THE OXFORD INSTITUTE FOR ENERGY STUDIES

April 2024

The Role of Carbon Markets in Enabling Carbon Capture and Storage (CCS)

1. Introduction

The Paris Agreements calls on signatory Parties to '**achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century**, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty'.[1] This balance is often expressed in terms of 'net-zero' of greenhouse gas (GHG) emissions. Net-zero goals recognize the importance of achieving deep reductions in anthropogenic emissions of economic activities, but also that of removing GHGs from the atmosphere. The Paris Agreement also reaffirms the commitment of UNFCCC Parties to conserve and enhance sinks and reservoirs of greenhouse gases.[2]

Carbon Capture and Storage (CCS) and Carbon Capture, Utilization and Storage (CCUS)[3] have long been recognized as key technologies to address climate change and meet net-zero targets across a diverse range of applications. The IEA identifies CCS as one of the decarbonization pillars in addition to energy efficiency, behavioral changes, electrification, renewables, hydrogen and hydrogen-based fuels, and bioenergy.[4] According to the IEA[5], CCS can reduce emissions from existing assets such as fossil fuel-based plants in power generation and industrial facilities; reduce emissions in hard-to-abate sectors; enable the production of low-emission energy sources such as blue hydrogen; and enable carbon dioxide removal (CDR) technologies such as bioenergy with carbon capture and storage (BECCS) and direct air capture with carbon storage (DACCS).[6]

---

[1] UNFCCC (2015), The Paris Agreement, Article 4, Section 1. https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf

[2] UNFCCC (2015), The Paris Agreement. https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf

[3] The IPCC (2018) defined CCS as "a process in which a relatively pure stream of carbon dioxide (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". CCU is defined as a "process in which CO_2 is captured and then used to produce a new product. If the CO_2 is stored in a product for a climate-relevant time horizon, this is referred to as carbon dioxide capture, utilisation and storage (CCUS). Only then, and only combined with CO_2 recently removed from the atmosphere, can CCUS lead to carbon dioxide removal. CCU is sometimes referred to as carbon dioxide capture and use". IPCC, 2018, Special Report on Global Warming of 1.5°C (SR15), https://www.ipcc.ch/sr15/

[4] IEA (2021). Net Zero by 2050 - A Roadmap for the Global Energy Sector.

[5] IEA (2023). World Energy Outlook 2023.

[6] Depending on factors such as the source of emissions and the durability of storage, CCS can either result in emissions reduction or negative emissions. For instance, CO_2 captured from fossil fuels and stored underground counts as an emissions reduction whereas CO_2 captured from biomass or directly from the air and stored permanently counts as CDR.

Energy Insight: 147

Bassam Fattouh, Director, OIES
Hasan Muslemani, Head of Carbon Management Research, OIES
Andrea Maino, Research Fellow, OIES
Paul Zakkour, Director, Carbon Counts

Although oil, gas and coal are projected to fall sharply in most net-zero scenarios, CCS is still expected to play a key role. Leading analysis including the IEA's 'Net Zero Scenario' by 2050 (NZE)[7], the Intergovernmental Panel on Climate Change (IPCC)'s 1.5°C scenarios and the Energy Transition Commission (ETC)[8] all estimate that, by 2050, gigatonne-scale CCUS deployment will be required, with estimates of CO_2 captured ranging from 6.9 $GtCO_2$/year up to 15 $GtCO_2$/year.

Yet, despite this key role, financing and scaling of CCUS projects has, to date, proved challenging for governments and the private sector alike. According to the IEA's CCS tracker[9], the total annual carbon capture capacity in 2023 amounted to only 44 $MtCO_2$ – far below what is needed to be on track to deliver on its promised potential in climate change mitigation.

This paper examines the challenges and opportunities of making CCS an economically viable decarbonization solution through one of the most prominent financing vehicles for low-carbon projects, that is carbon markets. Carbon markets represent an important mechanism to achieve international cooperation, reduce marginal costs of abatement, and provide incentives for players in the form of subsidies, taxation and/or valuation of carbon sinks.[10] Specifically, we evaluate the treatment of CCS under different carbon market-based crediting programmes.

The paper is divided into four sections. Section 2 provides an overview of the development of CCS crediting programmes and methodologies. Section 3 discusses the integration of CCS within carbon markets, with focus on emission trading schemes (ETS), voluntary carbon markets (VCM), and Article 6 of the Paris Agreement. Section 4 highlights the limited role of carbon markets in financing CCS projects and evaluates other non-market mechanisms that can help support their deployment, while Section 5 concludes.

2. CCS and Crediting Programmes

There are various forms of market instruments that could be used to support the deployment of CCS.[11] One such mechanism is crediting programmes that enable CCS project developers to generate carbon credits for emissions reductions or carbon removals (where the CO_2 is captured from biogenic sources or directly from the air). These units can then be traded in carbon markets to allow various participants to fulfil certain obligations (under compliance markets) or to meet voluntary objectives such as carbon neutrality or other climate-related claims (under the voluntary carbon market) or for governments to meet their climate targets and nationally determined contributions (NDCs).[12]

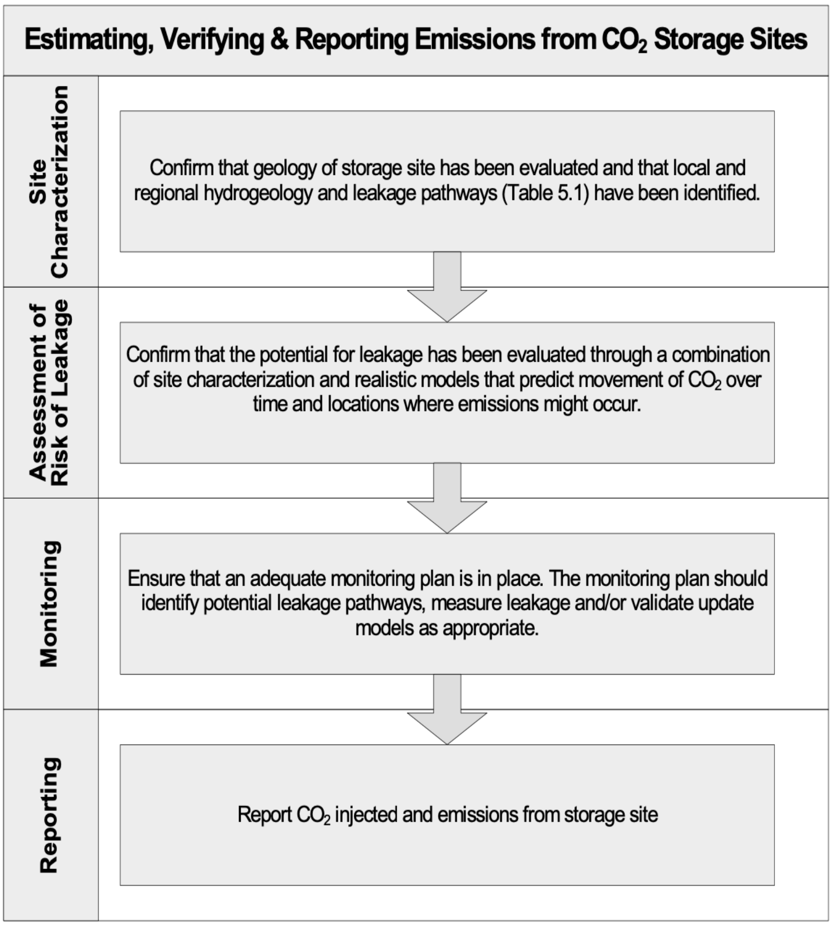
To date, there are only a few jurisdictions that allow reduction or removal credits to be surrendered to meet compliance obligations or carbon tax payments. Examples include Colombia, Korea, Alberta, Quebec, Mexico, and California. In California, for instance, carbon credits generated under specific voluntary carbon credit schemes can be used against companies' compliance obligations under the California ETS. Carbon credits can also be transferred from government to government, in the past under the Kyoto flexibility mechanisms and currently under Article 6 of the Paris Agreement.

CCS is recognized in the UNFCCC and was previously included in the Kyoto Protocol as a mitigation technology, including within its crediting programmes. Following many years of international negotiations, frameworks and guidelines were put in place to include CCS projects in the Clean

[7] IEA (2021), Net Zero by 2050: A Roadmap for the Global Energy Sector.
[8] ETC (2022) estimates that DAC and BECC when combined with permanent storage result in 2.6 Gt of carbon dioxide removals. ETC (2022), Carbon Capture, Utilisation & Storage in the Energy Transition: Vital but Limited, July 2022, https://www.energy-transitions.org/wp-content/uploads/2022/07/ETC-CCUS_Executive-Summary_final.pdf
[9] https://www.iea.org/reports/carbon-capture-utilisation-and-storage-2
[10] Hauman, H., Fattouh, B., Muslemani, H. (2023). The creation of a global carbon market: A taxonomy of carbon pricing under Article 6. Oxford Institute for Energy Studies, Energy Insight 136, Oxford.
[11] Fattouh, B., Muslemani, H., & Jewad, R. (2024). Capture Carbon, Capture Value: An Overview of CCS Business Models. Oxford Institute for Energy Studies, Paper CM08, Oxford.
[12] Hauman, H., Fattouh, B., Muslemani, H. (2023). The creation of a global carbon market: A taxonomy of carbon pricing under Article 6. Oxford Institute for Energy Studies, Energy Insight 136, Oxford.

Development Mechanism (CDM) via agreement on the 'Modalities and Procedures for CCS as Clean Development Mechanism Project Activities' (referred to as CCS M&P) at COP17 in 2011.[13] Parties deploying CCS should measure and report these activities in line with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories[14] which provides a comprehensive methodology for CCS along the entire supply chain (capture, transport of CO_2 and geological storage) and includes requirements for site characterization, assessment of risk of leakage, monitoring, and reporting (Figure 1).

Figure 1: CCS and Carbon Removals. Procedures for estimating emissions from CO_2 storage sites



Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Chapter 5: Carbon Dioxide Transport, Injection and Geological Storage.

Requirements laid out in the 2006 IPCC Guidelines are also reflected in the CCS CDM modalities and the procedures, ensuring that CCS projects fulfil a set of criteria that are compatible with carbon markets funding. These requirements recognize the unique nature of CCS projects, as summarised in Table 1 below.

In the context of Article 6 of the Paris Agreement, as discussed later, uncertainty remains over the possibility to generate emission reductions from CCS projects in respect of whether the Supervisory Body (SB) will adopt, build upon or amend the UNFCCC modalities and procedures for CCS as CDM project activities under the Kyoto Protocol.

---

13 Dixon, T. Leamon, G., Zakkour, P., Warren, L. (2013), CCS Projects as Kyoto Protocol CDM Activities, Energy Procedia, Volume 37, 2013, Pages 7596-7604.

14 IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories.

Table 1: Summary of detailed technical requirements of modalities and procedures (CCS M&P) adopted by Executive Board under the CDM

Category	Description	Key Points
Host country participation requirements	Host countries need to establish regulations and legal frameworks functional to monitoring and permitting CCS projects within their jurisdiction.	1. Regulations and legal frameworks 2. Site selection and development 3. Financial provisions 4. Liability provisions 5. 'Net reversal of storage' issues
Validation and verification process	Before approval by the CDM Executive Board, CCS projects must undergo a validation and verification process by qualified external verifiers.	Impact assessment covering site characterization, risk and safety assessment, environmental and socio-economic impact. Confirmation by Designated National Authority (DNA).
New definitions pertinent to CCS as CDM project activities	Several definitions within the modalities and procedures are specific to CCS projects.	Includes 'Seepage' and 'Net Reversal of Storage' among others, with specific guidelines and monitoring requirements.
Monitoring, verification and crediting	CCS projects as CDM activities are subject to two phases of verification.	1. First phase during CO_2 injection (up to 7 years, renewable for 14 years). 2. Second phase after the last crediting period till the end of monitoring for net reversal of storage.
Liability	Liability is separated between the non-performance of the storage site and any local damages resulting from the site facility.	1. Legal framework of the host countries. 2. Transfer of liability from project participants to the host country after a specified period.

Source: Dixon et al. (2013)[15], IPCC (2006)[16]

[15] Dixon, T. Leamon, G., Zakkour, P., Warren, L. (2013), CCS Projects as Kyoto Protocol CDM Activities, Energy Procedia, Volume 37, 2013, Pages 7596-7604.
[16] IPCC, 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

2.1 CCS Methodologies

The development of robust methodologies is pivotal for integrating CCS into the new crediting programmes and carbon markets of the Paris Agreement. Methodologies are needed to ensure quality and accuracy of monitoring data, credibility of the crediting baseline, and whether impacts are accurately quantified using conservative and transparent methodologies which also account for potential leakage and reversals, permanence and avoid double counting.

To support these concepts, IETA[17] proposed high-level criteria for crediting carbon geo-storage activities which include two parts: methodological components and safeguards. Methodological components include applicability conditions, project boundary and leakage, baseline, additionality, non-permanence and liability, and monitoring (Table 2). Safeguards include political acceptability (which includes public acceptability and alignment with national development priorities and policy aims), the legal and regulatory framework (which includes the legal basis for injection and storage, effective site selection, robust oversight of site operations and closure, and liability for carbon removal) and environmental and social safeguards (which include sustainability, safety, and environmental and social impacts).

Table 2: Methodological Components for Crediting Carbon Geo-Storage Activities

Methodological component	Description
Applicability conditions	Defines the specific circumstances, attributes and other conditions that apply to eligible geological CO_2 storage activities. These can include the eligible sources of captured CO_2 (e.g. which types of CO_2 and from which sectors, both of which have implications for baseline selection; see below), the modes of transport, and the allowable storage media. Geographical and technical restrictions can also be applied (e.g. only countries with CCS laws; conditions on geostorage development/operations).
Project boundary & leakage	Defines the emissions by sources and removals by sinks that must be measured and accounted for across the capture>transport>storage chain (project boundary). Includes emissions occurring outside of the immediate control of the project operator (e.g. upstream emissions), but which are measurable and attributable to the project activity (i.e. 'leakage').
Baseline	Describes procedures and options to establish the baseline scenario and a methodology for calculating baseline emissions. The emissions from the project activity must be compared to the baseline to quantify the net emission reductions or carbon removals. Options include projection-based approaches (e.g. historical emissions, or estimated future emissions, without CO_2 capture) or standards-based

[17] IETA (2022). High level criteria for crediting carbon geo-storage activities.

	approaches (e.g. using benchmark emissions of a comparable activity without CO_2 capture)
Additionality	Demonstration that the activity delivers emissions reductions/removals that would not have occurred absent of the incentive created by carbon credit revenues. Different approaches and tests exist for demonstrating additionality (e.g. first-of-a-kind (FOAK); regulatory surplus; financial additionality). The primary purpose of CO_2 capture is climate mitigation, which generally means that most projects will be additional. Novelty also means that FOAK or technology penetration rates can be used to rapidly demonstrate project additionality. Financial additionality testing may also be used to discern the value of crediting where other incentives (e.g. tax breaks) or benefits also exist (e.g. commercial CO_2 utilization).
Non-permanence & liability	Methodologies should ensure that geological storage sites are appropriately characterized, selected, developed, managed and closed level to mitigate against the risk of carbon reversals (quality assurance). Liability to remedy the impacts of any carbon reversals must also be allocated (liability allocation). These safeguards can be implemented either by applying geographical applicability conditions (i.e. relying on local laws and regulations) and/or through other effective safeguards
Monitoring	Robust monitoring is needed to measure flows and emissions related to aboveground features of the activity and to check for CO_2 leaks in around the storage site. Results of monitoring are used to (i) quantify creditable reductions or removals and (ii) protect natural ecosystems and human health. The latter safeguard can be implemented either by applying geographical applicability conditions (i.e. relying on safety monitoring under local laws and regulations) and/or through other effective safeguards.

Source: IETA (2022)[18]

Methodologies can be developed independently, nationally, bilaterally, and/or internationally and linked to carbon pricing frameworks, crediting schemes, or subsidy/support schemes. Independent methodologies are mainly developed for the voluntary carbon market (VCM) but can also be adopted in national compliance markets. The VCM relies on its own ecosystem of standards and certification organizations, project developers, and verifiers to certify emission reductions and removals that are ‘real, measurable, and additional’.

[18] IETA (2022). High-level criteria for crediting carbon geo-storage activities.

Independent Methodologies

As far as CCS is concerned, many organizations have developed and continue to develop their own methodologies. Examples include the CCS+ Initiative which aims at developing carbon reduction and carbon removals methodologies and the Geologic Carbon Storage (GCS) requirements under Verra's Verified Carbon Standard (VCS) programme which contain specific details about monitoring, closure, non-permanence risk, and a pooled buffer account that holds a percentage of funds in case of CO_2 reversal; ACR has developed protocols and tools for GHG accounting including methodologies on the capture, transportation, and storage of anthropogenic CO_2. ACR is planning updates to its methodology to expand point source eligibility to include CDR projects such as direct air capture, and geologic storage options such as saline formations and depleted oil and gas reservoirs and projects that utilize CO_2 for Enhanced Oil Recovery (EOR). Most recently, the Global Carbon Council (GCC) launched a CCS methodology which represents a global framework in the voluntary carbon market for point source emissions, including guidance covering aspects such as site selection, environmental impacts assessment and monitoring requirements. The methodology also offers mechanisms to ensure conservative estimation of emission reduction and provides guidance for projects in regions without specific CCS regulations.[19]

National Methodologies

Methodologies for CCS could also be developed at the national level. An example is Australia's Emission Reduction Fund (ERF). The Australian Government's first Low Emissions Technology Statement identified CCS as one of the country's priority low emissions technologies and the ERF allows project developers that capture and store carbon permanently to issue credits known as Australian carbon credit units (ACCUs). ACCUs can be sold to the Australian Government, or to companies, state governments and other private buyers. The Australian Government has developed its CCS specific legislation and methodologies which include elements such as the net abatement calculation, reporting and monitoring requirements and procedures to address the longer-term risk of CO_2 reversal.

Sub-National Methodologies

Methodologies could also be established at the subnational level. An example is California's Low Carbon Fuel Standard (LCFS)[20] which introduced a CCS Protocol in 2019. The Protocol allows the issuance of credits for the reduction in lifecycle emissions of transportation fuels through CCS applications after the reductions are verified. It was developed as a trading mechanism with the purpose of lowering the CO_2 intensity of California's fuel mix. Under the Protocol, transportation fuels that have reduced lifecycle emissions through CCS applications become eligible for credits once these reductions are verified. Both new and existing CCS projects are eligible under the Protocol, provided they meet certain requirements for permanence. Interestingly, the LCFS allows for both the capture facility and the storage operator to be co-applicants.[21] Another example at the subnational level is Alberta's Quantification Protocol for CO_2 capture and permanent storage in deep saline aquifers.[22] Based on this Protocol, CCS project developers can generate emissions offset credits under the Alberta Emission Offset Scheme (AEOS) that can be retired in the compliance market known as the Technology Innovation and Emissions Reduction (TIER) regulation.[23]

---

[19] https://www.globalcarboncouncil.com/wp-content/uploads/2024/04/GCCM006-v1.1.pdf

[20] This protocol is an integral part of the LCFS, a program designed to reduce the carbon intensity of California's transportation fuel pool and promote low-carbon and renewable fuel alternatives: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/about

[21] https://ww2.arb.ca.gov/resources/documents/carbon-capture-and-sequestration-protocol-under-low-carbon-fuel-standard

[22] Quantification Protocol for CO_2 Capture and Permanent Storage in Deep Saline Aquifers: https://open.alberta.ca/dataset/73895a97-2e8b-4870-a1bc-0faece4ff896/resource/5461945c-8781-44b0-96be-020e5bbcd98f/download/quantificationprotocolCO2-jun23-2015.pdf

[23] https://www.aer.ca/providing-information/by-topic/carbon-capture

3. CCS Integration into Carbon Markets

Ensuring the development of robust methodologies for CCS is especially important for their integration into carbon markets. This section examines the potential for compliance markets (emission trading systems – ETSs), the voluntary carbon market (VCM) and Article 6 to finance CCS projects.

3.1 CCS and Emission Trading Systems

CCS project development can be incentivized in jurisdictions where ETSs are in place. An ETS is a 'cap-and-trade' scheme which places a limit on the total amount of GHG emissions that covered activities can emit, normally expressed as emission allowances or 'permits' (where an allowance corresponds to one tonne of CO_2). Within a certain commitment period, the operator must surrender enough allowances to account for its emissions or face a penalty. Allowances can be acquired by operators through free allocations or auctions by the scheme operators (e.g. government) and/or via subsequent carbon market trading.

There are different forms in which CCS can be incorporated within the scope of an ETS. In the most common form, such as in the UK ETS and EU ETS, a tonne of CO_2 captured and safely stored away is considered as 'not emitted', and the operator is thus absolved of the obligation to surrender emission allowances.

At its inception in 2005, the EU ETS Directive did not include CCS, but through various opt-in provisions, subsequent inclusion of capture, transport, and storage installations was integrated from 2010 onwards.[24] The ETS Directive has developed rules for the monitoring and reporting of GHG emissions presently referred to as the Monitoring and Reporting Regulation (MRR; Regulation 2018/2066). The MRR establishes the compliance procedures and includes reporting and monitoring requirements for installations, including CCS components.[25] Key to inclusion of CCS within the EU ETS was the establishment of the CCS Directive (2009/31/EC) setting out a regulatory framework for safe geological storage of CO_2. The CCS Directive underpins the MRR by covering areas such as the selection of storage sites and exploration permits, storage permits, obligations for operating, closing storage sites, and third-party access.

ETSs are generally technologically-agnostic, i.e., operators can claim emission reductions by adopting different emission reduction approaches. It follows that the decision by an operator as to whether to reduce emissions, regardless of choice of abatement technology, will in part depend on cost: if allowance prices reach the level of the operator's abatement costs, the operator will simply implement new abatement technologies such as CCS. In turn, the revenue from selling unused carbon allowances and/or savings from not having to buy them would cover the technology's operational expenses.

The historical levels of allowance prices and their volatility has resulted in no CCS project being fully financed through an ETS business model alone. More recently, the EU ETS (commanding the highest carbon price amongst other ETSs) reached a record carbon price of €100/tCO_2 in February 2023, yet the cost of CCS in most applications remains higher (Figure 2). Moreover, due to the capital-intensive nature of CCS projects, scaling the technology will require attracting private capital, which involves offering attractive returns over the projects' lifetime (20 years or more) to compensate investors for risk. Thus, allowance prices must offer a substantial return premium over abatement costs to achieve attractive levels of internal rate of return (IRR). The authors estimate the target level of allowance prices to incentivize mass adoption of CCS in Europe to be in the range of €150-160/t[26], which is around 50%

[24] Currently, carbon removals are not part of the ETS but their potential inclusion is will be considered by 2026.

[25] MRR deals partially with CCU where the CO_2 converted into products must be reported.

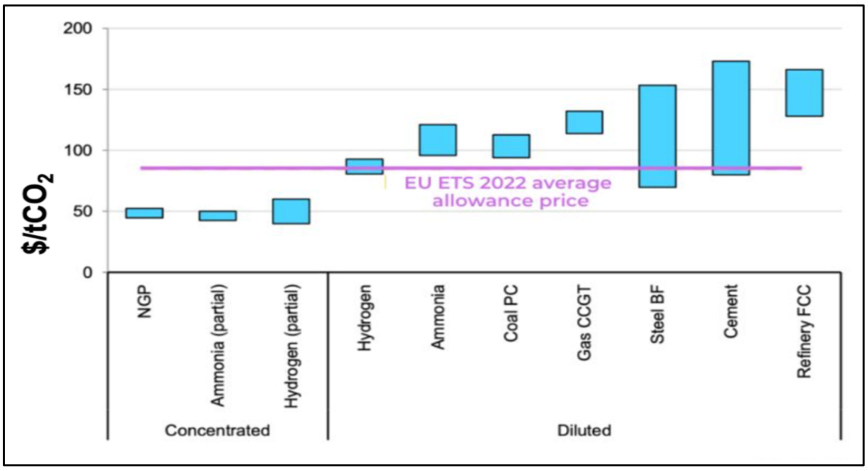
[26] Target EU allowance price calculations based on an average levelized abatement cost of €120/t across industries (based on Clean Air Task Force/Carbon Limits data). A 12% required return on investment is assumed for projects of this nature (based on assumptions by the US National Petroleum Council). An additional 10% price risk premium is added to account for volatility in the carbon price, and to assure decision-makers that even in adverse price trajectories, revenue from the project would be enough to meet stated IRR goals.

higher than the record price of €100/t, and more than double that of current levels (€63/t as of April 8 2024).[27]

Enhancing price stability is an important factor in fostering CCS deployment. Yet, price volatility coupled to the long permitting process that CCS projects undergo (currently averaging 6-7 years)[28], may continue to deter operators and private investors from adopting the technology as a decarbonization solution, at least in the short term.

Another issue pertinent to carbon pricing in the context of CCS is that current mechanisms tend to generate revenues for one part of the supply chain (the entity that captures the CO_2 and reduces emissions). This creates risks for other parts of the supply chain (transport and storage). One way to reduce risks is to disaggregate the incentives for capture, transport, and storage components of the CCS technology chain. This allows different market actors with different strengths and risk appetites to collaborate on CCS and to allocate risks more broadly across the chain.

Figure 2: Costs of CCS in different industries and applications (calculated with T&S costs of 30 $/tCO$_2$)



Source: IEA (2023)[29]

As far as CCS developments in Europe (and hence under the EU ETS) go, the potential for cross-border transport and storage of CO_2 is an issue that is highly relevant. Many EU Member States with high emissions do not have the required geological capacity for CO_2 storage (be it onshore or offshore), where CO_2 needs to be exported to regions with abundant storage capacities. It was not until recently that bilateral agreements for transporting CO_2 across European borders have been struck between countries, including Germany's and the Netherlands' agreement with Norway to transport and store CO_2 in the Norwegian continental shelf of the North Sea.[30] However, a more comprehensive set of cross-border regulations is needed to ensure streamlining of European CCS projects development. Outside Europe, some ETSs do not cover the entire CCS value chain; for instance, in the California ETS, CO_2 suppliers (entities capturing CO_2) are covered in the ETS's scope, but not the transport and geological storage components; under the New Zealand ETS, there are provisions for CCS but they are not currently in force.[31]

In parallel, regulatory steps have been taken by the European Commission through its Net-Zero Industrial Act (NZIA) to set a target for availability of CO_2 storage capacity of 50 Mt by 2030 on a

[27] https://carboncredits.com/carbon-prices-today/

[28] Society of Petroleum Engineers (2022). State-level permitting primacy may boost CCS. Available at: https://jpt.spe.org/state-level-permitting-primacy-may-boost-carbon-capture-and-storage

[29] IEA (2023). CCUS policies and business models.

[30] IEAGHG (2022). World's first commercial pact on cross-border CO_2 transport and storage.

[31] International Carbon Action Partnership (2023). Emissions Trading Systems and Carbon Capture and Storage: Mapping possible interactions, considerations and existing provisions.

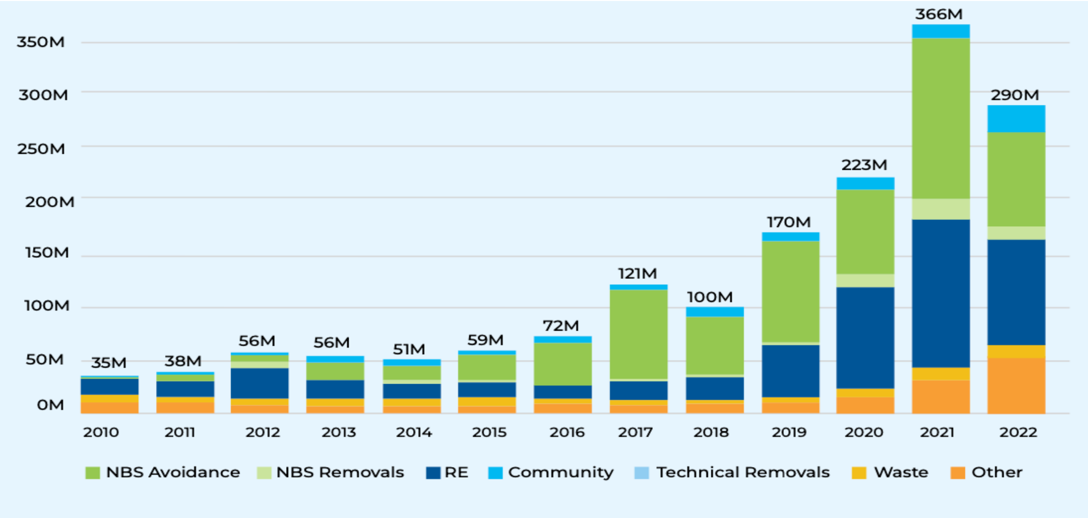
continental level.[32] This was later complemented in the EU Industrial Carbon Management Strategy with 2040 and 2050 targets of 280 $MtCO_2$ and up to 450 $MtCO_2$ captured per year, respectively. This is expected to provide higher investor confidence that the CO_2 captured will have an eventual storage outlet. Based on the current projects pipeline, the IEA forecasts that by 2030 around 70 $MtCO_2$ will be captured per year in Europe.[33] It is worth highlighting that, while realistic, the above storage target is a capacity-based one, encouraging the development of storage sites without a specific economic incentive for storing CO_2. Moreover, these figures represent a small part of the total volume of capturable CO_2 in Europe, estimated at 1,260Mt per year.[34]

3.2 CCS and Voluntary Carbon Markets

CCS projects can, in principle, be supported through the VCM. However, projects face several issues when it comes to the VCM, some of which are specific to CCS as a mitigation technology, as discussed earlier, and others which are more broadly relevant to the VCM as a climate financing tool.

For instance, the VCM remains relatively small in size compared to other climate finance mechanisms, with a value estimated at $2bn in 2022; compared to the aggregate size of compliance markets which is estimated at $850bn.[35] For perspective, a typical 1Mt/y capture project alone could cost in the range of +$1bn.[36] In addition, the makeup of the VCM so far has been geared towards activities such as renewable energy and emission reductions from nature-based solutions (NbS) such as avoided deforestation and degradation projects, which continue to dominate the market. Tech-based solutions such as CCS and carbon removals represent a very small fraction of credit supply (Figure 3). Moreover, prices in the VCM remain too low to render any CCS projects economically viable: while carbon credit prices can vary considerably, the bulk of issued carbon credits fell to single-digit figures recently (to around $1 for renewable energies and $5 for NbS solutions).[37]

Figure 3: Issuance of carbon credits by project type (2010-2022)



Source: Verra, Gold Standard, ACR and CAR.

---

[32] European Commission (2023). Net-Zero Industry Act: Making the EU the home of clean technologies manufacturing and green jobs.
[33] IEA, "Carbon Capture, Utilisation and Storage", Sep 2022, https://www.iea.org/reports/carbon-capture-utilisation-and-storage-2
[34] Clean Air Task Force (2023). The cost of CCS in Europe.
[35] Bonzanni and Diemert (2023). Challenges and opportunities for growth in the VCM: An overview. In Oxford Energy Forum (OEF) issue 138, Oxford Institute for Energy Studies, Oxford.
[36] Power Magazine (2023). PetraNova, pioneering power plant carbon capture unit, is up and running again, says JX Nippon.
[37] S&P Global (2024). Commodities 2024: Price slump in 2023 clouds outlook for voluntary carbon market.

That said, while overall issuance of carbon credits from technological solutions has been negligible, it may be surprising that some of the largest projects by issuance volume historically have been CCS-based, and were operational as early as 2000s. These include projects in the US states of Texas and Wyoming where credits were issued and registered with the ACR (project IDs: ACR117, ACR121 and ACR123).[38]

Yet, with increasing focus on quality and integrity in today's market, CCS-based credits may be subject to scrutiny. For example, in the case of the mentioned projects, waste CO_2 was captured and used for the purpose of EOR, a practice which many argue would ultimately lead to increased emissions, or 'leakage'. Here we highlight a few issues pertinent to CCS projects in the context of the voluntary carbon market, regardless of the fate of the captured CO_2 (i.e., permanent geological storage vs EOR/utilization).

First, in today's VCM, projects must pass increasingly stringent additionality tests, as required by leading credit quality frameworks including the recently published ICVCM's Core Carbon Principles (CCPs).[39] Additionality can be evaluated in multiple ways but at its core, it requires that revenue from the sale of carbon credits be requisite to the economic case of a climate mitigation project; put differently, the project should not have been viable in the absence of credit sale revenue. A project can also be additional if it is a first-of-its-kind in the applicable geographical area or is not considered common practice at the time of implementation[40], or if it were not going to be deployed anyway due to change in policy (e.g., new CCS deployment mandates on emitters).

For the aforementioned projects, additionality cannot be ascertained, as CCS-EOR has been a common practice in the named US states since the 1970s and the projects were economically viable before credit sales. In today's CCS landscape, where many projects are expected to be coupled with permanent storage rather than EOR, developers would benefit from different streams of financial support, be it through tax relief (e.g. in the US, Canada), a carbon contract-for-difference (CCfD)-type mechanism (e.g. UK, Netherlands), or strong direct financial support from government (e.g. Norway) which may not justify further sale of carbon credits. In fact, in its recently established CCS business models, the UK Government does not allow for stacking of revenue from sale of voluntary non-compliance carbon credits with revenue provided under its Industrial Carbon Capture (ICC) contracts.[41][42]

Second, as highlighted in Section 2.1, carbon crediting requires a baseline scenario to be established (i.e., what emissions would occur in the absence of the project) which remains difficult to estimate and would depend on multiple variables. These include potential changes in policy or in the makeup of the grid powering the project (which impacts the emissions factor against which reductions are calculated). This would also bring into question issues of activity shifting leakage and perverse incentives, for if the incentive to capture and store CO_2 is high enough, it may deter emitters from reducing CO_2 emissions through other means in order to sustain the economic viability of the project.

This speaks to a third key point, that is the public acceptance of CCS as a legitimate abatement solution. This is especially relevant in the VCM where demand is voluntary and is driven by buyer preferences for specific abatement pathways. Yet scepticism about the role of CCS in mitigating climate change, citing factors such as high costs, technical viability, and fears around the safety and permanence of storage may act as deterrents. Perhaps more critically, some potential buyers may consider that CCS

---

[38] Based on the voluntary registry offsets database (updated as of November 2023) provided by the Goldman School of Public Policy: https://gspp.berkeley.edu/

[39] https://icvcm.org/the-core-carbon-principles/

[40] Carbon Market Watch (2012). First-of-its-kind and common practice.

[41] UK BEIS (now DESNZ) (2022). Carbon Capture, Usage and Storage – Industrial carbon capture business models summary: 'Under the UK ICC business models, a 90% deduction of the gross revenues generated from the sale of voluntary non-compliance carbon market credits will be made from the subsidy payment each month. The gross revenues will be self-reported on an open book basis. The 10% of the gross revenues retained by the Emitter are expected to cover the costs of participation and related reporting/admin costs within the voluntary non-compliance carbon markets'.

[42] The US allows stacking of tax credits under 45Q with VCM credits.

perpetuates the continued use of fossil fuels and thus discourages change in societal behavior and reinforces existing dependencies, providing a social license to operate for high emitters. It is also argued that CCS could divert funds away from clean technologies.[43]

Fourth, the voluntary carbon market is experiencing an increasing shift towards procuring carbon removal solutions over avoidance/reduction credits (such as CCS on point sources) aligned to net-zero aspirations. Specifically, frameworks such as the Science-based Targets Initiative (SBTi), the ICVCM's CCPs, the VCMI's Claims Code of Practice, and the newly-revised Oxford Offsetting Principles[44], all emphasize the need to rely on (durable) carbon removal solutions to offset residual emissions. This is expected to increase demand for these solutions – however scarce their supply may be today – while lowering demand for other reduction-based solutions such as CCS on fossil-based energy and/or industrial facilities. From a buyer's perspective, therefore, there is a clear market signal that reduction credits will be regarded as lower value than removals, which in turn is expected to further lower the price they can command in the market.

Fifth, the impacts of Article 6 on the development of the VCM, as highlighted in the following section, remains a major source of uncertainty where a question of fungibility of credits issued by and transacted within various carbon crediting programmes is brought to light. Some are of the view that there is a need to align VCM rules with the Paris Agreement and for registries such as Gold Standard and Verra to align their methodologies and rules with Article 6's rulebook (for instance, on approaches on how to set baselines and assess additionality as noted above).[45] In fact, Gold Standard and Verra have already applied Article 6 authorized labels to credits issued in their registries, including from cookstove projects in Rwanda[46] and Malawi[47], where corresponding adjustments (CAs) would be applied.

3.3 CCS and Article 6 of the Paris Agreement

At COP 26, Parties finalized the Article 6 Rulebook, a market-based mechanism which sets the rules for international cooperation and trading of certified emission reductions, forming the basis of global carbon markets.[48] A study conducted by IETA shows that establishing market-based mechanism for emission trading at international level under Article 6 would reduce the cost of achieving emissions reduction compared to a scenario when all parties implement their NDCs independently (more than $300 billion a year in 2030) and the savings could be reinvested to increase ambition. The market value of financial flows between countries could exceed $1 trillion per year in 2050.[49]

As stated earlier, CCS projects have been eligible under the CDM since 2012 following COP 17.[50] However, there were no CCS projects registered under the CDM.[51] Most of the funding for CCS projects

[43] Lazarus, M., and van Asselt, H. (2018), 'Fossil fuel supply and climate policy: exploring the road less taken' Climatic Change 150: 1-13; Parmiter, P. & Bell, R. (2020). Public perception of CCS: A review of public engagement for CCS projects. 2nd Report of the Thematic Working Group on: Policy, regulation and public perception, EU CCUS PROJECTS NETWORK.

[44] https://www.smithschool.ox.ac.uk/sites/default/files/2024-02/Oxford-Principles-for-Net-Zero-Aligned-Carbon-Offsetting-revised-2024.pdf

[45] See Fattouh, B. & Maino, A. (2022). Article 6 and Voluntary Carbon Markets. Oxford Institute for Energy Studies, Energy Insight 114, Oxford: OIES.

[46] https://verra.org/program-notice/verra-announces-first-issuance-of-article-6-authorized-labels-for-cookstove-project-in-rwanda/

[47] https://www.qcintel.com/carbon/article/malawi-is-second-country-to-issue-a6-authorisation-for-vcm-credits-19733.html

[48] See Fattouh, B. & Maino, A. (2022). Article 6 and Voluntary Carbon Markets. Oxford Institute for Energy Studies, Energy Insight 114, Oxford: OIES.

[49] IETA (2021). The Potential Role of Article 6 Compatible Carbon Markets in Reaching Net-Zero.

[50] https://cdm.unfccc.int/about/ccs/index.html

[51] In 2008, the ACR methodology applied to CCS with Enhanced Oil Recovery (EOR) was halted and projects were no longer able to generate carbon credits (Sylvera, 2023). Problems included not accounting for the increase in carbon footprint associated with the increase in oil production, lack of evidence of additionality, over-crediting, and lack of third-party data and sufficient granularity.

to date has been achieved through a combination of non-market mechanisms such as direct government support and government subsidies.[52]

Article 6.2 establishes a framework in which Parties can engage in bilateral or multilateral agreements to implement and trade GHG emission reductions by issuing and transferring internationally transferred mitigation outcomes (ITMOs) to help them achieve their NDCs.[53] ITMOs can be transferred from the credit-generating country (often referred to as the Host Country) where the reduction in GHG is achieved and can be used in several ways; they can be:

- Transferred to credit-buying countries (often referred to as the Receiving Countries) towards achieving their NDCs;
- Transferred and used in market-based schemes such as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) (referred to as 'other international mitigation purposes'); or
- Transferred and used by companies to offset their emissions (referred to as 'other purposes').

Article 6.2 promotes a bottom-up approach in which Parties are allowed to approve their own methodologies and decide on key aspects such as quantification, monitoring, verification, and authorization of emission reductions or removals. Under Article 6.2, countries can engage in agreements to implement and trade emission reductions from CCS projects. This requires that Parties develop and adopt CCS methodologies that follows Paris Agreement guidelines on cooperative approaches (e.g., ensuring that there is no double counting through applying CAs). For instance, Japan has included CCS in its Joint Crediting Mechanism (JCM) and has been developing CCS methodologies including guidelines on detecting CO_2 leakage, and the establishment of a credit reserve account which allows for the cancelation of credits if CO_2 leakage is detected. Through the JCM, Japan and Indonesia are working towards realizing a CCUS demonstration project.[54]

A second type of crediting mechanism is the one under Article 6.4 of the Paris Agreement. Article 6.4 Emission Reductions (AR6.4 ERs) will be generated from a centralized mechanism (referred to as the 'Mechanism'). The Mechanism is governed directly by the UNFCCC for the authorization and issuance of ERs similar to the CDM credits under the Kyoto Protocol.[55] Management of the Mechanism lies firstly with the Supervisory Board (SB), which is responsible for operationalizing the 6.4 mechanism, e.g., by approving methodologies, setting guidance and implementing procedures, etc.

In principle, the crediting mechanism under Article 6.4 could unlock the potential for CCS by allowing countries and corporations to trade emissions reductions based on the development of CCS projects. Capturing and storing CO_2 can result in emissions reductions and countries can use these either towards meeting their NDCs or trade in the form of ITMOs under Article 6, a key element of which is avoiding double counting. However, financing CCS projects through Article 6.4 could face similar challenges to the CDM and the VCM when it comes to many applications of CCS. Moreover, the appetite for countries or corporations to purchase credits generated by CCS projects may be limited and could be restricted to a small group of like-minded buyers and investors, as discussed in the following section. Also, the availability of such credits for trade could be constrained as CCS projects may be essential for many countries to meet their NDCs.

[52] Fattouh, B.; Muslemani, H.; & Jewad, R. (2024). Capture Carbon, Capture Value: An Overview of CCS Business Models. Oxford Institute for Energy Studies, Paper CM08, Oxford: OIES.

[53] UNFCCC (2022). 'Draft recommendation. Recommendations for activities involving removals under the Article 6.4 mechanism'.

[54] Kyodo news (2020). Japan firms to demonstrate underground CO_2 storage in Indonesia.

[55] The CDM is considered as the first global credit scheme for emission reduction units (often referred as CER credits) and represent a one tonne of CO_2eq emission reduction. It allowed countries with commitments under the Kyoto protocol to trade CER credits to help achieve their targets and reduce the overall abatement costs while promoting sustainable development in developing countries.

4. Challenges in financing CCS through market mechanisms alone and alternative mechanisms

The above discussion suggests that while integrating CCS into carbon crediting programmes and carbon markets could in theory contribute to the deployment of CCS, financing, and scaling CCS projects through carbon markets alone and without additional support mechanisms remains a challenge. In countries that have established carbon pricing through either an ETS or a carbon tax, those instruments can provide players with economic signals and potentially a source of revenues to offset CCS costs and recoup capital investment. Action is still needed to bridge the cost gap, however. One option is to introduce a CCfD mechanism which can cover the differential between the prevailing carbon price in the market (the reference price) and the cost of abatement through CCS (the strike price). The assumption here is that the size of the subsidy would decrease in time as the carbon price appreciates. This seems to be the emerging choice in Europe, where countries such as the Netherlands (through its SDE++ mechanism) and the UK through its ICC contracts have implemented CCfD-like mechanisms to guarantee developers a certain level of return on their investment.[56]

But for other jurisdictions, alternative approaches may be needed if CCS and CDR are to achieve their critical role in meeting climate targets, where some uncertainties need to be resolved. This may include the introduction of other types of complementary innovative mechanisms and a greater focus on bilateral approaches and multilateral clubs of liked-minded countries and private players.[57] One such option is complementary supply-side climate actions, as discussed next.

4.1 Supply-side Policies

Rather than only targeting entities that capture CO_2, as incentivized by an ETS or carbon taxes, supply-side policies can enable the financing of CCS by establishing crediting mechanisms for CO_2 storage. This can be achieved through technology or innovation support mechanisms.[58]

For instance, Country A may have a comparative advantage in developing a CO_2 storage hub given its geology and infrastructure, but lacks the financial resources or the appropriate incentive. To enable investment in the storage hub, a group of countries can establish a 'CCS fund' to finance the CO_2 storage project to enable Country A to meet its climate targets, increase its climate ambition or to scale up the technology.[59] Such financing schemes could be structured as part of results-based financing, a form of financing which rewards countries/project developers after agreed-upon results are achieved and verified.[60] In return, funders can make climate-related claims (though the types of claims that can be made need to be clarified). For instance, the WBCSD, through its Low Carbon Technology Partnerships initiative (LCTPi), previously proposed the creation of a Zero Emission Credit (ZEC) awarded for each tonne of CO_2 stored in the geosphere by a storage operator. A group of like-minded governments (for instance, countries in the Net-Zero Producers Forum) and investors (e.g., a group of energy companies) could establish a fund to purchase these credits.[61] In a similar vein, Zakkour and Heidug[62] propose the creation of Carbon Storage Units (CSUs) which are awarded to storers for each tonne of CO_2 that is permanently stored. The CSU, representing a monitored, verified, transferable record of the addition of a tonne of CO_2 to a carbon sink and not an emission reduction, would not be added or subtracted from countries' inventory of emissions. Rather, CSUs could be used to generate a

[56] Lockwood, T. (2024). Designing Carbon Contracts for Difference: A comparison of incentives for carbon capture and storage in Europe. Clean Air Task Force..

[57] Stern, N. & Lankes, HP. (2022). Collaborating and delivering on climate action through as Climate Club; Zakkour, Paul and Wolfgang Heidug (2019), A Mechanism for CCS in the Post-Paris Era, KS-2018-DP52. Riyadh: KAPSARC.

[58] Zakkour, P. M. Kuijper, P. Dixon, R.S Haszeldine, M. Towns, M. Allen (2024), Carbon storage units and carbon storage obligations: A review of policy approaches, International Journal of Greenhouse Gas Control, Volume 133.

[59] Result based finance has been applied to other applications such enabling investment in low-carbon off-grid energy sector, solar PV, and clean cookstoves in rural areas.

[60] Zakkour, P. and Heidug, W. (2019), A Mechanism for CCS in the Post-Paris Era, KS-2018-DP52. Riyadh: KAPSARC.

[61] World Business Council for Sustainable Development (WBCSD), 2015, 'Innovative Solution to Accelerate CCS', November.

[62] Zakkour, P. and Heidug, W. (2019), A Mechanism for CCS in the Post-Paris Era, KS-2018-DP52. Riyadh: KAPSARC.

stream of revenues for CO_2 storage developers when linked to the offtakers managing the aforementioned fund.

One of the features of the Paris Agreement is the variety of ways that ratifying countries can pledge their targets, including non-GHG targets. On this basis, governments can also include a CO_2 storage target as part of their NDCs. Other types of non-GHG targets have included the deployment of renewables by a certain year (expressed in MW of installed capacity) or developing areas of forested land (expressed in hectares).[63] Under this arrangement, for every tonne injected, countries can issue CO_2 storage or CCS certificates or CSUs that could be used towards making climate-related claims such as demonstrating that the country has met its announced targets.[64]

Capture and storage targets could be set in absolute values or in relation to some benchmark. For instance, for oil and gas producers, this could be a fraction of the annual volumes of oil and gas production and this fraction could be increased over time.[65] CCS certificates or CSUs could then be surrendered against an oil and gas country's production as evidence that the country has taken measures towards reducing the carbon footprint of its oil production and balancing between the carbon generated through extraction and the carbon injected and stored in reservoirs.[66] This can enable producers to market their crude more effectively and compete in a carbon-constrained world and/or charge a premium for selling lower carbon intensive oil and gas or petroleum products.[67]

A variation of the above is for part of the CSUs or CCS certificates generated to be sold to end-consumers/importers to generate a revenue stream for the storage investor and operator. For instance, a Country A exporting a certain volume of oil, gas and petroleum products to Country B can store CO_2 and generate CCS certificates to cover the volumes exported and sell these CCS certificates alongside the physical cargoes to a dedicated fund or fuel importers. This allows the cost of CCS projects to be shared between the parties incentivizing investment in CCS projects. A key advantage of such a scheme is that no emission reductions are being traded and hence countries do not need to adjust their GHG inventories.

Other variations are the Carbon Storage Obligation (CSO) or Carbon Takeback Obligation (CTBO) which propose that governments mandate fossil fuel producers to store CO_2 permanently to offset the CO_2 released into the atmosphere associated with fossil fuel extraction or supply. The initial fraction of CO_2 stored could be small but increases over time to be consistent with net-zero targets.[68] Fossil fuel producers could surrender CSUs or CCS certificates to discharge their obligations or meet the mandate.

4.2 Linking ETSs and Harmonization

Collaborative frameworks are increasingly needed in contexts where the CCS supply chain extends across different countries (e.g., where CO_2 is captured in jurisdictions different from where it is being stored). An emitter in Country A is subject to a carbon tax or an ETS providing an incentive for the emitter to invest and capture CO_2 to reduce compliance obligations. However, the emitter may not have access to CO_2 storage sites in Country A due to geological constraints, public opposition to CO_2 storage or government policy not allowing to store CO_2. On the other hand, CO_2 storage operator in Country B (Country B may not necessarily have an ETS in place) has invested in the CO_2 transport infrastructure and has access to underground CO_2 storage. This could potentially give rise to carbon trading across borders. The emitter in Country A would pay the CO_2 storage operator in Country B a fee (in effect a

---

63 Zakkour, P. and Heidug, W. (2019), A Mechanism for CCS in the Post-Paris Era, KS-2018-DP52. Riyadh: KAPSARC.
64 Zakkour, P. and Heidug, W. (2020). Supply-side Climate Policy for Crude Oil Producers. KS-2020-DP19. Rizadh: KAPSARC.
65 IEAGHG (2023), Integrating CCS in international cooperation and carbon markets under Article 6 of the Paris Agreement.
66 Allen, MR., Frame, DJ., and Mason, CF. (2009). 'The case for mandatory sequestration?' Nature Geoscience 2: 813-814. Under this approach, if the mass of carbon extracted matches the carbon stored over the same period of time at a global level, then we could reach the geological net zero (GNZ) where the atmospheric CO_2 concentrations stabilizes.
67 Hauman, H., Fattouh B., and Terazawa, T. (2024), Carbon Intensity: This Overlooked Metric is Key to the Green Transition, World Economic Forum, https://www.weforum.org/agenda/2024/02/carbon-intensity-a-key-and-overlooked-metric-for-the-climate-transition/, February 6.
68 Zakkour, P., Kuijper, M., Dixon, P., Haszeldine, R.S., Towns, M., Allen, M. (2024), Carbon storage units and carbon storage obligations: A review of policy approaches, International Journal of Greenhouse Gas Control, Volume 133.

service fee) in return for CCS certificates or CSUs which represents a monitored and verified record of the addition of a tonne CO_2 to the reservoir. These could then be surrendered by the emitter in Country A to a registry as evidence of permanently stored tonnes of CO_2 to reduce its compliance obligation.

Such schemes require close coordination and harmonization between countries especially in terms of MRV. MRV of CCS certificates could be based on existing methodologies developed by the IPCC or the voluntary market to ensure that CO_2 is being permanently stored. There are also issues of potential CO_2 leakage and liability provisions. In principle, the storage operator in Country B in the above example should bear the liability, and in case of CO_2 leakage, the storage operator could surrender allowances if the operator falls under the scope of an ETS. But extending the scope of an ETS system to include storage operators in other countries is practically difficult. Therefore, the issue of liability in case of leakage remains a key obstacle and the liability may have to fall on the emitter in Country A exporting the CO_2.[69]

There should also be clarity over the entity that can claim the emission reduction to avoid double counting. In this example, only the emitter in Country A can claim the reduction under the ETS. However, not all countries/regions allow for entities to claim emissions reduction if CO_2 is stored in another jurisdiction. For instance, under the EU ETS, while storing CO_2 outside the EEA is not banned, entities capturing the emissions can not surrender allowances under the scheme.[70] This would limit the incentive for emitters to store CO_2 abroad. Another related issue is the claims that the storage operator or Country B can make for storing CO_2 and whether this should count towards their NDCs. Finally, transporting CO_2 across boundaries is subject to international agreements such as the London Protocol on the Prevention of Marine Pollution which has been amended to allow for two countries to trade CO_2 for storage purposes if intergovernmental bilateral agreements are signed.[71]

4.3 Non-Market Mechanisms

Additional support mechanisms/incentive schemes have been and are being proposed to support the deployment of CCS in most applications, where staking revenues from carbon markets alongside public funding and support can help CCS projects cross the funding line.[72]

Additional support mechanisms have been developed at the national or the regional level and involve tax credits, state grants, R&D subsidies. The most notable of these has been the recent support provided under the US Inflation Reduction Act (IRA) which includes an enhancement of tax credits for CCS projects starting from 2026 to 2033, with the objective to increase the financial viability of CCS projects in the US and expand the application of the technology in uses such as DACCS and in manufacturing and power generation.[73] In the EU, €3bn is dedicated towards cleantech projects as part of the bloc's REPowerEU initiative, EU Innovation Fund, which aims to allocate over €38bn towards low-carbon technologies by 2030. The European Commission has announced that it will invest €1.8 billion towards 17 large-scale innovative cleantech projects of which 7 include a CCS or CCU component.[74] In Australia, the government also announced CCS funding in its federal budget, with more than AUD 550 million investments in supply chain related to CCS and CCUS.[75]

In Europe, as noted earlier, the recently-agreed Net-Zero Industry Act (NZIA) provides a wide definition for net-zero technologies but focuses on 8 specific areas with CCS listed as one of these key technologies. The EU's ambition is to scale up net-zero technology manufacturing to provide at least

[69] S. La Hoz Theuer and A. Olarte. (2023). Emissions Trading Systems and Carbon Capture and Storage: Mapping possible interactions, technical considerations, and existing provisions. Berlin: International Carbon Action Partnership.
[70] S. La Hoz Theuer and A. Olarte. (2023). Emissions Trading Systems and Carbon Capture and Storage: Mapping possible interactions, technical considerations, and existing provisions. Berlin: International Carbon Action Partnership.
[71] IEA (2023). CCUS policies and business models.
[72] For more detailed analysis, see: Fattouh, B.; Muslemani, H.; & Jewad, R. (2024). Capture Carbon, Capture Value: An Overview of CCS Business Models. Oxford Institute for Energy Studies, Paper CM08, Oxford: OIES.
[73] https://www.thetaxadviser.com/issues/2023/jan/the-inflation-reduction-acts-energy-and-climate-related-tax-provisions.html#:~:text=Under%20prior%20law%2C%20eligible%20carbon,decreases%20the%20annual%20capture%20requirements
[74] See for more information: GCCS Institutes reporting, and GCCS Institutes press release and EU Commissions RePowerEU.
[75] https://www.globalccsinstitute.com/news-media/latest-news/australian-government-announces-ccs-funding-in-federal-budget/

40% of the EU annual deployment needs by 2030. As far as CCS is concerned, the NZIA establishes an EU-wide target of developing 50 Mt CO_2 available storage capacity by 2030, proportionally contributed to by EU-based oil and gas producers on a pro-rata production basis over the period 2020-2023. The NZIA also sets an obligation to publish all geological data related to oil and gas when decommissioning. Investment projects may request the recognition as a 'net-zero strategic project' by a Member State. To receive support as a 'net-zero strategic project', the CCS project must be operational by 2030 or earlier and should have applied for a CO_2 storage permit, in accordance with Directive 2009/31/EU.

To further enhance the support framework for CCS, it is important to consider additional regional policies, such as those in Asia, where countries like Japan and South Korea are actively investing in CCS through government incentives and technological development. International collaborations, such as the Carbon Sequestration Leadership Forum (CSLF), are vital for the exchange of policy and technical expertise (Table 3).

Table 3: Summary of main government policy in support of CCS worldwide

Region	Type of Policy	Details
EU	Direct Funding	• €3 billion towards cleantech projects as part of its REPowerEU initiative. • EU Innovation Fund aims to allocate over €38 billion towards low-carbon technologies by 2030. • The European Commission announced an investment of €1.8 billion towards seventeen large-scale innovative clean tech projects, seven of which include a CCS or CCU component[76].
EU	Direct Public Policies (Communication on Sustainable Carbon Cycles)	• In December 2021, the Commission adopted the 'Sustainable Carbon Cycles' Communication, which outlines carbon removal objectives and principles[77].
US	Tax Credit and Direct Public Funding (The U.S. Inflation Reduction Act of 2022)	• Includes an investment of $369 billion in climate and energy funding, with enhancements to the IRS section 45Q on carbon capture and storage; • 45Q enhancements: Increasing the credit amounts for captured and sequestered CO2 up to $85/tonne, and for CO_2 that is reused up to $60/tonne, with direct air capture (DAC) at $180/tonne for CCS and $130/tonne for capture and utilization of carbon[78].

[76] https://www.globalccsinstitute.com/news-media/latest-news/eu-innovation-fund-to-invest-in-seven-ccs-and-ccu-projects/ ; https://ec.europa.eu/commission/presscorner/detail/en/FS_22_3133
[77] https://ec.europa.eu/commission/presscorner/detail/en/fs_21_6691; https://climate.ec.europa.eu/eu-action/sustainable-carbon-cycles_en
[78] https://cdn.catf.us/wp-content/uploads/2022/08/19102026/carbon-capture-provisions-ira.pdf?swpmtx=5712cb0fb95805bbb7631ed38d6a1ba9&swpmtxnonce=ddcfad6b82 ; https://www.catf.us/2023/08/one-year-later-how-the-inflation-reduction-act-is-making-an-impact/#038;swpmtxnonce=ddcfad6b82; https://www.catf.us/2023/08/from-act-action-inflation-reduction-act-accelerating-

Australia	Direct Public Funding	• The Australian Government has allocated funding pertinent to CCS in the 2022-2023 Federal Budget, with investments of over AUD 550 million in supply chain related to CCS and CCUS.[79]

Authors' Compilation: Various Sources

5. Conclusion

CCS is one of the key pillars of decarbonization. Carbon markets, both compliance or voluntary, can in principle play a vital role in scaling up this mitigation technology. Yet currently, carbon markets, particularly voluntary markets, are not sufficient on their own to enable funding of CCS in all applications and at scales large enough, so project developers must rely on staking revenues from carbon markets alongside other non-market mechanisms and incentive schemes to help projects cross the funding line. Over time, the price of carbon credits generated by CCS can increase if geological storage is perceived to be more reliable and as tech-based carbon removals linked to CCS increase in importance.

For carbon markets to play their role in advancing CCS, robust methodologies and modalities must be established. Much progress has been made in this area where rules for accounting, monitoring, quantification, and third-party validation and verification have been developed and frameworks to address issues such as risk of reversal, avoidance of leakage and of negative environmental and social impacts and contribution to sustainable development have been put in place. These are being developed and implemented at multiple levels: global, regional, national, subnational, and voluntary. While coordination across the various initiatives remains low, as more projects are developed and as various methodologies and approaches come under scrutiny, convergence is expected to increase.

Given that the CCS supply chain can extend beyond national jurisdictions, it is important that mechanisms are in place to ensure that revenues can flow through the supply chain and across countries. Herein lies the importance of Article 6 of the Paris Agreement which could form the cornerstone of a global carbon market and enhance collaboration between countries in achieving their climate targets. At one level, Article 6 can enhance funding for CCS projects in countries with comparative advantage in various segments of the CCS chain and increase the trade in carbon credits under Article 6.2 or Article 6.4. At another level, it may allow for countries to collaborate on sharing risks and costs and on funding segments of the supply chain such as storage hubs, especially between countries with high potential for CO_2 capture but limited capacity to store CO_2 due to geological limitations or lack of public support for CCS. This necessiates the harmonization of rules and methodologies across trading partners. While the role of CCS varies in significance in countries' strategies towards meeting climate targets, such harmonization efforts and innovative funding mechanisms could be developed initially by a small group of like-minded countries.

Acknowledgement

The authors acknowledge the review and valuable inputs of Andrea Bonzanni at IETA into this paper.

decarbonization-united-states-carbon-capture-storage/#038;swpmtxnonce=ddcfad6b82 ; https://www.catf.us/2022/08/inflation-reduction-act-what-it-is-what-it-means-how-it-came-to-pass/#038;swpmtxnonce=ddcfad6b82

[79] https://climatepolicydatabase.org/policies/federal-budget-2022-23