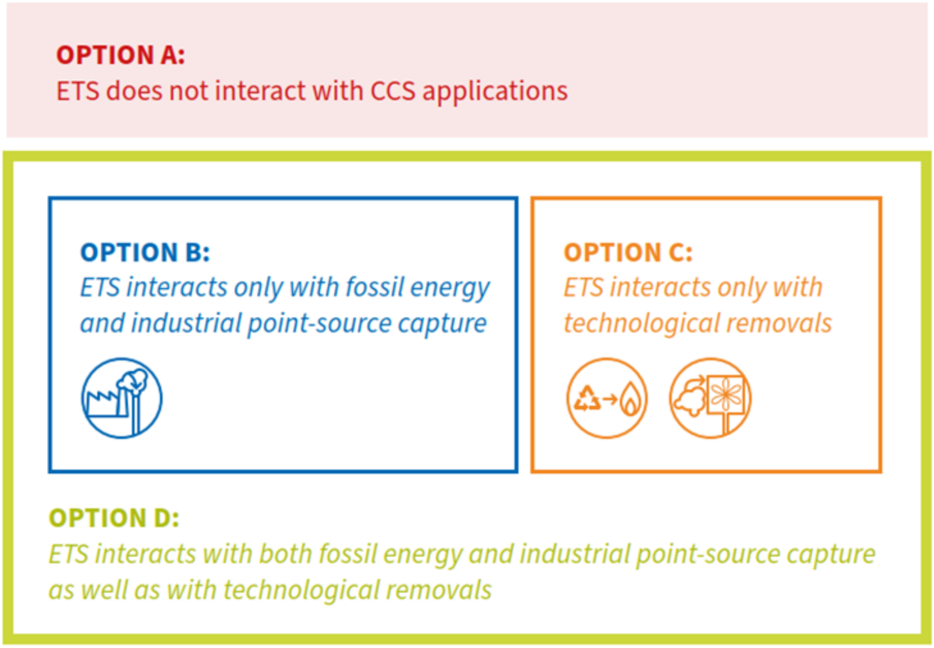
- **Option A: No interaction.** Under Option A, the ETS does not interact directly with any CCS applications. Entities covered by the ETS cannot reduce their compliance obligations by undertaking CCS – the ETS does not recognize the captured CO_2 as "not emitted". There are also no provisions for technological removals. This can be a deliberate policy choice or the (potentially unintentional) result of there being no explicit regulation.
- **Option B: Interaction with fossil energy and industrial point-source capture applications.** Under Option B, the ETS interacts with CCS applications by allowing fossil energy and industrial point-source emitters to reduce their emissions by capturing them. If such point-source emitters are covered by the ETS (which is usually the case), this leads to a reduction in ETS compliance obligations and provides an incentive to implement CCS applications.
- **Option C: Interaction with technological removals.** Under Option C, the ETS interacts with technological removals such as BECCS and DACCS, but not with CCS applications related to fossil energy or industrial point-source capture. This can be the case in ETSs that

[8] It is useful to note that this approach could also reflect the use of sustainable biomass in fossil fuel power plants.
[9] For a detailed analysis on the interactions between ETSs and removal units, see La Hoz Theuer et al. (2021).
[10] It is important to note that, as elaborated above, each of the options is flexible in terms of sectoral coverage, which means that ETSs can interact with CCS applications irrespective of whether the relevant sectors are formally covered by the ETS.

regulate emissions upstream and that include provisions for credits from technological removals.

- **Option D: Interaction with fossil energy and industrial capture as well as with technological removals.** Option D combines Options B and C, and interacts with (and provides incentives to) fossil energy and industrial capture as well as to technological removals.

Figure ES. 4 – Four options for interaction between ETSs and CCS



Source: Authors' elaboration

Interactions between ETS and CCS applications increase the flexibility for regulated entities in meeting compliance obligations, but can also affect companies' abatement decisions. The absence of any possibility to make use of CCS applications under the ETS means regulated entities must meet compliance obligations by reducing emissions through e.g., process changes or by adjusting production levels, as well as by purchasing offset credits (if available) and allowances. Including CCS applications under the ETS gives regulated entities additional means to meet their obligations, potentially reducing compliance costs. More flexibility can mean lower compliance costs for covered entities, but can also affect companies' abatement behavior and could extend the economic lifetime of fossil fuel infrastructure. Moreover, the inclusion of removal units in the ETS can have a "mitigation deterrence" effect (see e.g., Grant et al. 2021), whereby regulated entities may be less incentivized to reduce their emissions now if they expect removal units to come online in the future.

Increasing the points of interaction between ETSs and CCS can ease concerns related to ETS market functioning and price discovery as the ETS cap approaches zero. As the cap approaches zero and companies decarbonize their production processes, the number of participants in the ETS and the system's emissions coverage will decrease, giving rise to issues of liquidity and market power and decreasing the effectiveness of the system. Allowance prices for residual emissions are also likely to be high. Interactions with technological removals can increase the number of players in the ETS and the supply of compliance units into the system, alleviating some of these issues.

Increasing the points of interaction between ETSs and CCS can further incentivize CCS development and deployment, but this is contingent on price differentials and on the availability of additional support. At one end of the spectrum, Option A offers no incentive from the ETS for CCS applications, which means that actors interested in developing CCS applications must seek incentives outside the ETS, potentially leading to missed abatement opportunities. At the other end of the spectrum, Option D offers the broadest ETS-based incentive to CCS by including both categories of CCS applications. Without further support policies, however, the strength of any price incentive provided by the ETS will be subject to market and price risk — just as the future price of allowances cannot be known with certainty, neither can the return on investment from CCS installations and activities. Moreover, the current and projected price of allowances can be too low to incentivize various applications.

Systems may not fall clearly within any of the 'options'. This could be the case when an ETS has no CCS-specific provisions, but regulated entities could nevertheless reflect captured emissions in compliance obligations, notably through broader provisions related to the rules that determine compliance obligations and MRV requirements. In ETSs where the compliance obligation relates to *emissions that are released into the atmosphere* (as opposed to ETSs that regulate emissions upstream, e.g., at the point of fuel distribution), and where MRV includes provisions for continuous monitoring and/or for case-specific deviations, the system could be interpreted to allow for – or at least not explicitly hinder – the reflection of captured emissions in the emissions reports of covered entities. Entities interested in investing in CCS applications, however, would likely need a more explicit regulatory endorsement of CCS applications before investments in CCS infrastructure were made. In practice, this uncertain interaction is likely to result in a lack of incentives for CCS applications.

ETS design considerations

Considerations related to price dynamics and incentives for CCS applications are impacted by aspects of legal tender. Interactions with fossil energy and industrial point-source capture *inside* the scope of the ETS relate to simply reducing the compliance obligations of regulated entities. But others – such as interacting with fossil energy and industrial point-source capture *outside* the scope of the ETS – can entail *awarding units* to such activities. The units awarded can be allowances or credits. An allowance would be fully fungible, but a carbon credit need not be – and can be subject to e.g., quantitative restrictions on its use. [11,12]

To the extent that units (allowances or credits) are allocated to entities involved in CCS applications, an important question is the relationship between such units and the ETS cap. If the allocated units are part of the cap, the allocation of units to CCS applications can create additional scarcity for other entities under the ETS. Regulators may choose to establish unit reserves, although this could effectively limit any incentive for CCS applications through unit allocation. If units allocated to CCS applications are generated *in addition* to the cap, and especially if there is no limit on the number of units that can be generated, the system effectively has no "cap". Gross emissions under the ETS are then not limited, with the risk that emission reductions and removals from regulated entities would rely on CCS applications rather than on actual reductions.

If an ETS allows entities to reduce compliance obligations by capturing CO_2, any free allocation of allowances could be affected by a reduction in reported emissions from entities capturing CO_2. Under benchmarking, this can reduce compliance obligations for entities capturing CO_2, and also lower the overall benchmark, affecting allocation to other entities. Under grandparenting, a reduction in free allocation in line with CO_2 capture could dampen the incentive for said CO_2 capture.

ETSs need strict and enforced criteria on what constitutes renewable biomass to ensure the environmental integrity of any biomass use in the ETS. This is important in terms of interacting with BECCS and WtE with CCS applications, and in the context of the transition of e.g., fossil-based power plants towards biomass use. There is a need for rules that reflect the spectrum of CO_2 reductions and removals that CCS applications and biomass use can generate.

The treatment of operational emissions and CO_2 leaks from the CCS value chain (capture, transport, and storage) within the ETS must be clear. The CCS value chain has two main categories of sources of emission. The first is *operational emissions*, generated from processes inherent to the capture, transport, and storage of emissions (e.g., fuel emissions in energy and transport equipment). The second is *CO_2 leaks (or leakage emissions)*, emissions not inherent to a process but that are fugitive, vented, or result from the failure of one or more components of a process. From a GHG accounting point of view, it is key that all these emissions are visible in national inventories. It is also important to understand whether a jurisdiction wishes to make use of the ETS as a tool for monitoring emissions and redress in case of CO_2 leaks.

The ETS can be used as a tool to monitor operational emissions and CO_2 leaks from the CCS value chain and provide economic incentives to reduce them. Whether these emissions fall under

[11] Allocating units to CCS applications outside jurisdictional borders would entail mechanics similar to those applied to international credits/offsets, although aspects related to e.g., CO_2 leaks out of storage and the treatment of operational emissions would still need to be taken into account.
[12] Irrespective of choices over legal tender, it will be important to make sure that only one unit is issued for each tonne reduced or removed – otherwise, double counting may occur.

the scope of application of the ETS is regulated primarily through regulations on ETS scope and on MRV. Including them in the scope of the ETS would provide incentives to reduce emissions, as operators would face allowance surrender obligations for their emissions. Their inclusion would also likely improve the accuracy of the emissions monitoring of these sources given the MRV requirements in the ETS. Both the monitoring and options for redress in case of leaks, however, can also be managed outside the ETS.

Liability provisions in case of CO_2 leaks out of geological storage sites are necessary to ensure the environmental integrity of the use of CCS applications. [13] Liability for such leaks typically falls on the entity that operates the storage facility. If liability is to be enforced through the ETS (such that the storage operator must surrender allowances in case of leaks), relevant storage sites must be included within the scope of the ETS. This may be challenging in instances where CO_2 is stored outside jurisdictional borders. Another relevant question relates to the time period during which the storage operator must monitor emissions and for how long allowance surrender obligations apply. Responsibilities can also change hands over time. For example, in the EU ETS and the UK ETS, responsibility for monitoring emissions – and surrendering allowances – in case of leakage from storage remains with the storage entity for a minimum of 20 years after the closure of the storage site. After this point, the responsibility for monitoring and leakage can be handed over to the national government under specific conditions.

Only the EU ETS and the UK ETS currently explicitly include the entire CCS value chain within the ETS scope. [14] Some other ETSs cover part of the CCS value chain: in the California program, for example, "CO_2 suppliers" (entities involved in the capture of CO_2) are covered by the ETS, but transport and geological storage are not. The Québec Cap-and-Trade System acknowledges that multiple entities may be involved in the CCS value chain, but the economic incentive is provided only to the industrial facility that would have emitted the CO_2 had it not been captured.

Some ETSs can reflect storage outside their jurisdictional borders, while others cannot. Upcoming CCS projects often involve the export of CO_2 to geological storage sites outside of jurisdictional borders. Different ETSs have different provisions for the export of CO_2 for storage. Under the New Zealand ETS (NZ ETS), for example, the export of GHGs as well as the GHGs embedded in products are subtracted from entities' compliance obligations. This allows the NZ ETS to interact with emissions captured within its borders but used or stored outside them. Under the EU ETS, provisions on CCS are subject to storage being carried out in accordance with the EU CCS

[13] Leaks can also happen during CO_2 transportation, and provisions for such leaks are also necessary. Since most concerns related to leaks pertain to those out of geological storage sites, the analysis focuses on leaks out of storage, noting that many of these considerations apply also to leaks during transport.

[14] As of January 2023, provisions under the EU ETS and the UK ETS only cover the transport of CO_2 through pipelines. For the EU ETS, the ongoing revision process is likely to result in an expansion of these provisions to all means of transport (see section 7.1).

Directive, which only regulates storage within the EU and the European Economic Area (EEA). If CO_2 is stored in the EU and the EEA in accordance with the directive, the emitted CO_2 will be considered as “not having been emitted” under the ETS, and industrial point-source emitters can subtract the captured emissions from their compliance obligations. Storing CO_2 emissions outside the EU and EEA is allowed, but such emissions cannot be used to reduce compliance obligations, providing little incentive to store CO_2 abroad (European Commission 2022a).

Brief considerations on CCU

CCU applications vary widely and have different environmental outcomes. Some CCU applications lead to the long-term binding of CO_2 into a product, which will not be re-emitted on use or during disposal (e.g., construction materials). For this type of product, the environmental effect depends primarily on the source of the CO_2 that is embedded: using CO_2 from fossil sources leads to emission reductions, whereas using CO_2 from renewable biomass and ambient air can lead to removals. Most CCU applications, however, only bind the CO2 *temporarily* and the CO_2 is released into the atmosphere during use or disposal. This is the case for CCU applications that produce synthetic fuels, plastics and carbonated drinks.

Provisions related to the triggers for compliance obligations are important in determining whether an ETS interacts with CO_2 that is captured and used in a product. In ETSs where the compliance obligation stems from physically releasing emissions into the atmosphere, the regulations *could be interpreted* to implicitly allow regulated entities to reduce their compliance obligations through CCU applications by demonstrating that the CO_2 was not emitted within the boundary of the installation, even if the CO_2 is ultimately released into the atmosphere during use or disposal. Under the Schaefer Kalk court case,[15] for example, the definition of “emissions” under the EU ETS Directive in force at the time was key in arguing that the production of precipitated calcium carbonate (which binds CO_2 chemically in a stable product) does not lead to emissions and should not be subject to compliance obligations.

Depending on the provisions related to permanence, MRV and the ETS scope, reflecting CCU applications under the ETS can lead to a shift in emissions out of the ETS. The Québec Cap-and-Trade System, for example, allows regulated entities to reduce compliance obligations in cases where CO_2 is re-used or transferred out of the installation. The NZ ETS contains provisions to issue units to entities that either produce a product in which a GHG is permanently embedded, or produce a product in which a GHG is temporarily embedded and the product is exported with the substance embedded. Both systems can be said to enable regulated entities to reduce compliance obligations if they engage in CCU, irrespective of whether the product leads to long-term or short-term CO_2 storage. Indeed, several of these products would ultimately see the release of the embedded CO_2, either during use (in the case of synthetic fuels) or during the end-of-life phase (e.g., during

[15] Schaefer Kalk GmbH & Co. KG v Bundesrepublik Deutschland (2017).

decomposition and incineration). If these emission sources are not subject to the scope of the ETS, emissions from inside the ETS are effectively shifted out of the system. [16] By contrast, MRV regulations under the EU ETS valid as of January 2023 include provisions for reducing compliance obligations through CCU only for precipitated calcium carbonate, where the CO_2 is bound in a long-term fashion.[17] Enhanced oil recovery (EOR) activities present a difficult case for inclusion in ETSs due to the complex effect of CO_2 storage on the one hand vs an increase in fossil fuel supply on the other, which can also increase emissions outside the system.

CCS (and CCU) relevant regulations within current ETSs

Of the 26 ETSs currently in force, only five have regulations related to CCS or CCU applications. These are the EU, the UK, Québec, New Zealand, and California. (See Figure ES. 5).

The EU ETS has detailed regulations for the use of CCS applications and is an example of a jurisdiction employing Option B. In the EU ETS, point-source emitters can subtract from their compliance obligations the CO_2 originating from fossil carbon in activities covered by the EU ETS that is not emitted from the installation and that is transferred out of the installation for capture and geological storage. The elements of the CCS value chain (capture, transport and storage) are subject to the scope of application of the EU ETS. Despite its detailed provisions, however, there are currently no facilities under the EU ETS that are reducing compliance obligations through CCS applications. As of January 2023, CCU is reflected in EU ETS regulations only for one specific product. A revision of EU ETS rules is expected to be formally adopted in early 2023, and may entail expanded provisions on CCS and CCU.

The UK ETS has incorporated several elements of the EU ETS and is an example of a jurisdiction employing Option B. In terms of CCS and CCU regulations, the rules under the UK ETS are the same as those that were valid under the EU ETS as of 2018. As the UK is no longer a member state of the EU, revisions effected to EU ETS documents after 2018 do not apply to the UK ETS. A process is ongoing to determine the role of CCS applications under the UK ETS. There are currently no facilities under the UK ETS that are reducing compliance obligations through CCS applications.

The Québec Cap-and-Trade System contains some provisions that recognize the use of CCS and CCU and is an example of a jurisdiction employing Option B. GHG emissions that are captured, stored, re-used, eliminated or transferred out of regulated entities are subtracted from the compliance obligation of regulated entities. The CCU/CCS sub-part of an emitter's GHG declaration is analyzed individually by the province. While the system does not cover any large CCS facility, 4% of large emitters covered by it benefit from CCS/CCU provisions. As the GHG Reporting Regulation

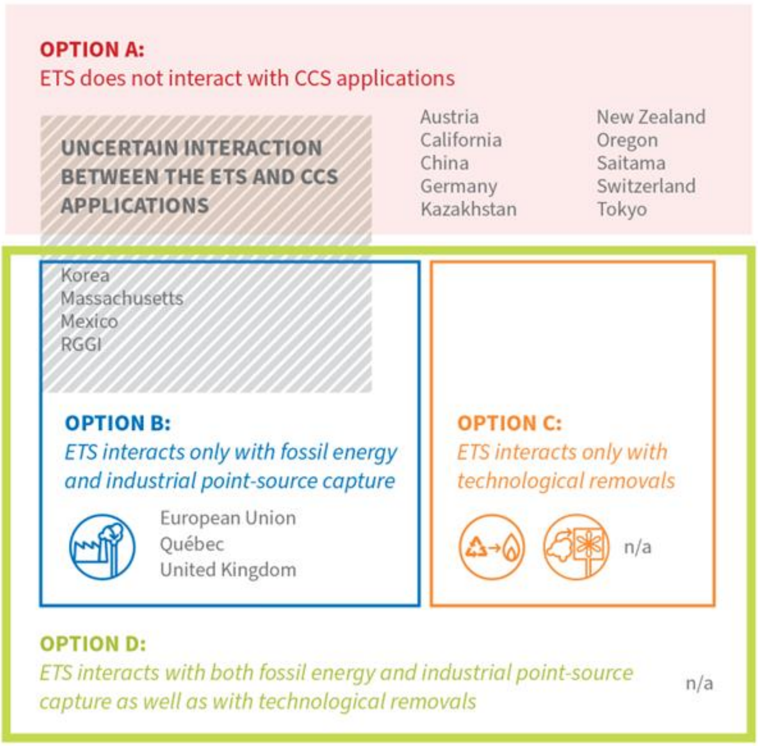
[16] Synthetic fuels may substitute other fossil emissions with no overall net increase in emissions. This highlights the importance of considering life cycle assessments when including CCU in ETSs, including an understanding of alternative mitigation pathways and avoiding loopholes and inconsistencies.
[17] This is likely to change as part of the ongoing EU ETS revision process. See section 7.1.

does not yet contain specific measurement protocols or methods to calculate the captured and stored, re-used, eliminated or transferred emissions, these calculations are currently done on an ad-hoc basis by individual installations.

The NZ ETS has operational provisions that are relevant for CCU; it also contains some provisions on CCS, but these are not in force and New Zealand is an example of a jurisdiction under Option A. The NZ ETS contains provisions for reducing compliance obligations by permanently embedding GHG in a product (which includes some CCU applications) as well as some provisions for carbon storage (which is relevant for CCS applications). The provisions on carbon storage, however, are not in force. From the point of view of enabling CCS applications, New Zealand currently falls under Option A, although this may change if and when the relevant provisions are enabled and outstanding MRV requirements are put in place.

The California Cap-and-Trade Program does not currently recognize CCS or CCU as a means for a covered facility to reduce its emissions and compliance obligations, nor does it have provisions for enabling technological removals. It therefore falls under Option A. The only CCS-relevant provisions under the California Program relate to the compliance obligations of "suppliers of CO_2", which include facilities with production processes that capture CO_2 to supply it to another entity or to use it for geological sequestration. The current CO_2 supplier provisions, however, do not enable a covered facility to reduce its compliance obligations by capturing its CO_2 and supplying it to a sequestration site. Amendments would be required to the Cap-and-Trade Regulation and MRV requirements to recognize CCS/CCU projects and to allow a covered facility to reduce its compliance obligations by capturing and sequestering or utilizing CO_2. California's Low Carbon Fuel Standard (LCFS) Program incentivizes entities that supply transportation fuels to invest in CCS projects.

Figure ES. 5 – Interactions between selected ETSs and CCS applications



Source: Authors' elaboration

Conclusions

Considerations on the interactions between ETSs and CCS (and CCU) are still in their infancy. Of the 26 ETSs in force, only five have any provisions on CCS, only two (the EU ETS and the UK ETS) have detailed provisions, and only one (Québec) has facilities that reduce compliance obligations through CCS applications.

No empirical data on the interaction between ETSs and CCS is available, and many additional issues and questions are likely to arise as CCS projects materialize and jurisdictions engage with them. The fast pace of innovation and technological development presents a challenge for policy makers, who may have to establish regulatory frameworks that can adapt to changing technological circumstances.

However, as the pipeline of CCS projects grows, so will pressure from stakeholders for clarification about the relationship between these projects and ETSs worldwide. Now is the time for jurisdictions to start grappling with these questions.

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Acronyms

BECCS	Bioenergy with carbon capture and storage
CAPEX	Capital expenditure
CARB	California Air Resources Board
CBAM	Carbon border adjustment mechanism
CCS	Carbon capture and storage
CCU	Carbon capture and utilization
CCUS	Carbon capture, utilization, and storage
CDR	Carbon dioxide removal
COD	European Commission Document
CO_2	Carbon dioxide
DACC	Direct air carbon capture
DACCS	Direct air carbon capture and storage
EEA	European Economic Area
EOR	Enhanced oil recovery
ETS	Emissions trading system
EU	European Union
EU ETS	European Union Emissions Trading System
GDP	Gross domestic product
GHG	Greenhouse gas
IEA	International Energy Agency
ICAP	International Carbon Action Partnership
IPCC	Intergovernmental Panel on Climate Change
LCFS	Low carbon fuel standard
LT-LEDS	Long-term Low Greenhouse Gas Emission Development Strategy
MRR	EU ETS Monitoring and Reporting Regulation
MRV	Monitoring, reporting, and verification
$MtCO_2$	Metric tonnes of carbon dioxide equivalent
NDC	Nationally Determined Contribution
NZ ETS	New Zealand Emissions Trading Scheme

OPEX	Operational expenditure
PMR	Partnership for Market Readiness
RGGI	Regional Greenhouse Gas Initiative
R&D	Research and development
RU	Removal unit
tCO_2	Tonne of carbon dioxide equivalent
TRL	Technological Readiness Level
UNFCCC	United Nations Framework Convention on Climate Change
UK	United Kingdom
WRI	World Resources Institute
WtE	Waste-to-Energy

1 Introduction

When drawing up their decarbonization pathways, jurisdictions have several policy instruments they can employ to support low-carbon development in various sectors of the economy. These sectors, in turn, have access to different mitigation options, and jurisdictions can choose if and how policy instruments interact with them. This report focuses on the interaction between one of the key instruments to drive decarbonization – emissions trading systems (ETSs) – and one of the key decarbonization technologies – carbon capture and storage (CCS).

CCS applications can support decarbonization by helping to reduce emissions from emissions-intensive industries and through the retrofitting of existing infrastructure. Moreover, some CCS applications can reduce atmospheric concentrations of CO_2 and are a key component in compensating for residual emissions and achieving net zero by mid-century.

CCS applications can deliver climate change mitigation within ETSs, and ETSs can support their development and deployment. At present, there is limited literature on the interactions between ETSs and CCS, and this report aims to contribute to filling this gap. It aims to understand:

a) How ETSs could interact with CCS applications, and the attendant opportunities and risks;

b) The challenges faced when designing ETS regulations related to CCS; and

c) The specifics of how different ETSs implemented to date interact with CCS applications.

While the focus of the report is primarily on CCS applications, a few considerations on carbon capture and utilization (CCU) are also provided.

This report aims to address issues associated with possible interactions between ETSs and CCS, and does not aim to advocate for any one approach. Any interactions, as discussed throughout this report, are political and societal decisions that must consider different opportunities and challenges. The report helps to inform such decisions by examining what the various approaches for interactions between ETSs and CCS applications could be in theory, and what elements should be taken into account by jurisdictions. The report builds on a survey conducted among ICAP member jurisdictions on their regulations relevant for CCS and CCU.

The report is structured as follows:

- **Section 2** provides essential background in terms of the key definitions used throughout the report, the potential importance of CCS applications for economic activities under ETSs, and the role ETSs could play in supporting the development and deployment of CCS. It also discusses important societal issues that policymakers must take into account when considering the use of CCS applications in decarbonization pathways.
- **Section 3** explores *how* an ETS can interact with CCS applications. We distinguish two broad categories of CCS applications and discuss the mechanics of their interaction with an ETS, depending on whether the activities capturing CO_2 fall inside or outside the scope of the ETS.

- **Section 4** discusses the key risks and opportunities of ETSs interacting with CCS applications. The analysis focuses on *whether* (and not how) the ETS interacts with each of the two categories of CCS applications.
- **Section 5** draws on the preceding sections to discuss ETS design aspects that relate to CCS applications, including issues around unit choice, cap-setting, scope, and MRV.
- **Section 6** contains a few considerations on CCU.
- **Section 7** summarizes the key provisions of the five ETSs in force that have regulations related to CCS or CCU applications. It also includes a table summarizing the current approach of the 17 selected ETSs currently in force.
- **Section 8** concludes.

2 CCS and ETS: Why does it matter?

2.1. Definitions

Technical terms relevant to CCS and CCU are defined differently by different sources. The atmospheric impact of using these technologies is also often a source of confusion. This section clarifies the use of various terms used throughout the report.

2.1.1. Clarifying key terms

The Intergovernmental Panel on Climate Change (IPCC) Glossary defines carbon capture and storage as *"[a] process in which a relatively pure stream of CO_2 from industrial and energy-related sources is separated (captured), conditioned, compressed, and transported to a storage location for long-term isolation from the atmosphere"* (IPCC 2022c). The IPCC does not clarify what "long-term isolation from the atmosphere" entails, but the section dedicated to CCS and CCU (IPCC 2022a; Chapter 6, section 6.4.2.5), refers exclusively to geological storage in the context of CCS. The IPCC also notes that *"CCS and CCU applied to CO_2 from fossil fuel use are not CO_2 removal methods as they do not remove CO_2 from the atmosphere. CCS and CCU can, however, be part of CDR methods if the CO_2 has been captured from the atmosphere, either indirectly in the form of biomass or directly from ambient air, and stored durably in geological reservoirs or products"* (IPCC 2022b: Chapter 12, Box 8).[18]

Simply put, **carbon capture and storage (CCS)** is understood as a suite of technologies (or "applications") that capture and geologically store CO_2. CCS technologies can be used to capture and store CO_2 from large emission sources (referred to as "point-source" capture) as well as

[18] It is worth noting that Enhanced Weathering (EW, which the IPCC defines as *"[a] proposed method to increase the natural rate of removal of CO2 from the atmosphere using silicate and carbonate rocks"*) is not typically characterized within the realm of CCS applications. Note also that EW does not entail the conditioning, compression and transportation steps included in the IPCC definition of CCS.

directly from the atmosphere. They can deliver emissions reductions or, in very specific circumstances (see section 2.1.2 below), CO_2 removals.

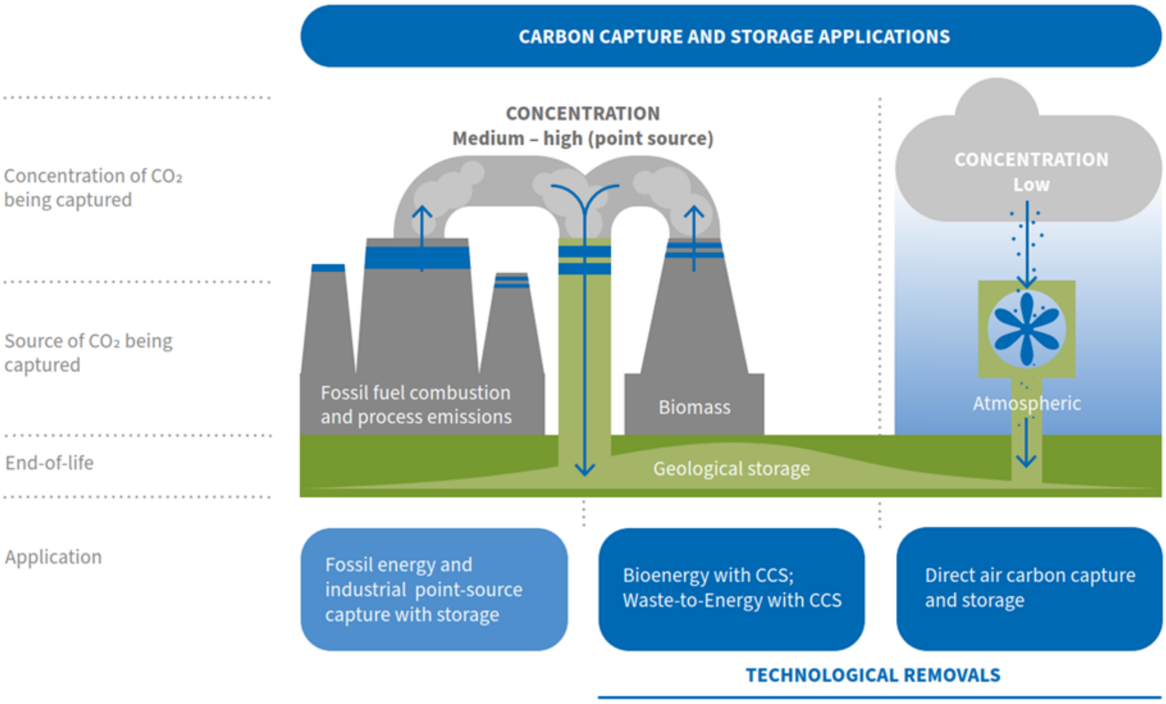
As illustrated in Figure 1, CCS applications differ in terms of the concentration and the source of the CO_2 being captured.

- Among point-source capture applications, for the purpose of this report, it is useful to distinguish between those from emissions typically covered by ETSs – that is, emissions from fossil fuel combustion (e.g., for electricity generation) and industrial process emissions (from e.g., the chemical, cement, steel and aluminium sectors) – and those that are typically not (notably, emissions from biomass). For brevity, this report will refer to the point-source capture of emissions from the combustion of fossil fuels and process emissions as **"fossil energy and industrial point-source capture"**, noting that this includes emissions from fossil-based energy but excludes emissions related to energy generation from biomass. These are CCS applications that **reduce CO_2 emissions.**
- Biomass is associated with processes like **bioenergy with carbon capture and storage (BECCS)**, which the IPCC (2022c) defines as a *"CCS technology applied to a bioenergy facility"*; and with **Waste-to-Energy (WtE) with CCS**,[19] to the extent that the combusted waste contains biogenic fraction.
- The capture and storage of CO_2 directly from the atmosphere is associated with **direct air carbon capture and storage (DACCS)**, which the IPCC (2022c) defines as a *"chemical process by which CO_2 is captured directly from the ambient air, with subsequent storage"*.

Applications such as BECCS, DACCS, and WtE with CCS can lead to the **removal of previously emitted CO_2 from the atmosphere** and are collectively often referred to as 'technological removals' or 'CCS-based removals'. It is also important to note that real-life applications may employ combined approaches, e.g., a power plant with CCS may combust fossil fuels and renewable biomass.

[19] The European Environment Agency defines Waste-to-Energy as the "incineration of waste with recovery of generated energy. WtE schemes turn waste into steam or electricity to heat, cool, light and/or otherwise power homes and industry through the process of combustion". Capturing and geologically storing CO_2 emissions from WtE facilities is akin to BECCS for the biogenic component of the waste. For the non-biogenic component of the waste, the process results in emission reductions.

Figure 1 – Categorization of CCS applications



Source: Authors' elaboration

In **carbon capture and utilization (CCU)** processes and applications, the sources of CO_2 and technologies used to capture carbon are the same as in CCS. The distinguishing feature between CCS and CCU is that in the case of CCU, the CO_2 is used in a product. The IPCC (IPCC 20221c) defines CCU *as "a process in which CO_2 is captured and then used to produce a new product"*, noting that the *"climate effect of CCU depends on the product lifetime, the product it displaces, and the CO_2 source (fossil, biomass or atmosphere)".*

CCS and CCU applications have sometimes been collectively referred to as "CCUS" or "CC(U)S".

2.1.2. Most applications do not lead to "removal": Clarifying the relationship between CCS, CCU, and "removals"

It is important to clarify the relationship between the different CCS and CCU applications with climate change mitigation – notably, emission reductions and removals.

"Mitigation" refers to *"human intervention to reduce emissions or enhance the sinks of greenhouse gases"* (IPCC 2022c). This includes a variety of different environmental outcomes – such as reducing the volume of emissions that would otherwise go into the atmosphere, avoiding emissions, reducing the carbon intensity of products and processes, and removing emissions from the atmosphere.

In particular, **carbon dioxide removal (CDR)** is defined as *"anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products"* (IPCC 2022c). As seen below, some CCS applications relate to CDR, but most do not.

Different CCS and CCU applications have different mitigation results. This is summarized in Figure 2.

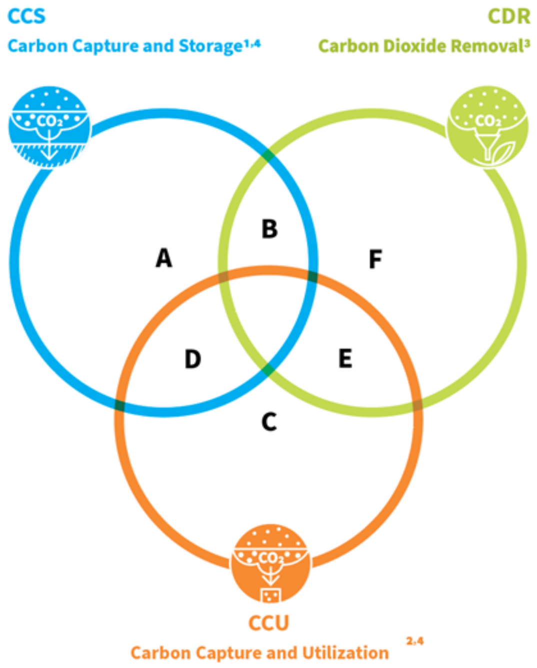
- Some CCS applications lead to reductions in CO_2 emissions but can, at best, be "zero" carbon. For example, point-source capture in a coal plant can, at best, yield zero emissions[20] (see element A in Figure 2).
- Other CCS applications can entail carbon removals. This is the case for e.g., BECCS, if renewable biomass binds atmospheric CO_2 and is then burned, with the resulting CO_2 being captured and stored geologically.[21] Another example is DACCS, where the CO_2 is captured from ambient air and then stored geologically (see element B in Figure 2).
- Many CCU applications entail products of short-term use, such as synthetic fuels and carbonated beverages. Short-term CCU products that use fossil CO_2 can, at best, help reduce emissions (but they still cause emissions as the fossil CO_2 is still released).[22] Short-term CCU products using atmospheric CO_2 can be zero emissions[23] (see element C in Figure 2).
- Some CCU applications entail products where the CO_2 is bound in such a way that under normal use the CO_2 would not be released from the product into the atmosphere. This is the case of e.g., construction materials. When the CO_2 bound into these long-term products comes from fossil fuels, emissions can, at best, be zero (and in this case, CCU can be said to overlap with CCS, although the carbon is not stored in geological reservoirs – see element D in Figure 2).[24] When the CO_2 that is bound into long-term products comes from atmospheric CO_2, CCU can lead to removal (see element E in Figure 2).
- There are also several technologies that lead to CO_2 removal, but are not related to CCS or CCU. These include, among others, the planting of forests and increasing the content of

[20] It is worth noting that current point-source capture installations typically capture up to 90% of the available CO_2. With current technologies, therefore, such applications typically do not deliver zero emissions.
[21] It is important to note that only renewable biomass can lead to removals through BECCS. Capturing CO_2 from the combustion of non-renewable biomass would not lead to carbon removal.
[22] For products such as plastics, the effect depends also on end-of-life choices, e.g., landfilling versus incineration (with or without CCS), versus recycling. Some end-of-life choices may lead to longer retention of the CO_2 in the product.
[23] For products such as synthetic fuels, the mitigation effect also depends on whether the use of such fuels displaces the use of fossil fuels.
[24] EOR is often considered a CCU application. Whether it leads to climate change mitigation depends on a number of factors, notably the source of the CO_2, the permanence of the storage, and the balance of storage versus increased fossil fuel combustion.

carbon in e.g., agricultural soil (see element F in Figure 2). These technologies can vary widely in the permanence of the carbon storage.

The relationship between CCS, CCU, and removal technologies is presented in Figure 2 below.

Figure 2 – Relationship between CCS, CCU and removal technologies in different applications



A
CCS APPLICATIONS THAT REDUCE EMISSIONS AND HAVE PERMANENT STORAGE BUT DO NOT LEAD TO CO_2 REMOVAL
Industrial point-source capture (e.g. fossil combustion and process emissions) with geological storage

B
CCS APPLICATIONS THAT CAN LEAD TO CO_2 REMOVAL
DACCS, BECCS (if using renewable biomass)

C
CCU APPLICATIONS THAT CAN REDUCE CARBON INTENSITY BUT DO NOT LEAD TO PERMANENT STORAGE OR REMOVALS OF CO_2
Capture of CO_2 from any source and use in products of short term use (e.g. synthetic fuels, plastics, carbonated drinks)

D
CCU APPLICATIONS THAT REDUCE EMISSIONS AND HAVE LONG-TERM (ALBEIT NON-GEOLOGICAL) STORAGE BUT DO NOT LEAD TO CO_2 REMOVAL
Capture of CO_2 from fossil fuel and process emissions and use in products where CO_2 is chemically and permanently bound (e.g. construction materials)[5]

E
CCU APPLICATIONS THAT CAN LEAD TO CO_2 REMOVAL
Capture of CO_2 from renewable biomass and from atmosphere and use in products where CO_2 is chemically bound in a long-term way (e.g. construction materials)

F
CDR TECHNOLOGIES THAT ARE NOT CCS OR CCU
Forests, Soil Carbon, Biochar, Enhanced weathering, Ocean fertilization

1 – CCS is defined as technologies that capture and geologically store CO_2. Can be applied to both point-source capture as well as to atmospheric capture.
2 – CCU is defined as a process in which CO_2 is captured and then used to produce a new product.
3 – Removal of CO_2 from the atmosphere means anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products.
4 – CCS and CCU applications that do not lead to removals can be classified as emissions reductions, except for EOR (see note 5).
5 – Enhanced oil recovery is often considered a CCU application. Whether or not it leads to climate change mitigation depends on a number of factors, notably the source of the CO_2, the permanence of the storage and on the balance of storage versus increased fossil fuel combustion.

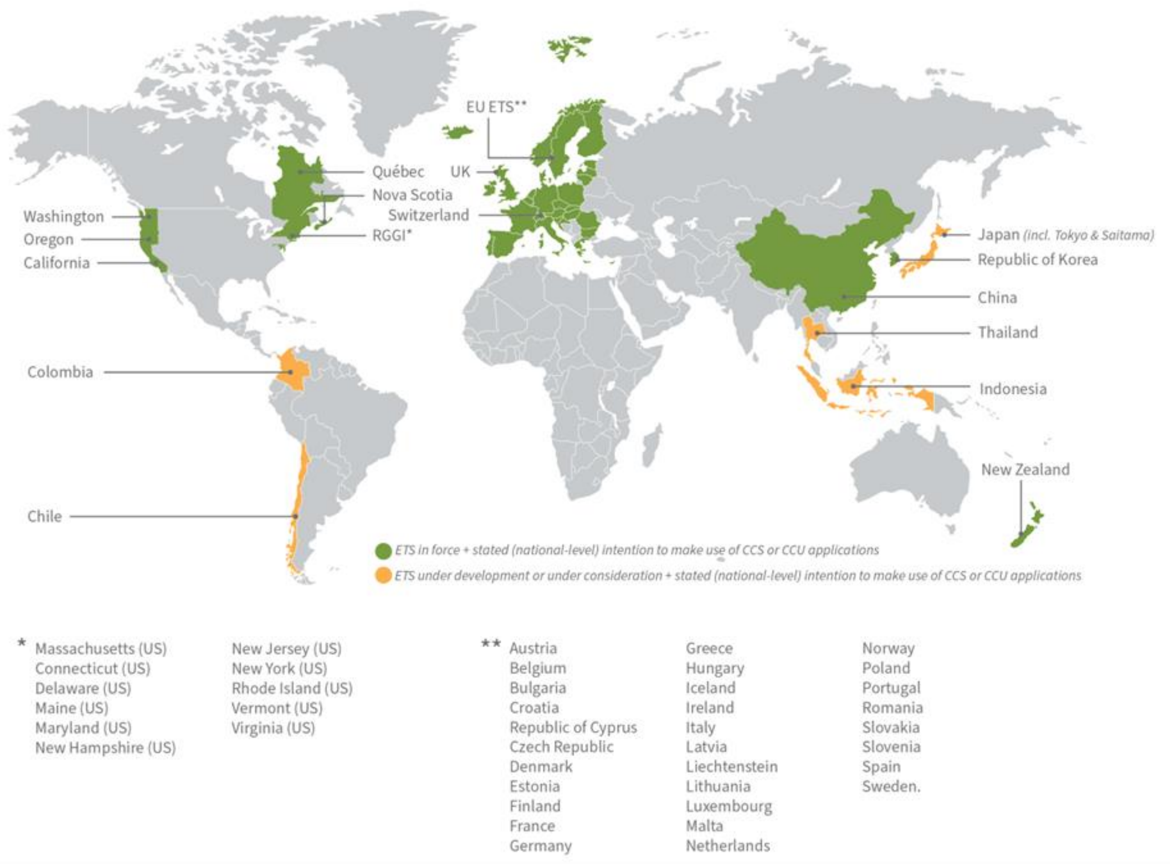
Source: Authors' elaboration

2.2. Why CCS matters for ETSs

Most jurisdictions with ETSs in force either already have policies on CCS or intend to make use of CCS applications, as evidenced by their (country-level) Nationally Determined Contribution (NDC) or their Long-term Low Greenhouse Gas Emission Development Strategies (LT-LEDS). Countries like Norway, Canada, the US, and China mention CCS in their NDC (Global CCS Institute 2021a), whereas countries like the UK, Sweden and France mention technological CO_2 removals (which include CCS applications such as BECCS and DACCS) in their LT-LEDS (WRI, 2022).

Figure 3 below presents a map of operational ETSs that have stated the intention to make use of CCS or technological removal applications. Several ETSs are implemented at a sub-national level, but the map presents data at a country level in line with NDC and LT-LEDS submissions to the UNFCCC. Information on NDCs and CCS comes from the Global CCS Institute (2021a), while information on LT-LEDS comes from the WRI (2022). It is expected that as more NDCs and/or LT-LEDS are submitted or updated, more jurisdictions will consider CCS to meet climate targets.

Figure 3 – Map of ETSs alongside intentions to make use of CCS and CCU applications



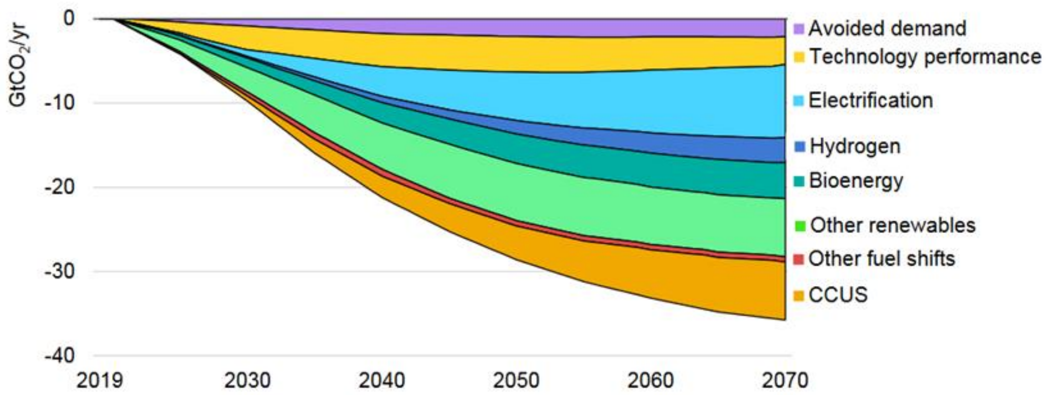
Source: Authors' elaboration. ICAP (2022) for information on ETSs; [25] CCS Institute (2021a) for mention of CCS in NDCs; WRI (2022) for mention of technological removals in LT-LEDSs. [26]

There is an important overlap between the sectors typically covered by ETSs and those in which CCS and CCU applications show most promise. The International Energy Agency (IEA 2020b, 2022) and

[25] Countries colored green have an ETS in force and a CCS directive and/or mention of CCS in their NDC and/or mention of technological removal in their LT-LEDS.
[26] "Technological removals" are referred to in WRI (2022) as "technological CDR", which includes CCS applications such as BECCS and DACCS.

the IPCC (IPCC 2022d, Figure SPM.7) have identified an important role for CCS and CCU in achieving ambitious climate targets across the energy and industry sectors, which are the main sectors covered by ETS.[27] Under the IEA "Sustainable Development Scenario" (IEA-SDS - IEA [2020b]), for example, CCS and CCU applications are responsible for approximately 13% of energy sector CO_2 emissions reductions in 2050 (see Figure 4). In industries like cement, regulated by most ETSs operational today, CCS and CCU sit at the heart of net-zero strategies; by 2050, 36% of the cement sector's decarbonization effort relies on CCS and CCU applications (GCCA 2020).

Figure 4 – Global energy sector CO_2 emissions reductions by measure in the Sustainable Development Scenario relative to the Stated Policies Scenario, 2019-2070



Source: IEA (2020b), Figure 2.1

According to the IEA-SDS (IEA 2020b), the contribution of CCS and CCU to CO_2 emission reductions varies over the projection period, with distinct phases. Until 2030, priority is given to absorbing emissions from existing power plants and industry. Most of the CO_2 emissions captured in the power and industry sectors during this decade come from coal and gas-fired power plants, chemical plants, cement factories, and steel mills. During the second phase, between 2030 and 2050, CCS and CCU deployment is expected to expand most rapidly in the cement, steel, and chemical industries, accounting for approximately one third of the overall increase in CO_2 capture worldwide.

[27] The level of reliance on CCS and CCU applications varies significantly across scenarios, differing by up to ten times on how much they rely on applications such as BECCS and DACCS (IEA 2022, Figure 3.6). In all cases, however, such applications are expected to deliver several $GtCO_2e$ of mitigation in 2050.

Box 1 – CCS and CCU value chain: a primer

The value chain of CCS and CCU applications is composed of three elements: capture, transport and end-of-life, which might be storage (in the case of CCS) or usage (in the case of CCU).

- Capture: As described in the definitions section, capture can occur from point sources or from the atmosphere. Capture technologies for point sources, grouped from least to most common, are oxyfuel combustion, pre-combustion and post-combustion. Post-combustion technologies remove CO_2 after fuel combustion. They are the most common form of capture having the most advanced technological readiness level (TRL) of the three categories (Oxford Energy 2022). In oxyfuel combustion, pure oxygen is used to burn the fuel, which facilitates the post-combustion capture process. In pre-combustion, CO_2 is taken out of the fuel before it is burned. Pre-combustion applications are better suited for incorporation into newly constructed facilities, whereas post-combustion and oxyfuel technologies can be adapted into existing plants.
- Transport: CO_2 is transportable by pipelines, ships, trains, and trucks. Each method's cost-effectiveness depends on the distance to be travelled, the volumes transported and the number (and location) of capture sites that feed into the network (transportation, storage/utilization). Of these four options, pipelines are the most mature option due to their prevalent use and technological advances in the oil industry. Ships are more competitive over long distances and for carrying lower volumes of CO_2 (Energy Transitions Commission 2022) [28] and are likely to play a crucial role in the future.
- Storage: CO_2 can be safely stored in geological formations if the conditions are right and the process is well controlled. CO_2 storage involves injecting the collected CO_2 into a geological reservoir of porous rock under an impermeable layer of rock, which covers the reservoir and prevents migration or "leakage" of CO_2 upward into the atmosphere. Several reservoir types are ideal for CO_2 storage with deep saline formations and depleted oil and gas reservoirs having the most significant capacity.
- Utilization: Utilization refers to any use in which CO_2 is incorporated into a product rather than geologically stored (Energy Transitions Commission 2022). The number of possible ways to use CO_2 is vast and includes both direct uses, in which CO_2 is not changed chemically, and indirect uses, in which CO_2 is turned into fuels, chemicals, or building materials through chemical and biological processes (IEA 2019). [29]

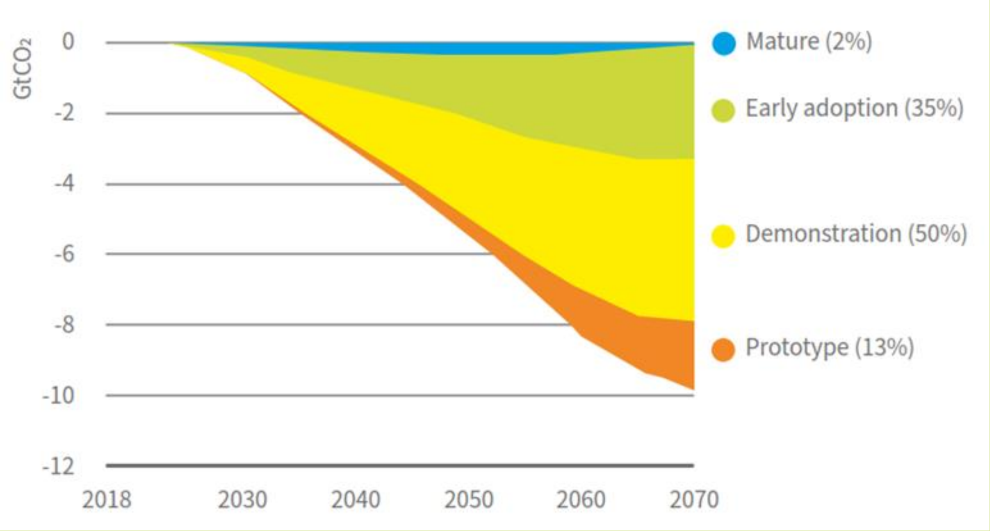
The CCS value chain has two main categories of emissions: operational emissions, which are those generated from the processes inherent to capture, transport, storage or use (e.g., fuel emissions in energy and transport equipment); and CO_2 leaks (or leakage emissions), which are emissions not

[28] Transport by ship or truck requires liquefaction of the CO_2, which is an energy-intensive process.
[29] It is worth noting that the CO_2 embedded in CCU products can also be recaptured, e.g. capturing CO_2 emissions from the combustion of synthetic fuels or from the incineration of CCU products.

inherent to an industrial process, but that are fugitive, vented, or result from the failure of one or more components of a process. [30]

The origins of CCS and CCU applications can be traced back to the oil industry's early EOR methods. Transport and storage technologies associated with EOR are the most mature today thanks to decades of experience transporting and injecting CO_2 for EOR. However, most CO_2 capture technologies that promise mitigation in line with net-zero targets are still in the early stages of development, demonstration, or prototyping (Tcvetkov 2021). According to the IEA (2020b), mature technologies are expected to deliver only approximately 2% of the cumulative CCS and CCU emission reductions projected by 2070 (Figure 5), even with a move beyond power sector CCS towards industry sector CCS and DACCS.

Figure 5 – World CO_2 emissions reductions from CCUS by technology readiness category in the IEA Sustainable Development Scenario relative to the Stated Policies Scenario



Source: Adapted from IEA (2020b), Figure 3.2. Pertains to the IEA's Sustainable Development Scenario. Values are in comparison to the Stated Policies Scenario, which considers national energy/climate policies in the year 2020.

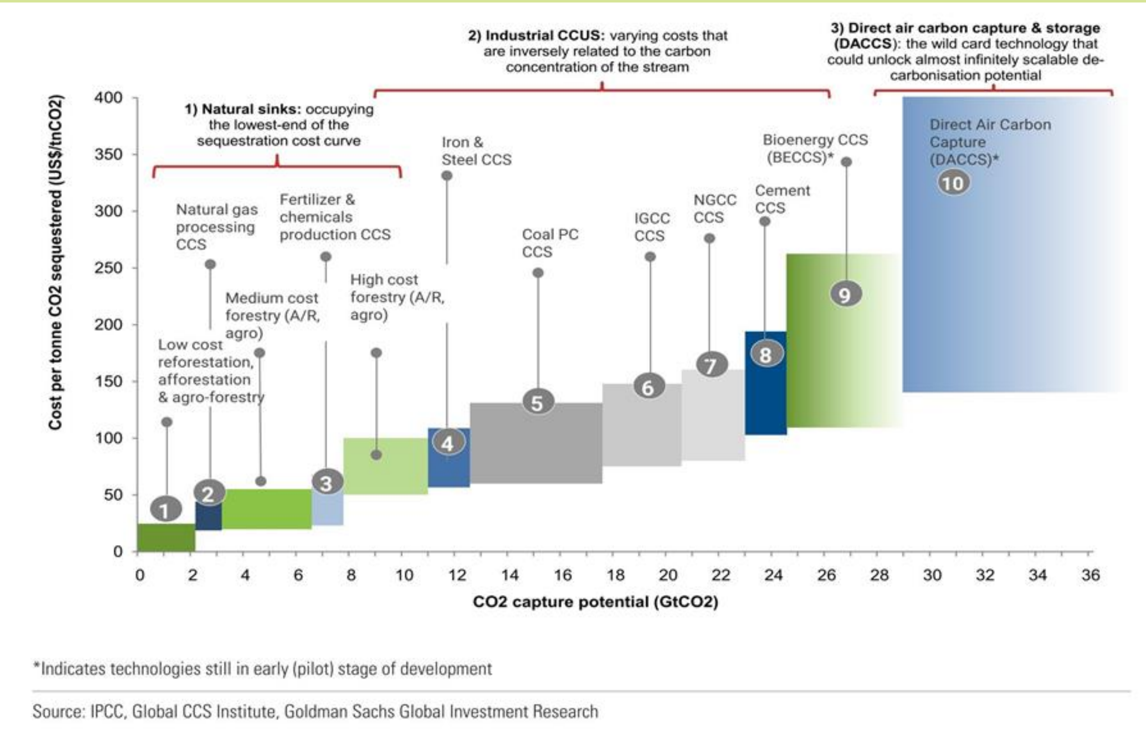
Historically, CCS projects tended to be vertically integrated with a capture plant having a downstream transportation system (Global CCS Institute 2021b). This approach favored large-scale projects, where economies of scale made downstream costs reasonable. Recently, projects have consisted of "CCS networks": clusters of multiple proximate emission point sources which feed into shared hubs of CO_2 transport and storage infrastructure such as pipelines, ships, port facilities, and storage wells (Global CCS Institute 2020a).

[30] The leaks referred to here pertain to CO_2 that physically escapes e.g., pipelines and storage sites. It is not related to the concept of "leakage" used elsewhere in the carbon pricing literature, whereby the avoidance of emissions in one place can lead to higher emissions elsewhere.

In recent years, CCS technologies have advanced rapidly thanks to testing in numerous pilot projects and experience gained during the deployment of large-scale projects (Fasihi et al. 2019). According to the Global CCS Institute (2020a), many CCS networks are being formed and are expected to expand. The Alberta Carbon Trunk Line,[31] for example, is already operational and delivers CO_2 from two plants near Edmonton to oil and gas reserves. Under the Longship[32] project in Norway, European emitters will be able to use transport and storage facilities to geologically store captured CO_2. Similarly, the Porthos[33] project in the Netherlands is expected to transport CO_2 from industry in the Port of Rotterdam and store it in empty gas fields under the North Sea.[34] In the UK, the Northern Endurance Partnership[35] will provide shared infrastructure to several emitters for CO_2 storage in the North Sea.

The costs of CCS and CCU applications vary significantly across technologies, and there is considerable uncertainty regarding future costs. Figure 6 outlines the costs of carbon capture across industries and applications.

Figure 6 – Carbon capture cost curve (USD/tCO_2e) in 2020 and abatement potential (GtCO_2 eq)



[31] https://enhanceenergy.com/actl/
[32] https://norlights.com/about-the-longship-project/
[33] https://www.porthosco2.nl/en/
[34] As of November 2022, the project is awaiting final investment decision.
[35] https://www.netzeroteesside.co.uk/northern-endurance-partnership/

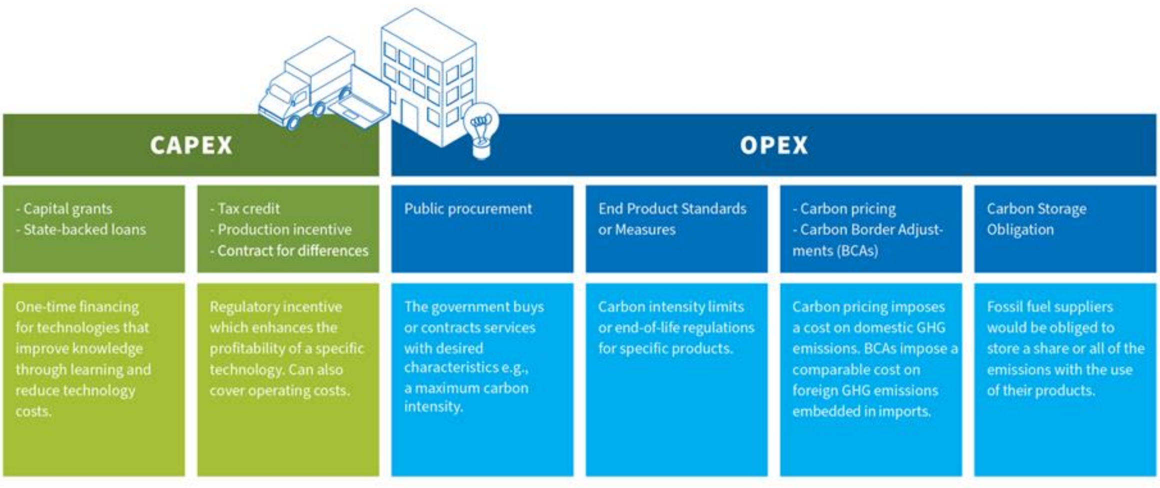
Source: Goldman Sachs (2020)

2.3. Why ETS matters for CCS

Achieving the level of CCS and CCU deployment envisaged in projected decarbonization pathways requires the deliberate development and planning of technology chains, backed by many policies and mechanisms operating in parallel.

The Energy Transitions Commission (2022) identified a series of enabling policies for capture technologies targeting capital (CAPEX) or operating (OPEX) expenditures, as outlined in Figure 7. CAPEX supported policies are intended to be one-time payments to support "first-of-its-kind" projects, and can include capital grants, state-backed loans, tax credits, production incentives, and contracts for difference. OPEX supported policies, on the other hand, are intended to be permanent policies that provide support for carbon capture investments in the medium and long term and can include public procurement, end product standards or measures, carbon pricing, carbon border adjustment mechanisms (CBAM), or coal storage obligations.[36] Almost all CCS and CCU projects currently in operation have benefited from some form of public support, largely in the form of capital grants (IEA 2020b).

Figure 7 – CAPEX and OPEX support measures for CCS and CCU



Source: Adjusted from Energy Transitions Commission (2022)

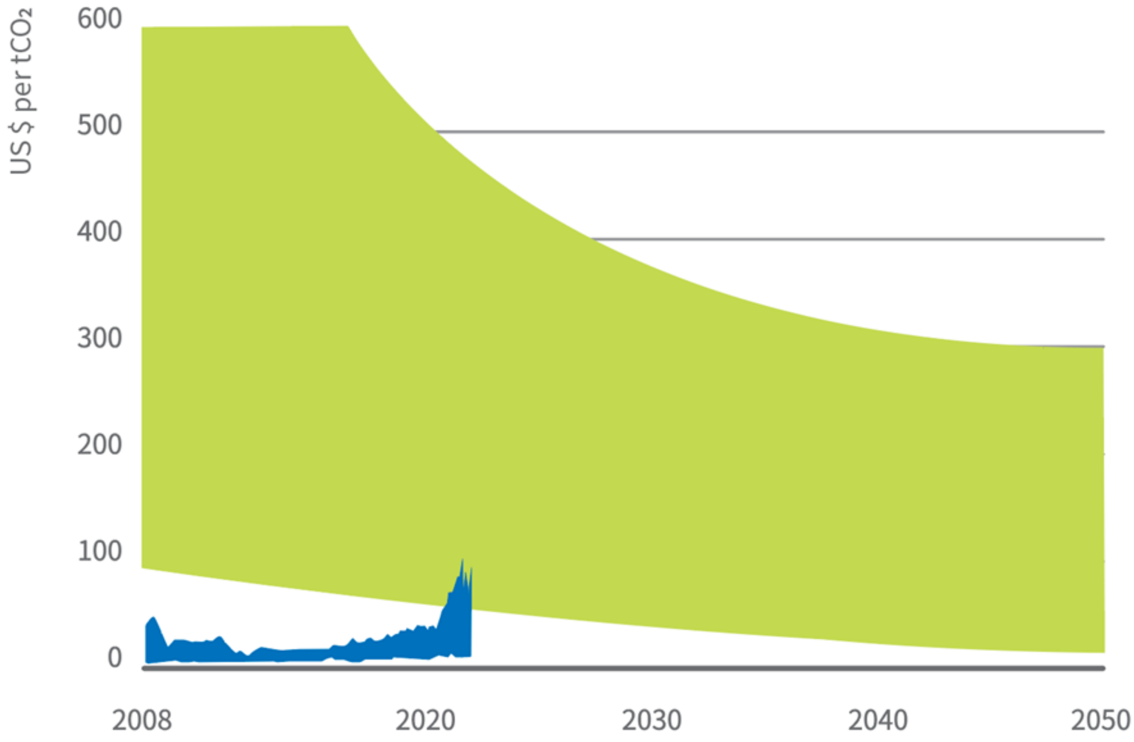
[36] It is useful to note that the categorization is not fixed. Contracts for difference, for example, can also be employed to support operating expenses and are listed as an OPEX measure by the IEA (2020b, Table 5.1). Policy instruments may also not follow this dichotomy strictly; the EU Innovation Fund, for example, funds both CAPEX and OPEX for up to ten years.

In practice, a combination of measures will be needed (IEA 2020a; Energy Transitions Commission 2022), tailored to the local context, sectors, and applications. According to the IEA (2020b), a fundamental element is designing a framework that supports the creation of a sustainable and viable market for CCS and CCU. In so doing, the IEA highlights that the private sector is unlikely to invest in the technology unless (a) it is obliged to do so, or (b) it can make a profit from the sale of the CO_2 or through revenues related to the emissions avoided under carbon pricing arrangements.

ETSs are a key means of pricing carbon and changing market circumstances to support low-carbon production processes, products, and technologies. The price signal makes new low-carbon technologies such as CCS and CCU more competitive, which encourages short- and medium-term investments (Energy Transitions Commission 2022). Beyond the increased deployment of otherwise uncompetitive low-carbon technology, ETSs have been shown to stimulate incremental innovation in manufacturing processes and inputs, especially where fundamental technologies already exist, and a moderate carbon price (or the expectation of a higher price) is sufficient to motivate change. Yet many CCS and CCU applications still require significant research and development (R&D) investments to reach technological maturity and deployment at scale, which requires additional R&D support. Even in their mature phase, CCS and CCU are expensive technologies that require significant capital expenditures and impose ongoing operating expenses requiring sustained, long-term price support to encourage deployment (Marcu et al. 2021).

In most of the world, carbon pricing is still non-existent, and in most jurisdictions where carbon pricing is operational, emissions reductions from CCS are not taken into consideration or prices are not high enough to incentivize emitters to capture CO_2. This leaves industrial and power facilities without a commercial driver for capturing CO_2 instead of emitting it, even where capture and storage can be done at low cost (IEA 2020b). Figure 8 contrasts the gap between observed allowance prices to date and (roughly) estimated costs for carbon capture over time (note that costs for CO_2 transport and storage are not included).

Figure 8 – Economic gap: Carbon price versus cost of carbon capture



Range of observed ETS allowance prices

Includes prices from the ETSs in California, China, European Union, Germany, Korea, New Zealand, Nova Scotia, Québec, RGGI, and the UK.

Range of values observed in studies estimating / forecasting cost of CO_2 capture.

Range of values for CO_2 capture (that is, excluding transportation and storage costs). Broadly speaking, direct air capture costs determine the upper end of the range, while fossil energy and industrial point-source capture costs determine the lower end.

Source: Authors' elaboration. Allowance prices based on data from ICAP (2022). Capture costs estimated based on data from Global CCS Institute (2020b), Fasihi et al. (2019), Evans (2017); Shayegh (2021); Fuss et al (2018); and IPCC (2022b)

Price volatility also presents a significant challenge for the growth of CCS (IEA 2020c). For example, the price instability and oversupply of EU allowances observed in the EU ETS throughout the 2005-2018 period contributed to the cancellation of a large number of planned CCS projects (Marcu et al. 2021). Also, although the EU CCS directive has been in force since 2009, there are still no operational applications of CCS in the framework of the EU ETS.[37] To our knowledge, only the Québec Cap-and-Trade System has facilities that are reducing compliance obligations through CCS applications.

Pioneering CCS initiatives are likely to require additional support in the form of carbon contracts for difference or similar "carbon price top-up" approaches to provide a price signal that is more significant and less volatile. The Porthos project in the Netherlands, for example, will receive most of its grants through a subsidy from the Netherlands Enterprise Agency (the SDE++ subsidy), which bridges the difference between ETS allowance prices and the total costs for the capture, transport, and storage of CO_2 (CATF 2021). In the UK, the GBP 1 billion CCUS Infrastructure Fund will provide revenue streams for carbon capture projects through contracts for difference (CATF 2021). As the technology matures and is increasingly deployed, the market should require less government support, such that targeted subsidies are phased out and economy-wide measures such as carbon pricing become the primary measure to support investment (IEA 2020b).

Provisions to strengthen the carbon price signal, such as tightening the ETS cap and adopting complementary pricing instruments, are therefore also important components of an effective CCS and CCU policy. Marcu et al. (2021), for example, propose a scheme of carbon storage obligations, whereby companies in the fossil fuel industry would be obliged to geo-sequester an increasing percentage of the carbon embedded in their products. Credits would be issued for storing (rather than capturing) carbon. Such a mechanism could complement an ETS by establishing a secondary price signal that incentivizes a separate set of actors.[38]

2.4. Societal considerations

There are numerous risks associated with the use of CCS and CCU applications. The main sources of criticism are concerned about such applications legitimizing business-as-usual, heavy reliance on immature technologies to achieve decarbonization, "mitigation deterrence", and uncertainty regarding social and environmental trade-offs related to the expected expansion of these technologies. Moreover, it is increasingly recognized – for instrumental, regulatory, and substantive reasons – that public awareness and acceptance of CCS are crucial prerequisites for its large-scale commercialization and the achievement of expected mitigation goals (Whitmarsh et al. 2019).

Considering the risk of legitimizing business-as-usual activities, the Energy Transitions Commission (2022) notes that some scenarios propose a large role for CCS and CCU, which may justify a larger role for fossil fuels in the future. This is fuelled by widespread skepticism towards oil and gas companies and compounded by EOR's early prominent involvement in the development of CCS and

[37] However, some are already underway, such as the Northern Lights project in Norway and Porthos in the Netherlands.
[38] This is relevant in particular because interactions between ETS and CCS applications relate primarily to the capture of CO_2, as this is where carbon pricing instruments mainly value the emission reductions or removals. From the point of view of incentivizing CCS development and deployment, this presents a challenge to the remaining activities in the CCS value chain (notably transport and storage), which rely primarily on the economic incentives provided at the point(s) of capture.

CCU applications. Furthermore, currently most CCS/CCU projects are EOR projects to produce more oil or gas, indirectly resulting in even more GHG emissions (IEEFA 2022a), although this is likely to change as new CCS projects ramp up in the coming years.

There is also doubt as to whether CCS and CCU applications will be able to deliver the projected reductions, as the current pace of technological development is far below what is needed. Over the past decade there have been project cancellations and government funding failures (Global CCS Institute 2021b). The projects to date have delivered below expectations and still have great technical and financial barriers to overcome (Energy Transitions Commission 2022). Since 2010, a global average of less than 3 million tonnes CO_2 ($MtCO_2$) has been captured per year, and annual capture capacity stands at around 40 $MtCO_2$. Annual storage capacity needs to rise to 1.6 billion tonnes CO_2 ($GtCO_2$) by 2030 to meet a net-zero emissions trajectory in 2050 and requires CCS and CCU to be available and operational on a gigantic scale by mid-century. Assumptions that CCS and CCU can be deployed at an extremely fast rate should be balanced with important questions around feasibility, scale, and cost (IEA 2021). For example, significant technological and economic constraints exist that may slow the predicted growth of technologies like DACCS. Taking this technology alone, the risk of thinking that DACCS can be deployed at scale and then realizing it is unavailable would result in a 0.8°C global temperature overshoot (Realmonte et al. 2019). Likewise, there are concerns that the magnitude of CDR deployment expected in many scenarios could dilute incentives to reduce emissions now, a phenomenon known as “mitigation deterrence” (Grant et al. 2021). [39]

There are polarized opinions regarding the risk of CO_2 leakage (particularly out of storage) and the integrity of these technologies, which has led to public concern (Batres et al. 2021; Energy Transitions Commission 2022; IEEFA 2022b). The risk of CO_2 leaks out of storage sites is dependent on the site in question. [40] The IPCC (2005) states that the fraction of CO_2 retained in geological reservoirs that have been correctly identified and managed is very likely to exceed 99% over 100 years and remains likely to exceed 99% over 1,000 years. In other words, the likelihood of leakage is negligible at well-selected and maintained storage facilities. However, the same IPCC report states that *“CO_2 storage is not necessarily permanent. Physical leakage from storage reservoirs is possible via gradual and long-term release or sudden release of CO_2 caused by disruption of the reservoir”.* This

[39] The term is commonly used in the literature, and we therefore use it here. It is useful to note, however, that both abatement and removals are part of “mitigation” (see Honegger et al. 2021).

[40] This work adheres to Vinca et al.’s (2018) definition of leakage, which refers to unintended CO_2 emissions into the atmosphere due to infrastructural or storage failures. CO_2 can leak during transportation, subsurface injection, and after storage. Pipeline leaks cause leaks during transport. Additionally, the injection method can result in undesirable CO_2 leakage. Injection requires a well and a pipeline with the capacity for up-flows. Lastly, improper storage site sealing might result in unintended CO_2 leakage from storage sites. Leakage from storage sites is delayed in time so that CO_2 can leak out of the subsurface several years after capture. In this instance, CO_2 leakage is proportional to the total amount of CO_2 stored in the past. This element is crucial as the long-term viability of storage choices is one of the primary challenges associated with CCS deployment.

underscores the need to implement robust and reliable criteria for site selection, as well as monitoring systems that measure CO_2 fluxes.

There are also concerns related to the local impacts of the large-scale deployment of CCS applications. The large-scale application of BECCS, for example, could mean significant additional demand for biomass, putting pressure on limited natural resources, increasing conflicts over land, biomass and water (Fern 2018). Significant DACCS expansion rates would also necessitate considerable sorbent production and enormous energy inputs in the coming years (Realmonte et al. 2019). It is therefore crucial to discuss assumptions about the scale of deployment and contextualize the magnitude of the possible trade-offs (Creutzig et al. 2021).

Concerns regarding CCS and CCU applications vary by context. People in different countries may have different perceptions of risk and expect a different role for these technologies in the transition to a low-carbon economy (Cox 2020), leading to different degrees of support (Evensen 2022). In addition, support for CCS and CCU could also be conditioned by the source of the emissions captured, the part of the value chain under discussion, and the public's experience with energy projects (Evensen 2022), as well as the specific enabling policies employed (Bellamy et al. 2019).

3 In or out? The impact of ETS sectoral scope in the mechanics of the interaction with CCS applications

The interactions between ETSs and CCS applications can be discussed based on two key dimensions:

1. The relationship between the ETS scope and the sectors employing CCS applications; and
2. The CCS applications with which the ETS interacts.

This section focuses on the first item, while the second is the topic of section 4. The discussion below includes examples from specific ETSs. For more information on the approach of various ETSs to CCS, see section 7.

We distinguish between two main categories of CCS applications (for more details see section 2):[41]

- *Fossil energy and industrial point-source capture.* These are applications that reduce CO_2 emissions. They relate to CO_2 emissions typically (though not always) covered by the ETS, notably those from the combustion of fossil fuels (e.g., for electricity generation) as well as process emissions from the e.g., chemical, cement and aluminium sectors.
- *Technological removal*, or CCS applications that remove previously emitted CO_2 from the atmosphere. This application relates primarily to activities and to CO_2 emissions typically

[41] It is important to note that combined approaches may also exist, e.g., a power plant with CCS may combust both fossil fuels as well as renewable biomass.

not covered by ETSs to date, such as DACCS, as well as BECCS and WtE with CCS.[42] It is useful to note that both BECCS and WtE with CCS entail the combustion of biomass in point-source capture, but such activities typically do not face compliance obligations under ETSs as the emissions factor of biomass is usually zero.

The sectoral scope of an ETS refers to the gases, sectors, and types of activities that are regulated by the system, i.e., which emissions lead to compliance obligations under the ETS, and who is legally responsible for complying with the ETS regulations.

An ETS can interact with CCS applications inside and outside the ETS scope. Whether or not the activities capturing CO_2 are covered by the ETS will, however, be key in determining how the ETS interacts with CCS applications. It is also an important factor in determining how incentives are provided to CCS applications.

3.1. Fossil energy and industrial point-source capture

Interacting with fossil energy and industrial point-source capture means the ETS is able to reflect the capture of (fossil) emissions that would otherwise go into the atmosphere. The mechanism through which an ETS interacts with the capture and storage of these emissions depends on the formal relationship between the ETS and the source of the emissions.

3.1.1. Fossil energy and industrial emissions within the ETS scope: ETSs that regulate emissions at source

Regulating emissions at source means the ETS places compliance obligations on the entities that physically release GHGs into the atmosphere, [43] e.g., a coal power plant. The majority of ETSs currently in force cover energy and industry emissions at the point where the GHG enters the atmosphere (see Figure 9).

The point at which a GHG is emitted is also the point at which CO_2 capture can take place. The ETS incentivizes CCS applications by allowing regulated entities to reduce their compliance obligations by capturing their emissions (and, therefore, reducing their ETS compliance costs). This is the case under the EU ETS, the UK ETS, and the Québec Cap-and-Trade System, which allow covered entities to reduce their compliance obligations by capturing their emissions in specific circumstances.

Alternatively, ETSs could allocate compliance units to regulated entities for the capture of CO_2. If these are allowances, this amounts to a reduction in compliance obligations; if the allocated units are offset credits, the incentive effect depends on the restrictions placed on the use of such credits. For a discussion on the different types of units see section 5.1 below.

[42] Capturing and geologically storing CO_2 emissions from WtE facilities is akin to BECCS for the biogenic component of the waste.

[43] Regulating emissions at source is sometimes referred to as regulating emissions “downstream”. This term, however, is used in different ways in the ETS literature; we therefore do not use it here, so as to avoid confusion.

3.1.2. Fossil energy and industrial emissions outside the ETS scope: upstream ETSs

Regulating emissions upstream means the ETS places compliance obligations on fossil fuel importers and distributers. Under the coal example, an upstream ETS could place compliance obligations on the distributer that supplies coal to the power company. The ETSs in Germany, Austria[44] and Oregon, for example, cover emissions exclusively upstream (see Figure 9).

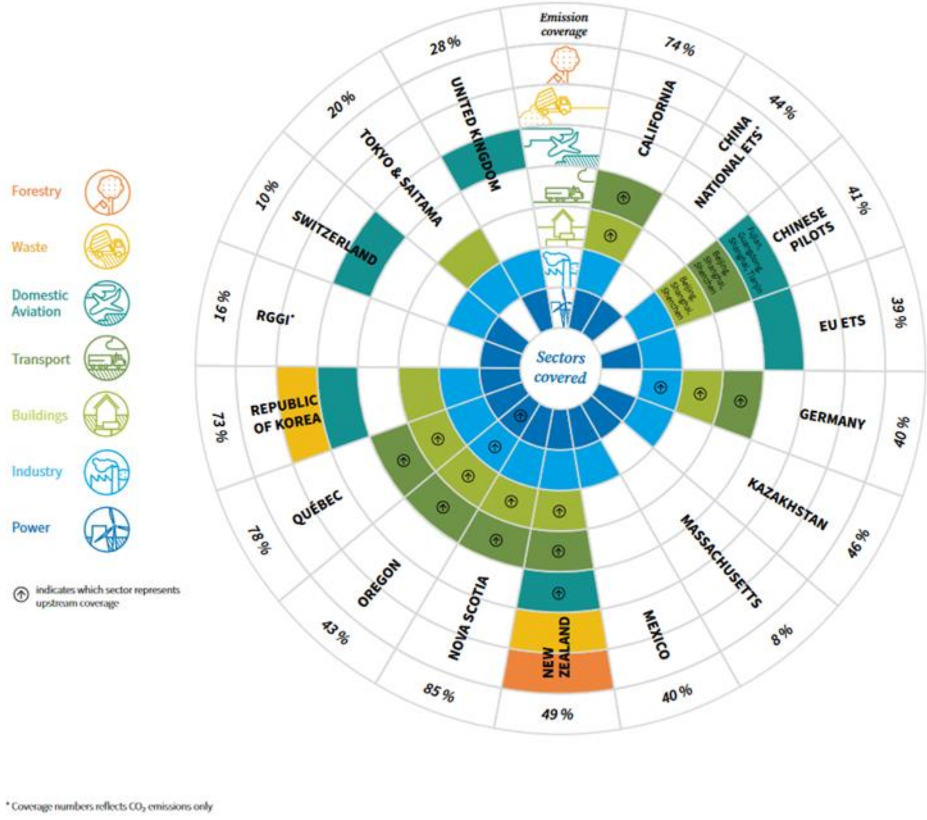
ETSs with upstream coverage that wish to interact with industrial point-source capture could operationalize that in at least three ways.

1. The first approach is to award a unit to entities performing carbon capture from an industrial point-source. This unit could then be sold by that entity in the ETS market.
2. The second approach is to allow (certain) entities (for example, a coal power plant) to voluntarily participate in the ETS. Under this example, the company supplying coal would be released from ETS compliance obligations for the portion of coal supplied to the power plant. The power plant would buy the coal at a correspondingly cheaper price, but would be faced with ETS compliance obligations. The power plant could capture and store its emissions and reduce these compliance obligations. The economic incentive for the CCS application stems from the possibility of purchasing cheaper coal without having to surrender allowances. The NZ ETS, for example, covers energy emissions upstream, but enables entities performing certain activities to voluntarily participate in the ETS and receive NZUs, although provisions relevant for CCS are not yet in force (see section 7.4).
3. A third possible approach is to establish a system whereby the covered entity (e.g., a coal distributer) receives the information that a consumer of its fuels (e.g., a coal power plant) has captured emissions from the fuel it had acquired. An economic incentive through the ETS could exist if the system allowed the fuel distributer to reduce its compliance obligations in accordance with the CO_2 captured by the fuel consumer. In exchange, the fuel consumer could pay a reduced fuel price or have their costs reimbursed.

Some ETSs have mixed coverage, e.g., covering power and industry at the point of GHG emissions, and covering the buildings and transport sectors upstream (by covering fuel distributers/importers inasmuch as they supply fuels to these sectors). This is the case of e.g., California, Québec and New Zealand (see Figure 9). In ETSs with mixed coverage, incentivizing industrial point-source capture could require mixed policy approaches (e.g., through both reduced compliance obligations from point-source emitters and through the issuance of units for emissions that are not covered by the ETS at source).

[44] The ETSs in Germany and Austria cover heating and transport fuels, which are not covered by the EU ETS.

Figure 9 – Sectoral coverage of ETSs



Source: ICAP (2021b)

3.2. Technological removals

The avenues for the ETS to interact with technological removals depends on the sectoral coverage of the ETS and on the type of CCS application. This section presents relevant considerations, noting that to date, no ETS interacts with technological removals.

3.2.1. Interacting with technological removals within the ETS scope

Technological removals that entail point-source capture – such as BECCS and WtE with CCS – could, in principle, be covered directly under the ETS. Rickels et al. (2021), for example, suggest that BECCS plants could be covered under the ETS and that they receive free allocation of allowances *"if allowances were freely allocated to biomass installations, these allowances could be sold by using BECCS instead of surrendered for emissions. As such, biomass installations would implicitly receive allowances for the removal of CO_2 from the atmosphere".* This could be operationalized by including BECCS (and WtE with CCS) plants in the scope of the ETS (potentially as voluntary participants), and freely allocating allowances on the basis of the volume of renewable biomass (see section 5.6) used by the plant. The plants would have compliance obligations for their emissions, but would be allowed to subtract from their compliance obligations emissions captured for the purpose of storage. The economic incentive to CCS applications is provided by the value of the freely allocated allowances that do not have to be surrendered and can be sold to the market. This approach could also reflect the use of renewable biomass in fossil fuel power plants with CCS.

Technological removals that do not entail point-source capture – such as DACCS – could not be reflected in the ETS through such a mechanism, but could nevertheless be included in the scope of the ETS. The ETS could, for example, allow the voluntary participation of DACCS plants, which could receive an allowance for each tonne of CO_2 removals. This approach would be akin to how New Zealand manages removals from forestry activities in its ETS.

3.2.2. Interacting with technological removals outside the ETS scope

Alternatively, the ETS could interact with technological removals by excluding them from its scope, but by awarding removal units (e.g., through a separate certification mechanism) and allowing such units to be used for compliance obligations within the ETS. In this case, two distinct 'markets' would exist: a market for allowances (the ETS) and a market for removals. Following the models proposed by La Hoz Theuer et al. (2021), removal units could enter the ETS in at least two ways:

1. Removal units could, for example, be purchased by the government, which could introduce them into the ETS. By acting as an "intermediary" between the ETS and the market for removals, the government could also provide additional support to certain technologies by e.g., purchasing removal units that are costlier than allowance prices. This approach could be particularly relevant for technological removals such as DACCS, whose costs are still high (see section 2.3).
2. Alternatively, the removal units could be purchased directly, through transactions between ETS-covered entities and removers — akin to offset provisions in ETSs. In this case, the government could place qualitative and quantitative limits on the transactions between the two markets.[45]

4 ETSs and CCS: Whether to interact, and with what

Section 3 discussed how an ETS could interact with CCS applications, showing that the various potential avenues are strongly influenced by whether CCS applications fall inside or outside the scope of the ETS.

In this section we discuss whether ETSs can interact with CCS applications, irrespective of how this interaction takes place. An ETS can interact with none or with either or both categories of CCS applications, as described in section 4.1 below. For ease of reference, we refer to each of these possibilities as "options". Section 4.2 briefly discusses the key advantages and disadvantages each

[45] The two approaches for use of removal units in the ETS described here correspond to Models B and C of La Hoz Theuer et al. 2021. Model D, as described by the aforementioned authors, corresponds to the approach described in the previous bullet, in which removal technologies fall within the scope of application of the ETS.

of these options according to three criteria. Section 4.3 discusses what happens when the ETS regulations are such that the interaction with CCS applications is unclear.

4.1. ETS and CCS applications: interacting with none, either, or both

ETSs can interact with none of the two categories of CCS applications, with either one or with both. We distinguish these as four "options" as described below and in Figure 10.

a) **Option A: No interaction.** In Option A, the ETS does not interact directly with any CCS applications. This means that entities covered by the ETS cannot reduce their compliance obligations by undertaking CCS; the ETS does not recognize the captured CO_2 as "not emitted". Moreover, under this option no units from technological removals can be used in the ETS. In short, the ETS does not provide any direct incentive for CCS applications. Option A may be the result of a *deliberate* policy decision, e.g., where policymakers decide to keep CCS applications out of the ETS. Alternatively, it can be the (*unintentional*) result of ETS regulations which ignore CCS applications, e.g., because MRV regulations for covered entities rely exclusively on calculations of input materials and standardized emission factors, and are therefore not able to reflect CO_2 capture — but there was no deliberate policy decision to impede the use of CCS technologies inside the ETS.

b) **Option B: Interaction only with fossil energy and industrial point-source capture.** Under Option B, the ETS interacts with CCS applications by allowing fossil energy and industrial point-source emitters to reduce their emissions by capturing them for the purpose of storage. If such point-source emitters are covered by the ETS (which is usually the case), this leads to a reduction in ETS compliance obligations and incentivizes CCS applications. [46,47] Under Option B, however, the ETS does not interact with technological removals.

c) **Option C: Interaction only with technological removals.** Under Option C, the ETS interacts with technological removals such as BECCS, WtE with CCS or DACCS, but does not interact with CCS applications related to fossil energy or industrial point-source capture. This can be the case in e.g., ETSs that regulate emissions upstream (ICAP 2021a) [48] and that include provisions for credits from technological removals. [49]

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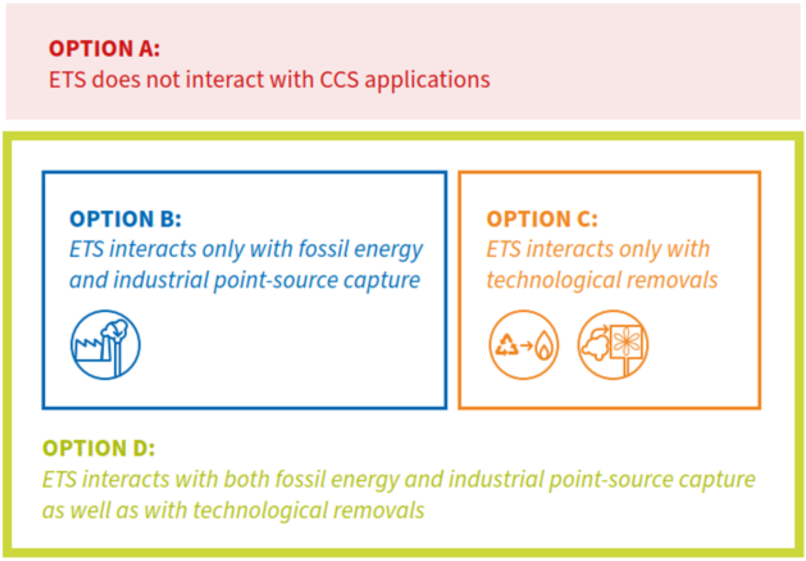
[46] In ETSs where such emitters do not face compliance obligations under the ETS, the incentive can be provided by issuing units (e.g., offsets or allowances) to them that can be sold to covered entities and submitted for compliance. See section 0 for a discussion on sectoral coverage.
[47] It is worth noting that the incentive for CCS applications exists also in the presence of the free allocation of allowances. This is because even though companies do not pay to purchase allowances, they are still exposed to the opportunity cost of reducing their emissions and of freeing up allowances that can be sold in the market.
[48] Upstream coverage in an ETS refers to covering fossil fuels at the point at which it is first commercialized by extractors, refiners or importers (PMR and ICAP 2021).
[49] It seems likely that a jurisdiction with an upstream ETS that chooses to interact with technological removals would also wish to interact with CCS applications related to fossil energy and industrial point-

d) **Option D: Interaction with fossil energy and industrial capture as well as with technological removals.** Option D combines Options B and C, and interacts with (and provides incentives to) fossil energy and industrial capture as well as technological removals.

Figure 10 – ETSs and reduction/removal CCS applications: Four options



Source: Authors' elaboration

It is useful to note that, irrespective of the "option" of interaction chosen, the ETS can interact *indirectly* with CCS applications through, for example, the use of auction revenues to provide financial support for technological development and innovation.

4.2. Nothing, a lot, or in between: A discussion on the spectrum of interaction

The options described above differ in various aspects related to the ETS and the incentive provided to CCS applications. The sections below offer a brief discussion on a few of the most relevant dimensions. Rather than trying to pitch options against each other (which would offer a limited picture in the absence of local context and implementation details), this section aims to present the various issues and the range within which they vary across the options. [50]

source capture, and would therefore fall under Option D and not Option C. Nevertheless, since the interaction only with technological removals is a theoretical possibility, we list it here for completeness.

[50] See La Hoz Theuer et al. 2021 for a detailed assessment of the pros and cons of various models for the interaction between the ETS and removal units.

4.2.1. Flexibility for covered entities and governmental control over mitigation pathways

The level of interaction between the ETS and CCS applications alters the amount of flexibility covered entities have in meeting ETS compliance obligations, as does the amount of control the regulator retains over decarbonization pathways. In the absence of any possibility to make use of CCS applications under the ETS (Option A), regulated entities can meet compliance obligations by reducing emissions through e.g., process changes or adjusting production levels, as well as by purchasing credits (if available) and allowances. Enabling CCS applications (Options B, C and D) gives regulated entities additional means to achieve their obligations, be it through reductions in compliance obligations or by having access to a pool of additional abatement options (and corresponding compliance units).

More flexibility can mean lower compliance costs for covered entities, but can also affect companies' abatement behaviour. The possibility of capturing emissions from fossil fuel combustion (Options B and D), for example, can extend the economic lifetime of fossil fuel infrastructure. Moreover, regulated entities could anticipate cheap future CCS solutions for fossil energy and industrial processes, and decide to reduce investments in process changes that could result in higher carbon efficiency independent from CCS applications.

Similarly, under Options C and D there is the risk of "mitigation deterrence" (see e.g., Grant et al. 2021), whereby regulated entities anticipating future removal units are less incentivised to reduce emissions now. Keeping technological removals disconnected from the ETS (Options A and B) has the advantage that incentives (and targets) for emission reductions under the ETS are separate from those for removals, as recommended by McLaren et al. (2019). This approach provides more long-term certainty for investors, removing the risk that their investments in abatement technologies under the ETS are rendered unprofitable by the availability of cheaper removal options in the futureThis approach also alleviates concerns about high-carbon lock-in due to myopic behaviour and uncertainty about the future supply of removal units. The extent to which the regulator retains control over mitigation pathways also depends on the level of control over the influx of removal units into the ETS: the higher the allowed influx of removal units, the higher the possible substitution of emission reductions for removals. The expectations of regulated entities about the influx and price of removal units in the future is also likely to affect present abatement choices. Including the unlimited use of technological removals within the scope of the ETS would mean that regulated entities could risk facing an effective allowance price ceiling imposed by the costs of eligible removal technologies.

4.2.2. ETS market functioning and price discovery

As the ETS cap approaches zero and companies decarbonize production processes, the number of players in the ETS and their respective covered emissions is also likely to decrease, giving rise to issues of liquidity and market power, decreasing the effectiveness of the system. Market participants may become hesitant to trade, auctions may be distorted and secondary markets may not function as intended. Allowance prices for these remaining emissions are also likely to be high as they will be from sectors and processes that are the hardest to decarbonize and cheaper abatement options will have been exhausted. Some interaction options between ETSs and CCS applications could help alleviate these issues. The interaction with technological removals (Options C and D), in particular, could increase the number of players and the supply of compliance units into the system. [51]

4.2.3. Strength and type of incentive for CCS

Interactions between ETSs and CCS will also influence the strength of the price signal offered to the various CCS applications. At one end of the spectrum, Option A offers no incentive from the ETS for CCS applications, meaning that industrial players interested in developing CCS applications must seek incentives outside the ETS. This approach may lead to missed abatement opportunities in situations where covered entities could deploy CCS technologies but have no incentives to do so (as they would also have to surrender allowances for the emissions captured). At the other end of the spectrum, Option D provides incentives for both categories of CCS applications and offers the broadest ETS-based incentive for CCS.

However, as highlighted in section 2.3, including CCS provisions in the ETS is no panacea. Under all options, and in the absence of further support policies, the strength of any incentive provided by the ETS will be subject to market and price risks. The future price of allowances cannot be known with certainty nor can the return on investment in CCS installations and activities. This fact is important as investments in CCS infrastructure are highly capital intensive. Moreover, the (current and projected) price of allowances can be too low to provide an incentive for several application types. This effect is even stronger in the case of technological removals. Removals are projected to remain more expensive than CCS applications in the energy and industrial sectors, and price differentials vis à vis allowance prices can be substantial.

4.3. Uncertain interactions: when ETS regulation leaves space for interpretation

ETSs may not fall neatly into either of the Options described above, which is often the case when the ETS has no provisions directly related to CCS applications. This, however, does not automatically mean that the ETS does not interact with CCS applications (Option A); in some cases, the ETS regulation *could be interpreted* to allow for the reflection of captured emissions in companies' compliance obligations, even if this is not stated explicitly in the regulations.

This issue pertains mainly to two ETS design elements: what triggers the compliance obligation and requirements for MRV.

- **What triggers the compliance obligation** relates to the fundamental rules that determine what conditions lead an entity to have to surrender a compliance unit under the system. In upstream systems such as those in New Zealand and Germany, this can relate to the sale

[51] The flip side of this is that gross emissions under the ETS would possibly be higher than under Options A and B. See section 5.2.

or purchase of a fossil fuel. In systems that regulate emissions at source, this can relate to the release of GHG emissions into the atmosphere.

- **MRV regulation.** Under ETSs, MRV can be done in roughly two ways: by calculation or through continuous emissions monitoring. A coal power plant covered by an ETS, for example, may be offered the option of (a) calculating its emissions by multiplying the volume of coal burned over a period by a standard emissions factor, and/or (b) having sensors in its process that measure the amount of CO_2 being emitted in real time. MRV regulations can also allow for flexibility and case-specific deviations.

In ETSs whose compliance obligation pertains to emissions released into the atmosphere, and where MRV includes provisions for continuous monitoring and/or for case-specific deviations, the system *could be interpreted to allow* for (or at least not explicitly hinder) the reflection of captured and stored emissions in the emissions reports of covered entities (H. Egeland, pers. comm., 2022). In other words, there could be space for the ETS to reflect the capturing of emissions in covered entities (e.g., fossil energy and industry installations) even in the absence of explicit regulations on CCS.

Yet to the extent that regulators wish to use the ETS as an avenue for incentivizing CCS applications, this uncertain situation provides, at best, a weak incentive for the development and deployment of CCS. ETS and MRV regulations that theoretically allow for the reflection of captured/stored emissions, but do not make such an incentive explicit, provide a weaker incentive than an explicit provision with detailed rules and guidelines on captured/stored emissions. The lack of explicit references can create uncertainty; there is no endorsement of CCS applications and there could be concerns about varying interpretations of existing rules.

In the absence of regulations that explicitly make space for CCS applications, the policy interaction between ETS and CCS remains uncertain and any incentive from the ETS is unlikely to be strong enough for new CCS projects to materialize. Entities interested in investing in CCS applications are likely to need a more explicit regulatory endorsement of CCS applications before the investment is made. On-the-ground, this uncertainty is likely to result in the lack of any incentive for CCS applications. Where regulated entities do *perceive* an incentive to implement CCS applications through the ETS, the effects would be those outlined under Option B, albeit moderated by a weaker incentive.

On the other hand, this uncertainty also means that in situations where ETS regulators specifically wish to not reward emissions reductions by CCS, the absence of rules may not suffice to guarantee that this is the case. Rather, the legislation may have to explicitly say so for that to become the rule. (H. Egeland, pers. comm., 2022)

5 Considerations on ETS design

The sections above highlighted that the ETS can interact with CCS applications in multiple ways. This section outlines several resulting considerations for ETS design.

5.1. Unit choice

As highlighted in section 3, the relationship between the ETS scope and the activities employing CCS applications dictate important aspects of the mechanics of the interaction. Some configurations, such as interacting with fossil energy and industrial point-source capture *inside* the scope of the ETS, relate to simply reducing the compliance obligations of regulated entities. Others, such as interacting with fossil energy and industrial point-source capture *outside* the scope of the ETS, can entail *awarding units* to such activities. The units that are awarded can be allowances or credits.

This choice of unit (or "legal tender") is important: notably, an allowance would be fully fungible with other units in the ETS, but a carbon credit need not be and can be subject to e.g., quantitative restrictions on its use (PMR and ICAP 2021). This impacts the various considerations discussed in section 4.2, including price dynamics and the strength of the incentive provided to CCS applications.

5.2. Cap-setting

To the extent that units (whether allowances or credits) are allocated to entities involved in CCS applications, an important question is the relationship between such units and the ETS cap (i.e., the total number of allowances under the system) as well as the impact on gross emissions by regulated entities, which is determined by the cap plus any additional eligible compliance instruments.

ETS A may, for example, have a cap of 100 MtCO_2e, and allow for the use of up to 5 million removal units (credits or allowances), generated by technological removals outside the system and in addition to the cap. While the cap within ETS A is 100 MtCO_2e, its gross emissions (if the removal units are used, which would depend, among others, on price differentials across allowance prices and removal costs) could reach 105 MtCO_2e. The result for the atmosphere is 105 – 5 = 100 MtCO_2e.

ETS B, by contrast, may also have a cap of 100 MtCO_2e, and allow for the use of up to 5 million removal units (credits or allowances). But in ETS B, the 5 million removal units are taken from the cap. For example, the ETS regulator may issue only 95 million allowances, earmarking the remaining 5 MtCO_2e for the issuance of removal units. In this case, gross emissions within the system stay at 100 MtCO_2e, and the result for the atmosphere is 100 – 5 = 95 MtCO_2e.

The examples above pertain to interactions with technological removals, but similar examples could be built for the interaction with fossil energy and industrial point-source capture. What the examples above highlight is that if units allocated to CCS applications are generated *in addition* to the cap (as in the case of ETS A above), and especially if there is no limit on the number of units that can be generated, then there is effectively no limit to the aggregate gross emissions of regulated entities under the ETS. There is also a higher risk of substitution of emissions reductions within regulated entities for emission reductions and removals generated by CCS applications. Most of the concerns in the literature pertain to the substitution of emissions reductions for removal activities. This aspect is most critical when the ETS interacts with technological removals (see e.g., Geden et al. 2019; McLaren et al. 2019; Geden and Schenuit 2020).

If regulators desire gross emissions under the system to be the same as the number of allowances, then no additional compliance instruments beyond the cap can be generated. Each unit allocated to a CCS application must then either be an allowance or entail the conversion or cancellation of one. This can be implemented by reducing free allocation (which would tend to increase costs for regulated entities) or by reducing allowance auctions (which could lower government revenues) (Oxera, 2022). Regulators may choose to establish unit reserves especially dedicated for this purpose, although this would limit the incentive for CCS applications through unit allocation. Total scarcity in the system would remain unchanged, provided that the market price of units allocated to CCS applications is no higher than that of allowances.[52]

5.3. Free allocation

If an ETS allows entities to reduce their compliance obligations by capturing CO_2, and if (part of) the allowances are allocated for free, the free allocations could be affected by a reduction in reported emissions from entities capturing CO_2.

If the system uses *grandparenting*,[53] the regulated entity capturing the CO_2 could see its free allocations reduced, which could reduce the incentive for CO_2 capture.

If the system uses *benchmarking*,[54] at least two effects are possible. First, the individual installation capturing CO_2 would report fewer emissions and come closer to (or under) the benchmark, reducing compliance costs or possibly freeing up allowances for sale. Second, the overall system could also see an impact, with the benchmark itself lowered as regulated entities reduce their reported emissions, reducing free allocations to other regulated entities.

In both benchmarking and grandparenting approaches, the precise impacts will be context dependent. It is important that ETS regulators consider the effect of interactions with CCS applications and free allocation, as certain configurations could affect the incentive for CCS applications.

5.4. The semantics of defining the "ETS scope"

The sectoral scope of an ETS refers to the gases, sectors, and types of activities regulated by the system, namely which emissions lead to compliance obligations under the ETS and who is legally responsible for complying with the ETS regulations. In the current ETS literature (see e.g., PMR and ICAP 2021), matters related to the participation of legal entities in the ETS pertain primarily to *obligations*: the obligation of a regulated entity to surrender compliance units for emissions released into the atmosphere. Interactions with CCS applications could challenge this definition. Regulators

[52] ETSs interacting with technological removals could, for example, purchase removal units as a way of enabling a (soft) price ceiling, as proposed by Rickels et al. (2022). The regulator could purchase units in the removals market and reduce the availability of allowances accordingly in the short term, but introduce the acquired removal units in the market only much later, e.g., once a certain price threshold is achieved. Such an approach would increase the short-term scarcity in the ETS.
[53] Grandparenting pertains to the free allocation of allowances based on historical emissions.
[54] Benchmarking pertains to the free allocation of allowances on the basis of emissions intensity per unit of product.

could wish to state, for example, that if a CCS application receives an allowance for reducing emissions or removing CO_2, this entity is then "covered" by the ETS. This thinking could impact the ETS scope and the idea that legal entities have the *right* to receive an allowance (e.g., for a removal) and have legal implications that may have to be addressed in the ETS regulation. For an elaboration on some legal issues under the EU ETS, see Rickels et al. (2021) and Nehler and Fridahl (2022).

5.5. Credits for domestic versus international activities

The sections above implicitly assume that the CO_2 capture activities that interact with the ETS are located within jurisdictional borders. Yet ETSs could potentially interact with reduced emissions and CO_2 removals outside jurisdictional borders. In this case, the mechanics would be similar to those applied to international credits/offsets, although aspects related to e.g., CO_2 leakage out of storage and the treatment of operational emissions from CCS applications would still need to be taken into account.

5.6. Interactions with the voluntary carbon market

CCS applications (both those that reduce emissions and those that deliver removals) can aim to obtain credits from crediting programmes (such as the Verified Carbon Standard, and the Article 6.4 mechanism under the Paris Agreement, among others) for their activities. This can be particularly relevant for applications that face very high price differentials vis à vis current ETS allowance prices: voluntary demand for removal units from DACCS, for example, is small but existent, and is able to reflect current costs of DACCS plants (Climeworks 2022). This means that CCS applications could potentially receive credits under such crediting mechanisms before inclusion in an ETS. It would be important to ensure that only one unit (a credit or an allowance) is issued for each tonne reduced or removed – otherwise, double counting may occur.

5.7. Dealing with quality and quantity spectrums of biomass use

Biomass can be used by fossil energy and industrial installations (e.g., a coal plant that also makes use of agricultural waste) as well as by technological removals (notably BECCS). Two key considerations relevant for ETS design are worth highlighting.

A first important consideration is that biomass that is not truly renewable (or "sustainable") does not lead to removals. For example, a coal plant with CCS that uses non-renewable biomass (e.g., from deforestation, such that the harvested biomass does not grow back) would, at best, be delivering zero emissions through its biomass component (with all the attendant damage due to deforestation). The same applies to a BECCS plant that uses non-renewable biomass. BECCS with renewable biomass, on the other hand, can lead to removals. ETSs need strict and enforced criteria on what constitutes renewable biomass. This will be key to ensure the environmental integrity of any biomass use in the ETS and to provide incentives for applications such as BECCS and WtE with CCS. Such criteria may have to reflect GHG emissions in the biomass production lifecycle and take into account the climate impact of releasing into the atmosphere, in the short term, a large amount of CO_2 that will take several years (or decades) to be re-absorbed into biomass (EASAC 2019). The criteria may also have to straddle and provide consistency across the reporting of and accounting for emissions at various levels, e.g., across national and company-level inventories, sectors and policy instruments.

A second important consideration is that even when using renewable biomass, installations may fall somewhere *between* 0% and 100% of renewable biomass use. For example, a BECCS plant may be found to have used non-renewable biomass, such that not all of its captured emissions pertain to removals. Moreover, a power plant employing CO_2 capture may gradually transition from coal to renewable biomass use, such that over time, the CO_2 capture moves gradually from delivering CO_2 reductions towards delivering CO_2 removals. This has two important consequences:

a) It may not be possible to establish rules that create a strong dichotomy between emission reduction and removals, or a strong dichotomy between fossil-based and (renewable) biomass-based installations. There is a need for rules that can reflect the spectrum of CO_2 reductions and CO_2 removals that CCS applications and biomass use can generate. This is relevant also for WtE with CCS plants, which are likely to deliver emission reductions and removals.

b) ETSs looking to interact exclusively with technological removals (and not with CCS applications related to fossil energy and industrial emissions: Option C in section 4.1) may face difficulties. Once the ETS starts interacting with removals from the use of renewable biomass, it may be difficult to rule out a possible interaction with non-renewable biomass, and consequently a possible interaction with fossil energy point-source capture.

5.8. Monitoring, reporting and verification

MRV provisions are key to maintain environmental integrity in the interaction between ETSs and CCS applications, and to enable the ETS to provide an incentive to CCS applications. The IEAGHG (2016) lists three key requirements in this regard. These are:

a) Recognizing captured CO_2 for storage as "not emitted", such that the captured CO_2 be deducted from the relevant inventory (e.g., at installation level);

b) Including transport and storage within the scheme accounting rules; and

c) Creating a mechanism to address permanence, such that any leaks are quantified and there is assurance that the injected CO_2 remains in the intended geological formation.

The IEAGHG report also lists a few "special cases" which require specific considerations:

d) Recognizing negative emissions from BECCS: GHG accounting schemes and MRV rules are needed to evaluate, attribute and reward any negative emissions;

e) Accounting for EOR: MRV rules can address emissions associated with incremental oil production; and

f) Accounting for CCU: the different mitigation pathways associated with these CCU applications must be evaluated and suitable MRV rules developed if such applications are to be recognized and supported.

All these aspects are touched on in this report, even if briefly. [55] A couple of additional aspects are also worth mentioning.

In relation to aspect (a) above, it is useful to note that current point-source capture installations typically only capture up to approximately 90% of the available CO_2 (Brandl et al. 2021). This fact should be taken into account in MRV frameworks as they should not assume that e.g., a power plant equipped with capture technology would cease to emit carbon from its energy generation operations.

Moreover, and more importantly, there seems to be uncertainty around the interaction between ETS-level MRV and international-level MRV and accounting – notably, in terms of national GHG inventories and corresponding IPCC inventory guidelines. A first point of contention relates to rules for DACCS as the IPCC does not yet have guidance on how to account for removals through DACCS. While this does not strictly prevent the inclusion of DACCS projects in ETSs, it may affect countries' ability to reflect those removals in their national inventories and, consequently, in their national reports tracking progress towards nationally determined contributions. Country representatives also seem to have differing interpretations about the flexibility available to individual countries to employ ad-hoc quantification methodologies to reflect DACCS in national inventories: some countries assume that ad-hoc inventory provisions reflecting DACCS removals are possible, whereas others assume such ad-hoc provisions are out of reach.

A second point of contention around national GHG accounting relates to how emission reductions and removals from CCS applications are accounted for in national inventories in case of transboundary transport and storage. Conversations with experts in the field indicate there is no clear view on which of the countries involved would be able to record the removal or the emission reduction.

5.9. Addressing operational emissions and CO_2 leaks: ETS scope and MRV

To the extent that an ETS includes provisions for CCS applications, an important question is whether activities within the CCS value chain fall within the scope of the ETS, i.e., whether they face

[55] Section 3.1 discusses how to ETSs can interact with point source emissions such that captured CO_2 be recognized as "not emitted". Section 4.3, moreover, outlines the role of MRV (in particular continuous emissions monitoring) as a potential avenue for recognizing captured CO_2 as "not emitted" even in the absence of explicit CCS provisions under the ETS. Section 5 addresses operational emissions from transport and storage, as well as provisions for CO_2 leaks. Sections 3 and 4 address the various pathways related to the recognition of CO_2 removals through e.g. BECCS and DACCS. Section 6 addresses, briefly, a few issues related to CCU and EOR.

obligations under the ETS for their emissions. Fundamentally, *operational emissions* from the CCS value chain (i.e., those generated from the processes inherent to the capture, transport, storage, or utilization, such as fuel emissions in transport equipment), as well as *CO_2 leaks* (i.e., emissions that are fugitive, vented or result from failures) must be visible in national inventories so they can be appropriately accounted for, also in relation to jurisdictional targets. Whether these emissions fall under the scope of application of the ETS is regulated through provisions on ETS scope and on MRV. Two considerations are of particular relevance when considering whether to cover these emissions under the ETS.[56]

- **Monitoring.** The ETS can be used as a tool to monitor operational emissions and CO_2 leaks from the CCS value chain. The ETS is not, however, the only tool that can monitor these emissions. Even if operational emissions and CO_2 leaks from the CCS value chain fall outside the scope of the ETS, they should in any case be accounted for in the national inventory (e.g., following relevant IPCC inventory guidelines) and fall under the purview of national climate targets. Ultimately, if the jurisdiction has an economy-wide ambitious NDC and if the emissions are visible in the inventory, the emissions will be accounted for and environmental integrity will be safeguarded. Nevertheless, the ETS may provide a more granular set of MRV guidelines, although this depends on what other MRV provisions are in place.
- **Economic incentives (and costs):** Covering operational emissions and CO_2 leaks from the CCS value chain under the ETS provides an economic incentive to keep them in check as transport and storage entities would be liable to monitor their emissions and to surrender allowances e.g., in case of CO_2 leaks. This harmonizes the price signal across the CCS value chain and can be particularly valuable in the absence of regulations or incentives in non-ETS sectors.

It is also worth noting that even if the ETS does not *explicitly* include CCS value chain activities in its scope of application, it can *implicitly* cover operational/leakage emissions. This can happen in systems where MRV provisions stipulate that regulated entities have to report each and every GHG emission that occurs within their emissions reporting boundary (the Mexico ETS, for example, contains provisions requiring that every emission within the boundary of the covered entity be subject to compliance obligations under the ETS). To the extent that elements of the CCS value chain take place inside the boundary of the regulated entity/installation, operational emissions and CO_2 leaks would be reported under the ETS. Such a provision, however, would likely only cover emissions related to capture, as all other activities within the CCS value chain would likely happen outside the boundaries of regulated entities.

Currently, the only ETSs that explicitly include the entire CCS value chain within the ETS scope are the EU ETS and the UK ETS (restrictions on transport apply; see section 7 for details). Some ETSs

[56] It is useful to note that both functions listed below could be performed by other instruments, such as carbon taxes or other regulations.

cover only part of the CCS value chain; in the California ETS, for example, "CO_2 suppliers" (entities involved in the capture of CO_2) are covered by the ETS, but transport and geological storage are not. In the Quebec ETS there is acknowledgement that multiple entities may be involved in the CCS value chain, but the economic incentive is provided only to the industrial facility that would have emitted the CO_2 had it not been captured.

5.9.1. Liability provisions for CO_2 leaks

The transport and geological storage of CO_2 can entail physical leaks of the gas into the atmosphere. Provisions for such leaks are necessary to ensure the environmental integrity of CCS applications. From a system design point of view, past experience indicates that robust regulations are key to preventing future problems: rigorous criteria on storage site selection, for example, can go a long way in preventing CO_2 leaks.

In addition to ensuring that CO_2 leaks are visible in the national inventory, jurisdictions may wish to impose liability[57] (notably, sanctions and/or redress measures) to entities within the CCS value chain in case of leaks during transport and storage. For this, it is important to clarify the extent of the liability of the various involved entities over time, and to make sure these liabilities can be enforced. A few aspects merit further consideration. Since most concerns relate to leaks out of geological storage sites, the sections that follow focus on these leaks, noting that many of these considerations apply also to leaks during transport.

How is liability enforced?

If a jurisdiction wants to impose liability provisions in case of CO_2 leaks out of storage to entities within the CCS value chain, the first question is to whom this liability should apply. Most, if not all, current regulatory frameworks for CCS liability have in place liability provisions for leaks out of storage on the entity that operates the storage facility (see Global CCS Institute 2019). This means that in the case of leakage, the operator of the storage facility would be responsible for any applicable sanctions or redress measures.

The second question is through what instrument is liability for CO_2 leaks out of a storage site applied and for what is the storage operator responsible?

Policymakers may regulate that redress for CO_2 leaks be applied **through the ETS**, i.e., by surrendering ETS allowances. In this case, the storage operator would have to be inside the scope of the ETS. This is the approach of the EU ETS and of the UK ETS, where point-source emitters can subtract CO_2 that leaves their installations for capture and geological storage, and where the various

[57] Liability in the context of CO_2 storage can pertain to three distinct issues: (a) civil liability where another party seeks compensation for damages; (b) administrative liability where an entity is subject to specific requirements imposed by the regulator, e.g., on storage site selection, monitoring, reporting, and inspections; and (c) climate change liability where CO_2 leaks may require the entity to provide economic redress (Global CCS Institute 2019). We focus here on the third element.

entities involved in the CCS value chain are responsible for their respective operational and leakage emissions.

Another (theoretical) avenue for covering liability under the ETS could be to place the liability on the point-source emitter. In this case, the reduction in compliance obligations for the industrial emitter (or, potentially, the removal unit generated for technological removals) would pertain to what could be demonstrated to have been safely *stored* (as opposed to, for example, CO_2 that was captured and transported to geological storage). This approach could ensure that liability for CO_2 leaks stays inside the ETS even in situations where the CCS value chain is not within the scope of application of the ETS (e.g., in case of transboundary CO_2 storage). This approach could work well in vertically integrated CCS value chains that include the point source and where the point-source entity is also able to control or influence what happens in the rest of the value chain.[58] As soon as the value chain is no longer vertically integrated, however, this option places the responsibility on the industrial emitter even though this entity has no control over what is happening. Moreover, this approach is difficult in instances where multiple point sources share the same transport and storage infrastructure (which is the approach of many of the new CCS endeavours under development) as it is not possible to attribute a leak at the point of storage to a particular point source. It would be possible to attribute liability for leakage proportionally to all point sources that use the storage infrastructure, although this could be further complicated if the storage site is used both for ETS and non-ETS emissions.

Yet the liability can also be applied by **provisions other than the ETS**. In this case, the jurisdiction can put in place other provisions for economic penalties in case of leakage, such as fixed monetary sanctions. Alternative approaches to address leaks or reversals have been in place in crediting mechanisms. For removals from forestry projects, for example, some crediting mechanisms employ reserves or "buffer pools", which retain a percentage of all credits issued and act as a collective insurance mechanism against reversals. Such instruments could potentially be adapted to the case of CCS. Whatever the approach to enforce liability, clarity is important. Provisions for liability at jurisdictional level clarify the liability between the actors involved, removing the need to deal with such issues on an ad-hoc basis in commercial contracts. Placing the economic liability with the actor that causes leaks/emissions (such as under the EU ETS), for example, removes the need for contractual redistribution of liability. If the liability for emissions from the whole value chain is placed with the capturing operator, that operator would likely engage in contractual redistribution of liability with the transport and storage operator in non-vertically integrated value chains (H. Egeland, pers. comm., 2022).

Where CO_2 is stored outside jurisdictional borders (see section 5.10), it seems that it would not be possible to cover storage leaks under the ETS, unless (a) the jurisdiction effecting the CO_2 storage

[58] This vertical integration would need to be maintained throughout the operational lifetime of the chain.

has an ETS which covers leaks out of storage and is linked to the ETS of the jurisdiction exporting the CO_2; or (b) the industrial point source emitter is made liable under the ETS exporting the CO_2.

Liability over leakage of which emissions?

The second question pertains to how leakage liability provisions under the ETS deal with the fact that storage sites may receive CO_2 from multiple sources. This clarification is important because in cluster/integrated projects, transport and storage infrastructure will be shared by many sources of capture, and it will not be possible to connect the leakage of one tonne to any particular point source. Further, not all point sources may relate to emissions regulated under the ETS. The fact transportation and storage networks can be used also by DACCS plants makes the picture even more complicated. Including the CCS value chain under the ETS (such that operators of storage sites are responsible for CO_2 leaks) may mean that the ETS will also cover leaks of emissions that were not originally covered by the ETS.

This can be of particular relevance, for example, in situations where multiple policy instruments interact with individual CCS applications. Nehler and Fridahl (2022), for example, note that if a policy (other than the ETS) establishes economic incentives that reward technologies such as BECCS, then perverse incentives to catch and release CO_2 might be created if the reward for the capture is higher than the penalty for the leak.

Liability for how long?

While “permanent” storage may mean “forever”, an infinitely long period of liability is not compatible with business operations. It is important that ETS rules determine for how long monitoring needs to happen and by whom, for how long liability for leakage is in place and to whom it applies. Responsibilities can also change hands over time. For example, in the EU ETS and in the UK ETS, the responsibility for monitoring (and leakage) remains with the storing entity for a minimum of 20 years after the closure of the storage site. Thereafter, the responsibility for monitoring and leakage can be handed over to the “relevant authority” under specific conditions (see section 7.1).

It is also useful to note that the *responsibility for monitoring* leaks need not be contingent on, and can be decoupled from, *the economic liability* of surrendering allowances in the event of leaks. Ultimately, environmental integrity for leaks is safeguarded by making sure such leaks are monitored and are visible in the national inventory in the context of an ambitious national climate target. This means that responsibility for monitoring is key, even if it is not always accompanied by economic liability for handing in allowances in the case of leaks.

5.10. When the CO_2 leaves jurisdictional borders: ETSs and exported emissions

While all steps of the CCS value chain tend to be in the same country in existing projects, upcoming CCS projects, which rely on broad networks of capture, transportation and storage, often do not. A crucial element for the integration of such CCS networks into ETSs lies in the regulation of cross-border issues. This aspect relates to ETS regulations covering the export of emissions. The integration of CCS networks is expected to involve the export of CO_2 to geological storage sites outside jurisdictional borders. In September 2022, for example, Northern Lights (Norway) made the world's first cross-border commercial agreement to transport and store CO_2 from the Netherlands (TotalEnergies 2022).

Different ETSs have different provisions for the "export" of CO_2 for storage. Under the NZ ETS, for example, the Climate Change (Other Removal Activities) Regulation 2009 (SR 2009/284) [59] establishes that GHGs that are exported (e.g., as liquid CO_2, as synthetic GHGs (HFCs and PFCs) and the GHGs "embedded" in products such as methanol and liquid petroleum gas), are to be subtracted from entities' compliance obligations. This allows the NZ ETS to provide an incentive for emissions that are captured within its borders but stored outside them.

The EU ETS has a different approach due to the fact its provisions on CCS are subject to storage carried out in accordance with the EU CCS Directive, which can only regulate storage within the EEA. If CO_2 stored in the EEA is done so in accordance with the directive, the emitted CO_2 will be considered as "not having been emitted" under the EU ETS, and industrial point-source emitters can subtract captured emissions from their compliance obligations. Storing CO_2 emissions outside the EEA is not banned, but these emissions cannot benefit from the possibility of not surrendering allowances under the EU ETS, providing little incentive to store CO_2 abroad (European Commission 2022a). This also includes CO_2 transported for storage from the EEA to the UK.

The issue of cross-border CO_2 transport and sub-seabed storage also relates to the London Convention and the London Protocol on the Prevention of Marine Pollution caused by the dumping of wastes and other matter. Since 2006, the London Protocol has served as the basis for international environmental law to permit CO_2 storage beneath the seafloor where it is safe to do so and to control the injection of CO_2 into sub-seabed geological formations for permanent isolation. Article 6 of the London Protocol bans the export of waste or other substances for disposal in the marine environment. Contracting Parties to the London Protocol enacted a resolution in 2019 to allow the temporary application of the 2009 amendment to Article 6 of the Protocol to permit the export of CO_2 for storage in sub-seabed geological formations prior to its ratification, which had been proceeding slowly. This eliminated the final substantial international legal obstacle to CCS, allowing CO_2 to be transported internationally for offshore storage (IEAGHG 2021). Countries, however, must ratify the resolution and establish bilateral intergovernmental agreements to make use of its provisions. As of September 2022, only a few countries, including Belgium, Denmark, Estonia, Finland, Islamic Republic of Iran, Netherlands, Norway, Republic of Korea, Sweden and the UK, had ratified the resolution (European Commission 2022b). A recent analysis by the European Commission, however, concluded that EEA countries can make use of a simplified process under the existing EU legal framework to benefit from the resolution's provisions (European Commission 2022b).

[59] https://www.legislation.govt.nz/regulation/public/2009/0284/latest/DLM2381201.html

6 Brief considerations on CCU

As described in section 2.1, CCU applications vary widely and have different environmental outcomes. These depend, among other factors, on the source of the CO_2 (fossil or not), on the permanence of the embedded CO_2 (that is, whether the CO_2 embedded in a product can be released back into the atmosphere or not), and on the product that is displaced.

- Some CCU applications, for example, lead to the long-term binding of CO_2 into a product, meaning it would not release the CO_2 into the atmosphere during use or disposal. Construction materials such as concrete, for example, bind CO_2 for decades or centuries.[60] For this type of product, the environmental effect depends primarily on the source of the embedded CO_2. Using CO_2 from fossil sources leads to emission reductions as the CO_2 that would otherwise have been emitted gets "trapped" in the concrete and is not released; using CO_2 from renewable biomass or from the atmosphere can lead to removals as CO_2 is sucked out of the atmosphere and bound into a product.
- Most CCU applications, however, only bind the CO_2 temporarily and the CO_2 is released into the atmosphere during use or disposal. This is the case for CCU applications that produce synthetic fuels, carbonated drinks and plastics.[61] While the precise environmental effects vary depending on the source of the CO_2, emissions are generally reduced by e.g., displacing virgin fossil fuels and using the same molecule of CO_2 more than once. In such cases, life-cycle analyses are key to understanding environmental outcomes.
- EOR is often considered a type of CCU as CO_2 is used to increase fossil fuel extraction. On the one hand, CO_2 (e.g., from coal power plants) is captured and geologically stored; on the other, the activity may increase fossil fuel supply. Whether or not EOR leads to climate change mitigation depends on several factors, notably the source of the CO_2, the permanence of the storage, and the balance of emissions stored versus increased emissions from fossil fuel combustion.

Whether and how an ETS interacts with CCU applications relates to several ETS design aspects.

The **ETS scope** is an initial starting point. The interaction between the ETS and CCU can happen: (a) at the point of CO_2 capture, such that entities that would face compliance obligations can reduce their obligations by demonstrating that the CO_2 is bound into a product; and/or (b) at the point of CO_2 emission from the product when entities that make use of products produced from CCU applications or that deal with the end-of-life of such products (notably waste management) have

[60] Whether a long-term storage in the range of decades or centuries can be said to be "permanent" is a relevant question that we do not expand upon here. For the purpose of this report, we assume this type of long-term storage to be sufficient for ETS purposes, but future research may wish to investigate this matter further.
[61] For plastics, different modes of disposal (e.g., recycling versus landfilling versus incineration) may have different effects in terms of how much and when CO_2 is released to the atmosphere.

their emissions covered by the ETS. Since the latter option is a relatively "standard" case of covering emissions from point sources under the ETS, we focus this section on the first element, namely if and how the ETS interacts with CCU applications at the point of CO_2 capture.

Our analysis examines the possibility of reducing the compliance obligations of ETS-covered entities that engage in CCU applications, where CO_2 is embedded in products instead of being emitted within the boundaries of an installation. It is key to understand *which provisions and grounds lead to reductions in compliance obligations.*

This question relates, first, to **understanding what triggers compliance obligations**, namely, what conditions lead an entity to have to surrender an allowance under the system (e.g., engaging in a specific type of process or economic activity and/or the act of physically releasing emissions into the atmosphere). In ETSs where the compliance obligation stems from physically releasing emissions into the atmosphere, the regulations *could be interpreted* to implicitly allow regulated entities to reduce their compliance obligations through CCU applications by demonstrating that the CO_2 was not emitted. Higher level provisions under the ETS, however, can also be relevant to address this question. Under the Schaefer Kalk court case, [62] for example, the definition of "emissions" under the EU ETS Directive was key in arguing that the production of precipitated calcium carbonate (which binds CO_2 chemically in a stable product) does not lead to emissions and should not be subject to compliance obligations.

Conditions related to **permanence, MRV, and ETS scope** are also relevant. Some systems do not require the embedding of CO_2 in a product to be permanent or long-term. The Québec Cap-and-Trade System, for example, allows regulated entities to reduce compliance obligations in cases where CO_2 is re-used or transferred out of the establishment. The NZ ETS contains provisions to issue units to entities that make (a) a product containing a GHG that is permanently embedded; or (b) a product containing a GHG that is temporarily embedded and the product is exported with the substance embedded. Both systems can be said to enable regulated entities to reduce compliance obligations if they engage in CCU, irrespective of whether the product leads to long-term or short-term CO_2 storage. Several of these products would, however, ultimately see the release of the embedded CO_2 either during use (in the case of synthetic fuels) and/or during the end-of-life phase (e.g., during decomposition and incineration). If these emission sources are not subject to the scope of the ETS, emissions from inside the ETS are effectively shifted out of the system. [63] Similarly, EOR presents a difficult case for the inclusion in ETSs due to the complex effect of CO_2 storage vs an increase in fossil fuel supply, which can also increase emissions outside of the system.

By contrast, MRV regulations under the EU ETS valid as of January 2023 have provisions for reducing compliance obligations for CCU only in the case of precipitated calcium carbonate, which binds CO_2

[62] Schaefer Kalk GmbH & Co. KG v Bundesrepublik Deutschland (2017)

[63] In the case of synthetic fuels, it is possible that the use of such fuels substitute other fossil emissions, leading to no net increase in emissions overall. This highlights the importance of life-cycle assessments when considering including CCU in ETSs, including an understanding of alternative mitigation pathways and ways to avoid loopholes and inconsistencies.

long-term. The EU ETS revision is likely to include CCU provisions only to the extent that GHGs are permanently chemically bound in a product and cannot enter the atmosphere under normal use and disposal (see section 7.1). This approach would exclude products like synthetic fuels, which are burned and release CO_2 during their use, and products like plastics, which can release CO_2 during decomposition or waste incineration.

7 CCS (and CCU)-relevant regulations within current ETSs

Out of the 26 ETSs currently in force, only five have regulations related to CCS or CCU applications: the EU, the UK, Québec, New Zealand, and California. The sections above have provided some insights into their provisions on various aspects of the interaction with CCS applications. This section offers a more cohesive description of the regulations under each of the five systems. It also provides a table with a brief summary of the CCS and CCU relevant provisions found in the 17 selected ETSs currently in force.

7.1. EU ETS

The EU ETS has detailed regulations for the use of CCS applications and is an example of a jurisdiction that enables the point-source capture of fossil energy and industrial emissions (Option B, interacting with fossil energy and industrial emissions inside the scope of the ETS). The EU ETS regulates emissions at source, which means that interactions with fossil energy and industrial emissions point-source capture takes place inside the scope of the ETS. In the EU ETS, point-source emitters can subtract from their compliance obligations the CO_2 originating from fossil carbon in activities covered by the EU ETS that is not emitted from the installation and that is transferred out of the installation for capture and geological storage (see Article 12 paragraph 3a of the EU ETS Directive[64] and Article 49 of the Monitoring and Reporting Regulations[65]). Despite its detailed provisions, however, there are currently no facilities under the EU ETS that are reducing compliance obligations through CCS applications.[66] The CCS Directive[67] provides detailed requirements for the safe geological storage of CO_2. Under current regulations, reductions in compliance obligations are allowed only if the captured CO_2 is stored in a site permitted under the CCS Directive.

The elements of the CCS value chain (capture, transport, and storage) are subject to the scope of application of the EU ETS, as per Annex 1 of the EU ETS Directive.[68] Operational and leakage

[64] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02003L0087-20210101, as of January 2023.
[65] https://eur-lex.europa.eu/eli/reg_impl/2018/2066/2022-01-01, as of January 2023.
[66] The Sleipner and Snøhvit projects have been capturing and storing CO_2 in Norway since 1996 and 2008 respectively; they are supported through the Norwegian carbon tax and other state funds (Global CCS Institute 2020c). The CO_2 captured is not subject to the EU ETS.
[67] https://eur-lex.europa.eu/eli/dir/2009/31/2018-12-24
[68] https://eur-lex.europa.eu/eli/dir/2003/87/2021-01-01. It is worth noting that under the EU ETS Directive and MRV regulation valid as of January 2023, explicit provisions for the transport of CO_2 cover

emissions for activities within the CCS value chain are covered by the legal entities conducting these activities, and MRV provisions for such emissions are contained in the Monitoring and Reporting Regulations. There is also a provision for the monitoring of and liability related to storage to be transferred, under specific conditions, to member states 20 years after a storage site is closed (European Commission 2022a).

Under the current regulations, the EU ETS does not provide incentives for technological removals through BECCS, DACCS or for the biogenic component of WtE with CCS.

As of January 2023, CCU is reflected in the EU ETS only to a very limited extent. CCU is currently not explicitly incentivized under the EU ETS, with one exception. Under the current ETS Directive and MRR, there is no provision to subtract from compliance obligations CO_2 captured and converted into products. The only exception is for CO_2 that is captured and used to produce precipitated calcium carbonate, as per the result of the Schaefer Kalk court case. This is reflected in Article 49 of the MRR, Paragraph 1(b).

The EU ETS is currently undergoing a revision. Commission document 2021/0211(COD), [69] which proposes amendments to the EU ETS, contains several provisions that pertain to CCS and CCU. The European Parliament and the Council of the European Union have adopted proposed amendments[70,71] to the Commission document. As of January 2023, trilogue negotiations have reached a provisional agreement, [72] which is expected to be formally adopted by co-legislators in early 2023. On CCS, the proposed revisions could include a new preambular element which would state that GHGs *"not directly released into the atmosphere should be considered emissions under the EU ETS and allowances should be surrendered for those emissions unless they are stored in a storage site in accordance with [the CCS Directive] (…)"*. This would further specify the conditions that trigger a compliance obligation, enabling EU ETS regulations more discretion to define under what conditions a GHG can be considered to not have been emitted and, consequently, under what conditions regulated entities can be freed from the obligation of surrendering allowances. The proposed amendments could also increase the ETS scope to include all means of CO_2 transport (at the moment, EU ETS provisions refer to transport by pipelines). On CCU, the revision could allow a reduction in compliance obligations *"in respect of emissions of greenhouse gases which are considered to have been captured and utilized to become permanently chemically bound in a product so that they do not enter the atmosphere under normal use and disposal"*.

only transport by pipelines. (For a discussion on this see Hegeland [2020]). The current EU ETS review process (see below) may address this question.

[69] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0551

[70] https://www.europarl.europa.eu/doceo/document/TA-9-2022-06-22_EN.html#sdocta1

[71] https://data.consilium.europa.eu/doc/document/ST-10796-2022-INIT/x/pdf

[72] https://www.europarl.europa.eu/legislative-train/package-fit-for-55/file-revision-of-the-eu-emission-trading-system-(ets)

7.2. UK ETS

The UK ETS incorporates several elements of the EU ETS, including the EU ETS Directive, the EU ETS Monitoring and Reporting Regulation and the CCS Directive.[73] In terms of CCS and CCU regulations, the rules under the UK ETS are the same as those that were valid under the EU ETS as of 2018. The UK ETS employs Option B, interacting with fossil energy and industrial emissions inside the scope of the ETS, although there are currently no facilities covered by the system that are reducing compliance obligations through CCS applications.

As the UK has left the EU, revisions to the EU ETS regulatory documents mentioned above will not apply to the UK ETS. The UK government has been considering the role of CCS applications under the UK ETS, particularly in the context of CO_2 removals. A consultation process by the UK government has invited views and inputs on this issue and is due to be further discussed in 2023.

7.3. Québec Cap-and-Trade System

The Québec Cap-and-Trade System contains some provisions recognizing the use of CCS and CCU and is an example of a jurisdiction under Option B (and interacting with fossil energy and industrial emissions inside the scope of the ETS).[74]

According to section 6.9 of chapter Q-2, r. 15 "Regulation respecting mandatory reporting of certain emissions of contaminants into the atmosphere" (the GHG Reporting Regulation),[75] *"GHG emissions that have been captured, stored, re-used, eliminated or transferred out of the establishment"* are subtracted from the verified emissions of the covered entity. The system therefore contains basic provisions for CCS and CCU. The CCU/CCS sub-part of the emitters' GHG declaration is analysed individually by the province. While the system does not cover any large CCS facility, 4% of large emitters under its remit benefit from CCS/CCU provisions. As the GHG Reporting Regulation does not yet contain specific measurement protocols or methods to calculate the captured and stored, re-used, eliminated or transferred emissions, these calculations are currently done on an ad-hoc basis by individual installations.

[73] The Greenhouse Gas Emissions Trading Scheme Order 2020: https://www.legislation.gov.uk/uksi/2020/1265/made
UK ETS MRV Regulation: https://www.legislation.gov.uk/eur/2018/2066/data.xht?view=snippet&wrap=true

[74] Chapter Q-2, r. 46.1 - Regulation respecting a cap-and-trade system for greenhouse gas emission allowances (Cap-and-Trade Regulation): https://www.legisquebec.gouv.qc.ca/en/document/cr/Q-2,%20r.%2046.1?&target=

[75] Chapter Q-2, r. 15 - Regulation respecting mandatory reporting of certain emissions of contaminants into the atmosphere (GHG Reporting Regulation): https://www.legisquebec.gouv.qc.ca/en/document/cr/Q-2,%20r.%2015

7.4. New Zealand ETS

As described below, New Zealand has provisions for reducing compliance obligations by permanently embedding GHG into a product (which includes some CCU applications) and some provisions for carbon storage (which is relevant for CCS applications). The provisions on carbon storage, however, are not in force. From the point of view of enabling CCS applications, the NZ ETS currently falls under Option A and does not interact with CCS applications. This may change if and when the relevant provisions are enabled and missing MRV requirements are put in place.

The NZ ETS has operational provisions that are relevant for CCU, albeit only in respect of emissions that would have resulted in the surrender of obligations. Even though the NZ ETS has a mechanism for awarding units in respect to "removals" (see note on this below) and some CDR technologies, such as forestry, are covered in the ETS, current regulations do not include incentives for technological removals such as BECCS, DACCS or WtE with CSS. [76]

Under the NZ ETS, provisions relevant to CCU and CCS applications are operationalized through the issuance of "removal units" (see note below on the definition of "removals" under the NZ ETS). Entities engaged in "removal activities" can voluntarily participate in the NZ ETS as per the provisions of Schedule 4 of the Climate Change Response Act[77] and receive New Zealand Units (NZUs). In addition to forestry removal activities, these include:

a) *Producing products.* This includes: producing a product containing a GHG that is permanently embedded; or producing a product containing a GHG that is temporarily embedded and the product is exported with the substance embedded. In both cases, the provisions only apply if an entity would be subject to surrender obligations under the NZ ETS in respect of the emissions that would result if the GHG were not embedded. The Climate Change (Other Removal Activities) Regulations 2009[78] lists the activities and monitoring provisions for them. These are:

    i. producing methanol;

    ii. exporting liquid petroleum gas; and

    iii. producing liquid CO_2 for export.

b) *Storing of CO_2 after capture*, where an entity would be subject to surrender obligations under the NZ ETS in respect of the emissions that would result if the CO_2 were not captured and stored. This provision is not yet in force, and no MRV provisions for it have been put in place. This means that currently, the NZ ETS does not provide incentives for activities that would capture and store CO_2 in the domestic territory.

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[76] It could be possible, however, to add these to the list of eligible activities as long as the removals can be included in New Zealand's target accounting.
[77] https://www.legislation.govt.nz/act/public/2002/0040/latest/DLM1662864.html
[78] https://www.legislation.govt.nz/regulation/public/2009/0284/latest/whole.html#LMS152788

c) Exporting or destroying *hydrofluorocarbons or perfluorocarbons*.

Section 162[79] of the ETS legislation allows the Minister to add to that list of activities. If a DACC activity were close to becoming operational in New Zealand, for example, the Minister could add this to the list above and create the MRV regulations to enable ETS recognition within one year.

"Removals" under the NZ ETS: Under the NZ ETS, removals are defined broadly to include not only carbon dioxide removals, but also emissions reductions (see Climate Change Response Act 2002, Part 1, Item 4 Interpretation,[80] emphasis added):

"removals,—

a) in relation to a removal activity, means carbon dioxide equivalent greenhouse gases that are, as a result of the removal activity,—

*i. **removed** from the atmosphere; or*

*ii. **not released into** the atmosphere; or*

*iii. **a reduction from emissions reported** in—*

(A) New Zealand's annual inventory report under section 32 as required under the Convention or Protocol for any year; or

(B) any emissions report from New Zealand under a successor international agreement; and

b) in Part 1B and the definitions of net accounting emissions and offshore mitigation, means greenhouse gases that are removed from the atmosphere."

This means that under the NZ ETS, the concept of a "removal" is broader than what is often referred to as CDR (see section 2.1), as it also includes emission reduction activities.

Entities performing "removal" activities can either be those mandatorily covered by the NZ ETS, as per Schedule 3 of the Climate Change Response Act,[81] or other entities, meaning multiple legal entities can be involved in the above-mentioned activities.

This flexibility is particularly important because fossil fuels are covered upstream, meaning that energy-related point-source emitters are not under the scope of the (mandatory) application of the NZ ETS. For example, should a coal power plant implement a facility to capture CO_2 and export it as liquid CO_2, it would have to become a voluntary participant under the NZ ETS and issue NZUs to receive an incentive through the NZ ETS. However, if the coal power plant "opted in" to take the NZ ETS compliance obligations off a coal mining company (an option only available for large fossil fuel consumers above certain thresholds), the MRV regulations could be adjusted to ensure the plant

[79] https://www.legislation.govt.nz/act/public/2002/0040/latest/DLM1662739.html
[80] https://www.legislation.govt.nz/act/public/2002/0040/latest/DLM158592.html
[81] https://www.legislation.govt.nz/act/public/2002/0040/latest/DLM1662841.html

only reports and surrenders emission units for its actual emissions. This would negate the need for additional reporting on removals by the plant.

If an entity is a mandatory participant under Schedule 3 and wishes to engage in one of the "removal" activities listed above, it must apply the calculations contained in the Climate Change (Other Removal Activities) Regulations 2009. In this case, the entity's monitoring report or "emissions return" contain an assessment of its liability to surrender units in respect to emissions and entitlement to receive units in respect to removals (see Article 65).[82] As per Article 64A,[83] the transfer of NZUs is done after deducting any NZUs to be surrendered in respect of the entity's compliance obligations.

CCS value chain activities (i.e., capture, transport, and storage activities) are not explicitly covered by the NZ ETS. Persons undertaking "removal activities", such as exporting hydrofluorocarbons or perfluorocarbons, are only entitled to emission units for the GHG actually exported, not those collected and stored prior to export. Because the ETS is designed around an upstream obligation, any downstream, processing, operational or leakage emissions are counted when the potential greenhouse gas emissions are imported, manufactured, or mined.

7.5. California Cap-and-Trade Program

California's Cap-and-Trade Program does not currently recognize CCS or CCU as a means for a covered facility to reduce its emissions and compliance obligations, nor does it have provisions for enabling technological removals. It therefore falls under Option A.

The only CCS-relevant provisions under the California Program relate to the compliance obligations of "suppliers of CO_2". These are, among others, facilities in California that capture CO_2 from production processes, or that extract or produce CO_2 as a byproduct of oil production, and then supply the CO_2 to another entity for use or for geological sequestration. The current CO_2 supplier provisions, however, do not enable a covered facility to reduce its compliance obligations by capturing its CO_2 and supplying it to a sequestration site. Amendments would be required to both the Cap-and-Trade Regulation and MRV requirements to recognize CCS/CCU projects and to allow a covered facility to reduce its compliance obligations by capturing and sequestering or utilizing CO_2.

However, the California Air Resources Board (CARB) has adopted a CCS Protocol,[84] which describes the requirements that transportation fuel producers must meet for a CCS project to be recognized in the Low Carbon Fuel Standard (LCFS)[85] Program. CARB's LCFS Program is a market-based tool for transportation fuel producers that includes credit trading as a potential compliance pathway.

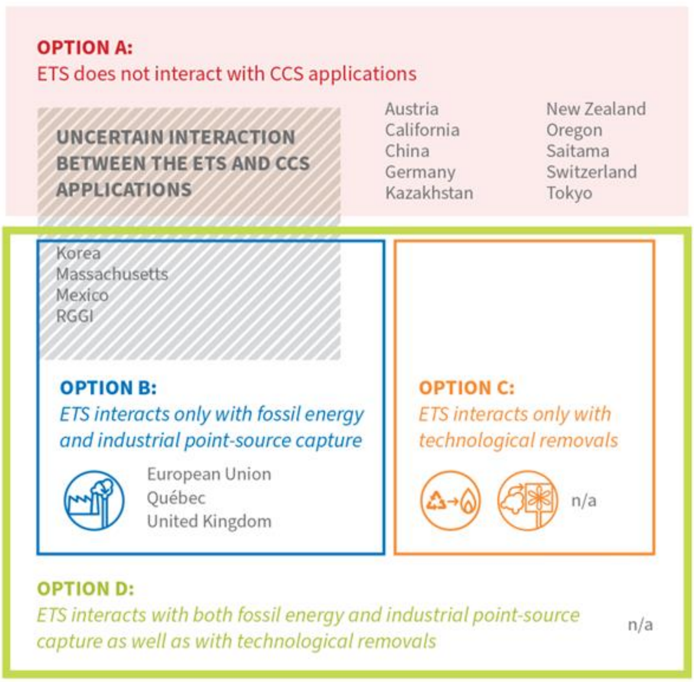
[82] https://www.legislation.govt.nz/act/public/2002/0040/latest/DLM1662495.html
[83] https://www.legislation.govt.nz/act/public/2002/0040/latest/LMS366359.html
[84] https://ww2.arb.ca.gov/resources/documents/carbon-capture-and-sequestration-protocol-under-low-carbon-fuel-standard
[85] https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard

In passing Assembly Bill 1279[86] in August 2022, the California Legislature set targets to achieve statewide carbon neutrality no later than 2045 and to ensure anthropogenic emissions are reduced 85% from 1990 levels by 2045. The legislation requires CARB to identify and implement policies that enable carbon dioxide removal and CCS/CCU projects in California to support the 2045 target. The Legislature also passed Senate Bill 905[87] in August 2022, giving CARB significant authority to establish a Carbon Capture, Removal, Utilization and Storage Program, while prohibiting carbon dioxide injection for EOR (California State 9/26/2022). CARB's 2022 Scoping Plan Update, [88] which lays out how California can achieve statewide carbon neutrality by 2045 reflects the direction on CDR and CCUS from both pieces of legislations. The 2022 Scoping Plan Update will inform potential new measures and updates to existing CARB policies and programmes, and include the CCS Protocol in the Cap-and-Trade Regulation to advance CDR and CCS/CCU in support of California's long-term carbon neutrality goal.

7.6. CCS regulation in selected jurisdictions: Summary

The figure and table below provide a summary of CCS regulations in selected ETSs.

Figure 11 – Interactions between selected ETSs and CCS applications



Source: Authors' elaboration

86 https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB1279
87 https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220SB905
88 https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan/2022-scoping-plan-documents

Table 1 – Summary table of CCS provisions in selected ETSs

Option A – ETS does not interact with CCS applications
• **Austria**: upstream coverage and no possibility to reflect emission reductions from CCS. • **California**: emission reductions from CCS not deductible from ETS covered emissions (but support for CCS projects is provided to transportation fuel producers through another instrument). • **China national**: no mention of CCS and emission reductions from CCS not deductible from ETS covered emissions. • **Germany**: upstream coverage and no possibility to reflect emission reductions from CCS. • **Kazakhstan**: no mention of CCS and emission reductions from CCS not deductible from ETS covered emissions. • **New Zealand**: CCS provisions exist but are not in force, and elements for their operationalization are missing. • **Oregon**: upstream coverage and no possibility to reflect emission reductions from CCS. • **Saitama**: no mention of CCS, and emission reductions from CCS not deductible from ETS covered emissions. • **Switzerland**: no mention of CCS, and emission reductions from CCS not deductible from ETS covered emissions. • **Tokyo**: no mention of CCS, and emission reductions from CCS not deductible from ETS covered emissions.
Unclear interaction between ETS and CCS applications
• **Republic of Korea**: no explicit CCS provision, but continuous monitoring could potentially reflect emission reductions from CCS. Offset provisions could in theory cover CCS-related projects. • **Massachusetts**: no explicit CCS provision, but continuous monitoring could potentially reflect emission reductions from CCS. • **Mexico**: no explicit CCS provision, but continuous monitoring could potentially reflect emission reductions from CCS. • **RGGI**: no explicit CCS provision, but continuous monitoring could potentially reflect emission reductions from CCS.

Option B – ETS interacts (only) with fossil energy and industrial point-source capture
• **European Union**: provides CCS-specific provisions. Emission reductions from CCS are deductible from ETS covered emissions. CCS value chain activities are in the ETS scope. • **United Kingdom**: provides CCS-specific provisions. Emission reductions from CCS are deductible from ETS covered emissions. CCS value chain activities are in the ETS scope. • **Québec**: emission reductions from CCS are deductible from ETS covered emissions, yet technical specifications for this are yet to be developed. CCS value chain activities fall outside the ETS scope.
Option C – ETS interacts (only) with technological removals
n/a
Option D – ETS interacts with both fossil energy and industrial point-source capture as well as with technological removals
n/a

8 Conclusions

Considerations on the interactions between ETSs and CCS (and CCU) are still in their infancy. Of the 26 ETSs in force, only five have any provisions on CCS, only two (the EU ETS and the UK ETS) have detailed provisions, and only one (Québec) has facilities that are reducing compliance obligations through CCS applications.

No empirical data on the interaction between ETSs and CCS is available, and many additional issues and questions are likely to arise as CCS projects materialize and jurisdictions engage with them. The fast pace of innovation and technological development presents a challenge for policy makers, who may have to establish regulatory frameworks that can adapt to changing technological circumstances.

However, as the pipeline of new CCS projects grows, so will the interest and pressure from stakeholders for policy makers to clarify the relationship between these projects and ETSs worldwide. Now is the time for jurisdictions to start grappling with these questions.

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