Technology Collaboration Programme
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Evaluating technology options to mitigate greenhouse gas emissions

IEAGHG Technical Report
2023-01
January 2023

# Integrating CCS in international cooperation and carbon markets under Article 6 of the Paris Agreement

IEA GREENHOUSE GAS R&D PROGRAMME

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**INTEGRATING CCS IN INTERNATIONAL COOPERATION AND CARBON MARKETS UNDER ARTICLE 6 OF THE PARIS AGREEMENT**

**(IEA/CON/21/275)**

This work assesses the status of and outlooks for international cooperation under Article 6 of the Paris Agreement and considers how approaches could support the deployment of carbon capture and storage (CCS). It provides an up-to-date look at the Article 6 rules, the types of markets and mechanisms that could evolve, and the units that could be traded. It then considers how Article 6 could apply to CCS through linked emissions trading systems, crediting systems and alternative approaches.

## Key Messages

- Article 6 of the Paris Agreement is an enabler that will help countries cooperate in order to meet global emissions reductions targets by using international carbon markets, allowing transfers of emission reductions between countries and providing a framework for greenhouse gas emissions to be balanced globally,
- CCS has been consistently noted as a key technology for achieving deep and sustained cuts in atmospheric $CO_2$ levels, with geological storage critical for meeting the goals of the Paris Agreement,
- CCS could be incorporated into Article 6 through emissions trading or crediting, within compliant or voluntary markets, through governmental transfers of mitigation outcomes, and through CCS-specific approaches,
- These actions may be national conditional measures, or supplementary to national measures,
- This study looks at three core models for CCS cooperation under Article 6:
    1. Linked carbon pricing policies between countries (a representation of the mainstream climate policy approach of today),
    2. Voluntary (or partially regulated) system of storage targets for fossil fuel producers (a more novel concept someway from actual implementation),
    3. Multilateral "CCS club" of Parties to the Paris Agreement (another more novel concept).
- It is uncertain if technology neutral market-based mechanisms (such as in model 1) can deliver significant amounts of geological $CO_2$ storage. These mechanisms are poorly suited to support the deployment of higher cost mitigation techniques such as CCS without supplementary measures (such as targeted support and incentives),
- Carbon markets could lead to some near-term deployment of low-cost CCS projects, even under low carbon prices,
- Carbon storage unit (CSU) based policies (such as in models 2 and 3) could provide a supplementary mechanism to ensure geological $CO_2$ storage is included in more mitigation options,
- A top-down, country-led approach (as in model 3) could be more effective in enhancing geological storage. However, gaining agreement to adopt storage targets across multiple countries could be challenging,
- Model 2 may be more practical for implementation when bolstered by a few pioneering countries,
- An approach based on CSUs could help to provide additional financing for CCS and enhance progression in Nationally Determined Contributions (NDCs),
- The likelihood of a CSU mechanism being implemented remains highly uncertain but all models described can be considered as actions to help utilise CCS.

## Background to the Study

The Paris Agreement is a legally binding international treaty to limit global warming to well below 2°C, and pursuing efforts to limit it to 1.5°C, whilst aiming to strengthen each country's ability to deal with the impacts of climate change and as a support mechanism to achieve national goals.

Article 6 of the Paris Agreement is an enabler that will help countries cooperate in order to meet global emissions reductions targets by: using international carbon markets; allowing transfers of emission reductions between countries; and providing a framework for greenhouse gas emissions to be balanced globally. Article 6 includes the following important subdivisions:

- Article 6.2 'provides an accounting framework for international cooperation' and transfer of carbon credits between countries.
- Article 6.4 'establishes a central UN mechanism to trade credits from emissions reductions generated through specific projects'.
- Article 6.8 'establishes a work programme for non-market approaches'.[1]
- CCS fits under Article 6 as 'an emission reduction technology and carbon removal technology'.[2]

In 2019, KAPSARC (King Abdullah Petroleum Studies and Research Center) produced a paper providing new thinking on Article 6. It argued that the benefits of a storage crediting scheme should complement carbon pricing and overcome barriers. 'A Mechanism for CCS in the Post-Paris Era'[3] proposes the creation of a new transferable asset, a 'carbon storage unit' to assist with cooperation between Parties. However much of the research done for this work was carried out several years ago, and so a new insight and approach would be helpful.

Other regions are adopting mechanisms to contribute to the reduction in greenhouse gas emissions, such as the Japanese Joint Crediting Mechanism (JCM). The JCM facilitates the 'diffusion of leading low carbon technologies, products, systems, services, and infrastructure, as well as implementation of mitigation actions, contributes to the sustainable development of developing countries. It appropriately evaluates contributions to GHG emission reductions or removals from Japan in a quantitative manner, by applying measurement, reporting and verification (MRV) methodologies, and uses them to achieve Japan's emission reduction target. The JCM contributes to the ultimate objective of the UNFCCC by facilitating global actions for GHG emission reductions or removals, complementing the Clean Development Mechanism (CDM).'[4]

The accelerated deployment of a number of low-carbon technologies, including CCS, is required to meet the goals of the Paris Agreement. The IEAGHG Multilateral Organisations Group[5] recognised the importance of Article 6 in facilitating this accelerated deployment and the implications for the future of

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[1] WRI, **'What You Need to Know About Article 6 of the Paris Agreement'**, 2nd December 2019, https://www.wri.org/blog/2019/12/article-6-paris-agreement-what-you-need-to-know

[2] GCCSI, '**The Role of CCS in the Paris Agreement and its Article 6'**, April 2020, https://www.globalccsinstitute.com/wp-content/uploads/2020/04/Article-6-and-CCS-GCCSI-April-2020.pdf

[3] King Abdullah Petroleum Studies and Research Center (KAPSARC), '**A Mechanism for CCS in the Post-Paris Era'**, April 2019, https://www.kapsarc.org/file-download.php?i=28368

[4] The Joint Crediting Mechanism, https://www.jcm.go.jp/

[5] IEAGHG Multilateral Organisations Group is a small group made up of IEAGHG Executive Committee members to help facilitate the better communication of IEAGHG messages into the multilateral groups such as UNFCCC, IPCC etc., and to help prioritise targets for work needed and areas needing more detail.

CCS. Previous work has looked at Article 6 but namely Article 6.2. Article 6.4 and 6.8 had not been looked at in real detail.

## Scope of Work

The aim of this study was to review and summarise the recent and ongoing work in the area of CCS in an Article 6 context, and to provide a detailed overview. The study then aims to test these ideas to obtain more formal feedback and to review the practicality of different models and mechanisms that could be applied to CCS.

The study starts with a comprehensive snapshot of the Article 6 rules, the types of markets and mechanisms that could evolve, and the units that could be traded. Ideas taken from the initial literature review and information gathering were then used to develop three models for potential Article 6 cooperation on CCS. The first links carbon prices based on the trading of emission reductions / removals units. The second involves supply side offsetting based on voluntary pledges by major independent energy companies. The third involves supply side offsetting, based on country pledges, to support geological carbon storage before transitioning to other types of cooperation built upon the adoption of storage targets in nationally determined contributions (NDCs). The contractors have undertaken an evaluation of these three models against criteria that reflect the overall goals of international cooperation and the issues facing CCS deployment.

IEAGHG is particularly suited to the publication of such an analysis due to its recognised status as a provider of technically sound, objective knowledge that is not policy prescriptive.

## Findings of the Study

### Outlooks for International Cooperation

Article 6 is an enabler of the Paris Agreement that aims to follow on from the market-based approaches of the Kyoto Protocol, which previously had ‘flexibility mechanisms’. This approach allowed developed country Parties, that were subject to quantitative emission limitation and reduction obligations (QELRO), to trade in assigned amount units (AAUs) between themselves. Acquired emissions reduction/removal credits from projects-based activities could be counted towards QELROs; for example, the clean development mechanism (CDM) and joint implementation (JI). This experience has provided learnings for how governmental targets, set out in climate policy, could be used to incentivise private sector entities to invest in climate mitigation. The Kyoto Protocol’s mechanisms used a top-down approach whereas the Paris Agreement requires Parties to pledge bottom-up contributions. Consequently, there are additional complications posed for the accounting of transfers of mitigation outcomes between Parties.

The different target types and timeframes pose new challenges for how mechanisms under Article 6 can be linked together to help countries achieve their goals while preserving the overall objectives of the Paris Agreement. The creation of an accounting framework that encompasses the diversity of target types, actions and measurements, that has been proposed, will be key to successful implementation. Two concerns predominate: the avoidance of double counting and the avoidance of ‘hot air’ transfers (meaning when estimates for emissions under a business-as-usual scenario are exaggerated, credits could be awarded to activities that would have happened anyway – credits generated from ‘hot air’). Other features of Article 6 that could affect the integrity of the Paris Agreement include: the potential to disincentivise NDC progression; the potential to deter mitigation among buyers; and the nature of the future carbon markets driven by Article 6 (i.e. whether voluntary market units / transactions may be incorporated into the Paris Agreement’s accounting system). Other work in this area is ongoing and these issues will need to be addressed through future guidance agreed on and adopted by Parties at future sessions.

International cooperation on mitigation is mostly conceptualised as occurring through several types of policy instruments, such as crediting programmes, carbon taxes allowing for credit surrender, emissions trading systems (ETSs) and government to government transactions. In voluntary markets, the use of credits is voluntary (rather than the credits themselves). There is also the possibility that voluntary transactions could be incorporated into the Paris Agreement accounting system, with aspects of voluntary markets used to develop ongoing implementation of Article 6, but there is uncertainty as to whether voluntary market units and transactions can be incorporated in to the accounting system.

The Paris Agreement embeds the concept of net zero into global climate change mitigation, with a dual emphasis on both emission reductions at source and removals by sink enhancements, which focusses attention on the types of offsets that can be used to make net zero claims. Some have suggested that offsetting strategies must be increasingly focussed on removals rather than reductions or avoided emissions, whilst others seem less convinced by the near-term focus on removals. An emerging idea to address the potential risk of mitigation deterrence is the separation of targets between emission reductions and removals, because this would result in greater transparency regarding how climate neutrality targets are intended to be met. It also removes the potential for adverse interactions to occur with emission reduction base policies. Figure 1, below, illustrates a taxonomy of carbon offsets, reductions versus removals.

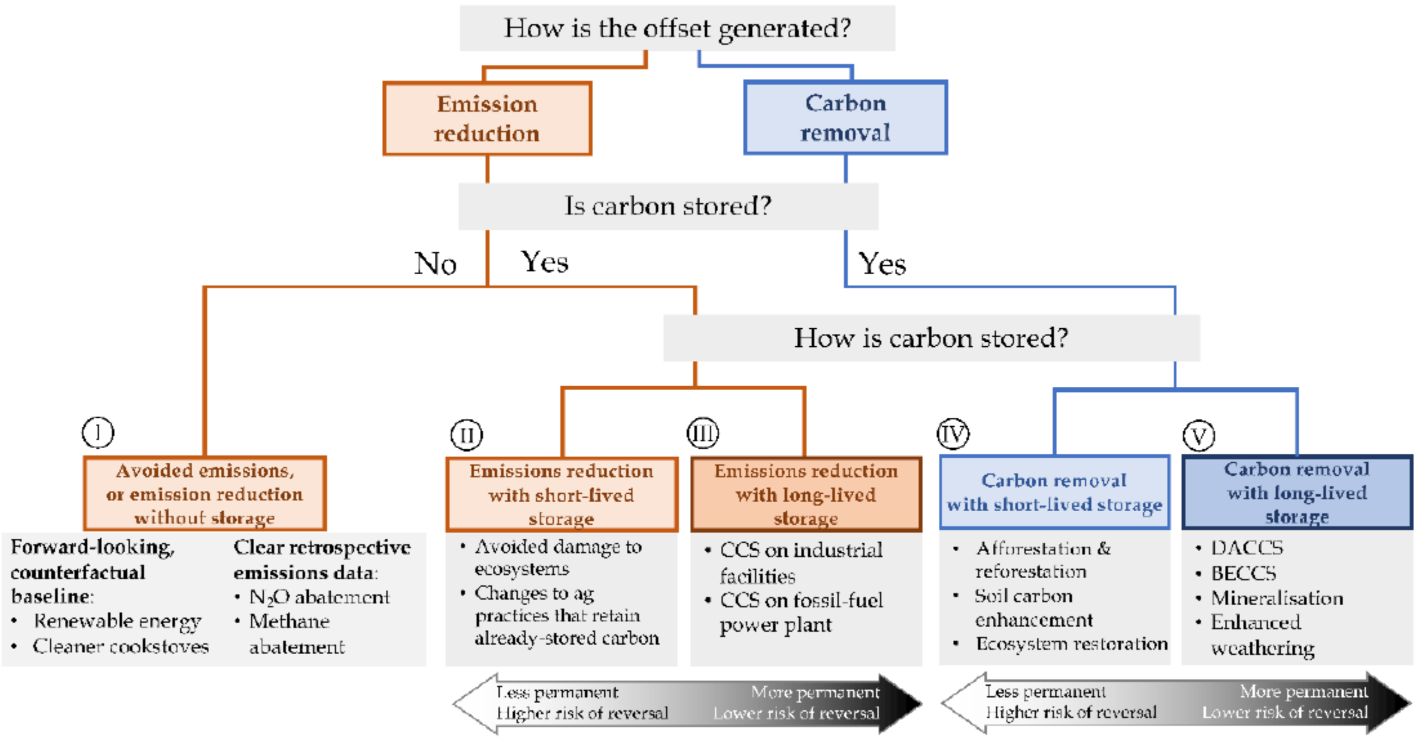



Figure 1. **Taxonomy of carbon offsets**, IEAGHG, 2023. *(Taken from Allen et al., 2020)*

<u>CCS and International Cooperation</u>

The report considers how CCS could be further integrated through potential international cooperative policies and programmes under the Paris Agreement. CCS has consistently been noted as a key technology in pathways for achieving deep and sustained cuts in atmospheric $CO_2$ levels and projections from the IEA and IPCC confirmed the mitigation potential of the technology, with a significant body of research suggesting that geological $CO_2$ storage will be a critical technology for meeting the Paris Agreement's goals.

CCS could be incorporated into Article 6 through emissions trading or crediting in various forms, within compliance markets or voluntary markets, or government to government transfers of mitigation outcomes outside of market-based mechanisms. There have also been proposals for CCS-specific approaches such as the use of a carbon storage unit (CSU) as a transferrable mitigation outcome a 'supply-side offsetting' approach, which are not yet recognised as being a definite possibility under Article 6, but will depend on further guidance agreed by Parties at future COPs (Conference of the Parties, the United Nations' climate change conferences). A CSU would represent tonnes of $CO_2$ stored, rather than being measured as emissions or emissions reductions, and could be used as a basis for targeted international cooperation on geological storage.

**Models for CCS Cooperation**

There are a range of possible pathways that international cooperation through Article 6 could take place whilst working to support CCS deployment. These measures include trading of emissions allowances and emission reduction/removal credits, arising from linked carbon markets (i.e. under more conventional notions of carbon market based approaches that apply to the fossil fuel users as emitters of $CO_2$), and more novel, targeted, approaches that base cooperation around carbon storage and the producers and suppliers of fossil carbon. These approaches are not mutually exclusive, but a difference in approach. The supply side offsetting mentioned earlier would act as a complementary mechanism in a conventional carbon market that acts to direct carbon finance towards geological storage, rather than replace it. This would allow for parallel market functions to be established according to emission reductions / removals (a measure which generates tradable units measured in $tCO_2$ reduced/removed from the atmosphere, to be awarded to entities capturing $CO_2$) and carbon storage (which generates tradable units measured in $tCO_2$ stored in the geosphere, to be awarded to entities storing $CO_2$). This creation of the two units: CRRUs (carbon reduction/removal units) and CSUs, and two points of compliance (carbon emissions and carbon reduction), trades in CSUs could act as a supplement to carbon price signals in the conventional carbon market.

Moving forward from these ideas, this report looks into three core models for cooperation and trading under Article 6 that are used to evaluate various aspects regarding their utility and risks.

MODEL 1 – Linked carbon pricing policies between countries

This model is based on the trading of CRRUs and sees increasingly linked carbon markets between countries with international trading of emissions allowances and credits generated by various types of emissions reduction, emissions avoidance, sink conservation and carbon removals activities. For CCS, CRRUs are awarded to operators of $CO_2$ capture facilities or project-based entities acting in unison. Trading could take place directly between governments or involve companies for compliance or voluntary purposes, as shown in figure 2, below.

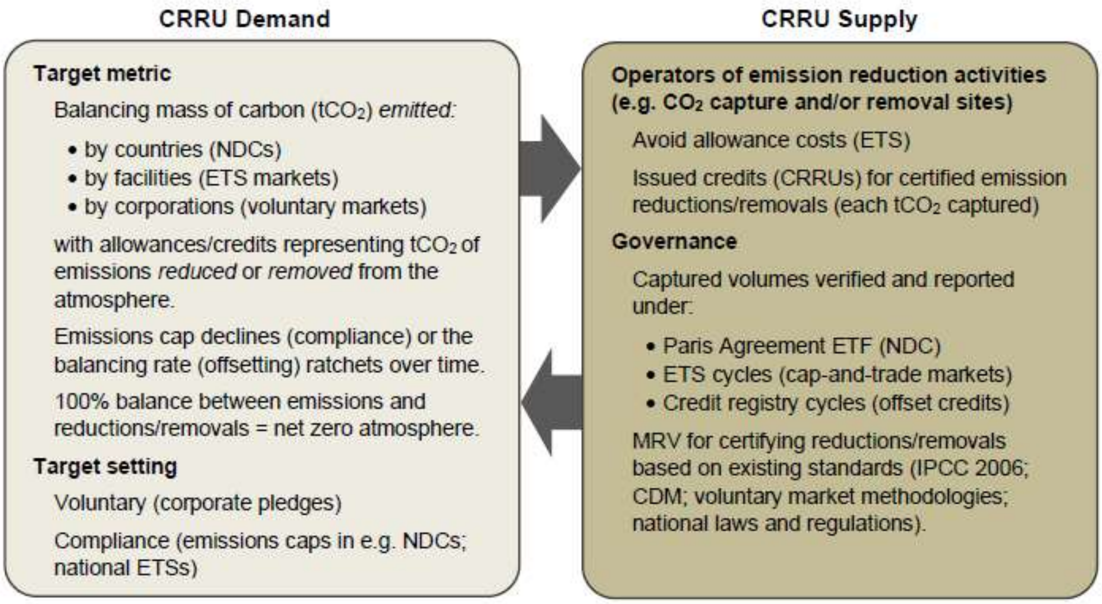



Figure 2**. Carbon reduction/removal market arrangements, as described for Model 1**, IEAGHG, 2023.

MODEL 2 – Voluntary (or partially regulated) system of storage targets for fossil fuel producers

This model is based on using CSUs to drive bottom-up actions by corporations and countries for supporting CCS deployment. The relevance to Article 6 in a voluntary corporate context is limited, although voluntary actions could be supported by domestic measures in supportive countries. Energy corporations with net zero targets would voluntarily implement CSUs to track progress and demonstrate net zero emissions on the supply side of markets. Implementation would be through a voluntary register that tracks the amounts of carbon produced from the geosphere and the amounts of geological carbon storage (measured through the acquisition and retirement of CSUs). See also figure 3, below.

MODEL 3 – Multilateral "CCS club" of Parties to the Paris Agreement

This model is based on a select group of likeminded countries with a common interest in fossil fuel production and CCS adopting CSUs to cooperate on plurilateral basis. With similar principles to model 2, however this model is based on top-down country pledges to store $CO_2$ geologically rather than corporate net zero targets. A phased approach to implementation could be taken starting with finance involving CSU transfers among a select club of countries without Article 6 transfers, but potentially evolving into a system of Article 6 CSU transfers between club members with specific storage targets in NDCs. Figure 2, below, summarises model 2 and 3 in terms of their potential market designs.

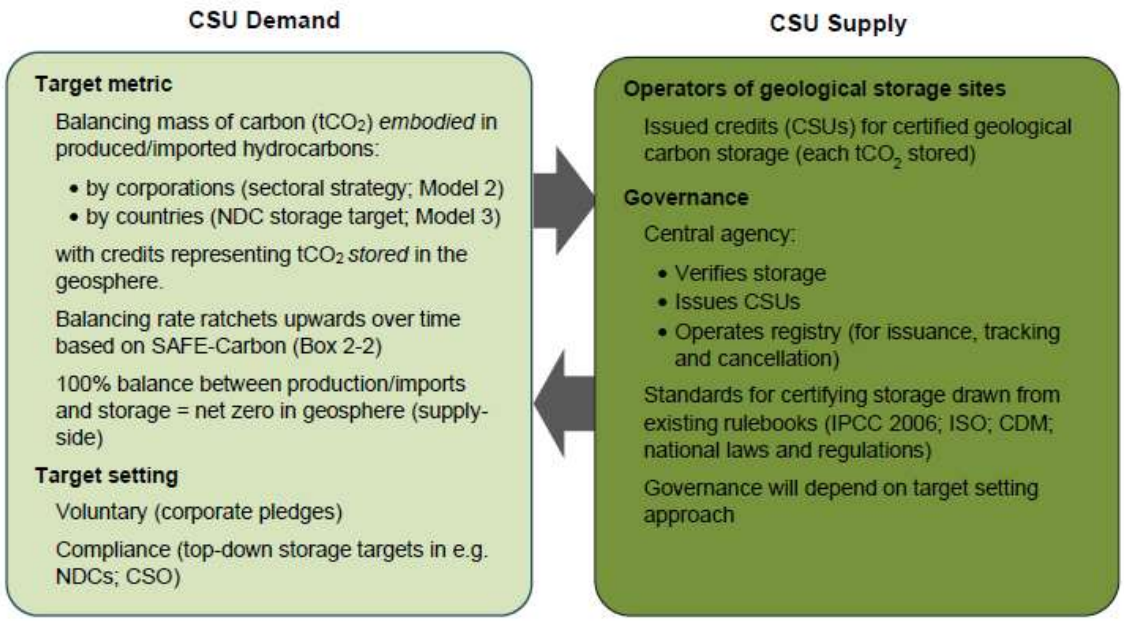



Figure 3**. Potential CSU market structures, as described in Models 2 & 3**, IEAGHG, 2023.

## Evaluating CCS Cooperation Models

To evaluate the three models for Article 6 cooperation, a range of criteria relevant to Article 6 performance and CCS deployment were developed which reflect the core demands of Article 6. This evaluation assumes that CCS is critical to achieving the goals of the Paris Agreement. The assessment criteria used to evaluate the models are as follows:

- **Effectiveness**: effectiveness in accelerating cost-effective CCS deployment and implementations, and potential interface CCS policies and mechanisms with other removal solutions.
- **Environmental integrity**: Quality of capture and storage estimates, determined through consideration of additionality and CCS policies, as well as MRV standards and processes. Accounting of transfers and use towards targets, the application of corresponding adjustments to avoid double counting, and ability to operate with different target types and avoidance of perverse outcomes.
- **Commercial and financial**: Commercial viability of CCS technologies and the availability of sufficient and predictable finance.
- **Progression**: Promotion of mitigation ambition, transformative change and NDC progression and the longevity of the approach to be relevant prior to and during the net-zero emissions phase.
- **Policy performance**: Facilitation of broad participation, coherence with other policy instruments and political viability with governments, private sector and civil society.

The outcomes of the evaluation for each model with regards to each criterion are described below.

<u>Effectiveness</u>

This looks into whether the approach could deliver significant volumes of geological $CO_2$ storage, the degree of certainty offered in achieving such levels, the extent to which deployment contributes towards deployment levels, that are consistent with the IEA's 2021 estimate of net zero, and the alignment with other types of $CO_2$ removal options.

Model 1: With model 1, outlooks for the size of the potential market for trading CRRUs vary significantly in scope and assumptions, with estimated traded volumes in global carbon markets varying by market size in 2050 from 1.7 to 13 $GtCO_2e$ depending on the study the estimate is based upon (studies investigated in this working include those from Edmonds et al, 2019, Yu et al, 2021, and TSVCM, 2021). These differences highlight the uncertainty in respect of CCS deployment under international cooperation, so a key question will be whether market standards will adapt to direct crediting activities toward storage or not. Based on the evaluation on CCS deployment through linked carbon markets under model 1, the potential for deployment is highly uncertain. Analysis linked to country and corporate commitments in unconvincing in the potential to deliver significant amounts of geological storage in the near term.

Models 2 & 3: These models have a targeted approach to geological storage and so can offer greater certainty for the deployment of such storage. The supply side offsetting approach is proposed to complement conventional carbon markets under model 1, which could be effective in driving market behaviour under model 1 towards these types of investments (CCS and technological removals). The potential for model 3 exceeds model 2's expectations to mobilise investment into CCS.

Environmental Integrity

Maintaining high levels of environmental integrity involves robust MRV and accounting, avoidance of double counting and the avoidance of perverse outcomes, which are all applicable to the three potential cooperation models.

In models 2 and 3, the metric used for MRV, and accounting, is $tCO_2$ stored (whereas Model 1uses $tCO_2$ emissions reduced / avoided / removed). Further work is needed to clarify accounting methods, such as the carbon production inventories of participating parties that CSUs will be counted and the point of compliance in a voluntary market.

With two different credits for the same activity (CRRUs and CSUs), concerns can arise with the risk of double accounting so it is essential to avoid interaction of the two units whereby CRRUs are only counted against targets expressed as $tCO_2$ emissions reduction or removals. Alternatively, CSUs are counted only against targets expressed in $tCO_2$ stored primarily linked to tCO2 produced from the geosphere and/or imported. According to the report, Article 6 rules mean that all three cooperation models will require corresponding adjustments to be applied to transfers of CRRUs / CSUs to count towards NDCs, but the supply-side offsetting quota system in Models 2 and 3 is not suitable for such adjustments. Therefore, CSUs would be credited to storage site operators and in these cases, the CSU can only be used once so that no double counting can occur.

Potential accounting issues could arise from specific CCS configurations, such as the reinjection of reservoir $CO_2$ that is a by-product of hydrocarbon production and the injection of $CO_2$ for the purposes of EOR. In all of the Models (1,2 & 3), potentially perverse outcomes could occur when the injected volume of $CO_2$ is counted as an offset against the $CO_2$ embodied in the produced hydrocarbons so care will be needed particularly in the implementation of Models 2 & 3. In Model 1, environmental integrity can be maintained if the produced oil is utilised in a country with an ambitious climate pledge. For Models 2 and 3, integrity of the CSUs would not be compromised by awarding CSUs for $CO_2$ injected for EOR, with any incrementally produced oil resulting added to the relevant compliance metric.

Commercial & Financial Viability

Commercial and financial challenges are something that all projects may face. Possible approaches to address risks in Model 1 include carbon contracts for differences (CCfDs) where governments pay capture entities the difference between prevailing carbon prices and a pre-agreed strike price (and vice versa). When compared with Model 1, Models 2 and 3 may offer enhanced certainty over the demand for geological storage, de facto license to operate, incentivising of actors with the know-how to build storage sites, enduring price support mechanism and strategy for government funding, and a commercial transactional model that ensures geological storage sites get filled. In the absence of other revenue (for example from EOR) or incentives, private agreements may be insufficient so policies and measures that establish clear incentives for geological storage (independent of the principal parties' interests) – like those in Models 2 & 3 – may alleviate some risks. In addition, Model 3 would engage a wider set of countries in implementation that may offer greater likelihood of success.

Progression

Model 1: this linkage of carbon markets represents achieving mitigation goals at least overall cost, driving investment towards least-cost projects whilst constraining the capacity to deploy higher cost technologies, so more uncertain (in terms of financial viability) of high-cost technologies like CCS could hamper progress within some NDCs. Countries with limited experience of CCS are unlikely to commit to future use of the technology without clearer support, and it is uncertain as to whether Model 1 can overcome such uncertainty.

Models 2 & 3: The use of CSUs could help drive ambitions in NDCs with greater clarification around finance provision and deployment support. Model 3 could allow major fossil fuel producing countries to develop NDCs based on high levels of CCS deployment over time, with Model 2 potentially providing a bottom-up pathway to Model 3 but with less certainty in progression.

CSUs could provide a unit for net zero policy design in a world where allocations of allowances and crediting of avoided emissions (i.e. as in Model 1) will need to be replaced by crediting based only on removals (or storage), as in Models 2 and 3.

Policy Performance

Model 1: this model aligns with the assumption that carbon pricing will contribute greatly to achieving ambitious climate mitigation targets, with observable economic and political benefits. However, market-based instruments thus far have not deployed CCS at the scales envisaged to meet the goals of the Paris Agreement. Models 2 and 3 could provide a direct incentive for geologically storing $CO_2$, particularly when placed with the parallel incentive of capturing $CO_2$ (as described in Model 1), physical markets for $CO_2$ can emerge. A potential challenge for Models 2 and 3 is stakeholder acceptance; the supply-side offsetting approach provides greater certainty over demand for $CO_2$ storage but also acknowledges the use of fossil fuels for some time. Although an important view, this report considers the Paris Agreement and the acknowledgment that CCS plays a critical role in achieving climate targets. In addition, the need for such a mechanism would lessen over time as the use of alternate energy sources increases.

## Conclusions

Model 1 provides a representation of the mainstream climate policy approach of today and Models 2 and 3 are novel concepts that remain someway from actual implementation.

It remains uncertain whether technology-neutral market-based mechanisms can deliver significant amounts of permanent geological storage of $CO_2$ (Model 1). Experiences suggest that they are poorly suited in supporting deployment of higher cost climate change mitigation technologies such as CCS without the use of supplementary measures. Despite the assumption that carbon prices will rise over time and offer greater stability that may encourage investment in CCS, the evaluation of such a scenario like in Model 1 indicates high levels of uncertainty. Carbon markets could however lead to some near-term deployment of lower-cost CCS projects (such as those involving $CO_2$ utilisation or high purity $CO_2$ sources, for example) but crediting of such activities could pose some environmental integrity risks. Integrity concerns could be addressed with certain adjustments, but the effectiveness could be limited if the NDC is not particularly ambitious.

CSU based policies under Models 2 or 3, based on the use of storage targets or quotas, could provide a supplementary mechanism to ensure that more mitigation options include the geological storage of $CO_2$. The evaluation indicated that a top-down, country-led approach (Model 3) could be more effective in enhancing geological storage because the scope of the obligation would extend into national energy companies as opposed to only major independent countries (Model 2). Gaining agreement to adopt storage targets across multiple countries under Model 3 is likely to be challenging but Model 2, bolstered by a few pioneering countries implementing supporting policies, may be more practical for implementation. An approach built on CSUs could also help to provide additional financing for CCS and a pathway towards technological removals and at a national level, adoption of complementary storage targets can also help to enhance progression in NDCs.

The likelihood of a CSU mechanism being implemented remains highly uncertain. It may be seen as an unnecessary technology subsidy or a guaranteed route for fossil fuels in a net zero world. Conversely, achieving net zero depends on crediting the amount of $CO_2$ removed or stored to be counted as a balance against $CO_2$ emitted, which will need to be addressed. The use of CSUs in a secondary market could be used and interest is growing in such concepts, but greater efforts to raise awareness of the risks posed to net zero in current market arrangements and the opportunity to address such risks through supporting policies is needed.

## Expert Review

Seven experts with backgrounds in both industry and policy comprehensively reviewed this report. Overall, the reviewers were happy with the report and it was apparent that generally the reviewers felt that the report was interesting, thorough and well written.

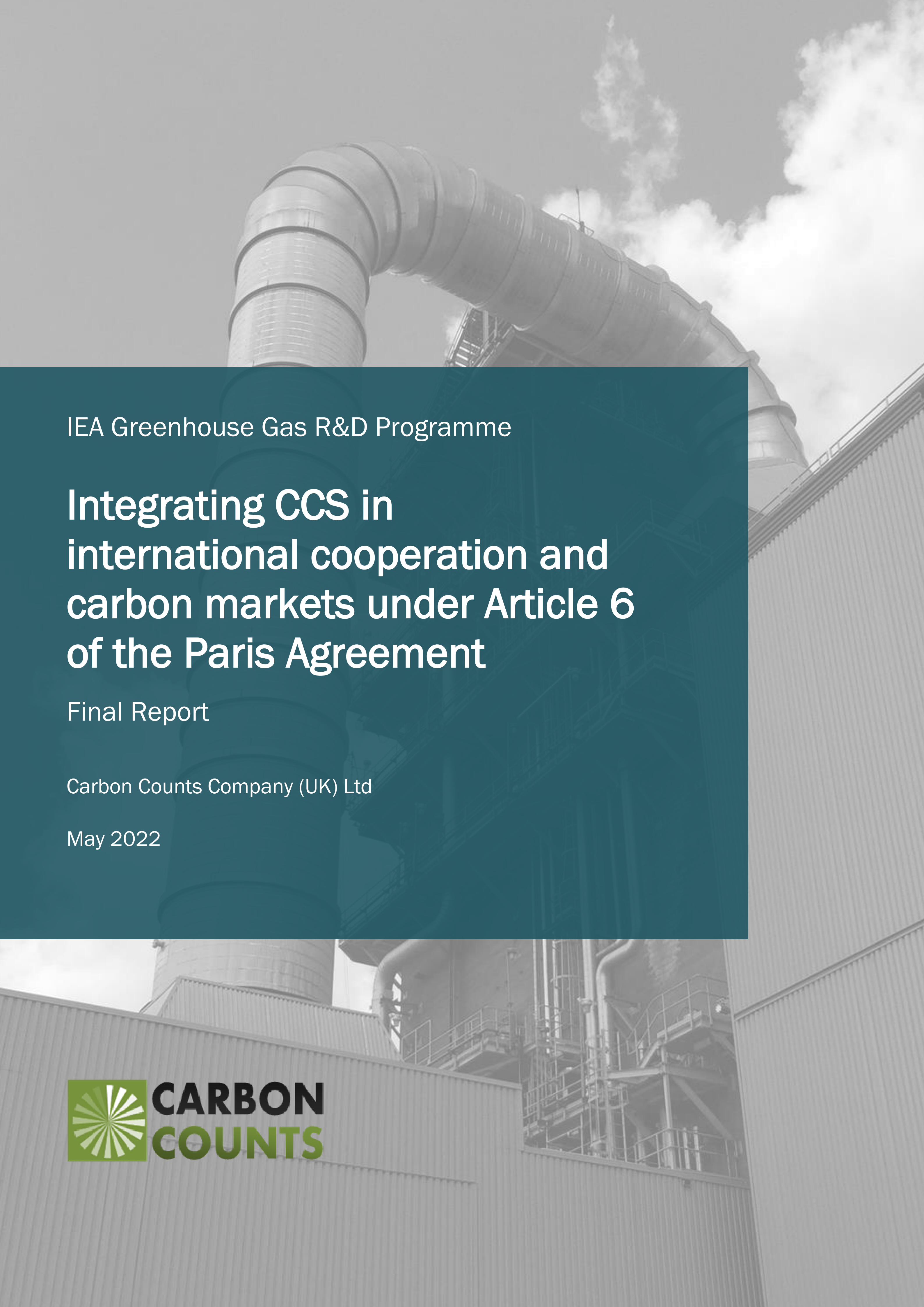
Reviewers asked for more clarity throughout the report, with a clearer definition of CSUs upfront with more on what they can and cannot do, and more specificities on the definition of removals versus reductions, which was done where needed and appropriate. More information was requested on the need for new Article 6 models toward the front of the paper and so the contractors provide more information to try and clarify, but they noted that the intention of this report was not to say there is a need but to objectively assess if there was a need. Some reviewers asked for more elaboration on Article 6 itself, its background and detailed goals, but this was not within the scope of the work and already exists in literature elsewhere; the contractors were cognisant not to repeat previous work.

There was a suggestion to link to emerging issues in coordinating NDCs with baselines, an important point but out of context of this paper so this study does not go into detail on such issues. The key point noted upfront in the paper regarding the risk of double counting was flagged by one reviewer who asked for more clarification on how this can be prevented. The contractors noted that many technologies are subject to double or triple incentives without problematic claims, for example renewable energy which has been subject to both feed-in tariffs and carbon pricing in the past to help overcome early cost barriers. Double counting is however an important topic and potential risk, and so following the expert review, more discussion and further clarification throughout the paper added.

## Recommendations

IEAGHG have drawn several key recommendations from this report on 'Integrating CCS in International Cooperation and Carbon Markets under Article 6 of the Paris Agreement':

- It would be valuable to look at societal acceptance of offsetting because this could affect potential growth of voluntary markets.
- Further work could be done on linking the outcomes of this report and the models to emerging issues in coordinating NDCs with baselines.
- In a CSU market, the metric used for MRV and accounting is $tCO_2$ stored and so further work is needed to clarify accounting methods that may arise with models 2 and 3 when in practice in terms of the inventories of produced $CO_2$ and points of compliance. The compatibility of models and approaches such as the CSU should be cross-checked with recent and future COP decisions.
- More work is needed on the extent of which the use of supplementary measures for CCS deployment could impact on the feasibility of linking emissions trading schemes from different jurisdictions.
- It could be useful to undertake work to assess whether any of the proposed models in the study would specifically aid CCS deployment in various countries. Once more specific case studies are undertaken, best practice guidelines can be developed to aid implementation of such models where appropriate.



IEA Greenhouse Gas R&D Programme

# Integrating CCS in international cooperation and carbon markets under Article 6 of the Paris Agreement

Final Report

Carbon Counts Company (UK) Ltd

May 2022

CARBON COUNTS

# Integrating CCS in international cooperation and carbon markets under Article 6 of the Paris Agreement

## Final Report

**Project number**

108

**Authors**

Paul Zakkour, Greg Cook and Andrew Howard

**Client**

IEA Greenhouse Gas R&D Programme

**Disclaimer**



*Cover photo: Boundary Dam $CO_2$ capture facility (Paul Zakkour)*

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# Acronyms and Abbreviations

| | |
|---|---|
| BAU | Business-as-usual |
| BECCS | Bioenergy with carbon capture and storage |
| CCfD | Carbon contract for difference |
| CCS | Carbon dioxide capture and storage |
| CDM | Clean Development Mechanism |
| CDR | Carbon dioxide removal |
| COP | Conference of Parties to the UNFCCC |
| CORSIA | Carbon Offsetting and Reduction Scheme for International Aviation |
| CRRU | Carbon reduction/removal units |
| CSO | Carbon storage obligation |
| CSU | Carbon storage unit |
| CTBO | Carbon takeback obligation |
| DAC | Direct air capture |
| DACCS | Direct air capture with storage |
| ETF | Enhanced transparency framework |
| ETS | Emissions trading system |
| IPCC | Intergovernmental Panel on Climate Change |
| ITMO | Internationally transferred mitigation outcomes |
| JI | Joint Implementation |
| MRV | Measurement, reporting and verification |
| NDC | Nationally determined contribution |
| NET | Negative emission technology |
| QELRO | Quantified emission limitation or reduction obligation |
| RBF | Results-based finance |
| TSVCM | Task Force on Scaling Voluntary Carbon Markets |
| UNFCCC | United Nations Framework Convention on Climate Change |

# Summary

We assess the status and outlooks for international cooperation under Article 6 of the Paris Agreement and consider how approaches thereunder could support the deployment of carbon capture and geological storage (CCS). First, we provide an up-to-date snapshot of Article 6 rules, the types of markets and mechanisms that could evolve, and the units that could be traded. Based on this outlook, we then consider how Article 6 could apply to CCS through linked emissions trading systems, crediting systems, and alternative approaches such as supply-side offsetting based on carbon storage units (CSUs) with storage quotas and obligations.[1]

Drawing from the review, we develop three models for Article 6 cooperation on CCS:

- **Model 1**. Linked carbon markets based on the more conventional trading of emission reductions and/or removals units.
- **Model 2**. Supply-side offsetting based on voluntary pledges by major independent energy companies (e.g. net zero or other types of commitments to carbon storage), potentially bolstered by national carbon storage obligation schemes in some countries. The approach operates through origination and trading of CSUs.
- **Model 3**. Supply-side offsetting based on country pledges to support geological carbon storage, potentially starting as results-based finance, before transitioning to other types of cooperation built upon the adoption of storage targets in nationally determined contributions (NDCs). The approach is also underpinned by CSUs.

Model 1 represents the mainstream climate policy approach at time of writing. Models 2 and 3 are novel concepts that are receiving some attention from industry, national governments and international forums, although they remain some way from implementation.

We undertake a comparative evaluation of the three models against several criteria that reflect the overall goals of international cooperation and the issues facing CCS deployment, namely: effectiveness, environmental integrity, commercial and financial viability, progression and policy performance. The assessment is largely qualitative and draws on the expert judgement of the authors. Our evaluation suggests the following:

1. **Implementation of supply-side offsetting approaches based on CSUs operating in parallel with conventional carbon markets may be effective in driving cooperative actions towards the permanent geological storage of $CO_2$.** A quantitative analysis of pledges by major independent energy companies suggests the

[1] Supply-side offsetting describes various policy proposals to apply a ratcheting geological storage quota to entities undertaking the extraction of geological carbon (either fossil carbon producing companies, countries, or both). The quota or mandate is satisfied through the acquisition and retirement of geological carbon storage units (CSUs). In some circumstances it is also referred to as a carbon storage or a carbon takeback obligation (CSO/CTBO).

approach could lead to almost 1 $GtCO_2$ stored in 2050 (Model 2), while a country led approach increases that to almost 4 $GtCO_2$ (Model 3). Although these estimates fall short of the anticipated tonnages of carbon storage in 2050 under net zero scenarios (e.g. 7.2 $GtCO_2$ estimated by the International Energy Agency; IEA 2021), they do suggest a stronger basis for progress in this direction relative to the uncertainty presented by the current directions in global carbon markets (Model 1).

2. **Without targeted measures to support geological carbon storage, the outlooks for CCS deployment through conventional carbon market cooperation remain uncertain over the mid-term (at least to 2030)**. Rather, units originated from sink conservation and avoided emission activities (e.g. renewable energy deployment, energy efficiency, waste management) could continue to dominate credit market supply, particularly in the voluntary market space. This potential is exacerbated by NDC pledges that involve a deviation from a business-as-usual level of emissions, which offer possibilities to generate significant volumes of tradeable mitigation outcomes based on "avoided emissions" rather than removals or storage. Modelling by Yu et al. (2021) indicates that where most countries instead adopt ambitious net zero targets in NDCs, almost all units traded through international cooperation must rapidly switch to mitigation activities involving enhanced carbon sinks and reservoirs (e.g. geological and biological).

The evaluation also suggests that supply-side offsetting approaches offer the potential to address issues for NDC progression (e.g. by providing more certainty over the financing pathway for CCS), overcome commercial challenges for CCS (e.g. by addressing cross chain risks and agency problems), and also offer strong sectoral alignment in policy design (e.g. by placing the incentive to develop and fill geological $CO_2$ storage sites in the hands of the industry most competent to do so).

The analysis and evaluation we undertook would benefit from wider consultation across a broad group of stakeholders from government, industry, academia and NGOs. Such a process could help to raise awareness of the modalities, risks and opportunities for different forms of international cooperation and help to refine the concepts and evaluation presented.

# 1 Introduction

The 2015 Paris Agreement sets out to strengthen the global response to climate change. All 193 ratifying Parties are obliged to commit to, and undertake, significant climate change mitigation actions pursuant to its ambitious warming limitation goals, which must be communicated at least every five years in nationally determined contributions (NDCs). Parties may also voluntarily cooperate to achieve their NDCs through the Agreement's Article 6, which establishes the building blocks for a new global carbon market.

This report considers the potential for international cooperation under Article 6 of the Paris Agreement to alter the global landscape for deploying large-scale carbon dioxide capture and geological storage (CCS) as a significant climate mitigation option for the 21st century. Although CCS has been widely considered as a key climate technology over the past 20 years or so – and features significantly in Paris-aligned global mitigation pathways – it has yet to achieve anticipated scale-up (IEA 2016; Lipponen et al. 2017; Zakkour and Heidug 2019; Martin-Roberts et al. 2021). The entry into operation of the Paris Agreement provides an opportunity to revisit the incentives and finance available for the technology and to implement novel options that could facilitate a renewed push for global CCS roll-out over coming years. We address several key questions in these respects:

- How might mechanisms established in Article 6 of the Paris Agreement facilitate wider deployment of CCS than was achieved to date under the United Nations Framework Convention on Climate Change (UNFCCC) and its implementation under the Kyoto Protocol?
- What sort of models for cooperation and financing could support CCS deployment?
- To what extent might these models confront and overcome previous challenges for CCS deployment?

In addressing these questions, the report covers the following areas

**Section 2** provides a synopsis of the status of international cooperative approaches and considers the possible evolution of Article 6 and ways in which CCS could be integrated.

**Section 3** proposes three core models for international cooperation that could potentially incentivise CCS deployment.

**Section 4** presents a multi-criteria evaluation of the models, according to their assessed effectiveness, environmental integrity, financing, progression and policy performance.

**Section 5** provides some concluding remarks based on the findings of the assessment.

# 2 Outlooks for International Cooperation

## 2.1 About Article 6

Article 6 of the Paris Agreement aims to follow on from the international cooperation that took place under the market-based approaches of the Kyoto Protocol. Under Kyoto, so-called ‘flexibility mechanisms’ allowed developed country Parties that were subject to quantitative emission limitation and reduction obligations (QELRO) to trade in assigned amount units (AAUs) between themselves and also to acquire emissions reduction/removal credits from projects-based activities that could be counted towards QELROs; namely, the clean development mechanism (CDM) and joint implementation (JI). These experiences provided significant learnings for how governmental targets set out in domestic and international climate policy could be used to incentivise private sector entities to invest in mitigation technology and solutions.

The Kyoto Protocol’s two-track system of multilaterally-agreed (‘top-down’) QELROs for developed countries and limited and qualitative obligations for developing countries provided greater clarity for flexibility mechanisms compared to the Paris Agreement. The Paris Agreement instead requires all Parties to unilaterally pledge (‘bottom-up’) contributions towards ambitious mitigation reflective of their highest possible ambition” and cognizant of the “common but differentiated responsibilities and respective capabilities of countries, in the light of their different national circumstances” (Article 4.3). As a consequence, additional complications are posed for the accounting of transfers of mitigation outcomes between Parties. In particular, the variety of national circumstances across ratifying Parties has produced a significantly divergent set of mitigation pledges within NDCs including (based on Graichen et al. 2016):

- Economy-wide absolute emission reductions against a base year (in the same way as QELROs were structured under the Kyoto Protocol)
- Deviations in emissions from a business as usual (BAU) projection
- Reductions in GHG emissions intensity (e.g. emissions per unit of GDP or per capita)
- Non-GHG targets (e.g. areas of forested land, expressed in hectares)
- Actions only (e.g. proposed mitigation concepts, policies or projects referred to as ‘actions only’).

Parties have also variously expressed targets in NDCs for a single year (e.g. reduction of X in 2030) or for multi-year periods covering the NDC period in a way similar to a carbon budget (e.g. reduction of Y over the period 2025-2030, like Kyoto Protocol commitment periods), and with variations in the choice of base years.

The different target types and timeframes pose new challenges for how mechanisms and approaches under Article 6 can link together to help countries achieve their goals while preserving the overall objectives and integrity of the Paris Agreement. This complexity is reflected in the Article 6 text, that is far more nuanced than the more straightforward Article 6 (JI), Article 12 (CDM) and Articles 3 and 17 (AAU trading) of the Kyoto Protocol:

> Article 6.1. Parties recognize that some Parties choose to pursue voluntary cooperation in the implementation of their NDCs to allow for higher ambition in their mitigation and adaptation actions and to promote sustainable development and environmental integrity.
>
> Article 6.2. Parties shall, where engaging on a voluntary basis in cooperative approaches that involve the use of internationally transferred mitigation outcomes towards NDCs, promote sustainable development and ensure environmental integrity and transparency, including in governance, and shall apply robust accounting to ensure, inter alia, the avoidance of double counting, consistent with guidance adopted by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.
>
> Article 6.4. A mechanism to contribute to the mitigation of GHG emissions and support sustainable development is hereby established under the authority and guidance of the [Conference of the Parties (COP)] for use by Parties on a voluntary basis. It shall be supervised by a body designated by the COP, and shall aim:
>
> (a) To promote the mitigation of GHG emissions while fostering sustainable development;
> (b) To incentivize and facilitate participation in the mitigation of GHG emissions by public and private entities authorized by a Party;
> (c) To contribute to the reduction of emission levels in the host Party, which will benefit from mitigation activities resulting in emission reductions that can also be used by another Party to fulfil its NDC; and
> (d) To deliver an overall mitigation in global emissions.

On this basis, as noted in Article 6.2, the creation of an accounting framework that encompasses the diversity of target types, actions and measurements being proposed by countries while also remaining sufficiently robust remains key to successful implementation. Two concerns predominate in these regards:

**Avoidance of double counting.** Unlike the CDM, because every country has a target within its NDC, it is less straightforward to package and transfer mitigation outcomes from emission reduction or removal activities without considering the effects such transfers might have on the capacity of the host country to achieve its own NDC goal. If the mitigation effect of an activity is allowed to be counted by both the host and acquiring country towards their respective NDC targets (i.e. double counted), global emissions will rise.[2] This concern is reflected in Article 6.4(d) above, where the aim of the sustainable development mechanism is reiterated to be the delivery of an overall mitigation in global emissions (OMGE). To resolve double counting, Parties transferring mitigation outcomes are required to apply *corresponding adjustments*. This means that transferred units can be deducted only from the acquiring

[2] This would be possible because the host country counted the emission reduction domestically, while the acquiring country would use the mitigation outcome to offset the need for it take action domestically.

country's NDC account/target and must be correspondingly added back on to the transferring country's NDC account/target. While such notions proved controversial across several years of lengthy discussions in UN negotiations, the rules on Article 6 agreed at the 26th Conference of Parties to the UNFCCC (COP26) in Glasgow, UK, in November 2021 require corresponding adjustments to be applied to all international transfers of mitigation outcomes (UNFCCC 2021a). Some accounting challenges related to timeframes still persist for implementation, however (e.g. see Siemens and Schneider, 2021).

**Avoidance of "hot air" transfers.** Concerns exist regarding the veracity of some NDC targets, in particular, those involving a deviation in emissions from a BAU scenario. Over-inflated emissions in the BAU scenario pose a risk that credits can be generated from "hot air". That is, credits are awarded for a deviation from BAU even though the ex ante estimate of BAU emissions was greatly exaggerated comparted to, for example, historic trends or likely development pathways. In these cases, credits could be awarded to activities that would have happened anyway, while corresponding adjustments pose little jeopardy for the host country because the amounts will only be deducted from the portion of "hot air" present in the NDC. In these regards, an assessment of 55 NDCs based on deviations from BAU suggested there could be between 0.4 $GtCO_2e$ and 5.4 $GtCO_2e$ of "hot air" in First NDCs up to 2030 (high and low mitigation scenarios respectively; La Hoz Theuer et al. 2017). These findings led the authors to propose that the volumes of transfers under Article 6 be subject to restrictions to mitigate the risk of "hot air" trades (ibid.).

Other features of Article 6 that could affect the integrity of the Paris Agreement include:[3]

- **Potential to disincentivize NDC progression**. The possibility to internationally transfer (i.e. sell) mitigation outcomes that exceed the ambition of the NDC may deter host countries from setting stronger emission targets within subsequent NDC cycles, and
- **Potential to deter mitigation among buyers**. The availability of cost-effective mitigation outcomes may prompt buyers to rely on these rather than take longer-term and potentially more costly domestic mitigation measures. This could lead to higher-emission technologies being "locked-in" and urgently-required mitigation being delayed.

Significant uncertainty also resides in the nature of the future carbon market(s) driven by Article 6, and in particular whether voluntary market units and transactions may be incorporated into the Paris Agreement's accounting system. The entwinement of voluntary markets into the UN system is leading to difficult question regarding the accounting of credits originated under voluntary crediting programmes, the potential issues for double claiming and double counting, and whether corresponding adjustments should be applied to units being

[3] These concerns should also be considered in light of quantitative analysis suggesting that effective cooperation under Article 6 towards meeting 2019 NDC targets could lead to global emissions reductions of approximately 5 $GtCO_2$-equivalents and cost savings of over €250 billion in 2030 compared to a situation where nations act unilaterally to achieve their NDC goals (Edmonds et al. 2021).

acquired for purposes other than being counted towards NDCs. Clear answers to these questions have yet to emerge, and the debate continues with a range of deeply entrenched views both for and against applying corresponding adjustments to voluntary market transfers.

The rules for Article 6 agreed at COP26 remain slightly ambiguous in respect of the voluntary carbon market. They require corresponding adjustments to be applied to internationally transferred mitigation outcomes (ITMOs) authorised by a Party for use for *other international mitigation purposes* (i.e. not for being counted towards NDCs). While this is generally considered to be limited to credits issued for use under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)[4] – and possibly for future agreements for international shipping – uncertainty remains as to whether the requirements should also extend to transfers related to offsetting by private entities as well (e.g. corporate offsetting strategies). This matter has yet to be resolved.

Taking into account the backdrop described, a brief overview of the types of markets that may evolve through Article 6, and the types of credits that may be traded, is reviewed below.

### 2.1.1 Types of carbon market mechanisms

International cooperation on mitigation among governments is mostly conceptualized as occurring through several types of specific policy instruments and programmes, each providing a basis for an international transfer of mitigation outcomes (see Howard et al. 2017). These basic archetypes are summarised below (Table 2-1). Possible approaches to implementation under compliance and voluntary carbon markets are considered below.

#### Compliance markets

Crediting options for countries may be considered through Article 6.4 in a manner similar to the CDM (in that it is governed centrally under the UNFCCC), or crediting programmes implemented by governments or independent bodies in the context of Article 6.2 (Kizzier et al. 2019). In the second case, for example, Japan's Joint Crediting Mechanism (JCM) or various voluntary systems (e.g. Gold Standard) that also issue carbon credits, would be subject to Article 6 rules if they are being counted towards NDC targets. A wide range of other bilateral and multilateral pilot initiatives are being developed in this context (IKI/BMU 2019; Greiner et al 2020).

Credits linked to offsetting quotas are also an emerging concept for climate policy. For example, since 2021, aeroplane operators have been required to offset their emissions according to emissions growth in the sector using approved credits under CORSIA. Similar quota systems have also been envisioned to support CCS, based on a requirement for fossil fuel suppliers to store increasing amounts of $CO_2$ in the geosphere in proportion to the carbon embodied in the fossil fuel they extract from the geosphere (discussed further in Section 2.2.3).

[4] CORSIA allows for participating aeroplane operators to use credits originated from a variety of voluntary carbon market registries, including Gold Standard, Verra, American Carbon Registry, Global Carbon Council etc., as offsets.

### Table 2-1 Possible forms of cooperation and mechanisms under Article 6

| Type | Description |
|---|---|
| Crediting programmes | Activities receive credits for verified reductions or removals of emissions, usually compared to a baseline that represents how emissions/removals could be expected to have evolved if the activity were not implemented.<br>The Article 6.4 mechanism is a specific centralised crediting programme to be operated by the UN similar to the CDM.<br>Other programmes may be implemented by governments, groups of countries or institutions by way of Article 6.2.<br>Credits issued under such programmes may be purchased by entities to fulfil regulatory obligations placed on them through separate policy instruments such as carbon taxes, emissions trading or sectoral quotas (i.e. the credits can avail the holder with a right to emit 1 $tCO_2$, thereby acting as an offset). |
| Carbon taxes allowing for credit surrender | Some carbon taxes allow emission reduction/removal credits (potentially originated via Article 6.4 or Article 6.2 pathways described above) to be surrendered in lieu of carbon tax payments (e.g. in Colombia, South Africa Mexico). |
| Emissions trading systems (ETSs) | Linkages established between ETSs can provide for allowances* to be transferred to and surrendered in ETSs in other countries.<br>Bilateral agreements regulating the linkage will provide the basis for eligibility of allowances across the systems and any restrictions thereunder.<br>Additionally, as noted above, some emission reductions or removals credits may be deemed eligible for surrender against companies' ETS obligations, in both linked and unlinked ETSs (e.g. the California ETS accepts some credits from voluntary registries such as the American Carbon Registry) |
| Government-to-government transactions | Direct transactions between governments may be possible, for example through bespoke government procurement programmes or in the context of providing development assistance.<br>While the key relationships are bilateral or multilateral at government level, such transactions may be implemented through public or private sector entities.<br>Transactions may be made subject to the registration and monitoring, reporting and verification (MRV) processes of specific crediting programmes or may be subject to bespoke MRV arrangements and direct agreement on transfer volumes. |

* An allowance is a right to emit 1 $tCO_2$ freely allocated or auctioned by the ETS operator.

Linking ETSs is challenging on technical, legal and political levels, as reflected in the few instances of linking undertaken to date and the length of time required to negotiate bilateral linking agreements.[5] Linking generally requires a relatively high degree of harmonization between the ETSs in relation to the scope of coverage, degree of stringency in emission caps, legal nature of allowances, methods of allowance allocation, MRV and methodological consistency, eligibility of offsets, price or market stability mechanisms, etc.

The nature of obligations may vary beyond the examples in Table 2-1. Companies may also voluntarily set themselves obligations that go beyond mitigation levels required by regulation, leading to transactions on the voluntary carbon market. Furthermore, the voluntary and regulatory carbon markets are becoming increasingly entwined (e.g. the use in CORSIA of

[5] Agreement on the linking of Switzerland's ETS with the European Union's ETS took around 10 years to complete, despite being considered relatively straightforward.

credits originated on voluntary offset registries), and there are some expectations that voluntary crediting could form the basis for regulatory systems under Article 6 in the future.

## Voluntary markets

Voluntary carbon markets have to date been a vehicle by which the private sector can engage in international efforts to mitigate climate change, backed by tangible investment and knowhow and with transaction volumes and values reaching into the hundreds of millions of USD.

The "use" of credits is the component that may be referred to as "voluntary", rather than the credits themselves or the standards under which they are issued. Standards that were initiated and evolved in the voluntary market, such as the Gold Standard and the Verified Carbon Standard (VCS), were at first associated exclusively with the voluntary uses of credits. However, the voluntary nature of these systems is steadily breaking down, with independent standards now considered by some to provide equal quality assurance as compliance counterparts, and with the credits they generate now also being accepted for use in regulated carbon markets (e.g. for carbon tax compliance in Colombia, Mexico and South Africa, under CORSIA, and for selective use in the California ETS).

As mentioned above, the application of corresponding adjustments to transfers of ITMOs for uses for other international mitigation purposes, as agreed at COP26, leaves latitude for voluntary type transactions to be incorporated into the Paris Agreement accounting system. Aspects of voluntary carbon markets can also be expected to be used to determine the ongoing development and implementation of Article 6, in particular in the origination of credits used under Article 6.4.[6]

The voluntary market has been undergoing a resurgence in demand over recent years, drawing upon increased pressure on the private sector to take greater responsibility for their role in creating emissions. A survey conducted in October 2020 indicated that 1,565 companies across all continents have established targets to achieve net zero emissions across their operations, most of which include some degree of offsetting based on acquiring credits from the voluntary market (NewClimate Institute & Data-Driven EnviroLab, 2020). The number of companies explicitly ruling out the use of offsets to achieve ambitious climate action is limited, despite being contrary to guidance on developing net zero targets set out by the Science Based Targets initiative (SBTi).

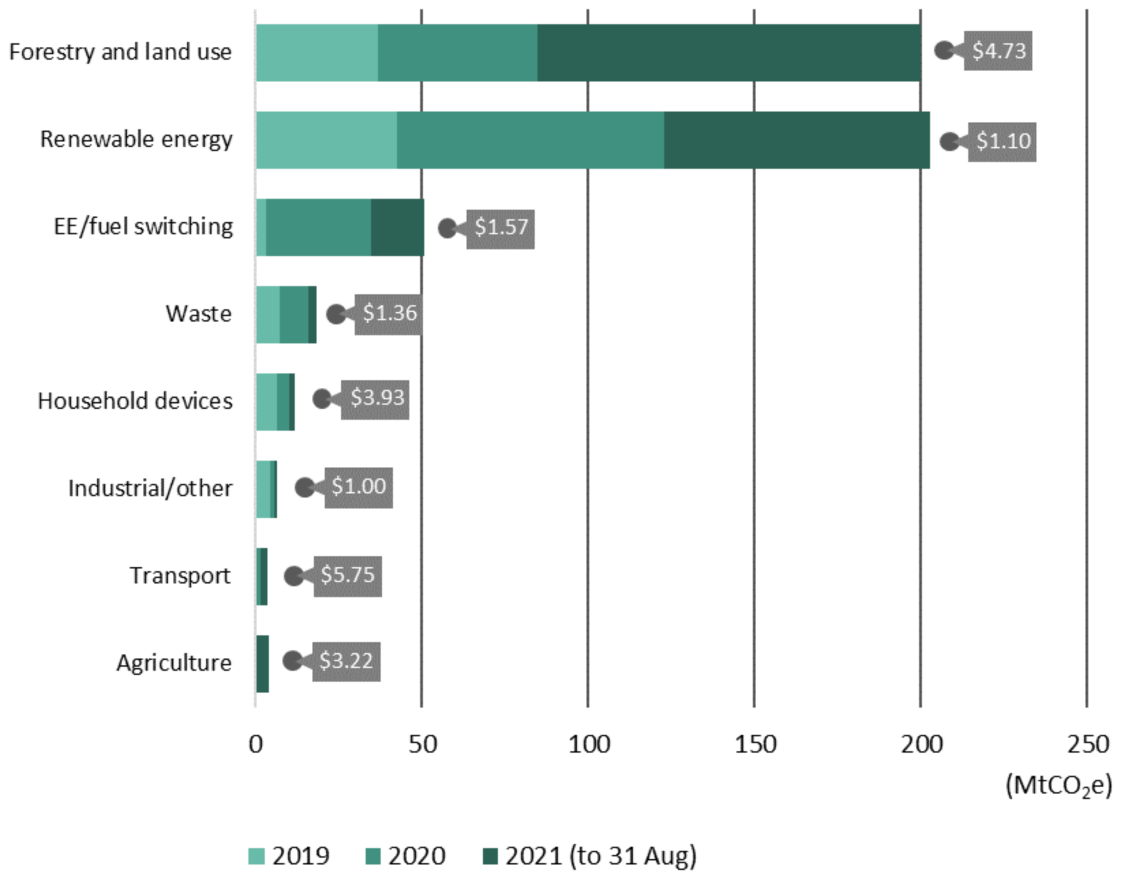
Traded volumes of voluntary market credits rose from 188 $MtCO_2e$ in 2020 to around 300 $MtCO_2e$ in 2021, with total market value more than doubling from USD 473 million to USD 1 billion (Forest Trends' Ecosystem Marketplace 2021a). The forestry and land use sector has accounted for most of this growth mainly in the form of forest conservation activities,[7] reaching 52% of the total volume of credits in 2021, followed by renewable energy projects (36%) and

[6] A Decision reached at COP26 requests the Supervisory Body mandated with overseeing the development of the rules for the Article 6.4 mechanism to *'consider the baseline and monitoring methodologies used in other market-based mechanisms'* alongside those of the CDM in the context of developing and approving new methodologies for the mechanism (UNFCCC 2021b).

[7] Known as reducing emissions from deforestation and land degradation or "REDD+"

energy efficiency and fuel switching projects (7%) (Figure 2-1). Data on voluntary market transactions indicates that carbon removals accounted for around 10% of the total, mainly from nature-based solution (Forest Trends' Ecosystem Marketplace 2021a; Forest Trends' Ecosystem Marketplace 2021b). The reported weighted average price of voluntary credits remains low at USD 3.37/t$CO_2$e in 2021, with the prevalence of extremely cheap renewable energy and energy efficiency credits as low as USD 1/t$CO_2$e masking higher prices in other sectors (Forest Trends' Ecosystem Marketplace 2021a).[8]

### Figure 2-1 Transacted voluntary carbon market volumes and average prices by project type 2019–2021




Source data: Forest Trends' Ecosystem Marketplace 2021a

Note: prices shown are average weighted prices per project category for the year 2021 (to 31 Aug)

The voluntary market is expected to grow significantly in coming years. Turner et al. (2021) examined the possible demand arising from emission pathways and net zero targets of around a third of the companies working under the SBTi, as well as potential demand from CORSIA and oil company scope 3 emissions in Europe. They estimate that 2020 demand (estimated at 95 Mt$CO_2$e) could grow as much as 5-10 times by 2030, 8-20 times by 2040, and 10-30 times by 2050, estimated to equate to around 2% of the emission reductions needed by 2030

[8] Average prices for removal-based offsets were reportedly up to five times as high as reduction-based offsets in 2021 (Forest Trends' Ecosystem Marketplace 2021b).

to arrive at a global emissions pathway consistent with the 1.5°C temperature goal. In their scenarios, credit prices could be expected to rise from a current weighted average of USD 3-5/t$CO_2$e to around USD20-50/t$CO_2$e by 2030 (Turner et al. 2021).

The Task Force on Scaling Voluntary Carbon Markets (TSVCM), a private sector-led initiative established to promote voluntary carbon markets, developed a scenario for voluntary credit supply in 2030 based on four different offset categories (TSVCM 2021). The group estimated the 'practical' potential of carbon credit supply to be 8 to 12 Gt$CO_2$ per year by 2030 (Figure 4-1).[9] When accounting for mobilization challenges, they reduce the estimated supply that could enter the market to 1 to 5 Gt$CO_2$ per year by 2030. As well as this representing a very broad range, the lower end (1 Gt$CO_2$e) is equal to the higher end of the scenario described in Turner et al. (2021), reflecting the high levels of uncertainty in voluntary carbon market scenarios at time of writing.

Despite the enormous growth in the voluntary market in recent years, and the bullish outlook, fundamental questions continue to be raised over the validity of offsetting. Societal acceptance of offsetting may therefore significantly erode the potential growth of voluntary markets. The SBTi, for example, in its guidance on Paris-compliant target-setting proposes that credits should only be used to finance emission reduction beyond the level of the science-based target or for neutralizing companies' remaining emissions once they reached their net zero positions (SBTi 2020).[10] The TSVCM (2021) also stresses that offsets do not replace the need to reduce value chain emissions and recommends that principles on the use of credits as offsets should be further developed by an independent body.

Furthermore, the concerns over the validity of offsetting notwithstanding, there are also significant questions regarding the types and quality of units that can and should be used for offsetting.

### 2.1.2 Types of traded units

Under Kyoto Protocol, the emphasis of climate action was firmly on emission reductions. The Paris Agreement, however, requires that Parties seek "to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century" (Article 4.1), thereby embedding the concept of net zero into global climate change mitigation approaches. The dual emphasis on both emission reductions at sources *and* removals by sink enhancements focuses attention on the types of offsets that can be used to make net zero claims both by governments and corporations alike. The basic principle of net zero is that, ultimately, any residual anthropogenic GHG emissions (either globally, remaining in a country or counted within the GHG inventory of a corporation)[11] must

[9] 'Practical' potential is described as excluding 'low-feasibility' supply according toa range of factors. The authors consider the estimated practical potential to be conservative, due to accounting for factors such as economic feasibility and additionality of emissions reductions (TSVCM, 2021).
[10] The SBTi Net Zero standard allows companies to factor in carbon offsets as part of their net-zero targets, but only after science-based emission reduction goals covering the next five to ten years have been adopted and companies have cut 90 % of their GHG emissions (SBTi 2021).
[11] Generally, the hard-to-abate emissions where non-fossil carbon alternatives do not exist or are costly.

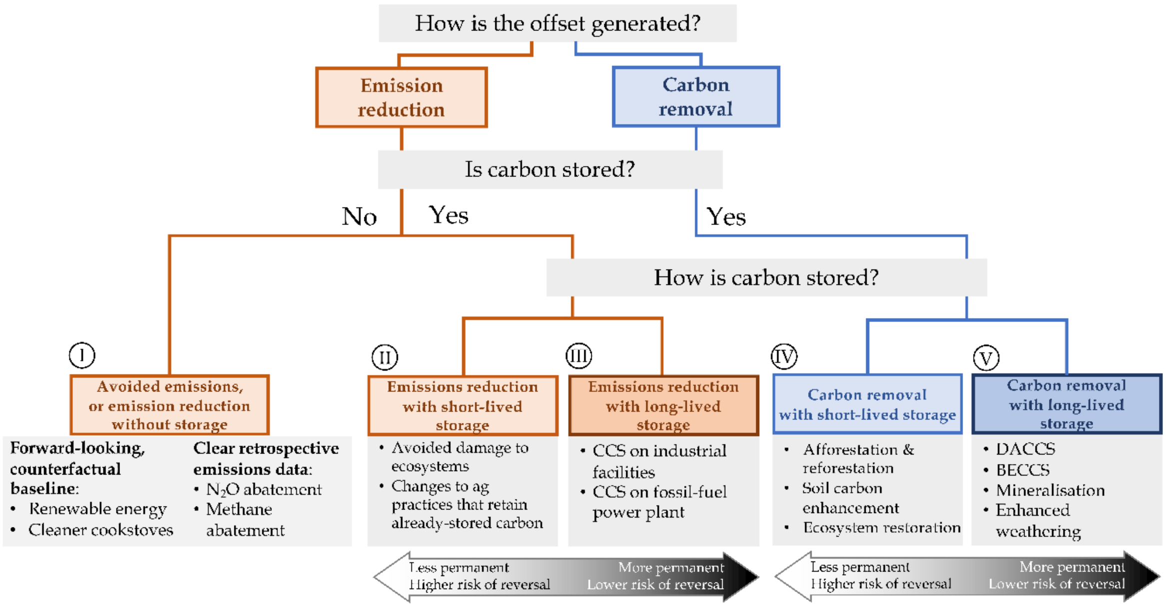
be balanced by an equivalent level of GHG removals by sink enhancements (widely referred to as carbon dioxide removal or "CDR" or negative emission technologies or "NETs", depending on context). Under an alternate accounting perspective, the total amount of $CO_2$ generated will need to be balanced by an equal amount of $CO_2$ storage.[12]

The fundamentals of net zero offsetting is subject to a growing body of work in both academic and grey literature. Aspects being discussed include the pathways to net zero emissions, the importance of CDR in balancing residual emissions, and the political and regulatory risks involved with pursuing $CO_2$ removals to meet net zero goals. The scope of this report does not encompass a full review of the literature in these contexts. However, a few observations can be made that relate to CCS and the various models for incentivising its deployment under Article 6.

In respect of the Paris Agreement, the types of NDC targets so far communicated by many developing countries are based on reducing GHG intensity or reductions against a BAU scenario (Section 2.1), either of which can allow for absolute emissions to rise over time. In many cases, at least a portion of the target is made conditional on receiving international finance. Drawing on experiences from the Kyoto Protocol, interest therefore remains strong among many countries in establishing crediting (or, to some extent, trading) that is based on actions that reduce emissions below a baseline level that would otherwise happen absent of the project. The resulting emission reduction units are essentially counting "avoided emissions" (Figure 2-2). Notably, the current carbon market encompasses a mix of approaches and credit types with limited distinction of whether the underlying action generating the unit involved emissions reductions, carbon removals or a combination of both.[13]

[12] In this case, the capture of $CO_2$ at sources would not be counted as an emission reduction, but rather the storage of $CO_2$ in geological reservoirs could be counted as a sink enhancement to balance the GHG emissions inventory.
[13] To note a few: Verra issues a Verified Carbon Unit (VCU) representing the "reduction or removal of one tonne of carbon dioxide equivalent ($CO_2e$) achieved by a project" (https://verra.org/project/vcs-program/verified-carbon-units-vcus/); Gold Standard similarly issues "Verified Emission Reductions (VERs)" (https://www.goldstandard.org/articles/gold-standard-emission-reductions). The Climate Action Reserve issues a Climate Reserve Ton (CRT) equal to "one metric ton of carbon dioxide equivalent ($CO_2e$) emissions reduction or sequestration" https://www.climateactionreserve.org/how/offsets-marketplace/. The American Carbon Registry issues an Emission Reduction Ton (ERT) equal to "one ton of $CO_2$ equivalent GHG emission reduction or removal" (https://americancarbonregistry.org/how-it-works/what-we-do). Conversely, Puro.earth only issues "$CO_2$ Removal Certificates" (CORCs) (https://puro.earth/), and Nori issues "Nori Carbon Removal Tonnes (NRTs)" representing "one tonne of removed $CO_2e$ stored for a minimum of ten years" (https://nori.com/generate-nrts).

## Figure 2-2 Taxonomy of carbon offsets




Source: Allen et al. 2020

On the buyer side of the nascent global carbon market, several developed countries have pledged ambitious emission reduction goals predicated on access to transferred mitigation outcomes from cooperative actions in third countries. Thus, cooperative actions that support deviations away from BAU, or reduce GHG intensity, could generate transferable mitigation outcomes that can be used to meet ambitious or net zero pledges by countries and companies alike. These sorts of arrangements are posing fundamental questions about the role of offsetting under Article 6, and the types of net zero claims that countries might be able to make through the acquisition of Article 6 units.[14]

Some observers (e.g. Allen et al. 2020, Zelikova 2020) have suggested that net zero requires offsetting strategies to be increasingly geared towards removals rather than emission reductions or avoided emissions. Allen et al (2020), in *The Oxford Principles for Net-Zero Aligned Carbon Offsetting*, furthermore propose that offsetting needs to be focussed on long-lived storage, primarily geological storage. Following similar lines of thinking, several corporations including, Shopify, Stripe and Microsoft have committed to pursuing carbon removals as part of their carbon offsets activities (Lütke 2019; Anderson 2019; Smith 2020). Offsetting service providers exclusively dealing in removals activities, such as Puro.earth[15] and Nori[16], have also emerged in the voluntary market. Firms like Climeworks also offer direct sales of $CO_2$ removals to customers, achieved using their proprietary direct air capture (DAC) technologies.

[14] For example, Switzerland has an advanced Article 6 pilot programme that is seeking around 54 million $tCO_2e$ of offsets that can meet 20% of its NDC goal to reduce 2030 emissions by 50%. Many of the activities noted in its offset credits pipeline to date relate to 'avoided emissions' (https://www.international.klik.ch/activities/mitigation-activities)
[15] https://puro.earth/ [Accessed, June 2021]
[16] https://nori.com/ [Accessed, June 2021]

Others seem less convinced by the near-term focus on removals. Gold Standard (2020), for example, has questioned the rationale for shifting to removals-based offsetting. It has instead asserted that Oxford Offsetting Principles of Allen et al. (2020) appear contradictory in highlighting a need to prioritise abatement in the short- to medium-term while in parallel initiating a removals pipeline to provide supply in the longer term. Gold Standard (2020) has therefore suggested that without dramatically accelerating abatement, the opportunity to reach net zero falls out of reach – or, put another way, we will have to remove emissions in the future that could have been abated today.

On the credit supply side, some have suggested that as governments ramp up their mitigation efforts and the costs of low-carbon technologies decrease, there will be less and less space for certain project types (World Bank 2021). In these respects, Verra has recently discontinued the registration of new renewable energy projects not located in Least Developed Countries (LDCs) on the basis that they no longer need carbon finance to be viable. The Gold Standard has also adopted similar requirements. Conversely, the TSVCM (2021), recommends that *all project types need financing now* including both emissions avoidance and removals. However, the TSVCM do also suggest the need to ensure early investment in technology-based removals to ensure sufficient scale at accessible costs, and proposed that heavy-emitting industries – such as oil and gas, aviation, and manufacturing – commit their voluntary activities towards developing higher-cost low carbon technologies (i.e. CCS, direct air capture with storage (DACCS), bioenergy with carbon capture and storage (BECCS) and others) (*ibid*). Some of these concerns may be addressed by the Voluntary Carbon Market Integrity Initiative (VCMI, 2021)[17] that aims to provide guidance on how voluntary carbon credits can be used and claimed as part of credible net zero decarbonisation strategies.

Other types of concerns have been voiced about moves towards removals-based offsetting and the potential moral hazard effects that can arise for policymaking. Fuss et al (2018) noted that these concerns centre around ‘mitigation obstruction’; that is, the assumed availability of large-scale NETs acts to disincentivize emissions reductions in the present. This view is based on the idea that because NETs can be used to offset emissions from certain activities, their use displaces the need for mitigation action in those sectors, at least for the time being. Furthermore, it has been argued that the apparent availability of NETs may have already possibly led to the deferral of climate action by policymakers because of the excuse they provide for near-term inaction (as suggested by Anderson and Peters, 2016, among others). McLaren et al (2019) sought to further define this type of risk, adopting the term ‘mitigation deterrence’ in the process.

An emerging idea to address the potential risk of mitigation deterrence is the separation of targets between emission reductions and removals (i.e. the establishment of specific new targets solely for removals that are independent of emission reduction goals, perhaps in NDCs; McLaren et al. 2019; Geden and Schenuit 2020; Jeffrey et al. 2020; Zakkour et al.

[17] The VCMI is a multi-stakeholder platform drawn from civil society, businesses, indigenous peoples and local communities, and governments; see https://vcmintegrity.org

2021). The justifying principle behind target separation is that it results in greater transparency regarding how climate neutrality targets are intended to be met (e.g. what combination of emissions reduction and removals will be sought to achieve net zero) and removes the potential for adverse interactions to occur with emission reduction-based policies, such as mitigation deterrence. As a consequence, activities that result in removals and negative emissions would not erode requirements to cut emissions. On the other hand, some have argued against the need for target separation, suggesting instead that improved transparency over net zero targets is needed (Smith 2021).

To date, proposals for target separation have lacked substance as to how a secondary target specific only to carbon removals could be practically implemented. Several models can be envisaged, including through the placement of the obligation to acquire removals (or storage) units on carbon suppliers rather than on carbon emitters as per the supply-side offsetting model described below (Section 0; Mitchell-Larson et al. 2020; Zakkour et al. 2021) or proposals that could emerge under 'FLAG Science Based Targets' in the land sector (SBTi 2022).

## 2.2 CCS and international cooperation

Taking into account the outlook for Article 6 described above, this section considers how CCS could be further integrated through potential international cooperative policies and programmes under the Paris Agreement. Given the current status and uncertainty over the evolutionary paths for international cooperation, the analysis is inherently based on some broad supposition.

### 2.2.1 Historical perspectives and outlooks for CCS

Technologies involving CCS have been widely seen as an important component of global climate change mitigation since the turn of this century. Over the period 2005-2010 – the zenith for Kyoto Protocol implementation – CCS was consistently noted as a key technology in pathways for achieving rapid, deep and sustained cuts in atmospheric $CO_2$ concentrations.

Over this period, the Intergovernmental Panel on Climate Change (IPCC) confirmed the technical mitigation potential, risks and costs of CCS technology among other aspects (IPCC 2005), established specific methods by which countries could incorporate emission reductions from CCS into their national GHG accounts (IPCC 2006) and presented scenarios for limiting atmospheric $CO_2$ concentration that were heavily reliant on CCS (the Fourth Assessment Report – AR4; IPCC 2007). Similar projections were also provided by the International Energy Agency (IEA; IEA 2009). In response, policymakers put in place ambitious goals to deploy 15 to 20 large CCS demonstration projects over the period 2010-2015 (Council of Ministers 2007; Group of Eight (G8) 2008).

These deployment goals proved far more elusive than envisioned, however. Around the period 2010-2012, a combination of factors led to most proposed CCS projects being cancelled or delayed (IEA 2016; Lipponen et al. 2017; Zakkour and Heidug 2019). At time of writing, around 26 large-scale commercial CCS projects are in operation around the world injecting around 40-50 $MtCO_2$ annually, six of which were commissioned prior to 2005 (Global CCS Institute 2021).

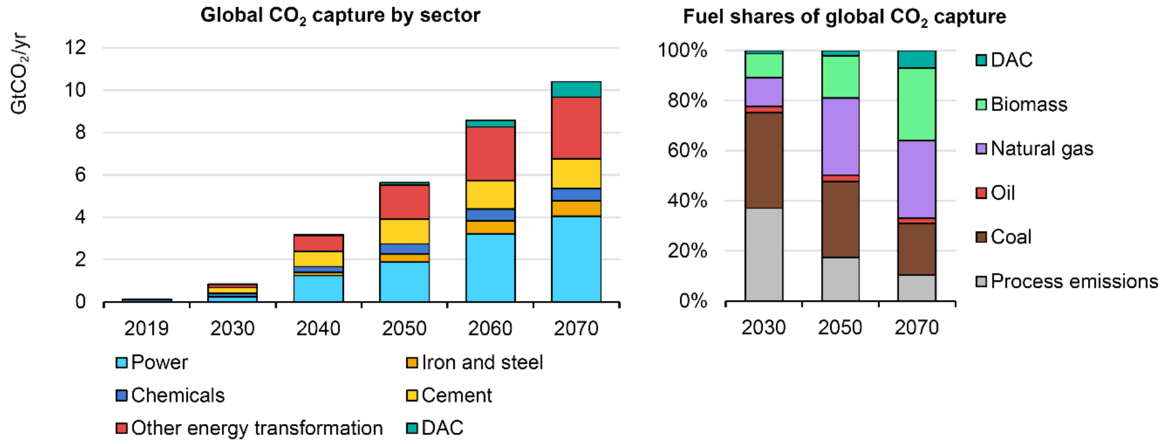
Despite lower-than-expected progress, a significant body of analysis still suggests that geological $CO_2$ storage will be a critical technology for meeting the Paris Agreement's goals. For example, three of the four 1.5°C aligned mitigation scenarios analysed by the IPCC in its Special Report on Warming of 1.5°C (IPCC 2018; SR1.5) suggest CCS deployment in the range 350–1200 $GtCO_2$ stored is needed by 2100 (p. 14; scenarios P2, P3, P4). Only the P1 scenario used in the SR1.5 analysis achieves atmospheric stabilisation of $CO_2$ concentrations without CCS, instead relying on deep social, economic and technological transformations (see the Low Energy Demand scenario described in Grubler et al. 2017).

The 1.5ºC aligned Sustainable Development Scenario from the IEA also suggests a significant role for geological storage, cumulatively reaching almost 6 $GtCO_2$ by 2050 and 10 $GtCO_2$ in 2070, derived from a variety of sources (IEA 2020a; Figure 2-3). The IEA's more recent roadmap for global net zero by 2050 (IEA 2021; the NZE scenario)[18] depicts over 400 significant milestones, including, from 2021, no new oil and gas fields being approved for development and no new coal mines or mine extensions. However, despite the significant curtailment of fossil fuel production, achieving its goals still relies on capturing and geologically storing around 7.2 $GtCO_2$ in 2050 (Figure 2-4).

The story of the last two decades suggests that, even though the specific metrics have moved around, the significance and magnitude of CCS in achieving ambitious global climate action remains broadly the same.

[18] Net zero emissions means the balancing of all anthropogenic GHG emissions sources with the commensurate removal of GHGs through the enhancement of GHG sinks and reservoirs.

Figure 2-3 Growth in global $CO_2$ capture by sector and fuel in the IEA's Sustainable Development Scenario, 2019-2070

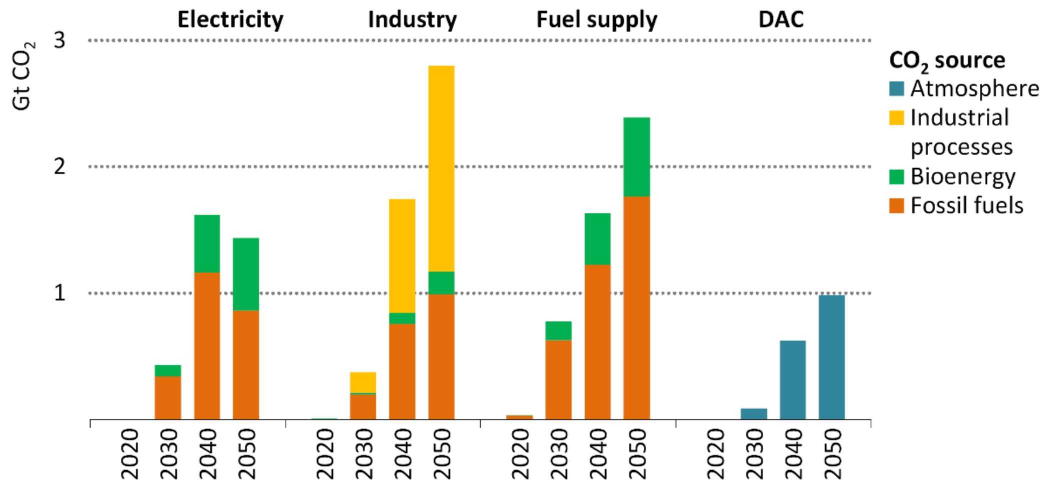





Note: DAC = direct air capture.

Source: IEA 2020a (p. 103)

Figure 2-4 CCS by sector and emissions source in net zero emissions






*Fossil fuel emissions account for almost 70% of total $CO_2$ capture in 2030 and almost 50% in 2050*

Source: IEA 2021 (p. 94)

## 2.2.2 Treatment of CCS under the Paris Agreement

Since the late 1990's, both Norway (Sleipner) and Canada (Weyburn-Midale) have reported CCS actions in their national communications to the UNFCCC. In the case of Norway, the emission reductions achieved at the Sleipner CCS project were counted towards the country's Kyoto Protocol targets. In the case of Weyburn-Midale, the injected $CO_2$ was imported from the United States (U.S.), so no emission reductions could be claimed by Canada in pursuit of its own target under the Protocol. In parallel, the U.S. also reports $CO_2$ injected in various enhanced oil recovery projects (EOR) in its national communication to the UNFCCC. However, because these sites were not subject to the same level of monitoring applied in Canada and Norway, the U.S. Environmental Protection Agency has so far elected to report the entire mass of injected anthropogenic $CO_2$ as being emitted to the atmosphere.[19]

These experiences provide valuable lessons for measuring CCS actions in pursuit of NDCs. Under Article 13 of the Paris Agreement, all countries must track their progress against actions and targets set out in their NDCs following the international rules for the enhanced transparency framework (ETF; UNFCCC 2018). The ETF requires nearly all Parties to use the 2006 IPCC Guidelines (IPCC 2006), meaning that specific guidance therein for CCS must be followed.[20] DAC is not presently covered by the 2006 IPCC Guidelines, although the transport and storage of any such $CO_2$ should, in principle, be covered the relevant parts of the 2006 IPCC Guidelines.

Furthermore, in respect of project-based crediting activities, following several years of protected negotiations Parties to the Kyoto Protocol agreed specific rules (modalities and procedures) for developing country Party's wishing to host CCS projects under the CDM (UNFCCC 2011; Zakkour et al. 2011a). The agreed rules set down import requirements for, inter alia, site selection, risk assessment, permanence and liability (a fuller review of the various measurement reporting and verification (MRV) standards for CCS can be found in IEAGHG, 2016).

As noted previously, the COP26 requested the Article 6.4 Supervisory Body to review baseline and monitoring methodologies from the CDM (none were ever approved for CCS) and also consider methodologies used in other market-based mechanisms (see Box 2-1) as complementary inputs to the development Article 6.4 methodologies.

### Box 2-1 CCS in non-UN mechanisms

CCS has featured in various regional, national and sub-national climate policies and programmes including the European Union (EU) emissions trading system, the EU Renewable Energy Directive (REDII), and California's low carbon fuel standard (C-LCFS). The C-LCFS CCS Protocol, for example, provide for upstream credits generated from CCS in oilfield operations to be counted within the system boundaries while the REDII and also the EU's Fuel Quality Directive both take account of CCS applied in bio- and fossil fuel production chains. The C-LCFS CCS Protocol also allows credits to be originated from DACCS anywhere in the world.

Various voluntary or bilateral national "offset" methodologies for CCS have also been established in the American Carbon Registry and the Alberta Offset System and are under consideration within the Joint Crediting Mechanism of Japan and Puro.earth (limited to DACCS and BECCS) – see Figure 2-5 and also IEAGHG (2016).

[19] It was, however, reporting injected $CO_2$ sourced from natural reservoirs as being sequestered.
[20] For example, the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2019). No revisions to the 2006 guidance on CCUS was included in the 2019 refinement.

Even though these efforts may not result in specific Article 6.4 methodologies for CCS, both the 2006 IPCC Guidelines and the CCS CDM modalities and procedures provide a firm basis upon which to integrate CCS within the Paris Agreement and to develop methodologies both inside and outside of the UNFCCC framework.

### 2.2.3 Approaches to CCS cooperation under Article 6

CCS could be incorporated into Article 6 through either emissions trading or crediting in various forms, occurring within either compliance markets, voluntary carbon markets, or government-to-government transfers of mitigation outcomes outside of market-based mechanisms (e.g. direct purchases).

In addition, proposals have been made for CCS-specific approaches involving the use of a carbon storage unit (CSU) as a transferrable mitigation outcome under Article 6 (Zakkour and Heidug 2019; Mitchell-Larson et al., 2020; Zakkour et al, 2021). Rather than being measured as emissions [rights] or emission reductions, CSUs would represent tonnes of $CO_2$ *stored*, which proponents suggest can be used as a basis for targeted international cooperation on geological storage of $CO_2$.

A brief overview of the possible models for cooperation and their relationship to CCS are considered below. The models described here are taken forward for further analysis in Sections 3 and 4.

#### Emissions trading systems

Cap-and-trade ETSs could facilitate investments into CCS. For example, in a scenario of linked ETSs, a capped entity in jurisdiction A could employ CCS to develop a surplus of emissions rights (e.g. allowances allocated under a national cap-and-trade system) that could then be sold to an entity in jurisdiction B.

In this scenario, the financial incentive would accrue to the entity in jurisdiction A capturing the $CO_2$ (by either by selling surplus allocated allowances or avoiding the cost of acquiring emission allowances to cover its regulated emissions). This benefit would need to be distributed through private contracts across the chain of operations (capture, transport, storage) in order to finance a complete CCS activity. Such a configuration mirrors the incentive structures for CCS available under existing policies and programmes, for example, the regional cap-and-trade system in the EU (the 'EU ETS'). Empirical evidence from the EU ETS suggests, however, that such arrangements alone have had limited impacts on low carbon innovation (Rogge 2016; Marcantonini et al. 2017), with the allowance price so far proving too low and too unstable to promote investments into higher cost, large-scale and long-term innovative low carbon technologies such as CCS (European Commission, 2015). Research suggests that the EU ETS has instead been effective in promoting short-term mitigation measures (e.g. with 3-5 year amortization rates; Marcantonini et al. 2017). Consequently, no CCS projects have been deployed in direct response to the price signal of the EU ETS despite almost 20 years of operation.

Given the current nascent commercialisation status of the technology, many commentators hold the view that additional and/or more targeted measures are needed to support CCS deployment (e.g. IEA 2016; IEA 2020b). In these respects, various efforts are underway that aim to reduce volatility within ETSs, including the introduction of price stability mechanisms such as:

- Carbon floor prices (e.g. as introduced in the UK in 2013 prior to its departure from the EU, and as proposed in The Netherlands)[21];
- The Market Stability Reserve (introduced by the European Commission in 2019); and
- Carbon contracts for differences (CCfDs), which involve governments paying capture entities the difference between the prevailing carbon price and a pre-agreed 'strike price' and vice versa (where the prevailing carbon price exceeds the strike price). This approach is being rolled-out in The Netherlands (under the SDE++ initiative)[22] is proposed in the UK (Department for Business, Energy & Industrial Strategy (BEIS) 2020) and is also under consideration for the European Union (European Commission 2021).

Targeted government funds raised from the sale of ETS emissions allowances are also seeking to provide direct grant support to CCS development (e.g. the EU Innovation Fund). The extent to which the use of such measures and subsidies could impact upon the feasibility of linking ETSs from different jurisdictions remains unclear, although analysis to date suggests several barriers will likely arise (Galdi et al. 2020).

Cross-chain risks, that is the risk that one part of a CCS project – capture, transport or storage – might fail or be delayed, incurring costs for the remaining parts, also remains challenging where the commercial model relies on applying a single carbon price to emitters (i.e. as in an ETS). In this situation, the revenue of the entities transporting and storing $CO_2$ remains reliant on payments from the capture entity, whose incentive is directly linked to the carbon price. Where the carbon price is too low, or too volatile, the capturing entity faces choices about whether to invest in, or whether to operate, the capture plant (should it prove cheaper to emit than capture), placing uncertainty on the commercial viability of the transport and storage system. Cross-chain risks can be reduced by price stability mechanisms such as CCfDs or in circumstances where $CO_2$ has intrinsic value, for example, in $CO_2$ utilisation which allows for an additional, separate and complementary price incentive for the users and storers of $CO_2$.[23]

The potential impacts on CCS deployment of linked ETSs under Article 6 are uncertain. On the one hand, since an objective of linking ETSs is to lower overall costs of meeting NDC targets, there are possibilities that Article 6 cooperation could actually lower the incentives for CCS as it should drive carbon price reductions through lower-cost mitigation actions. Analysis

[21] https://www.government.nl/latest/news/2019/06/04/bill-submitted-on-minimum-carbon-price-in-electricity-production
[22] https://english.rvo.nl/subsidies-programmes/sde
[23] In the case of mineralisation products and $CO_2$ EOR, storage is incidentally or purposefully achieved during utilisation.

by the International Emissions Trading Association (IETA) and the University of Maryland (UDM) for net zero emissions in 2050 showed that fully linked markets could result in greater deployment of nature-based rather than geological $CO_2$ storage toward 2030 (unlinked systems rely more heavily of geological $CO_2$ storage to 2030); notably, however, by 2050 the spread evens out and greater geological storage is needed as natural sinks become saturated (Yu et al. 2021). On the other hand, in the face of progressive ambition in future NDCs, linking could prove effective in discovering the lowest cost CCS opportunities and resolving distributional factors that hamper the capacity of some jurisdictions to utilise the technology in the face of large fossil $CO_2$ emissions (i.e. lack of storage capacity, or lack of public acceptance).

In reality, linking ETSs is very challenging, and only possible in cases where countries express similar levels of economy-wide absolute emission reduction ambition against a similar base year; such formulations offer the most straightforward way of comparing the alignment of climate ambition. Otherwise, differential ambition between countries or regions in linked ETSs will simply result in one-way flows of units from the less stringent to the more stringent jurisdiction. As such, the likelihood of significant developments in the direct linking of national ETSs anytime in the near future seems low (e.g. between EU and other countries); indeed, previous ETS linkages between U.S. and Canadian states and provinces have largely been shelved.

In any case, in accordance with Article 6.2 rules on the avoidance of double counting, transfers of units by private entities between countries within linked ETSs would need to be treated as international transfers of mitigation outcomes and subject to corresponding adjustments in the true-up of the NDCs of the countries' involved in linking.

## Crediting approaches

No CCS methodologies or projects were ever submitted or approved after agreement of the CCS CDM modalities and procedures (UNFCCC, 2011), and in general, geological storage technologies have been poorly represented in existing crediting systems to date relative to other types of climate mitigation solutions (Box 2-1; Figure 2-5). However, it is reasonable to surmise that crediting approaches under Article 6 could open up a wider base of possibilities for incentivising CCS investment relative to linked ETSs.[24]

[24] For example, CORISA accepts credits originating from CCS activities from some CORSIA-approved voluntary registries (e.g. CDM, albeit with no CCS methodology yet approved; American Carbon Registry) although not all (e.g. China GHG Voluntary Emission Reduction Program; Global Carbon Council) (ICAO 2022).

## Figure 2-5 Credits issued, registered activities, average 2020 price and sectors covered by crediting mechanisms

| Name of the mechanism | Crediting mechanism type | Credits issued ($MtCO_2e$) | Registered activities | Average price (USD) | Sectors covered |
|---|---|---|---|---|---|
| American Carbon Registry | Independent | 7.30 | 15 | 5.36 | Agriculture, CCS/CCU, Energy Efficiency, Forestry, Fuel switch, Industrial gases, Manufacturing, Renewable energy, Transport, Waste |
| Climate Action Reserve | Independent | 4.61 | 33 | 2.34 | Agriculture, Forestry, Industrial gases, Other land use, Waste |
| Gold Standard | Independent | 34.35 | 59 | 5.27 | Agriculture, Energy Efficiency, Forestry, Fuel switch, Fugitive emissions, Renewable energy, Waste |
| Verified Carbon Standard | Independent | 140.37 | 127 | 1.62 | Agriculture, Energy Efficiency, Forestry, Fuel switch, Fugitive emissions, Industrial gases, Manufacturing, Renewable energy, Transport, Waste |
| Clean Development Mechanism | International | 74.00 | 15 | 2.02 | CCS/CCU, Energy Efficiency, Forestry, Fuel switch, Fugitive emissions, Industrial gases, Manufacturing, Renewable energy, Transport, Waste |
| Joint Implementation Mechanism | International | - | - | N/A | Agriculture, Energy Efficiency, Forestry, Fuel switch, Fugitive emissions, Industrial gases, Manufacturing, Renewable energy, Waste |
| Alberta Emission Offset System | Domestic | 8.40 | 17 | 15.92 - 21.49 | Agriculture, CCS/CCU, Energy Efficiency, Forestry, Fugitive emissions, Industrial gases, Manufacturing, Renewable energy, Waste |
| Australia Emissions Reduction Fund | Domestic | 16.30 | 128 | 12.02 | Agriculture, Energy Efficiency, Forestry, Fugitive emissions, Transport, Waste |
| Beijing Forestry Offset Mechanism | Domestic | - | - | 2.10 - 9.28 | Forestry |
| Beijing Parking Offset Crediting Mechanism | Domestic | - | N/A | N/A | Transport |
| British Columbia Offset Program | Domestic | 1.60 | 3 | 6.37 - 11.94 | Energy Efficiency, Forestry, Fuel switch, Waste |
| California Compliance Offset Program | Domestic | 46.00 | 62 | 13.71 | Agriculture, Forestry, Fugitive emissions, Industrial gases |
| China GHG Voluntary Emission Reduction Program | Domestic | - | - | 1.52 - 3.04 | Energy Efficiency, Forestry, Fuel switch, Renewable energy, Waste |
| Fujian Forestry Offset Crediting Mechanism | Domestic | 0.16 | - | 1.52 - 3.04 | Forestry |
| Guangdong Pu Hui Offset Crediting Mechanism | Domestic | 0.60 | 10 | 2.59 | Forestry, Renewable energy |
| J-Credit Scheme | Domestic | 0.30 | 16 | 13.54 - 19.78 | Energy Efficiency, Forestry, Fuel switch, Renewable energy, Waste |
| Québec Offset Crediting Mechanism | Domestic | 0.11 | 1 | 14.6 | Waste |
| Republic of Korea Offset Credit Mechanism | Domestic | 17.61 | 308 | 20.31 - 36.02 | Energy Efficiency, Industrial gases, Renewable energy, Transport, Waste |
| RGGI $CO_2$ Offset Mechanism | Domestic | 0.01 | - | 5 | Energy Efficiency |
| Saitama Forest Absorption Certification System | Domestic | - | - | N/A | Forestry |
| Saitama Target Setting Emissions Trading System | Domestic | 1.00 | - | 4.23 | Energy Efficiency |
| South Africa Crediting Mechanism | Domestic | - | - | N/A | Agriculture, Energy Efficiency, Forestry, Fuel switch, Other land use, Renewable energy, Transport, Waste |
| Switzerland $CO_2$ Attestations Crediting Mechanism | Domestic | 2.10 | 8 | 59.19 - 159.61 | Energy Efficiency, Forestry, Fuel switch, Renewable energy, Transport |
| Thailand Voluntary Emission Reduction Program | Domestic | 6.01 | 156 | 0.64 - 9.46 | Agriculture, Energy Efficiency, Forestry, Renewable energy, Transport, Waste |
| Tokyo Cap-and-Trade Program | Domestic | - | 12 | 1.62 - 57.77 | Energy Efficiency, Renewable energy |
| Joint Crediting Mechanism | Domestic | 0.03 | 9 | N/A | Energy Efficiency, Renewable energy, Transport |

Sectors: Agriculture; CCS/CCU; Energy Efficiency; Forestry; Fuel switch; Fugitive emissions; Industrial gases; Manufacturing; Other land use; Renewable energy; Transport; Waste

Crediting mechanisms: Independent; International; Domestic

Source: World Bank 2021 (p. 75)

In particular, a number of developing countries host high purity $CO_2$ emissions sources that can be captured at relatively low cost, making them strong candidates for early opportunity deployment based on crediting approaches (Zakkour and Cook 2010; IEA 2021b). Previous analysis indicated that a CER price of USD 15 under the CDM could incentivise between 100 to 300 $MtCO_2$ emissions avoided from high purity sources in developing countries by 2020 (IEAGHG 2008; Zakkour et al. 2011b). Given the lack of CCS developments in these regions to date, estimates presented by Zakkour et al. (2011b) are likely to remain valid at the time of writing.

Where these early opportunity, high purity CCS projects are taken forward under Article 6 project-based crediting approaches, several opportunities and challenges can be envisaged:

**Baseline determination and additionality**. Generally little or no controls are in place to limit the emissions of high purity industrial $CO_2$ sources in most developing countries. As such, baseline and additionality determination should be relatively straightforward, drawing upon historical emissions and first-of-kind or regulatory additionality to demonstrate that the use of CCS is not BAU. The heterogeneity of some high purity $CO_2$ sources, in particular the processing of natural gas from high $CO_2$ content gas fields suggests that the application of forward-looking, performance or benchmark-based approaches – including standardised baselines applied at country levels – are unlikely to be suitable. Such baseline approaches could significantly erode the number of credits issued to CCS project activities at these types of facilities.[25] This, in turn, could erode the viability of applying CCS to these sources. As such, careful consideration of appropriate baselines for natural gas processing activities is warranted to avoid disincentivising deployment. On the other hand, measures to avoid perverse outcomes that, inter alia, encourage the development of highly contaminated natural gas fields, or result in the offsetting of emissions from natural gas combustion by the injection and storage of the $CO_2$ by-product arising from its sweetening, should be avoided to maintain environmental integrity.

**Relation to the NDC of the host country**. Despite views to the contrary in the lead up to COP26, the agreed rules on Article 6 require the application of corresponding adjustments to all ITMOs, irrespective of whether they are generated inside the scope of NDCs or otherwise.[26] As such, even though only a few developing countries have so far listed CCS as a mitigation action within their NDCs (Table 2-2), and even fewer have indicated quantitative estimates of emission reductions using the technology, the absence of the technology within current NDCs does not pose a barrier to the crediting of CCS activities.

### Table 2-2 CCS in first NDCs

| Group | Countries | |
|---|---|---|
| Countries with explicit reference to CCS technology | Australia<br>Bahrain<br>Canada<br>China<br>Egypt<br>Iran<br>Iraq | Malawi<br>Norway<br>Saudi Arabia<br>South Africa<br>United Arab Emirates<br>United Kingdom<br>United States |
| Countries listing CCS as a source sector category in their NDC | European Union*<br>Japan | Mexico<br>Montenegro |
| Countries not mentioning CCS but with potential interests | Brazil [1, 2]<br>Colombia [1]<br>Indonesia [3]<br>Nigeria [3]<br>South Korea [1] | Malaysia [3]<br>Russia [1]<br>Thailand [3]<br>Trinidad & Tobago [3]<br>Vietnam [3] |

Notes: * 27 member state countries. 1 = Member Country of either CSLF, IEA Greenhouse Gas R&D Programme or Global CCS Institute; 2 = Active CCS pilot, demonstrator or large-scale plant(s) in operation. 3 = Significant energy sector emissions and potential for low cost CCS from high purity sources.

Source: updated from Zakkour and Heidug 2019.

[25] This would be the case if the benchmark is established using a wide number of gas processing facilities that includes facilities treating raw natural gas with very low or trace $CO_2$ content.
[26] There was a line of argument proposing that emission reductions or removals occurring 'outside the scope of NDCs' need not be subjected to corresponding adjustments because such actions are immaterial in respect of the NDC goal. However, the definition of 'inside or outside of NDCs' lacks clarity, while counterarguments were made that without corresponding adjustments countries will be discouraged to progressively increase the scope of future NDCs over time.

However, applying corresponding adjustments to credits generated from early opportunity CCS activities will pose some risks to host countries' abilities to meet their NDC commitments. Emissions from high purity $CO_2$ sources – in particular, $CO_2$ venting from natural gas processing – tend to be poorly reflected in national GHG inventories; in principle, emissions from such activities fall within the general scope of the oil and natural gas sector fugitive emissions (IPCC Reporting Category 1.B.2) and therefore could be partially reported in national GHG inventories. But the specific source category relating to venting of $CO_2$ from gas processing (i.e. 1.B.2.a.ii) has generally not been well reported in the past.[27] Applying CCS to emissions sources that have so far been poorly reported offers no benefits to the host country from their mitigation; the action would count for nothing in respect of progress towards the host country's NDC target because the unreported emissions are not included in either the baseline or the mitigation scenario used to establish many developing countries' NDC targets.

Consequently, interest in supporting such mitigation actions may only come from international finance, for example, crediting under Article 6. Paradoxically, in such circumstances, the subsequent application of corresponding adjustments against the issued credits will result in the achieved emission reductions being added on to the account of the host country's NDC for accounting purposes, even though they cannot be deducted in the first place because they were never included in the design of the NDC target. As a result, crediting of such mitigation actions could make it harder for a host country to achieve its NDC target as it will likely need to increase mitigation efforts in other sectors to offset the effects of the corresponding adjustments.

In respect of broader aspects of CCS financing and cross-chain risk, crediting can potentially handle these issues better than emissions trading. Firstly, since crediting generally involves rewarding activities at the project level, all entities across the CCS chain would need to act in unison as a single project proponent. Such an arrangement can encourage effective risk-sharing between entities since – unlike with ETSs – no single entity is subject to the issuance of the credits. Second, capture and storage of high purity $CO_2$ vented from natural gas operations will tend to involve captive application by the field operator, very likely in situ or in close proximity to the producing field.[28] As such, cross-chain risks are eradicated since no transfers of physical $CO_2$ take place between different entities. These types of activities have proved the easiest to get off-the-ground so far, as evidenced by the existing large-scale single-entity CCS activities involving high purity $CO_2$ sources at the Sleipner and Snøhvit fields (Norway) and the Gorgon field (Australia).[29]

[27] Some observers have suggested that the absence of information on emissions, as well as the abatement potential, can often be a reason for not including certain sectors and activities within an NDC target in the first place (Spalding-Fecher 2017)

[28] The same principle would also apply to any $CO_2$ venting emissions from natural gas processing covered by an ETS. However, the overwhelming majority of $CO_2$ contaminated natural gas reservoirs occur in developing countries (see Zakkour and Cook 2010; Zakkour et al. 2011b), which are more likely to be candidates for crediting rather than the application of domestic ETS, at least in the near term.

[29] Application of CCS at Sleipner and Snøhvit, the two most significant $CO_2$ contaminated gas fields in Norway, was incentivised by firstly, the Offshore $CO_2$ Tax, and subsequently by a combination of this tax plus the EU ETS. The application of CCS at Gorgon was a condition of the field development approval.

Crediting of CCS can also achieve broader participation than just trading, allowing a greater number of countries, including countries with significant CCS early opportunities, to utilise the technology to reduce atmospheric $CO_2$ accumulation.

## Other types of trading and crediting

The Paris Agreement calls for NDCs to be expressed as emission reduction or limitation targets (Article 4.4). On the other hand, some countries have expressed targets in other metrics such as MW or MWh or renewable energy, and areas of land to be reforested. The situation has led to many observers suggesting that trading of non-GHG units under Article 6 faces significant obstacles when tracking progress towards NDCs (Climate Analytics, undated). Most consider that any transfers of non-GHG metrics would need to be converted to emission reductions/removals for the purpose of Article 6 tracking (e.g. see Schneider and La Hoz Theuer 2019; Climate Analytics, undated).

However, most also noted that such conversions are difficult to make and could pose environmental integrity risks. For example, the GHG effects of deploying a MW of renewable electric power capacity (or generating MWh of low carbon electricity) in one country will be different – and potentially significantly different – to the GHG effects of implementing the same action in another country. As such, subsequent accounting in relation to NDC targets, and related corresponding adjustments between the transferring countries (see Section 2.1), could be challenging. To address these issues, the rules for Article 6 agreed at COP26 require corresponding adjustments to be applied to a metric-specific registry held by each transferring party, rather than requiring any conversion to GHGs to take place prior to transfers.

Issues surrounding the transfers of non-GHG metrics should not, in principle, impact upon CCS specifically. As noted previously, non-GHG metrics tend to relate to NDC targets expressed in terms of renewable electricity or area (hectares) of land to be afforested/reforested. However, impacts could potentially arise where a non-GHG metric covers the broader term of 'low carbon electricity' (which could encompass CCS in the power sector), or if CSUs proposed under storage crediting models (see next) are considered a non-GHG metric.

## Crediting storage under Article 6

Approaches involving storage crediting are based upon proposals for supply-side offsetting that use CSUs as tradeable units through which countries – and also companies – can undertake CCS-specific cooperation (Zakkour and Heidug 2019; Mitchell-Larson et al. 2020; Zakkour et al. 2021; Kuijper et al. 2021; Portolano 2021; Jenkin 2021; Jenkins et al. 2021; Towns and Dixon 2022; Marcu et al. 2022). The policy approach is built upon establishing a geological storage quota for participating entities involved in the extraction of geological carbon (either companies, countries, or both) that must be satisfied through the acquisition and retirement of CSUs. The principles standing behind the concept are set out below (Box 2-2).

Since the proposed CSU credits record only geologically *stored* carbon rather than the more general metric of emissions *avoided* or *removed*, the approach offers a means to directly measure efforts to channel carbon finance into CCS.

### Box 2-2 SAFE-Carbon and net zero in the geosphere

Allen et al. (2009) proposed the introduction of a mandate on fossil fuel producers to geologically sequester carbon at rates increasingly aligned with the rates at which they extract carbon from the geosphere in the form of fossil fuels, ergo, supply-side offsetting. The balancing rate – which they called the 'sequestered adequate fraction of extracted' or 'SAFE-Carbon' – could start small and increase over time in response to different factors (e.g. the remaining carbon budget or observed rate of warming), ultimately ratcheting up to 100 % of produced carbon. Matching rates of carbon extraction from the geosphere (e.g. fossil fuel or limestone production) with rates of carbon deposition in stable geological reservoirs will achieve a net zero carbon balance in the geosphere, with the reciprocal result of net zero $CO_2$ emissions from fossil fuels and cement making.

Under the approach, the storage quota for participating entities can be set according to the following:

$$SQ_{y,P} = C_{FFyP} \times SAFE\text{-}C_y$$

*Where,*

$SQ_{yP}$ = storage quota in year y for participating entity P (CSU demand) ($MtCO_2$)

$C_{FFyP}$ = $CO_2$ produced from the geosphere in year y by participating entity P (company or country) ($MtCO_2$)

$SAFE\text{-}C_y$ = the SAFE-Carbon rate in year y (%)

Evolutions of the supply-side offsetting model set out in the literature propose the following ways through which CSUs could promote cooperation:

- **Acquiring CSUs under results-based finance (RBF)**. In the first instance, it has been proposed that CSUs could be piloted by a 'CCS club' cooperating under the auspices of Article 6.2 (Zakkour and Heidug 2019). The club, which could be made up of countries and potentially companies with a common interest in CCS, could establish a pooled fund that directly procures CSUs from storage site operators. The CSUs would provide a means to measure and confirm the effectiveness of the finance being provided but would be retired upon acquisition by the fund rather than being counted towards any targets in NDCs. The finance provided to $CO_2$ storers by CSU procurement would be additional and complementary to other incentives for the emission reduction component that incentives entities capturing $CO_2$ (e.g. emissions trading or crediting).
- **Acquiring CSUs against geological storage targets in NDCs**. In a future evolution, the CCS Club members could establish specific geological storage targets in their NDCs. These targets would exist in parallel with, but separate from, emission reduction targets in NDCs. CSUs would still be originated by entities storing $CO_2$, but under this model, they would be acquired by countries to demonstrate compliance with their NDC storage target.

The accounting and true up would be independent of the parallel emission reductions or removals created by CCS, which could be counted towards emission reduction targets in NDCs. Establishment of a CSU registry, as required for non-GHG metrics under Article 6, could facilitate this arrangement.

- **Using CSUs to decarbonise fossil fuels under extraction-based targets and accounts**. As a CSU measures geologically stored carbon, it could be used to establish net zero targets counted on the supply-side of fossil fuels markets. In such circumstances, a CSU could be used to offset fossil carbon *production* on the basis that matching rates of fossil carbon extraction from, and $CO_2$ sequestration in, the geosphere can also lead to a 'net zero' fossil $CO_2$ emissions outcome (Allen et al. 2009; Portolano 2021). Such an approach relies on countries establishing extraction-based targets and accounts[30] and the use of CSUs as a means to measure and trade compliance units against the target. Similar approaches can also be envisaged for private sector entities involved in fossil fuel production, with CSUs acting as a balance against the fossil carbon they produce (perhaps also through voluntary net-zero pledges and CSUs originated in the voluntary market).[31] Countries or companies on the supply-side achieving net zero in the geosphere (i.e. SAFE-Carbon at 100%) can ultimately to be in a position to claim the supply of decarbonized fossil fuels. In these circumstances, emissions from their use may not need to be counted in the territory in which they are combusted, in much the same way as emissions from bioenergy combustion do not need to be counted in the energy sector accounts (Zakkour et al. 2021).[32]

Proponents of the supply-side offsetting models suggest that they offer possibilities to address potential shortcomings posed for CCS deployment under carbon pricing alone. Since the CSUs directly target mitigation actions towards geological $CO_2$ storage, a direct incentive for $CO_2$ storers can be created that operates in parallel with, but independent of, any incentives for $CO_2$ capture created by carbon pricing or other policies. By providing an incentive focussed on fossil carbon producers, it can also channel incentives towards actors and locations that are well-endowed with $CO_2$ storage capacity, which, in turn, could potentially address distributional imbalances between global emission sources and geological storage capacity. On the other hand, the model may also face several conceptual and practical challenges for implementation, as discussed in more detail in subsequent parts of this report.

National-level interest in supply-side climate policies using CSUs is starting to emerge, based on introducing an obligation for fossil fuel suppliers to acquire and surrender CSUs in increasing proportions to the amount of carbon produced or imported. In the Netherlands, for

[30] Extraction based GHG accounts would measure the amount of carbon extracted from the geosphere in a territory, which could operate for the purposes of a target alongside the traditional territorial emissions and removals accounts applied under the UNFCCC and Paris Agreement

[31] Often reflected more broadly as Scope 3 emissions from the perspective of a fuel supplier (i.e. customers emissions).

[32] Under territorial emissions and removals accounting, biomass for energy use is assumed to be instantaneously oxidised to $CO_2$ upon harvesting. Thus, the land sector accounts record the balance between growth (removals) and harvesting (emissions) of biomass. Consequently, the downstream emissions from bioenergy use must be zero-rated to avoid the emissions being double counted in both the land sector and the energy sector.

example, a proposal has been made to implement a national 'carbon takeback obligation' (CTBO) in the natural gas supply sector, with CSUs acting as the mechanism for implementation (Kuijper et al. 2021). Similarly, in the United Kingdom, the Expert Policy Advisory Group to the Climate Change Committee[33] has recommended that the UK implement a carbon takeback scheme to accelerate CCS deployment, starting in 2023 with a 1% obligation on supplied carbon (i.e. SAFE-Carbon of 1%), expanding to 10% by 2030 and 100% by 2050 (Hepburn et al. 2020; p. 23-24).

Alternative approaches involving CSUs could also encompass voluntary net zero actions by fossil fuel producing corporations as a means to demonstrate a balance between the carbon they produce and carbon storage. A number of major independent energy companies – at time of writing, BP, Shell, Total, Eni, Equinor, Repsol and Occidental – have pledged to achieve net zero emissions on all Scope 1, 2 and 3 emissions, while several others are committed towards net zero on a more limited basis (see Zakkour and Heidug 2020).[34] In these contexts, the Sustainable Markets Initiative (SMI) CCUS Task Force has recently proposed support for a carbon storage obligation (CSO) approach for energy companies based on CSUs (Towns and Dixon, 2022).[35]

At a multilateral level, potential platforms for a 'CCS club' already exist, such as the Clean Energy Ministerial (CEM) and the Oil and Gas Climate Initiative (OGCI), both of which have expressed interested in the concept. New groups such as the 'Net zero Producers Forum' recently established between the energy ministries of Canada, Norway, Qatar, Saudi Arabia and the U.S. may also offer another pathway through which such actions could emerge (U.S. Department of Energy 2021).

[33] A group tasked with the remit to 'think beyond sectoral targets and to suggest cross-cutting, top-down views of how policy could accelerate progress towards achieving Net Zero emissions by 2050'
[34] See also www.zerotracker.net for more recent updates [accessed January 2022]
[35] See https://www.sustainable-markets.org/taskforces/ccus-taskforce/ [accessed January 2022]

# 3 Models for CCS Cooperation

## 3.1 Introduction

The previous chapter highlighted a range of potential pathways that international cooperation under Article 6 may take and considered how these could work to support CCS deployment. In the broadest sense, the approaches described can be separated as:

- Trading of emissions allowances and emission reduction/removal credits arising from linked carbon markets (i.e. under more conventional notions of carbon market based approaches that apply to fossil fuel users as emitters of $CO_2$); and
- More novel, targeted, approaches that base cooperation around carbon storage and the producers and suppliers of fossil carbon.

However, such a division is not to suggest that the two approaches are mutually exclusive but rather to highlight the basic difference of approach. Indeed, the supply-side offsetting model is proposed to function as a complementary and supplementary mechanism alongside a conventional carbon market, acting to direct carbon finance towards geological carbon storage rather than replace it (Zakkour and Heidug 2019). The idea is based on drawing two separable metrics, with resultant tradable units, from geological storage activities, each appliable to two different and separate compliance points (Figure 3-1). Separation of targets allow for parallel market functions to be established according to the following:

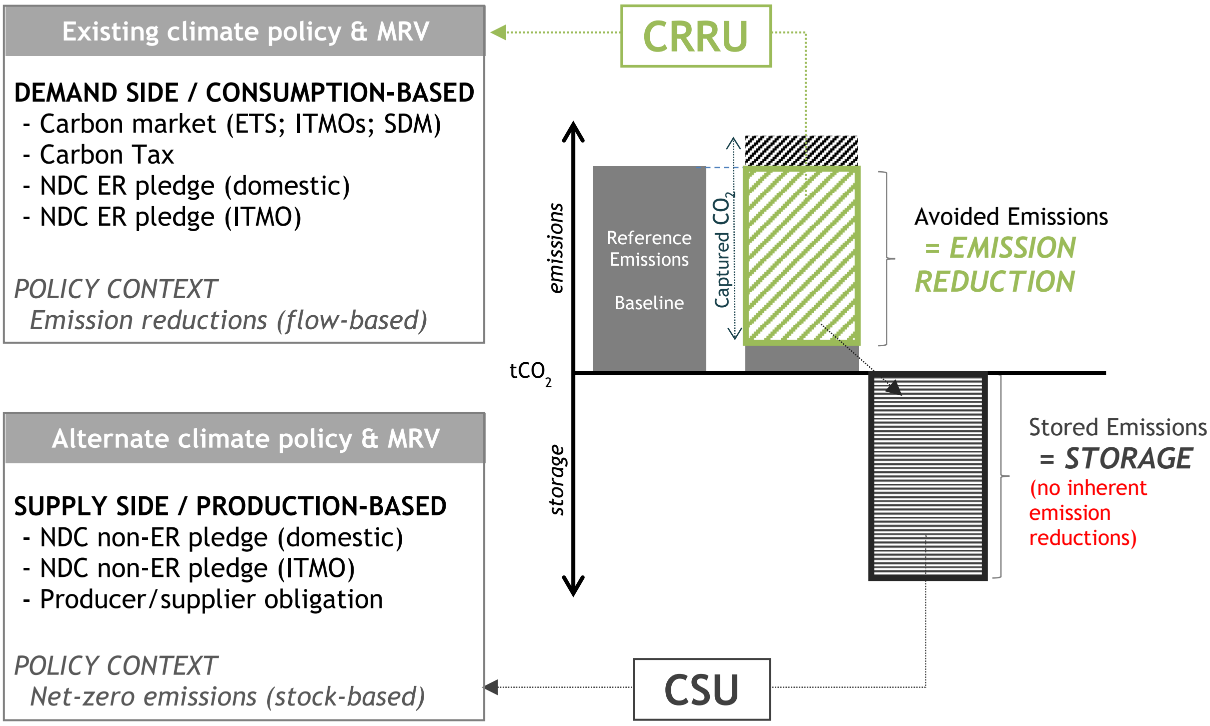
1. **Emission reductions/removals**. This measure, shown in the upper half of Figure 3-1, generates tradable units measured in $tCO_2$ *reduced/removed from the atmosphere.* These units can be used in conventional carbon markets to offset emissions to the atmosphere on the demand/consumption side of fossil fuel markets (hereafter we refer to these as carbon reduction/removal units or CRRUs). [36] CRRUs would be awarded to entities capturing $CO_2$.
2. **Carbon storage.** This measure, shown in the lower half of Figure 3-1, generates tradable units measured in $tCO_2$ *stored in the geosphere*. These units can be used in novel carbon markets to offset fossil carbon produced from the geosphere on the supply/production side of fossil fuel markets (carbon storage units, or CSU). CSUs would be awarded to entities storing $CO_2$.

By creating two units (CRRUs and CSUs) and two points of compliance (carbon emissions and carbon production), trades in CSUs can act as a supplement to carbon price signals in the conventional carbon market. In this sense, a quota-based obligation to offset embodied carbon in produced fuels would act as a marker that ensures at least a portion of actions driven

[36] As noted in Section 2.1.2, current credit registries offer limited distinction of whether the underlying action generating the unit involved emissions reductions, carbon removals or a combination of both.

by carbon pricing are diverted to permanent geological carbon storage. Similar combinations of supply- and demand-side pricing mechanisms have been used to promote renewable energy generation, for example, the establishment of renewable obligation schemes[37] operating alongside the implicit carbon price created by an ETS (Zakkour et al. 2021).

### Figure 3-1 Relationship between emissions reduction and carbon storage




Key: CRRU = Carbon Reduction/Removal Unit; CSU = Carbon Storage Unit; ETS = Emissions trading scheme; ITMO = Internationally Transferred Mitigation Outcome; SDM = Sustainable Development Mechanism under Article 6.4 of the Paris Agreement; MRV = Measurement, Reporting and Verification, ER = Emission reduction.

Source: Updated from Zakkour and Heidug 2019

Based on these ideas, the following sections describe three core models for cooperation and trading under Article 6 that we will use to evaluate various aspects regarding their utility and risks. The models are as follows:

> **Model 1 – Linked carbon pricing policies between countries.** This model is based on the trading of CRRUs following the approaches described in Section 2.1.1, and set out more specifically for CCS in the first parts of Section 2.2.3.
>
> **Model 2 – Voluntary system of storage targets for fossil fuel producers**. This model is based on using CSUs to drive bottom-up actions by corporations and countries for supporting CCS deployment. The relevance to Article 6 in a voluntary corporate context is limited, although, as we outline below, voluntary actions could be supported by domestic

[37] Renewable obligation schemes place a quota on electricity suppliers to source a ratcheting proportion of their supply from renewable sources. The obligation is typically satisfied through the surrender of renewable energy certificates or "RECs".

regulations in supportive countries. The latter evolution could lead to international trades of CSUs with a resultant need to incorporate storage targets in NDCs (e.g. by countries implementing CSO/CTBOs or similar measures, as per Section 2.2.3)

**Model 3 – Multilateral "CCS club" of Parties to the Paris Agreement.** This model is based on a select group of likeminded countries with a common interest in fossil fuel production and CCS adopting CSUs as a means to cooperate on plurilateral basis (see the last part of Section 2.2.3)

Each model is further elaborated below and characterised according to a common set of features at the end of the section.

## 3.2 Models for CCS cooperation

### 3.2.1 Model 1 – Linked carbon pricing policies between countries

This model sees increasingly linked carbon markets between countries with international trading of emissions allowances and credits generated by various types of emissions reduction, emissions avoidance, sink conservation and carbon removals activities.

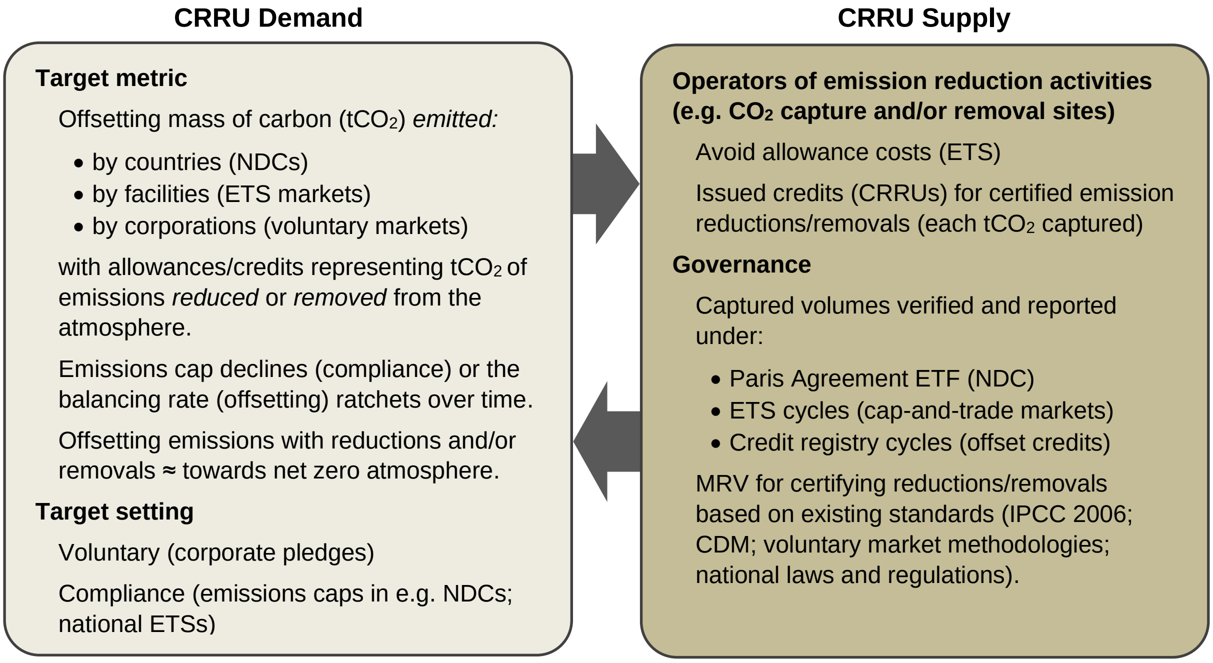
Demand for CRRUs under model 1 comes from:

- Governments seeking to meet NDC targets.
- Regulated entities meeting obligations under carbon pricing policies linked to government targets (e.g. companies purchase allowances and/or credits to meet caps under domestic and regional ETS),[38] and/or
- Corporations using voluntary markets to meet corporate targets (that may, to differing extents, be counted as ITMO trades, depending on how voluntary markets develop).

For CCS, CRRUs are awarded to operators of $CO_2$ capture facilities or project-based entities acting in unison. As described in Table 2-1, trading could take place either directly between governments[39] or involve companies for either compliance or voluntary purposes (Figure 3-2).

[38] For example, the purchase of certified emissions reductions (CERs) by operators covered by the EU ETS which were eventually used by EU Member States towards Kyoto compliance
[39] Direct trading between countries took place under Kyoto in the form of AAUs (assigned amount units)

Figure 3-2 Carbon reduction/removal market arrangements




### 3.2.2 Model 2 – Voluntary storage targets for fossil fuel producing companies

Under this model, energy corporations with net zero targets would voluntarily implement CSUs as a means to track progress and ultimately demonstrate net zero emissions on the supply side of fossil fuel markets. Implementation would be through a voluntary registry that tracks, over fixed periods of time (e.g. a calendar year), the following two components:

1. The amounts of carbon that participating firms produce from the geosphere, which can be proxied from fossil fuels based on the sum of Scope 1[40] and Scope 3[41] corporate emissions (i.e. $C_{FFyP}$ in Box 2-2); and
2. The amounts of geological carbon storage supported by participating firms, which would be measured through the acquisition and retirement of CSUs.

The quota of CSUs that firms must acquire each year would be based upon the SAFE-Carbon concept with a ratcheting rate to be agreed by all participating firms involved in implementation (Box 2-2; see also Towns and Dixon, 2022).

Such voluntary actions could be further bolstered by domestic measures where supportive countries put in place a requirement for national fossil fuel suppliers to demonstrate the same commitment to geological storage. Participating countries could establish a regulated registry that tracks domestic fuel production and imports, originates CSUs for geological storage site operators (potentially in any jurisdiction) and allows for CSUs to be retired on surrender by fuel suppliers as a balance against supplied carbon. These countries could also establish specific geological storage targets, which could be incorporated into NDCs, thereby resulting

[40] Direct $CO_2e$ emissions from operations, covering combustion, flaring, venting and other fugitive emissions.
[41] $CO_2e$ emissions arising from the combustion of fossil fuels they supply to end users.

in CSUs being integrated into the auspices of Article 6 transfers. Both the UK and the Netherlands are unilaterally considering implementing this type of supply-side offsetting approach.

### 3.2.3 Model 3 – Multilateral "CCS club" of Parties to the Paris Agreement

Model 3 would operate under similar principles to model 2 except that it would be based on top-down country pledges to geologically store $CO_2$ rather than on corporate net zero targets. As proposed by Zakkour et al. (2021), a phased approach to implementation could be taken starting with results-based finance involving CSU transfers among a selected club of countries without Article 6 transfers, but potentially evolving into a system of Article 6 CSU transfers between club members with specific storage targets in NDCs (see Section 2.2.3). The CSU acquisition quota could be determined among club members based on a SAFE-Carbon pathway (Box 2-2) and the mass of fossil fuel $CO_2$ produced and/or imported by each country.

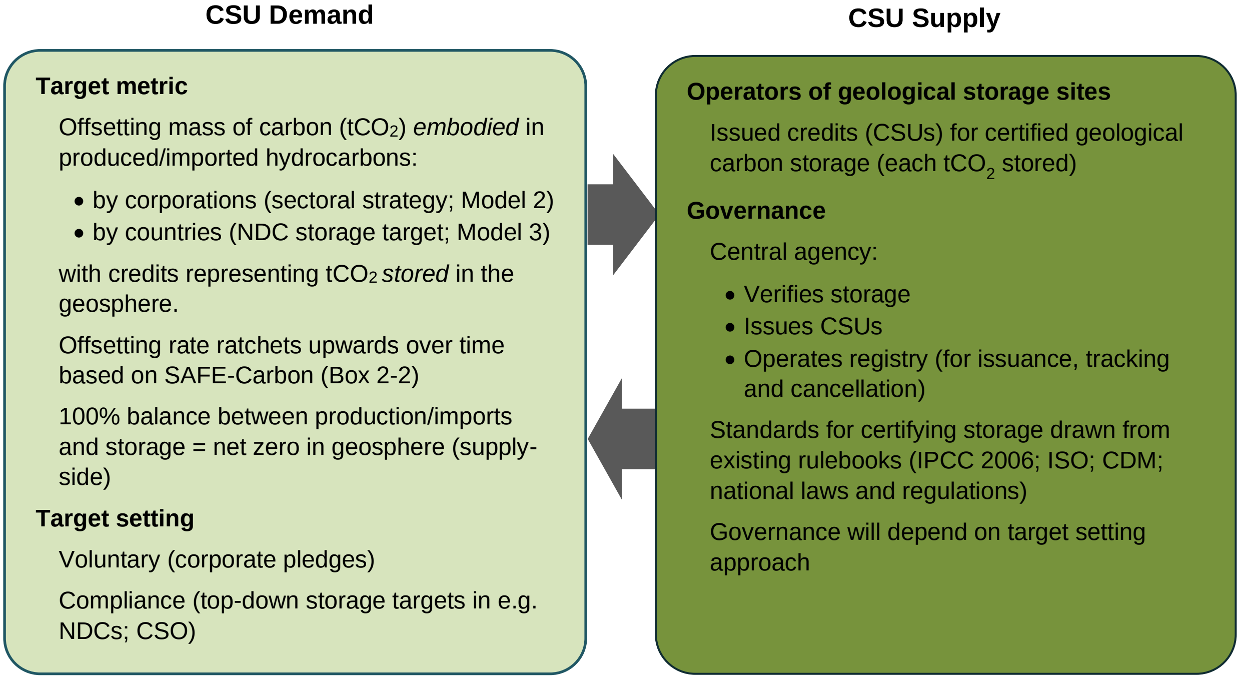
Further into the future, significant fossil fuel exporters could consider switching to alternative types of NDC pledges built upon achieving net zero in the geosphere (rather than atmosphere) following the SAFE-Carbon method (see also Portolano 2021). Such an approach would drive major fossil fuel exporting countries towards storing significant amounts of $CO_2$ on behalf of their customers, and ultimately require extensive domestic implementation of $CO_2$ removals (e.g. BECCS and/or DACCS).[42] A switch to extraction-based accounting would be necessary to support the tracking of countries adopting such targets, which could allow decarbonized fossil fuels to be claimed when a balancing amount of CSUs is bundled with the $CO_2$ embodied in fuel shipments.[43]

Major importer participation would strengthen these approaches insomuch as it would ensure tacit recognition of the effects of continued fossil carbon demand, establish a firm source of demand for CSUs linked to storage targets in NDCs, and support burden sharing between major suppliers and users in respect of the addition costs of reducing the climate impacts of fossil fuel production and use (Fattouh et al. 2021).

A schematic summary of both model 2 and 3 market designs is set out below (Figure 3-3).

[42] Because fossil fuel exporters export more carbon than they emit domestically, removal of $CO_2$ would ultimately need to be pursued in order to effectively balance the geosphere account at net zero carbon.
[43] Similar "green LNG" cargoes to date have been bundled with CRRUs of various origins (see e.g. Medlock et al. 2020)

## Figure 3-3 Potential carbon storage unit market structures




Summary features of all three models are provided below.

| | MODEL 1<br>**Linked carbon markets** | MODEL 2<br>**Voluntary system of storage targets for fossil fuel producers** | MODEL 3<br>**Multilateral "CCS club" of Parties to the Paris Agreement** |
|---|---|---|---|
| UNIT TYPES | ▶ Allowances ($tCO_2e$)<br>▶ Credited emission reductions or removals ($tCO_2e$) | ▶ CSUs ($tCO_2$) measuring carbon stored in geological reservoirs | ▶ CSUs ($tCO_2$) measuring carbon stored in geological reservoirs |
| MARKET TYPE/ MECHANISM | ▶ Globally linked carbon market<br>▶ Fungible units between countries/systems<br>▶ Credits and allowances are fungible | ▶ Quota system for offsetting carbon content of fossil fuels produced from geosphere, established either:[1]<br>○ Voluntarily by fossil fuel producing corporations<br>○ Mandated for fossil fuel suppliers under national carbon storage obligation (CSO/CTBO) policy<br>▶ Tradable CSUs used for compliance purposes | ▶ Quota system based on offsetting carbon content of fossil fuels produced from geosphere, established through a national carbon storage pledge[1]<br>▶ Tradable CSUs used for compliance purposes |
| TARGET METRIC | ▶ $tCO_2e$/yr emitted | ▶ $tCO_2$/yr produced in fossil fuels [2] | ▶ $tCO_2$/yr produced in fossil fuels |
| COMPLIANCE POINT | ▶ Facility emissions (under ETS cap)<br>▶ Corporate emissions (for voluntary targets against corporate scope 1, 2 and/or 3 GHG emissions) | ▶ Corporate inventory of $CO_2$ in produced fossil fuels<br>▶ Target ratchets over time vs. compliance metric, e.g.: 2020s (5-10%); 2030s (15-30%); 2040+ (60-100%) [1] | ▶ National inventory of $CO_2$ in produced fossil fuels<br>▶ Target ratchets over time vs. compliance point, e.g.: 2020s (5-10%); 2030s (15-30%); 2040+ (60-100%) [1] |
| UNIT SELLERS | ▶ Facility operators in national ETSs<br>▶ Developers (and/or intermediaries) under crediting programmes (emission reduction/removal activities) | ▶ Geological storage site operators | ▶ Geological storage site operators |
| CREDITED ACTIVITIES | ▶ Emissions reduction, emissions avoidance, sink conservation; carbon removals (CRRUs) | ▶ Geological storage (CSUs) | ▶ Geological storage (CSUs) |
| SOURCE OF UNITS | ▶ Compliance registries (e.g. via allocation process; through Article 6.4 mechanism)<br>▶ Voluntary registries (e.g Verra, Gold Standard etc) | ▶ Registry dedicated to MRV/origination of CSUs<br>○ Voluntary<br>○ National (under CSO/CTBO) | ▶ Registry dedicated to MRV/origination of CSUs, operated by the CCS club, either through UN or private system |
| UNIT BUYERS | ▶ Corporations acquire units through market<br>▶ Acquired units surrendered to governments | ▶ Fossil fuel producers/suppliers | ▶ National governments (direct CSU procurement)<br>▶ Fossil fuel producers/suppliers, where govts. devolve CSU acquisition through national CSO/CTBO policy |
| USE OF UNITS | ▶ Corporations surrender to government to demonstrate compliance with caps<br>▶ Government retires surrendered units to demonstrate compliance with NDC targets/caps<br>▶ Corporations retire units as offsets against corporate GHG inventory | ▶ Corporations retire CSUs in registry to demonstrate compliance against target metric | ▶ Govts. retire CSUs in registry to demonstrate compliance against target metric |

[1] Size of offsetting quota determined based on SAFE-Carbon rate described by Allen et al. (2009); see Box 2-2. [2] In Model 2, carbon extraction can be proxied as embodied carbon or corporate Scope 1 and Scope 3 emissions (emissions from operations excluding bought-in energy and emissions from combustion of sold products).

# 4 Evaluating CCS Cooperation Models

To evaluate the three core models for Article 6 cooperation described in Section 3, a range of criteria relevant to Article 6 performance and CCS deployment were developed. The criteria, as set out in Table 4-1 below, reflect the core demands of Article 6, for example, increasing mitigation effort, ensuring high integrity mitigation outcomes and forging progressive climate action over the medium-term, as well as the core needs for CCS, primarily finance and policy performance.

In making the evaluation it is assumed that CCS is critical to achieving the Paris Agreement's goals (see Section 2.2.1). The quantitative aspects of the evaluation are therefore judged against their capacity to support CCS deployment rates indicated in modelled scenarios for global climate change mitigation that include CCS.

For qualitative aspects, such as addressing past challenges faced by CCS and consistency with the overall objectives of the Paris Agreement (e.g. enhancing ambition, participation and progression) the evaluation draws upon the expert judgement of the authors.

The results of evaluation against each of the criteria is described below.

### Table 4-1 Assessment criteria used to evaluate CCS Article 6 cooperation models

| Criteria | Features |
| --- | --- |
| Effectiveness | Effectiveness in accelerating cost-effective CCS deployment and implementation.<br>Potential interface CCS policies and mechanisms with other removal solutions |
| Environmental integrity | Quality of capture and storage estimates, determined through consideration of additionality and CCS policies, as well as MRV standards and processes<br>Accounting of transfers and use towards targets, the application of corresponding adjustments to avoid double counting, and ability to operate with different target types |
| Commercial and financial | Commercial viability of CCS technologies<br>Availability of sufficient and predictable finance |
| Progression | Promotion of mitigation ambition, transformative change and NDC progression<br>Longevity of the approach to be relevant prior to and during the net-zero emissions phase |
| Policy performance | Facilitation of broad participation<br>Coherence with other policy instruments<br>Political viability with governments, private sector and civil society |

## 4.1 Effectiveness

Effectiveness describes whether the cooperation approach could deliver significant volumes of geological $CO_2$ storage ($tCO_2$ stored), the degree of certainty offered in achieving such levels, the extent to which such deployment contributes towards deployment levels consistent with the IEA's estimate of net zero (IEA 2021; Figure 2-4), and the alignment or otherwise with other types of $CO_2$ removal options.

Making a comparison of the effectiveness of the three models faces several challenges, primarily the uncertainty surrounding future carbon markets, the types of units traded and potential market size. Furthermore, it is difficult to judge what sort of future emissions reductions/removals activities could result from international cooperation and what could arise as domestic abatement, maybe with crediting, but without international trading (i.e. involve crediting outside of Article 6). The information and data presented below is difficult to disaggregate in these respects. Some analysis reflects total potential credited mitigation actions, while other such as the IETA/UMD work attempts to explore net international flows of such actions between countries rather than total mitigation. This places some limitations on the assessment of the effectiveness of international cooperation, although the overall effectiveness of CSU-based approaches can still be assessed

In respect of **Model 1**, outlooks for the size of the potential market for trading CRRUs vary significantly in scope and assumptions, as indicated by the summary of published estimates below (Table 4-2).

Table 4-2 Estimated traded volumes of CRRUs in global carbon markets

| Study | Basis | Market size ($GtCO_2e$ traded volumes) 2030 | 2050 |
|---|---|---|---|
| IETA/UMD/CLPC (Edmonds et al. 2019) | Volumes of international unit flows that could occur in fully linked markets to achieve mitigation expressed in First NDCs. Global abatement potential to meet 2019 NDCs estimated against GCAM reference case | 4.3 | 6.5 |
| IETA/UMD (Yu et al. 2021) | Volumes of international unit flows that could occur in fully linked markets to achieve global net zero by or after 2050 (with staggered and non-staggered implementation) | 3.4 - 3.5 | 1.7 - 2.4 |
| TSVCM (TSVCM 2021) | Survey results | 1.0 | 3.0 - 4.0 |
| | Analysis of integrated assessment model results consistent with 1.5ºC | 1.5 - 2.0 | 7 - 13 |

The IETA/UMD/CPLC study (Edmonds et al. 2019) assesses the effectiveness of using Article 6 linked carbon markets to achieve the stated goals in 2019 vintage NDCs based on accessing to the lowest cost abatement potential from across all world regions.[44] The abatement potential in the model is estimated as a deviation from a reference case that does not include the NDCs (i.e. current policy scenario without NDC pledges). Consequently, the tradable volumes are generated by the difference between the reference case and the NDC case, which essentially constitutes avoided emissions (see Section 2.1.2). This may or may not include some CCS; the authors do not provide a breakdown of technology types deployed in the Global Change Assessment Model (GCAM) in their modelled scenarios.

In the IETA/UMD study (Yu et al. 2021), the same GCAM model was subsequently used to estimate traded volumes under full linked Article 6 cooperation to reach net zero emissions in or shortly after 2050. This results in much smaller projected traded volumes for the year 2050 because of the increased global mitigation ambition; thereunder, with or without cooperative implementation under Article 6, the emissions from all countries decline toward net zero leaving few residual emissions and relatively little potential tradable volumes close to 2050 (Table 4-2). A key feature of the different assumptions in the second IETA/UMD study compared to the first is that GCAM is forced to deploy significant amounts of removals/storage to resolve to net zero, and thus the trades are essentially *all* in carbon removals/storage (both natural and geological sinks). Globally, the model indicates increases in sinks of around 8 $GtCO_2e$ in 2030, and 20 $GtCO_2e$ in 2050, of which, respectively, around 3 and 16 $GtCO_2$ is geological storage (only the international traded volumes from this total are shown in Table 4-2).[45] Clearly, if all countries adopt and implement ambitious 2050 net zero targets, significant amounts of, if not all, traded units under Article 6 will need to be derived from the $CO_2$ storage alongside CDR (as described in Section 2.1.2).

These two extreme sets of results from GCAM highlight the significant uncertainty in respect of CCS deployment under international cooperation: on the one hand, 2019 vintage NDC pledges may not deliver any geological storage, whereas, on the other hand, the rash of updated NDCs that included net zero targets ahead of COP26 in 2021 could, at least in theory, result in significant traded volumes arising from carbon storage activities (biological and/or geological). Thus, a key question in these respects is whether market standards and practices will adapt to push crediting activities towards storage or not? As noted previously (Section 2.1.2), this debate is only just starting to emerge, and can be expected to run for a while longer.

Alternative estimates of traded volumes in the voluntary market have been provided by the TSVCM (TSVCM 2021). These are based on two sources: a survey of TSVCM market participants and a review of integrated assessment model outputs under emissions scenarios

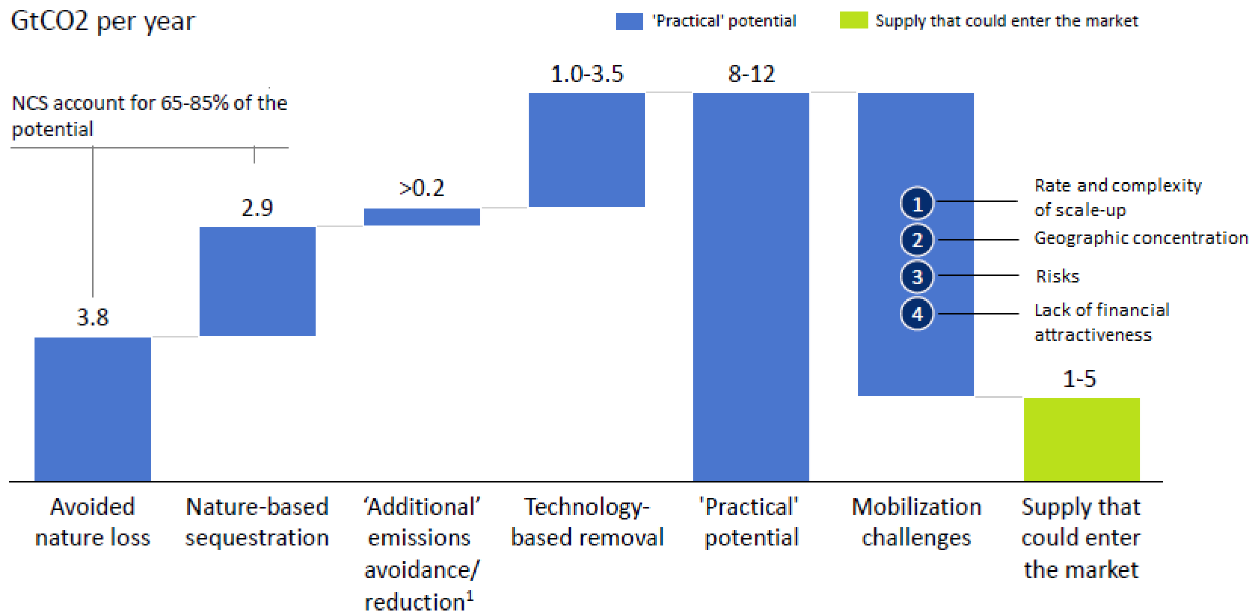
[44] The study uses the Global Change Assessment Model (GCAM), an integrated assessment model, to quantify the economic potential of Article 6 cooperation in delivering first NDCs with authors' extrapolation of NDCs mitigation targets post-2030; the results indicate the potential to reduce total costs of implementing NDCs by more than half. The study reflects 2019 NDCs, not more recent updates made ahead of COP26.
[45] Yu et al. (2021) do not specify the $CO_2$ sources but confirmed that the total includes some removals involving hydrogen production from biomass (Yu 2021 *pers. comm.*). The majority of modelled storage is derived from fossil sources.

consistent with a 1.5°C temperature limitation pathway (Table 4-2). The latter analysis led the TSVCM to project that the global carbon market could grow around 15-fold from 2020 to 2030, and up to a maximum of 100-fold by 2050 (Table 4-2).[46] Based on the results of the survey, of these traded volumes:

- Very little might derive from CCS. The 0.2 $GtCO_2$ of avoided emissions shown in Figure 4-1 is reportedly supplied from 'current inventory'.
- A significant proportion is assumed to be derived from technology-based removals, estimated at between 1 and 3.5 $GtCO_2$ in 2030 (e.g. BECCS, DACCS; Figure 4-1).
- A significant portion originates from sink conservation and sequestration from nature-based sink enhancements: 3.8 and 2.9 $GtCO_2e$ respectively in 2030 (Figure 4-1).

The basis for this voluntary market crediting scenario seems quite uncertain, however: is it realistic to expect a market to develop where half to two thirds of voluntary buyers opt to acquire natural carbon solutions credits at <USD 20/$tCO_2e$ while other buyers would be willing to pay much higher costs for technology-based removals credits? Although some pioneers are moving forward with ambitious technological removals offsetting concepts – like Microsoft, Shopify and Stripe etc – the contracted volumes are tiny, and demand is likely to be extremely limited where abatement costs lie in the range of USD 200-600/$tCO_2e$. The TSVCM's encouragement for heavy-emitting industries to commit their voluntary carbon mitigation toward technological removal activities may not be sufficient to push the market in this direction.[47]

## Figure 4-1 Estimated supply potential of voluntary carbon credits (in 2030)




Source: extracted from TSVCM 2021 (p. 61)

[46] Results are based on climate policy scenarios developed by the Network for Greening the Financial System (NGFS) using GGCAM, MESSAGEix-GLOBIOM and REMIND-MAgPIE
[47] The TSVCM does acknowledge "the significant mobilization challenges faced in realising the technological removals" (p. 4, 13).

Furthermore, assuming that trades in avoided emissions credits will be only a small fraction of the market in 2030, consisting of the currently registered projects on voluntary carbon exchanges (i.e. excluding any new registrations of avoided emissions projects), appears misplaced. This assumption does not fit with current market trends, where new renewable energy, fuel switching, waste and energy efficiency etc activities make up well over half the voluntary carbon market registrations at time of writing (Figure 2-1). These activities will continue to receive credits for quite some years into the future. The market directions described would also seemingly exclude CCS at existing emission sources, even though early opportunity low-cost deployment opportunities exist (see Section 2.2.3).

Based on the above, the potential for CCS deployment through linked carbon markets under **Model 1**, either under voluntary programmes or though other types of compliance crediting arrangements, seems highly uncertain. Analysis linked to country (NDC; Edmonds et al. 2019) and corporate (voluntary; TSVCM 2021) commitments is unconvincing in terms of the potential to deliver any sort of significant amounts of geological storage in at least the next decade or so (either CCS or technological removals). The present activities in national Article 6 programmes[48] and in voluntary markets (Figure 2-1) seem largely focussed on procuring credits from activities generating avoided emissions. Conversely, analysis that assumes firm commitments to net zero emissions by many countries suggests that internationally traded units would need to rapidly and exclusively be derived from the deployment of large volumes of CCS and technological removals (Yu et al. 2021). However, this outcome is also uncertain since it is predicated on effective commitments to net zero, although differential interpretations exist as to what achieving net zero actually means in practice (NewClimate Institute & Data-Driven EnviroLab 2020).

**Models 2** and **3**, because of their targeted approach to geological $CO_2$ storage, can offer greater certainty for the deployment of permanent geological storage. Furthermore, because the supply-side offsetting approach is proposed to complement conventional carbon markets under Model 1, the approach can be effective in pushing market behaviour described under Model 1 towards these types of investments, covering both CCS and technological removals.

To place the potential scale of **Model 2** in context, in 2020 selected major independent energy firms directly emitted around 370 $MtCO_2e$ (Scope 1 emissions) and supplied around 3.1 Gt of embodied $CO_2$ into the global energy system (see Box 4-1). The total supply from firms that have committed to net zero including scope 3 emissions was 2.1 $GtCO_2$ (scope 1 and 3 emissions; see Annex A). These levels of outputs equated to, respectively, around 14-15% and 9-10% of global $CO_2$ emissions from crude oil and natural gas use.

[48] e.g. the Swiss Article 6 ITMO procurement programme under the Klik Foundation, which appears focussed on development-related activities such as efficient cookstove projects, although it has signed a memorandum of understanding with Iceland to procure ITMOs from the DACCS demonstration project implemented by the Swiss firm Climeworks.

### Box 4-1 Methodology to assess effectiveness of Model 2 and 3

Drawing on the method in Box 2-2:

For Model 2, total carbon production from the geosphere by independent energy companies ($C_{FFyP}$) was estimated using data from company annual reports (Annex A). To make forward projections of CSU demand against a ratcheting SAFE-Carbon rate, the share of global production of oil and gas by the firms was assumed to remain constant against the declining level of demand in the IEA's NZE scenario (IEA 2021; see Annex A).

Similarly, for Model 3, total carbon production by countries that include CCS in their first NDCs (Table 2-2**;** $C_{FFyP}$) was estimated using data from the IEA Atlas of World Energy. In same way as for Model 2, forward projections of CSU demand were determined under the same ratcheting SAFE-Carbon rate and the share of global oil and gas production under the same declining IEA NZE demand scenario (Annex A).

The following SAFE-Carbon rates are assumed: 2025 (2.5%), 2030 (7.5%), 2035 (15%), 2040 (30%), 2045 (60%), 2050 (100%).

Requiring 7.5% of the produced $CO_2$ to be balanced by storage in 2030 would necessitate the origination of **170 to 195 million CSUs** (for, respectively, only those firms with net zero targets and all major independent energy companies). These figures reach **827 to 983 million CSUs** for a SAFE-Carbon rate of 100% in 2050, when these firms could be considered to have achieved net zero in the geosphere.

For this scale of CCS deployment to be commercially viable, at least some degree of cost passthrough would be needed to avoid these companies being outcompeted by producers not subject to the same commitment (i.e. the remaining 85-90% of the global energy supply market e.g. national oil companies; NOCs). At a CSU origination cost USD 50/t$CO_2$ stored,[49] the cost of supplied crude oil would increase by USD 1.6 per barrel (bbl) in 2030 and up to USD 21/bbl in 2050. For natural gas, the cost increase would equate to USD 1.2 per billion cubic metres (bcm) in 2030, rising to USD 24/bcm in 2050.

To provide secure market access these voluntary actions would likely need to be bolstered by domestic programmes in significant fossil fuel producing/importing countries (e.g. domestic CSOs/CTBOs, see Section 3.2.2). Countries taking such domestic measures could provide sufficient demand for the more expensive fuels bundled with CSUs. In these respects, two of the world's two largest fossil fuel importers, the European Union and Japan, would be sufficient to provide a route to market for the higher cost energy from participating companies (Table 4-3).

[49] This assumed to exclude the cost of $CO_2$ capture and transport, which could be covered by a carbon price under Model 1. If the carbon price is insufficient to fully cover the capture and transport costs, the cost of CSU origination would be higher because companies seeking $CO_2$ to generate CSUs would need to pay the cost difference to obtain sufficient volumes.

## Table 4-3 Potential CSU demand from two major importers imposing a CSO/CTBO on fuel suppliers

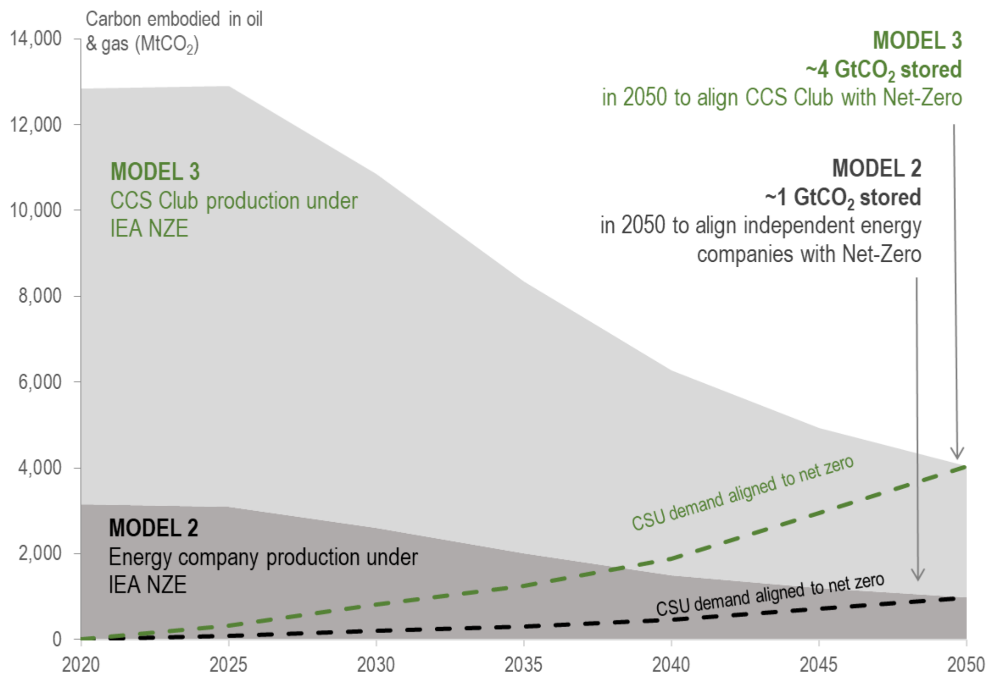
| Metric | Country/Region | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| Embodied $CO_2$ in produced/imported crude oil and natural gas (Gt) (2030 and 2050 based on IEA NZE aligned demand decline) | EU-27 | 2.2 | 1.85 | 0.73 |
| | Japan | 0.7 | 0.59 | 0.24 |
| CSU demand (millions) (at SAFE-Carbon rates in Box 4-1) | EU-27 | 0 | 135 | 730 |
| | Japan | 0 | 44 | 235 |
| **Total CSU demand (millions)** | | **0** | **179** | **965** |

The potential for **Model 3** to mobilise investment into CCS exceeds that of Model 2. Moving the supply-side offsetting pledge from firms to countries extends the scope of offsetting obligations to include NOCs. As a result, the size of the CSU demand could reach around **800 million CSUs in 2030**, and rise to over **4 billion CSUs in 2050** (i.e. 4 $GtCO_2$ stored). These estimates are based on the assumption that all countries expressing support for CCS at the current time are willing to reach net zero in their geosphere carbon account in 2050 (i.e. 100% SAFE-Carbon rate), which may not be the case. But even if half this potential can be realised (i.e. 50% SAFE-Carbon rate), significant volumes of $CO_2$ will need to be geologically stored by 2050. Indeed, such levels of CSU demand start to make some progress towards the levels of storage envisaged in the IEA's NZE scenario (7.2 $GtCO_2$ in 2050; Figure 2-4).

The potential effectiveness of Models 2 and 3 in creating demand for geological carbon storage is shown schematically below (Figure 4-2). Therein it is important to note that the volumes of CSU demand represent the global total, of which only a portion may ultimately be traded alongside oil and gas. Some CSUs may be used domestically, depending on how implementation of the approach evolves, which remains subject to significant uncertainty (see Section 2.2.3).

Based on the analysis set out above, suggestions are that the supply-side offsetting approaches based on CSUs could greatly reduce the uncertainty in carbon markets in respect of whether they will deliver significant amounts of permanent geological $CO_2$ storage in the foreseeable future.

Figure 4-2 Potential CSU demand ($tCO_2$ stored) in Model 2 and Model 3 (2020-2050)




Furthermore, it is important to note that in both Model 2 and Model 3, the source of $CO_2$ is immaterial to the policy approach. Indeed, the application of DACCS could be a key strategy for those countries that export more fossil carbon than they emit domestically. In these circumstances, a country would need to switch to sourcing $CO_2$ from the air (or the import of $CO_2$ captured in third countries) in order to obtain sufficient volumes of $CO_2$ to offset domestic carbon production from the geosphere. For example, if a country annually extracts 300 $MtCO_2$ from the geosphere in the form of oil and gas but has domestic point source emissions of only 50 $MtCO_2$ available for capture, a further 250 $MtCO_2$ of DACCS (or possibly BECCS or imported $CO_2$) would need to be sourced and injected for the country to achieve a SAFE-Carbon rate of 100%. The 250 Mt of DACCS removals would, in practice, be directly offsetting the climate change impacts of dispersed sources derived from the country's produced fossil fuels, including both domestic emissions sources (e.g. from transport) and those occurring in the countries that imported the fossil fuels. On this basis, Models 2 and 3 offer a coherent pathway to support technological removals, building off from CCS deployment approaches.

## 4.2 Environmental integrity

There are several essential elements involved in maintaining high levels of environmental integrity that apply to all three cooperation models:

1. **Robust MRV and accounting**. Ensuring that credited units are real, measurable, additional, permanent and do not result in leakage.

2. **Avoidance of double counting**. Ensuring that credited units cannot be claimed by more than one actor or counted towards more than one target.
3. **Avoidance of perverse outcomes**. Ensuring that crediting does not lead to circumstances where emissions may be able to increase or lock-in a future of high emitting practices.

These are considered in turn below.

### 4.2.1 Robust MRV and accounting

In terms of CRRU and CSU generation, site selection and monitoring requirements in all three models can draw upon the same basis (Section 2.2.3) – the only difference is the metric that is used to establish units: in the case of Model 1, $tCO_2$ emissions reduced, avoided or removed; in the case of Models 2 and 3, $tCO_2$ stored (Figure 3-1). No significant MRV issues are anticipated for any of the models.

In the case of **Models 2 and 3**, further work is needed to clarify accounting methods, in particular the carbon production inventories of participating firms and countries against which CSUs will be counted ($C_{FFyP}$ in Box 2-2), and the point of compliance in respect of a voluntary pledge or CSO/CTBO. In these respects:

1. **Inventories of produced $CO_2$** (i.e. the calculated value of $C_{FFyP}$). Countries and companies report production in various ways, using different conversion factors and assumptions regarding the carbon content of produced hydrocarbons. Firms also variably report own production, third party operated production and sales of third-party product (including refined product). Reporting will need to be standardised to ensure consistency in target-setting during implementation.
2. **Point of compliance** (i.e. the point in the fossil fuel value chain where $C_{FFyP}$ is calculated). Under Model 2, where a CSO/CTBO is applied to fuel suppliers at the border, upstream emissions of imported fuels will fall outside the scope of the national CSO/CTBO.[50] In this situation, domestically produced fuels could face unfair treatment, since upstream emissions associated with their production could be counted with the CSO/CTBO compliance metric. To address the possible differential treatment for domestic and imported natural gas under a CTBO in the Netherlands, Kuijper et al. (2021) proposed that a correction factor would need to apply to imported natural gas to account for the variable upstream emissions associated with different supply sources. However, including these upstream emissions within the compliance metric will present challenges because of the inconsistencies in the way fuel extraction and processing emissions are reported in different countries. Experiences with implementing the EU Fuel Quality Directive suggests that resolving these differences could prove contentious, and that either a fixed factor or complete exclusion of upstream emissions could prove more straightforward.

[50] If only the $CO_2$ embodied in fuels arriving at the border is used as the compliance metric

Wider consultation will be needed to address these issues.

### 4.2.2 Avoidance of double counting

The issuance of two different types of credits for the same activity – a CRRU and CSU – gives rise to concern over double counting. To avoid interaction of the two units, it is essential that:

- CRRUs be counted only against targets expressed as t$CO_2$ emissions reduction or removals, such as expressed in NDCs or in voluntary corporate pledges. This may be implemented through domestic ETSs or other types of policy based on crediting (Model 1);
- CSUs be counted only against targets expressed in t$CO_2$ stored primarily linked to t$CO_2$ produced from the geosphere (company or country) and/or imported (country). This may be based on a voluntary target of a fossil fuel producing company (Model 2), through a CSO/CTBO (Model 2) or a national pledge to support $CO_2$ storage (Model 3).

Under Article 6 rules, all three models will, in principle, require corresponding adjustments to be applied to transfers of either CRRUs or CSUs if they are used as ITMOs that are counted towards NDCs.

However, the supply-side offsetting quota system in **Models 2 and 3** is not suitable for applying corresponding adjustments. In principle, the CSUs would be credited to geological storage site operators, who could either:

- Retire them internally to satisfy a voluntary corporate pledge (where the company undertaking storage is an oil and gas producer).
- Sell them to an oil and gas producing company who could retire them to satisfy a voluntary corporate pledge (where the storage company is a separate entity).
- Sell or retire them to the host country government to meet a domestic storage target, perhaps expressed in an NDC or implemented through a CSO/CTBO.
- Bundle them with fuel supplies to satisfy a CSO/CTBO in an importing country, and ultimately counted against a storage target in the importing country's NDC.

In any of these cases, the CSU can only be used once, either by a corporation, the host country, or an importing country, meaning that no double counting or claiming can occur. Consequently, there is no potential secondary use that must be negated by a corresponding adjustment. Therefore, the obligation for Parties to apply corresponding adjustments to all ITMOs poses some complications in respect of Article 6 cooperation involving CSUs.

In respect of accommodating CSUs within voluntary and mandatory CSO/CTBO systems, Towns and Dixon (2022) have proposed a 'double tabbed' CSUs that could be used to satisfy accounting within both systems (i.e. one tab could be used to satisfy a voluntary reporting standard for a corporation, and a second tab from the *same* CSU could be used to satisfy a compliance systems).

### 4.2.3 Avoidance of perverse outcomes

The following specific CCS configurations could lead to potential accounting issues that apply under all three models:

- The reinjection of reservoir $CO_2$ that is a by-product of hydrocarbon production.
- The injection of $CO_2$ for the purposes of enhanced oil recovery (EOR)

While these are essentially accounting related issues, they are treated here in the context of the potential for perverse outcomes. Issues relating to carbon lock-in are briefly assessed below under 'Policy performance'.

Some natural gas reservoirs contain significant volumes of $CO_2$, which is co-mingled with produced hydrocarbon gases (e.g. see Zakkour and Cook 2010). The $CO_2$ 'contamination' is removed through a process of gas sweetening, where it is typically vented to atmosphere as a fairly pure stream. Such high purity sources can instead be injected for storage to avoid the emissions to atmosphere.

Under either of Models 1, 2 or 3, the crediting of reinjected reservoir $CO_2$ can present possibilities for potentially perverse outcomes where the injected volume of $CO_2$ is counted as an offset against the $CO_2$ embodied in the produced hydrocarbons. In a worked hypothetical example:

- If the total annual embodied $CO_2$ production from a reservoir is equivalent to 100 $tCO_2$, consisting of:
    - 50 $tCO_2$ in the form of by-product $CO_2$
    - 50 $tCO_2$ in the form of $CH_4$
- The 50 $tCO_2$ by-product could be reinjected and used to generate CRRUs and/or CSU, which could lead to:
    - The acquisition of 50 CRRUs by a country importing the hydrocarbons for use as an offset against the 50 $tCO_2$ resulting from combustion of the $CH_4$. In this case, corresponding adjustments must apply to the CRRUs to ensure the environmental integrity of the transaction. This would result in the country undertaking the $CO_2$ injection having to add the 50 tonnes of reinjected $CO_2$ back on to its GHG inventory
    - The 50 CSUs being counted against an inventory of embodied $CO_2$ in produced fossil fuels (i.e. the 50 $tCO_2$ embodied in the $CH_4$). In this case, it is essential that the point of compliance is at the wellhead and not further downstream (as described in Section 4.2.1 above). At the wellhead, 100 $tCO_2$ would be measured, whereas downstream measurement points could result in the 50 $tCO_2$ by-product falling outside the scope of the compliance system. This topic also has implications for the point of compliance discussed in Section 4.2.1.

A consequence of these potential arrangements is that some care will be needed in implementation of Model 2 or 3.

Awarding any type of credits to $CO_2$-EOR operations is likely to prove controversial. However, in the case of **Model 1**, environmental integrity can be maintained if the incrementally produced oil is utilised in a country with an ambitious climate pledge. How that may be practically enforced is a matter for debate that extends beyond the scope of this paper.

For **Models 2 and 3**, the environmental integrity of CSUs would not be compromised by awarding CSUs for $CO_2$ injected for EOR purposes. Any incrementally produced crude oil resulting from the EOR operation would need to be added to the relevant compliance metric subject to the SAFE-Carbon quota (i.e. it would be added on to $C_{FFyP}$ in Box 2-2)

## 4.3 Commercial and financial viability

The anticipated scale-up of CCS has been significantly curtailed by financial and commercial challenges in many parts of the world. Factors such as volatile carbon prices and cross-chain risk are commonly seen as reasons for project failure (Section 2.2.3; see also, e.g., UK Parliament 2019; Martin-Roberts et al. 2021).

In the context of **Model 1**, potential approaches to address these risks, such as CCfDs, were described previously and are not reiterated here (see Section 2.2.3). In terms of evaluating the possible models for CCS cooperation, a more pertinent question is whether **Models 2 and 3** offer any advantages compared to other approaches that seek to address the financing challenges of **Model 1**? This is a difficult question to answer since it lacks any empirical basis upon which to make an assessment.

In these respects, Element Energy (2018) suggested that a supply-side (or CCS obligation) approach would present administrative complexity, be unsuitable for application at a global level, and make little difference whether placed on emitters or suppliers. Zakkour and Heidug (2019), on the other hand, suggested that a CSU offers a complementary and supplementary price signal for CCS, targeted at a different set of actors, and could therefore help to secure investment in the technology from more sources, in particular, from the fossil fuel industry which has the most to gain (see Section 2.2.3). Jenkins et al. (2021) similarly concluded that a CTBO policy offers advantages of simple governance, speed, and controllability compared to a global carbon price. The assessment of effectiveness, presented above, supports these conclusions.

In respect of financing CCS activities, some observations regarding Models 2 and 3 as they compare to Model 1 can be made:

- **Enhanced certainty over the demand for geological storage**. By establishing a predictable quota for geological $CO_2$ storage services, a clear demand for $tCO_2$ stored is established as long as fossil fuels remain in use. This enhanced predictability can also help to drive greater certainty into the types of emissions reduction/removal actions that may be credited in the conventional carbon market under Model 1. This should help to reinforce the business case for CCS investment.

- **De facto license to operate**. A ratcheting SAFE-Carbon rate acts like a de facto license to produce fossil carbon, with only those operators capable of offsetting the impacts of their production being allowed to extract hydrocarbon fuels. By framing the approach as a supplier obligation, oil and gas firms may gain greater social license in terms of shareholder interests, while greater public acceptance of the technology may also be achieved (see Kuijper et al. 2021).
- **Incentivise actors with the know-how to build $CO_2$ storage sites**. As the CSU channels the obligation to build and use storage capacity to oil and gas producers, Models 2 and 3 will incentivise actors with the relevant experience to develop and operate $CO_2$ storage facilities. Since geological storage resources are generally located in sedimentary provinces with similar geology to oil and gas resources, Model 3 should also channel finance to locations that are well-endowed with $CO_2$ storage capacity.
- **Enduring price support mechanism and exist strategy for government funding**. The price stability mechanisms proposed to support CCS under carbon pricing (Model 1), including large government grant support, do not provide an enduring business model that supports widespread CCS deployment. At some stage, governments will likely require an exit strategy from price support mechanisms such as CCfDs, which could be filled through CSO/CTBO implementation.
- **Commercial transactional model that ensures geological storage sites get filled**. As noted in Zakkour et al. (2021), present arrangements for CCS lack incentives to ensure that storage sites are used, especially where they are funded by government grant support. Site operators are instead able to set a gate fee entirely independent of any climate policy driver, for example, according to their operating costs, risks, and internal margins. The situation reinforces cross chain risks in respect of the uncertainty about future $CO_2$ disposal costs for $CO_2$ capture plant operators. Where a separate and independent price signal is created that values stored $CO_2$ (i.e. the CSU value), commercial structures that support physical $CO_2$ transfers between parties can emerge based on the capture costs, transport costs, storage costs, prevailing carbon price (to offset $CO_2$ capture/removal costs), and CSU value (to drive value in $CO_2$ storage activities).

Some of the above considerations, and in particular the last bullet, highlight the classical 'agency problem' posed for deploying CCS.[51] Multi-party CCS projects involving two or more parties across the full chain of operations needs sufficient alignment of incentives and interests to ensure commercially viability. However, where carbon pricing places all the interests at the point of $CO_2$ capture, a storage site operator has insufficient 'agency' to act in the interest of principal (the capture operator) to facilitate project deployment. From the storage site operator's perspective, the risks of the project (e.g. the residual liabilities for stored $CO_2$) likely

[51] Principal-agent or the agency problem describes a situation where one party (the agent) is motivated to act in its own best interest despite being contrary to another involved party's (the principal's) best interests, primarily where the agent is not exposed to the same benefits to the outcome as the principal.

outweigh the potential rewards. As a result, it will be motivated to increase costs (e.g. a gate fee) reflective of the risk-reward proposition, perhaps to a point where the project becomes commercially unviable. In the absence of other revenues (e.g. $CO_2$-EOR) or financial incentives, private contractual arrangements may be insufficient to redress the asymmetric distribution of risks and rewards. Therefore, policies and measures that establish clear and separable incentives for geological storage of $CO_2$ independent of the principal's interest, such as those envisaged under Model 2 and Model 3, could help alleviate agency problems.

Furthermore, in a broader sense, first mover disadvantage is a problem. As noted previously, an entirely voluntary approach to supply-side offsetting (Model 2) may not be sustainable without some country level support that allows for cost passthrough. On the other hand, a few countries adopting a CSO/CTBO would similarly face disadvantages without some kind of border adjustments in place.[52] As such, an approach like Model 3 that engages a far wider set of countries in implementation may offer greater likelihood of success over the medium-term.

## 4.4 Progression

The Paris Agreement requires that "each Party's successive nationally determined contribution will represent a progression beyond the Party's then current nationally determined contribution and reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances" (Article 4.3). In this context, we consider the extent to which the different CCS cooperation models could serve to promote mitigation ambition, transformative change and NDC progression, as well as being relevant both prior to achieving, and during, an anticipated period of net zero global emissions.

The linkage of carbon markets envisaged under **Model 1** represents a technology neutral mitigation pathway based on cost containment; in other words, achieving mitigation goals at least overall cost. The approach therefore drives investment towards least-cost projects whilst constraining the capacity to deploy higher-cost technologies that may require a diversity of support mechanisms to get off-the-ground. The resulting lack of certainty around the financial viability of higher-cost technologies such as CCS is therefore likely to hamper progress within some NDCs. As noted by Zakkour and Heidug (2019), the absence of a clear pathway for financing and deploying CCS over the short- to medium-term can drive conservatism in NDCs, and thereby reinforce constrained pledges on CCS and other essential but higher cost mitigation technologies. On this basis, countries with limited or no experience of CCS technology are unlikely to commit to its future use without a clearer idea about available support for the technology (*ibid*). It remains unclear whether Model 1 can overcome such uncertainty absent of more significant targeted support and incentives.

[52] For example, the carbon border adjustment mechanism (CBAM) presently being considered by the EU, although the scope of this proposal excludes energy products are the current time.

In contrast, the use of CSUs envisaged under **Models 2 and 3** could potentially help drive ambition in NDCs by providing greater clarity around the provision of finance and support for CCS deployment. In particular, Model 3 could allow major fossil fuel producing countries, which have typically struggled to engage in meaningful climate action and define ambitious mitigation contributions, to develop NDCs based on extensive CCS deployment over time. Model 2 could provide a bottom-up pathway toward Model 3 but would offer less certainty in respect of progression because it would involve fewer (if any) countries.

The use of CSUs under Models 2 and 3 can also provide a coherent unit for net zero policy design. At some point along the net zero pathway, allocations of allowances and crediting of avoided emissions (like under Model 1) will need to end and be entirely replaced by crediting based solely on removals (or storage, depending on the accounting framework; see Section 2.1.2). Ambitious NDCs should therefore be seeking to include a carbon storage target at some stage, whether removed or captured from point sources. In this respect, the early adoption of CSUs can help to focus interest, driving the progression towards increased ambition.

## 4.5 Policy performance

Policy performance is considered in terms of the ability to facilitate broad participation, coherence with other policy instruments, and their political viability with governments, private sector and civil society.

**Model 1** is aligned with the prevailing assumption among many observers that carbon pricing will play a central role in achieving ambitious climate mitigation goals. This is very clearly reflected in the growing number of carbon pricing schemes implemented worldwide – including within a growing number of developing countries – as well as commitment to such actions within NDCs.[53] Notwithstanding the considerable challenges to effective scheme design and their subsequent linkage (Section 2.1.1) as well as political acceptability, a broad consensus exists concerning the economic benefits of carbon pricing. On the other hand, carbon pricing advocates have also noted that "carbon pricing by itself may not be sufficient to induce change at the pace and scale required for the Paris Agreement targets to be met, and may need to be complemented by a mix of other well-designed policies" (Carbon Pricing Leadership Coalition, 2017).

Thus, despite a broad consensus that carbon pricing policies drive mitigation outcomes, as noted in Section 2, market-based instruments such as ETSs have so far failed to deploy CCS to anywhere near the scale envisaged by the IPCC, IEA and others. Solutions to this shortcoming have mainly focused on bolstering the carbon price through the use of stability mechanisms, for example, the UK's proposals to use a CCfDs alongside a regulated asset

[53] Presently 97 Parties mention carbon pricing in their NDCs indicating that they are currently, planning or considering the use of climate markets and/or domestic carbon pricing to meet their NDC commitments; these cover around 58% of global emissions (World Bank, 2020).

base (RAB) funding model applied to transport and storage.[54] So far discussions in the UK over commercial models for CCS, including the CCfD-RAB concept, have continued over several years without conclusion, indicating the complexities involved. Uncertainty also remains over whether such an arrangement operating within ETSs (or other carbon pricing policy) can be effective in driving CCS deployment, nor how durable it might be over the longer term. More generally, such arrangements may not address the problems in creating a value proposition and business-case for building and operating $CO_2$ transport and geological storage infrastructure.

As highlighted above (Section 4.3), **Models 2 and 3**, can instead provide a direct incentive for storage site operators to source $CO_2$ to fill geological storage sites. When placed alongside the parallel incentive for capturing $CO_2$ (as provided for under **Model 1**) physical markets for $CO_2$ can emerge based on the cost of capture, the value of avoiding emitting (or removing $CO_2$ from the atmosphere), and the value of CSUs in providing a right to produce hydrocarbons and gain access to markets.

This type of approach, and in particular **Model 2**, offers a high degree of sectoral alignment. The oil and gas industry has the skills and knowhow to build storage infrastructure, and the greatest incentive for the technology to succeed (because it sustains market access for its products in a decarbonizing world). A carbon compliance system for the fossil fuel sector built upon the SAFE-Carbon concept and net zero geosphere accounting can offer a transparent and sector-relevant of way defining net zero for these actors (Towns and Dixon, 2022), and establishes a way to demonstrate meaningful climate action to shareholders and stakeholders.

**Model 3** offers political benefits arising from its nature as a ‘club’ comprising of a relatively small number of countries, and the potential these offer in designing, agreeing and implementing effective international agreements. Climate clubs have been widely discussed as a means of addressing the challenges involved in establishing an effective, all-encompassing, multilateral climate change agreement (e.g., Weischer 2012; Andresen 2014; Nordhaus 2015; Falkner 2015; World Bank 2016; Hovi et al. 2016). The basic concept is that a smaller group of enthusiastic countries with common interests in mitigating climate change can act more effectively and efficiently, absent of the diverse and sometimes conflicting interests that characterize collective action by all Parties to the UNFCCC (Zakkour and Heidug 2019).

The utility of fossil fuel producer based ‘supply-side climate treaties’ in addressing and overcoming the political economy challenges of reducing emissions has also been noted by some observers (Asheim et al, 2019; Jenkin, 2021). Such a club, comprising a relatively small number of countries based on agreed storage quotas as envisaged under Model 3, could be

[54] The RAB model has been applied to other capital-intensive technologies with high perceived investment risks such as nuclear power. It aims to incentivise the deployment of low cost capital where investors are given some form of Government backed protection against remote, low probability but high impact risk events.

formed within or outside the auspices of the UNFCCC, depending on political expediency, but in clear alignment with its aims.

One of the challenges for **Models 2 and 3** is gaining wider stakeholder acceptance. A supply-side offsetting approach creates something of a circular problem in that, on the one hand, it provides greater certainty over the demand for geological $CO_2$ storage, but on the other hand, it also tacitly acknowledges the continued use of fossil fuels for some time into the future. Some observers will likely consider that such an arrangement poses unacceptable risks of carbon lock-in. While such views may warrant careful consideration, the frame of reference used in this evaluation is the critical role of CCS seen in the overwhelming majority of Paris-aligned mitigation scenarios (see Section 2.2.1). The need for a supply-side offsetting mechanism should also diminish over time with the increased use of alternate non-fossil energy sources.

# 5 Concluding remarks

Three different models for international cooperation under the Paris Agreement were evaluated for their potential to support CCS deployment: linked carbon prices based on emission reductions/removals units (Model 1) and two alternative approaches using a supply-side offsetting quota based on carbon storage units (Models 2 and 3). Of the three, Model 1 represents the mainstream climate policy approach at time of writing, and where most of the energy for carbon policy development resides today. Models 2 and 3 are novel concepts that are receiving some attention from industry, national governments and international forums, although they remain someway from implementation.

In respect of Model 1, it remains uncertain whether technology-neutral market-based mechanisms can deliver significant amounts of permanent geological storage of $CO_2$. Experiences to date with policies such as the EU ETS suggests that they are poorly suited to supporting deployment of higher cost, nascent, climate change mitigation technologies such as CCS without the use of supplementary measures. Factors such as low prices, price volatility and cross-chain risk are all features that impact upon their effectiveness to support CCS. Despite a general assumption that carbon prices will rise over time and offer greater stability, which could encourage investment into CCS, the evaluation of effectiveness in Section 4 indicates high levels of uncertainty in these regards. The ongoing supply of low cost units from sink conservation projects (e.g. REDD+) and activities that count avoided emissions (e.g. renewable energy, energy efficiency, waste emission reduction etc) are likely to significantly impair the likelihood of significant volumes of geological $CO_2$ storage being supported by carbon markets before 2030.

Carbon markets could lead to some near-term deployment of low-cost CCS projects, however, even under scenarios of low carbon prices. In particular, the capture and storage of $CO_2$ vented from natural gas sweetening operations could provide early opportunities at costs of less than USD 20/t$CO_2$ (IEAGHG 2008). Crediting such activities does pose some environmental integrity risks: if the injection of by-product $CO_2$ receives credits that are subsequently used by importers of natural gas to claim carbon neutrality (e.g. through ‘green LNG’ cargoes), problems will arise. Such claims are only possible because the full lifecycle emissions of extracting, processing and supplying the gas are not fully counted in the combustion emissions. Corresponding adjustments can address these integrity concerns, but the effectiveness of such adjustments may be limited if the NDC of the producing country is not particularly ambitious.

The introduction of CSU based policies, backed by corporate and national commitments to $CO_2$ storage (possibly in NDCs) under Models 2 or 3, can provide a supplementary mechanism to ensure that an ever-increasing portion of mitigation actions consist of geological $CO_2$ storage. Such outcomes can reduce uncertainty about the quality of the types of units being traded as mitigation outcomes in the nascent carbon market. In these respects, the evaluation indicated that:

- A top-down, country-led, approach (Model 3) could be more effective in enhancing geological $CO_2$ storage. This is because the scope of the obligation would extend into national oil companies as opposed to only the major independent energy companies under Model 2.
- Gaining agreement to adopt storage targets across multiple countries under Model 3 is likely to be challenging, however, suggesting that Model 2 bolstered by a few pioneering countries implementing supporting national policies may be a more practical pathway for implementation. Pioneer countries imposing carbon storage obligations on national energy suppliers can secure market access for fuels bundled with CSUs that demonstrate offsetting of their climate impacts on the supply-side. Without a clear route to market, it seems unlikely that independent energy companies wishing to use CSUs to demonstrate progress towards net zero would be able to sustain the approach in the face of market competition from other, non-participating, fossil energy sources.
- An approach built upon CSUs can also help to provide additional finance for CCS and a coherent pathway towards technological removals. At a national level, adoption of complementary storage targets can also help to enhance progression in NDCs.

The likelihood of a CSU mechanism being implemented, even at a pilot scale, remains highly uncertain, however. Some observers may see it as unnecessary technology subsidy. Others may see it as creating carbon lock-in insomuch as it guarantees a route to market for fossil fuels in a net zero world. Together these views may be seen as diverting capital away from other types of mitigation not involving fossil fuels. Furthermore, the focus of most climate policy dialogue today remains firmly on conventional notions of carbon markets, and some stakeholders are wary of the potential confusion that can arise over what is being counted and credited: storage, emission reductions or removals? The basic concepts of emission reductions and removals and territorial and organisational emissions accounting are deeply ingrained.

But on the other hand, achieving net zero depends on crediting $tCO_2$ removed (or $tCO_2$ stored) that can be counted as a balance against ongoing $tCO_2$ emitted.[55] Modelling by Yu et al. (2021) clearly shows that when most countries are focussed on achieving a global net zero goal, virtually all traded volumes in carbon markets must be derived from activities delivering carbon storage. Thus, the crediting and trading of actions that represent emission reductions as a deviation from a notional business-as-usual scenario in NDCs, and the continued supply of credits from sink conservation under the premise of achieving net zero, will need to be

[55] The choice depends on whether $CO_2$ captured at source is deducted as an emission reduction at source, or whether it is instead counted as an emission to atmosphere and subsequently counted as a sink enhancement based on volumes of $CO_2$ injected and stored. Although these differing arrangements represent a fairly relatively straightforward change to accounting approach, these basic concepts can prove challenging to communicate.

addressed at some point. Procurement of these types of “avoided emissions” mitigation outcomes in pursuit of a net zero goals should have only limited relevance for future progressive and ambitious climate action. However, until such time that these structural issues for cooperation under Article 6 are addressed, the use of CSUs in a secondary market can provide an early means to address this risk.

Taking such an approach also offers a potential pathway to reduce the effects of mitigation deterrence – that is the deferral of ambitious emissions reductions – by providing greater clarity about the distribution of effort in net zero targets between cutting emissions, using CCS and relying on technological removals solutions.

On a political level, interest is growing in CSU concepts, albeit from a small base. Greater efforts to raise awareness of the risks posed to net zero in current market arrangements, and the opportunity to address these risks through supporting policies such as CSUs, is urgently needed in order to put the planet on a pathway towards net zero.

The analysis presented herein has drawn from only a few published studies, limited quantitative analysis, and the authors own expert judgement. Future work should seek to gain a broader set of views regarding the models and evaluation carried out herein. Engagement of key stakeholders through workshops and surveys could help to raise awareness of the concepts, opportunities and challenges, refine the initial ideas and reflections presented, identify other areas of risk and opportunity, and help to frame potential implementation pathways. Key groups to consult include:

- National governments (e.g. U.S., Canada, Saudi Arabia, UAE, Qatar, European Commission, UK, Norway, Netherlands,)
- Intergovernmental groups (e.g. Clean Energy Ministerial; International Energy Agency; Organisation for the Petroleum Exporting Countries; IEA Greenhouse Gas R&D Programme; Global CCS Institute; the International Centre For Sustainable Carbon)
- Industry groups (e.g. International Emissions Trading Association; Oil and Gas Climate Initiative; Ipieca; Sustainable Markets Initiative; American Petroleum Institute; Zero Emissions Platform; Carbon Capture Coalition; Sustainable Markets Initiative)
- Academia and think tanks (e.g. Oxford Net Zero; Scottish CCS Centre; King Abdullah Petroleum Studies and Research Centre; European Roundtable on Climate Change and Sustainable Development; Stockholm Environment Institute; Oxford Institute for Energy Studies)
- Environmental non-governmental organisations (e.g. Clean Air Task Force; Carbon Market Watch; Bellona Foundation)

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# Annex A – Assumptions and data underpinning CSU demand estimates

## Conversion factors

| Energy Conversion | Factor | Units |
|---|---|---|
| m3 to ft3 | 0.0283 | scm/scf |
| Natural gas to boe | 0.0066 | boe/scm |
| EJ to MMtoe | 23.88 | EJ/MMtoe |
| toe to barrels | 7.4 | bbl/toe |
| EJ to MMBtu | 947,817,100 | MMbtu/EJ |
| MMbtu to m3 | 28.3 | m3/MMBtu |
| M = 10 x E3 | | |
| MM = 10 x E6 | | |
| **Embodied Carbon** | | |
| Crude Oil/Liquids | 0.4200 | $tCO_2$/bbl |
| Natural gas | 0.0022 | $tCO_2$/scm |
| | 39.1 | MJ/m3 |
| | 0.0561 | $tCO_2$/GJ |

## Energy and Carbon Production by selected independent energy Companies (2019)

| Company | Net Zero pledge (incl. Scope 3) | Crude Oil & NGL (MMbbl) | Natural Gas (bcm) | Embodied Carbon ($MtCO_2$) |
|---|---|---|---|---|
| BP | Y[1] | 420 | 76 | 343 |
| Shell | Y | 646 | 88 | 465 |
| Total Energies | Y | 531 | 47 | 326 |
| Eni | Y | 326 | 73 | 297 |
| Repsol | Y | 93 | 25 | 94 |
| Occidental | Y | 286 | 15 | 153 |
| Equinor | Y | 357 | 54 | 269 |
| **Total** | | **2,659** | **378** | **1,946** |
| Chevron | | 681 | 74 | 448 |
| ExxonMobil | | 752 | 97 | 529 |
| ConocoPhillips | | 292 | 18 | 162 |
| Marathon Oil | | 102 | 8 | 61 |
| **Total** | | **4,485** | **576** | **3,147** |
| **World production (2019/2020)** | | **31,209** | **3,787** | **21,414** |
| **Share of global production (%)** | | **14%** | **15%** | **15%** |

Notes: Excludes 3rd party operated production. NGLs = natural gas liquids. World crude oil and natural gas production data sourced from IEA Atlas of Energy (http://energyatlas.iea.org/). [1] Excludes Rosneft.

### Energy and Carbon Production by countries with CCS in their NDCs (2019/2020)

| Company | CCS mentioned in NDC | Crude Oil & NGL (MMbbl) | Natural Gas (bcm) | Embodied Carbon ($MtCO_2$) |
|---|---|---|---|---|
| United States | Y | 5367 | 875 | 4174 |
| Saudi Arabia | Y | 3863 | 91 | 1821 |
| Canada | Y | 1923 | 174 | 1189 |
| Iraq | Y | 1525 | 12 | 666 |
| China | Y | 1444 | 179 | 1000 |
| United Arab Emirates | Y | 1308 | 47 | 653 |
| Kuwait | Y | 981 | 17 | 448 |
| Iran | Y | 977 | 223 | 900 |
| Mexico | Y | 725 | 31 | 371 |
| Norway | Y | 703 | 110 | 536 |
| United Kingdom | Y | 369<br>(48) | 38<br>(32) | 239 |
| Egypt | Y | 223 | 59 | 223 |
| Australia | Y | 145 | 143 | 374 |
| EU27 | Y | 156<br>(3,297) | 46<br>(301) | 166<br>(2,211) |
| Bahrain | Y | 69 | 15 | 62 |
| Japan | Y | 4<br>(1,115) | 3<br>(106) | 7.9<br>(708) |
| South Africa | Y | 0 | 1 | 2.4 |
| **Total** | | **19,624** | **2,018** | **12,668** |
| **World production (2019/2020)** | | **31,209** | **3,787** | **21,414** |
| **Share of global production (%)** | | **63%** | **53%** | **59%** |

World crude oil and natural gas production data sourced from IEA Atlas of Energy (http://energyatlas.iea.org/). Malawi excluded as it does not produce any oil or natural gas. Bracketed data show imports for selected countries/regions.

### Global crude oil and natural gas demand under IEA Net Zero scenario

| IEA Net-Zero 2050 Scenario | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| *Exajoules* | | | | | | | |
| Crude oil | 173 | 166 | 137 | 106 | 79 | 57 | 42 |
| Natural gas | 137 | 149 | 129 | 99 | 75 | 66 | 61 |

Source: IEA Net Zero data (https://www.iea.org/data-and-statistics/data-product/net-zero-by-2050-scenario)

Evaluating technology options to mitigate greenhouse gas emissions

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