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Unlocking the potential of geological storage of CO_2: what role for a Storage Climate Club?

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Carbon Capture and Storage (CCS) is a key carbon dioxide (CO_2) mitigation technology in climate change mitigation pathways that aim to limit the rise in temperatures to below 1. 5 and 2 °C, in line with the recommendations of the Intergovernmental Panel on Climate Change (IPCC). This policy brief focuses on the deployment at scale of geological storage of CO_2 as the last critical link in the CCS process chain. It proposes the establishment of a new Storage Climate Club led by a group of "enthusiastic" countries in order to operationalize a new asset class, Carbon Storage Units (CSUs) under Article 6 of the Paris Agreement and support the deployment at scale of geological storage of CO_2 and CCS technologies worldwide.

KEYWORDS

carbon capture & storage, CCS, geological storage of CO_2, Paris Agreement, Article 6, climate clubs, Intergovernmental Panel on Climate Change (IPCC)

Introduction

Carbon Capture and Storage (CCS) is a key carbon dioxide (CO_2) mitigation technology in climate change mitigation pathways that aim to limit the rise in temperatures to below 1.5 and 2 °C, in line with the recommendations of the Intergovernmental Panel on Climate Change (IPCC) (Intergovernmental Panel on Climate Change, 2007a; IPCC, 2018). CCS is benefiting from positive momentum worldwide, in spite of challenges and uncertainties.[1] Artificial Intelligence (AI) is set to further increase demand for CCS to decarbonize AI-driven data centers that consume large amounts of power.[2] However, CCS, a technology that is dependent on the availability of geological storage, will need to be deployed on an even more massive scale in order to meet climate objectives (Table 1).

1 Strong growth is expected in coming years in the United States, where CCS capacity is expected to increase fourfold from a baseline of 2024 through to 2030 in spite of uncertainties linked to the current White House administration, as well as in Europe, where it is expected to increase by a factor of twenty-three over the same timeframe (see Hieminga and Zhang, 2025), CCS momentum is also building in the Asia Pacific region (see Global CCS Institute, 2024).

2 AI models are extremely energy intensive: at 2.9 W-h per ChatGPT request, AI queries are estimated to require ten times the electricity of traditional Google queries that require 0.3 W-h each (see Electric Power Research Institute, 2024). AI has the potential to revolutionize the deployment of CCS, for instance by cutting down the time required for CCS modeling from 100 days to 24 h and for estimating CO_2 storage capacity. See https://www.powerengineeringint.com/emissions-environment/ai-breakthrough-shows-potential-to-advance-ccs/ and https://www.halliburton.com/en/energy-pulse/accelerate-carbon-capture-storage-innovations-with-artificial-intelligence.

TABLE 1 Required CO_2 storage from CCS, BECCS, DACCS in different scenarios (Unit: $GtCO_2$).

Scenarios and technologies	2023	2030	2050	2070	2100
IEA-SDS					
CCUS	0	0.6	4	6.9	
BECCS and DACCS		0	0.8	2.9	
IEA NZE by 2050					
CO_2 capture vol.	40 (Mt)	1.67	7.6		
Permanent geological storage			7.22		
BECCS and DACCS					
IPCC SR 1.5 (max)		0.6	5.9	13.1	23.6
IPCC SR 1.5 (median)		0	3.0	6.8	11.2
Shell Sky					
Emissions captured by CCS		0.20	5.2	10.03	11.19

Sources: "Global Energy Sector CO_2 Emissions Reductions by Measure in the Sustainable Development Scenario Relative to the Stated Policies Scenario – Charts – Data & Statistics" (International Energy Agency, 2020a) and "Carbon Removal through BECCS and DACCS in the Sustainable Development Scenario and IPCC SR1.5 Scenarios, 2030-2100" (International Energy Agency, 2020b, 2021); "What Are the Previous Shell Scenarios?" (Shell Global, 2024).

This Policy Brief focuses on the deployment at scale of the geological storage of CO_2 as the last, critical link in the CCS process chain.

CO_2 geological storage is a key element for the *avoidance* of or the *removal* of CO_2 emissions from the atmosphere to counterbalance residual emissions in "hard-to-abate" sectors, such as steel, cement or chemicals.

Emissions are avoided when CO_2 derived from the combustion of fossil fuel or from industrial processes is injected into geological reservoirs—a process referred to as carbon capture and storage. Removal and negative emissions result when the injected CO_2 is directly captured from the air (direct air carbon capture and storage or DACCS) or when it is of biogenic origin (bioenergy with carbon capture and storage or BECCS); in the latter situation, CO_2 that has been absorbed from air during the growth of biomass is submitted for storage. The unifying aspect of these diverse approaches is the geological sequestration of CO_2.

This Policy Brief highlights the strategic importance of adopting a paradigm based on managing carbon stocks and on developing removals markets using an innovative asset class, carbon storage units (CSUs; Heidug and Zakkour, 2019). By "removals" markets, we mean markets, such as emissions trading systems, that open up a space for the trading of carbon storage units (CSUs) that represent the removal or storage/sequestration of carbon, with one CSU corresponding to one ton of carbon geologically stored (Heidug and Zakkour, 2019). While the geological storage of CO_2 captured from point sources is a mature technology, removals technologies such as DACCS are still in the early phase of development.

It is the entity (a country or a company) that captures the CO_2 that is stored that would have ownership of the CSU. The entity that captures the CO_2 may be the same entity that stores the CO_2. In addition to storing domestically captured CO_2, these entities could also store imported CO_2 from entities that do not have readily available geological storage capabilities. While regional capture and storage hubs are being developed (particularly in Northern Europe, such as the Northern Lights project in Norway), longer transport routes (particularly shipping) are currently being planned, such as between Japan, Malaysia and Australia (Rystad Energy, 2023). Geological storage thus has the potential to become global, both physically and through the creation of CSU asset markets.

Specifically, we consider the role that a Storage Climate Club led by a small group of leading "enthusiastic" countries could play in accelerating the deployment of the geological storage of CO_2 globally. This follows the idea, championed by economists such as Nordhaus, that "Clubs" can be more effective than international agreements in pushing forward the global climate agenda more rapidly through concrete, innovative and ambitious actions (Nordhaus, 2020, 2015).

Toward a supply-side paradigm based on carbon stocks and carbon storage units (CSUs)

Geological storage of CO_2 remains largely untapped in the absence of a clear economic case

The IEA's Sustainable Development Scenario, the IPCC's 1.5 scenario, and the Shell Sky Scenario illustrate the massive extent to which CCS, carbon dioxide removals (CDR) and CO_2 storage projects need to be deployed to reach climate objectives, as shown in Table 1.

The same message was given more than 20 years ago, when CCS appeared on the agenda of climate change policy makers, with the publication of the IPCC Special Report on CCS in 2005. Yet the rate of deployment of CCS has not kept pace with what the scenarios require (IEA, 2016).[3]

CCS deployment has in effect faced historical barriers ranging from high upfront capital costs, low price signals, insufficient policy and regulatory incentives (including slow permits), technical challenges (such as limited storage availability), through to cross-chain risks (i.e., if one element of the value chain is deficient, none of the other elements can function) as well as social and environmental concerns, including public trust issues.

Consistent policy support to incentivize CCS that includes mandates and pricing incentives, is particularly critical, with policy shifts and removal of financial support, rather than technology or costs, considered to be responsible for the high failure rate of CCS projects (DNV, 2025).[4] The slow rate of CCS deployment is reflected in insufficient CO_2 geological storage rates compared to what the IPCC 1.5 and 2 °C median pathways require (Figure 1).

CO_2 storage capacity data between 1996 (when the first commercial geologic storage project in Sleipner, Norway, began) and 2020 indicate an annual growth rate of 8.6% in CO_2 storage, which could result in cumulative storage of 441 Gt if carried through to 2100 (Zahasky and Krevor, 2020). Yet this is still insufficient compared with the median IPCC 1.5 °C model pathway that has a target of 865 Gt in 2100 (Figure 1).[5]

In contrast, according to the IPCC, while there are uncertainties, the global capacity to store CO_2 deep underground is large. Depleted oil and gas reservoirs are estimated to have a storage capacity of 675–900 $GtCO_2$ (for comparison, the United States emitted 5.960 $GtCO_2$ in 2023; European Commission, 2024). Deep saline formations are very likely to have a storage capacity of at least 1,000 $GtCO_2$ (Intergovernmental Panel on Climate Change, 2007b).[6]

Geological storage of CO_2 does not inherently generate income, thus lacking a conventional business case for its implementation. Instead, its deployment has been facilitated through a variety of policy instruments, both regulatory and fiscal, such as the CCS 2009 Directive and the 2024 Net Zero Industry Act in the EU or the 45Q tax credit and the Inflation Reduction Act in the US (Carbon Gap Policy Tracker, 2009).[7]

To scale up geological storage of CO_2 to levels significant enough to contribute meaningfully toward achieving global net-zero emissions, a robust global carbon market framework for removals is essential. This framework would include high integrity carbon credits for verified CO_2 storage in the context of international compliance and voluntary markets that include a space for removals. These credits would be integrated into national and global targets. Harmonized monitoring, reporting and verification (MRV) methodologies as well as secure long-term legal and financial guarantees, would underpin this framework.

Guiding principles would include transparency, environmental integrity and additionality, as embedded in the provisions of Article 6 of the Paris Agreement, that can act as the global blueprint for such a framework, connecting markets worldwide (Michaelowa and Butzengeiger, 2017). Compared to the Clean Development Mechanism (CDM) under the Kyoto Protocol, Article 6 creates the basis for a more robust global carbon market that is more flexible, open to all countries on a bilateral or multilateral basis and that includes both market and non-market approaches, with stricter accounting rules (Asian Development Bank, 2018).

The inherent characteristics of CO_2 geological storage necessitate this approach: countries possessing the geological capacity and expertise for large-scale CO_2 storage would host these projects. The carbon credits generated from these projects could then be internationally transferred and utilized as offsets by both governments and the private sector.

Low-carbon policies and net-zero objectives can be addressed through CO_2 geological storage

The implementation of low-carbon policies and regulations, coupled with the commitment to net-zero emission goals, has significant implications. This shift is prompting governments, national energy companies, and private sector entities to diversify

3 Globally, around 70% of the 149 CCS projects proposed to be operational by 2020 and that aimed to store 130Mt of CO_2 annually, were not implemented (see Zhang et al., 2024).

4 According to DNV, carbon capture projects are estimated to have suffered from high failure rates of around 88% from 1972 to 2022, while it is estimated that much stronger government support could reduce failure rates down to almost 45%, comparable to the failure rate of early nuclear power plants in the United States. DNV forecasts that CCS deployment by mid-century will be less than one sixth of that required under its *Pathway to Net Zero Scenario*. See historical deployment and performance of CCS in DNV (2025) and Kazlou et al. (2024).

5 While the IPCC's Sixth Assessment Report projects subsurface carbon storage at rates of 1–30 $GtCO_2$ yr-1 by 2050, other evaluations of feasible global CO_2 storage rates are much more conservative and suggest a maximum global storage rate of 16$GtCO_2$ yr-1 by 2050, contingent on the United States contributing 60% of the total. See Zhang et al. (2024).

6 The CO_2 Storage Resource Catalogue—CCUS projects of the Oil and Gas Climate Initiative (OGCI) covers 1,272 storage sites in 54 countries (Cycle 4 Report) (OGCI, 2025) while the IEA's CO_2 Storage Site catalogue presents an overview of 22 CO_2 storage sites around the world (IEA, 2024).

7 These policies have encompassed the integration of CCS into the European Emissions Trading Scheme (EU-ETS) with the 2009 CCS Directive (Carbon Gap Policy Tracker, 2009) and into the Clean Development Mechanism (CDM) of the Kyoto Protocol in 2011 (UNFCCC, 2012), as well as significant government funding initiatives like the EU's NER 300 (Clean Air Task Force, 2023). The EU's 2024 Net Zero Industry Act (NZIA) moreover mandates the development of a 50 million tonnes per year (Mtpa) CO_2 injection capacity by 2030, assigning individual CO_2 storage obligations to 44 major oil and gas producers operating within the EU. See Official Journal of the European Union (2024).

Additionally, fiscal policies such as the 45Q tax credit, the Investment and Jobs Act, and the Inflation Reduction Act in the United States have played a crucial role in supporting this technology (Clean Air Task Force, 2023), with 45Q tax credit preserved and in some cases increased in the "One Big Beautiful Act" (Global Carbon Capture and Storage Institute (GCCSI), 2025).

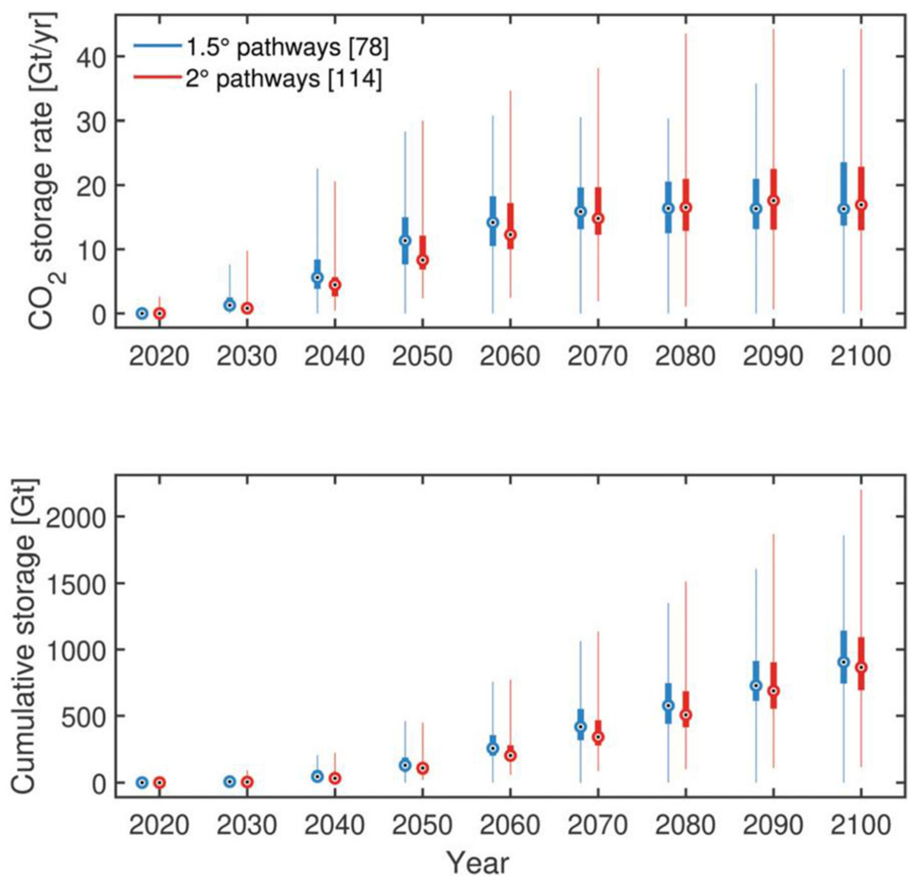

FIGURE 1
Boxplot of total CCS CO_2 Storage rate in Gt per year **(top)** and cumulative storage in Gt **(bottom)** based on the IPCC 1.5 °C (78 models) and 2 °C (114 models) pathways. Source: Zahasky and Krevor (2020) based on data from IIASA (Huppmann et al., 2019), reproduced via Creative Commons CC BY licence.

their energy portfolios and their economic structures, contributing to the expansion of the overall market for CCS that is expected to reach USD 14.51 billion by 2032, up from USD 4.51 billion in 2025 (Fortune Business Insights, 2025).

The goal of achieving net-zero emissions by 2050 poses a significant challenge for countries reliant on fossil fuel extraction and production. However, these nations possess the expertise and knowledge necessary for geological CO_2 storage. Implementing CO_2 storage could offer a viable pathway for these countries to "decarbonize" their products, facilitating the transition to a carbon-neutral economy while minimizing macroeconomic costs.

Supply-side climate policies focused on the supply of fossil resources need to play a role complementing the established toolbox of policy instruments on the demand side if carbon neutrality is to be achieved in a sustainable manner.[8] Specifically, these policies need to unlock the storage capabilities of fossil fuel-producing countries so that these countries can constructively contribute to the transition to net-zero emissions globally, including through the deployment of CDR technologies such as DACCS (Hovi et al., 2016).[9]

Addressing the geographical imbalance in CO_2 geological storage

Most of the current storage projects are concentrated in high-income countries with high historical oil and gas production (HOGP) and are located mainly in the Northern Hemisphere (USA, Canada, UK, Norway) and the Middle East (Saudi Arabia, UAE, Qatar; Alcalde et al., 2025).

Establishing carbon markets for geological storage can help address this imbalance by creating incentives for nations outside

8 Carbon neutrality requires that the amount of CO_2 emitted to the atmosphere be neutralized by an equivalent amount of CO_2 submitted for storage in either biological or geological sinks.

9 Removals technologies such as DACCS that capture CO_2 directly from the atmosphere for storage deep underground, will have an important role to play in reaching carbon neutrality as they can be used for residual emissions as well as providing the option of achieving net negative emissions. For a discussion on DACCS, see Realmonte et al. (2019).

the current group to host storage projects, thus creating a more just and geographically equitable distribution of these initiatives with their geological assets (United Nations Economic Commission for Europe, 2021; Rassool and Havercroft, 2021). Significant geological storage potential is present in countries like Russia or on the African continent (in Algeria, Nigeria or South Africa) (Esau, 2021).[10]

Participation in these markets will need to be supported by North/South and South/South transfers of carbon technologies that can be facilitated through joint ventures and existing technology mechanisms.[11] Financing of projects will require broad derisking investment strategies as well as continued support from multilateral climate Funds and global financial institutions (Sustainability Directory, 2025; Etefe, 2024).[12] These steps can support greater participation from emerging economies and developing countries in the new market mechanisms of Article 6.

Creating carbon markets and in particular effective operationalization of Article 6 can thus help address the geographical imbalance in the deployment of geological storage of CO_2 by connecting the storage potential and capabilities of developing countries directly to global markets, creating much more of a level playing field, with common standards and methodologies as well as de-risk investments (Sandler and Schrag, 2024).

High-income HOGP developing countries already have much of the infrastructure and expertise in place for CO_2 geological storage.[13] Middle or low-income developing countries that are not in this position would have the opportunity of creating a new storage industry domestically, with support from climate finance, international partnerships and multilateral development banks, thereby helping to alleviate poverty, unemployment and inequality.[14] The assetization of emissions avoidance or removals in the context of evolving carbon markets is in effect an important aspect of a just and equitable global energy landscape.

Developing countries would also thereby be provided with the option of using CO_2 geological storage to help reduce their carbon footprint and meet their nationally determined contributions (NDCs) under the Paris Agreement.

Article 6 market mechanisms, carbon markets and carbon storage units (CSUs)

Article 6 establishes a framework for international collaboration aimed at achieving climate goals in a more cost-effective way. It lays the groundwork for creating a global carbon market mechanism that could include emissions reductions or removals through geological storage.

In particular, the market mechanisms of Article 6 could create a space for stocks of geologically stored carbon to be marketed internationally using CSUs. The use of CSUs would both lean on and reinforce international linkage of regional, national and sub-national climate policies in support of collective ambition of the NDCs.[15]

CSUs, traded as Internationally Transferred Mitigation Outcomes (ITMOs) under Article 6 could help incentivize all types of CCS technologies, using a similar carbon credit concept (Heidug and Zakkour, 2019).

The availability of CSUs presents a potential new revenue stream for governments hosting storage projects. Countries looking to fulfill a portion of their NDCs through storage may drive demand for CSUs. Additionally, industries seeking to offset emissions that are challenging to reduce could purchase CSUs. These units could also support compliance with low-carbon fuel standards and regulations.[16]

A Storage Climate Club: membership, key action areas and operationalization

Article 6 as a Climate Club

Article 6 of the Paris Agreement has been compared to a climate club (Stua, 2022).[17]

10 An extensive CO_2 Storage Atlas for Nigeria has recently been published, in March 2025, with support from the World Bank Carbon Capture and Storage Trust Fund (CCS TF), in which prospective geological storage sites in Nigeria are catalogued (International Finance Corporation World Bank Group, 2025).

11 Such as the Technology Mechanism of the UNFCCC and the technology framework established under article 10 of the Paris Agreement (UNFCCC, 2015).

12 For an overview of financing of CCS projects, see Rassool and Havercroft (2021).

13 Oil and gas producing countries have in particular gained greater understanding of subsurface CO_2 injection and of the handling of large volumes of CO_2 stored underground, from the capture and use of CO_2 for Enhanced Oil Recovery (EOR), a technology that has been in use in oil and gas operations since the 1970s (see Thomas, 2008).

14 South Africa for instance recently inaugurated its first CCUS research center, with a view to developing CO_2 geological storage to help reduce its carbon footprint, in the context of an economy that is heavily reliant on coal. Creating a domestic CCS/CCUS industry that could be connected to carbon markets worldwide could moreover contribute to reducing levels of unemployment and very high rates of poverty in the country (see Mkoko, 2024).

15 For an analysis of climate policy linkages, see Mehling et al. (2018).

16 The effectiveness of Article 6 in promoting geological storage hinges on how it is implemented. Article 6.2 is now operational, with Switzerland and Norway being the first countries to have finalized a bilateral deal to transfer Article 6.2 durable carbon removal credits between the two countries in 2025. Negotiations regarding the modalities and procedures for establishing a multilateral carbon market under Article 6.4 have been progressing, with key new standards for the development and evaluation of carbon crediting methodologies and carbon removal activities having been adopted at COP 29 in Baku, thus paving the way for the issuance of a new class of carbon credits under the 6.4 crediting mechanism. Article 6.4 Emission Reduction credits (A6.4ER) are moreover expected to command a higher price than credits issued by the voluntary market or independent programs (see Van Doorn and Woydt, 2025).

The concept of climate clubs originates in the theory of economic clubs as proposed by Buchanan (1965), with William Nordhaus developing a theory of environmental clubs in 2015.[18] A Nordhaus Club would include (1) members that would commit to a binding carbon price and (2) penalties for non-compliance of members and non-participants (Nordhaus, 2015).

On the other side of the spectrum, a broader definition of Clubs includes Clubs that represent any form of minilateral arrangement by a group of countries, including discussion forums (Hall, 2024).

Article 6 represents the foundation for a governance framework or Club that facilitates the assetization of carbon emissions mitigation and is considered to be a potential basis for a low-carbon Bretton Woods (Stua, 2017). International organizations such as the World Bank are thus setting up their own climate clubs under Article 6 (Srinivasan and Zunin, 2020).[19]

A climate storage club: membership based on CSU certification

A Storage Climate Club, operating under the framework of Article 6, would thus enable a group of key "enthusiastic" countries (Hovi et al., 2016) to join forces to drive forward deployment of CO_2 geological storage at scale.

The essential service provided by the Club would be its definition and certification of CSUs that would be tradable under Article 6, operating on the basis that providing a non-rivalrous but excludable good can be more effective and flexible than relying on more general international agreements to help resolve "hard" global commons problems such as climate change and are better able to advance specific areas of action (Hovi et al., 2016; Stewart et al., 2013).

A Storage Climate Club (SCC) would work in support of objectives of the Paris Agreement, in the context of a transition to net-zero emissions by 2050. This means that storing carbon underground and managing stocks of carbon would supplement rather than contradict the key objective of reducing GHG emissions. Article 4 of the Paris Agreement explicitly mentions "sinks i.e. storage", as being key to reaching long-term temperature goals as set out in Article 2.[20]

Members of the Club would include those that have a direct interest in deploying these technologies, i.e. fossil fuel producers that have the know-how and the expertise to deploy CO_2 geological storage projects, together with governments and stakeholders that are already engaged in deploying CCS and CO_2 storage projects.

These members would provide critical political and economic momentum and help raise the profile of CO_2 geological storage as a key removal/sequestration technology in the move to net-zero.

This core group would provide basic membership stability for the Club. All members would join on the basis of their acceptance of CSUs as an asset class. This means that all members of the Club would adhere to the certification of CSUs that meet internationally recognized standards and quality thresholds, as well as to the trading of carbon storage credits on international markets on the basis of these CSUs.[21] CSUs would in effect certify the safe and permanent storage of CO_2.

The core group of members would also include stakeholders such as large corporations that have a direct interest in CCS and CO_2 geological storage or who wish to purchase CSUs as part of their carbon offsetting or ESG requirements. Over the long run, membership of the Club would become diverse, attracting all countries that have expressed an interest in CCS through their NDCS or that wish to develop their CO_2 geological storage potential. Different tiers of membership could thus co-exist within the Club.[22]

Key areas of action of a Storage Climate Club

A Club would also fulfill roles such as development and policy innovation that would establish robust and credible frameworks as well as promote regulatory/financial incentives (such as long-term national strategies, fiscal incentives, emissions trading schemes that include removals, etc.). The need to provide long-term visibility and certainty for investors is especially important given the high levels of upfront investment and long-term timeframes required for CO_2 geological storage projects.

A Storage Climate Club would set up common funding and finance partnerships as well as technical assistance to facilitate the development of large-scale joint projects, particularly in developing countries of the South, as well as support capacity-building such as mapping out CO_2 geological storage potential and Article 6 market readiness.[23]

17 As embodied in particular in Article 6.1 that states that "Parties recognize that some Parties choose to pursue voluntary cooperation in the implementation of their nationally determined contributions to allow for higher ambition in their mitigation and adaptation actions and to promote sustainable development and environmental integrity."

18 Nordhaus defines a Club as a "voluntary group deriving mutual benefits from sharing the costs of producing an activity inefficient due to structural flaws that include free riding and the absence of penalties for non-compliance that has public good characteristics" (see Nordhaus, 2015).

19 See Srinivasan and Zunin (2020).

20 Article 4.1 of the Paris Agreement states that "in order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of the century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty (UNFCCC, 2015).

21 While standards act as predefined criteria or benchmarks, certification is the process that confirms whether those standards have been met (see Shabanek and Heidug, 2023).

22 In line with the principle of equity and common-but-differentiated-responsibilities and respective capabilities (CBDR-RC) which was established at the first Earth Summit in Rio de Janeiro in 1992 and inherited by the 2015 Paris Agreement "in the light of national circumstances (UNFCCC, 2015)." The CBDR-RC is a fundamental principle of the international climate change regime (see Kumar and Chaturvedi, 2025).

A Club would be instrumental in supporting the deployment of CCS and removal technologies. This would include supporting the development of patents, helping establish joint ventures and partnerships, encouraging private sector participation, or helping scale up R&D activities.[24]

Supporting the proper design of carbon markets worldwide will also be key, with a view to supporting the acceptance of CSUs as credible carbon credits on well-functioning markets (both compliance and voluntary markets).

A Storage Climate Club would operationalize CSUs using a plurilateral trading model

A key role of a Storage Climate Club would be to make CSUs operational in the context of Article 6.2 of the Paris Agreement.

A CSU cooperative approach under Article 6 would correspond to a process whereby countries would verify whether their cooperative approaches fit the framework and guidelines of Article 6 as well as those of international law and of their respective national countries. A Storage Climate Club could assist in this process.

A sustainable and credible economic incentive for CO_2 geological storage would thereby be created.

The Storage Climate Club would adopt a plurilateral trading model, whereby a number of countries would sign up to a common set of rules and guidelines that would govern the relationship between all countries that participate in the Club, with CSUs being accepted as an asset class by all members of the Club and by carbon market participants beyond the Club.

CO_2 geological storage suffers from a disconnect in terms of public perception, that represents an obstacle to its deployment at scale through the trading of CSUs. The geological storage of CO_2 is not a very "popular" option, at least in comparison with renewables and energy efficiency, while negative emission technologies like direct air capture, which ultimately rely on geological storage, are held in much higher regard. A Storage Climate Club could help raise the profile of CO_2 geological storage and help correct public (mis)perception of CO_2 storage.

Concerns over environmental and safety aspects of CO_2 geological storage can be addressed by communicating scientific findings and industry experience through consultations with the public and through third party certification and verification (Mackie and Aarnes, 2022).[25]

Appropriate standards and certifications would apply to safety, permanence, issues of leakage or reversal, issues of liability, as well as monitoring, reporting and verification of storage projects over time.[26]

The governance model and regulatory framework of a Storage Climate Club and its role in the certification of CSUs

The founding members would take the key strategic decisions at the level of governments.

One key political decision that would need to be taken early on at this level would be whether to aim to deploy CO_2 geological storage on as large a scale as possible, i.e. involving a greater number of countries, in particular from the developing world, or whether to concentrate principally on developing CO_2 geological storage only in those countries that are already actively involved in developing CO_2 storage at present and that have the most impact on a global level in terms of carbon removal or avoidance. This goes to the heart of the climate change mitigation problem that needs to be balanced against sustainable development and equity concerns.

The Club would issue a CSU standard for certified geological carbon storage and then issue CSU certificates as its key function. The standard used could be drawn from existing standards that include the IPCC, ISO, CDM, national laws and regulations (Labregere and Van den Bogert, 2024). In other words, the Club would act as a type of "clearing house" for CSUs analogous to financial market clearing arrangements. Members of the Club would have the objective of contributing to a global net-zero objective and beyond, meeting and extending their commitments in their NDCs via measured and monitored CSUs.

This in turn would incentivize the deployment of all CCS and CDR technologies such as DACCS, with a Club working to avoid storage bottlenecks and create a de facto business case for this technology, as well as support R&D in process and materials required for this technology (Qiu and Yang, 2018) and provide much-needed policy support (Sovacool et al., 2022).[27]

23 Preparations to implement Article 6 are ongoing and progressing in a wide variety of developing countries (see Gold Standard Adelphi, 2023).

24 For instance on the model of the European Union's PilotStrategy, a research initiative that is investigating geological storage sites in industrial regions of Southern and Eastern Europe to support development of CCS, using a holistic approach. Its work packages range from geo-characterization to pilot development and social acceptance (see BRGM, 2021).

25 In its Sixth Assessment Report, the IPCC concluded that "if the geological storage site is appropriately selected and managed, it is estimated that the CO_2 can be permanently isolated from the atmosphere" (Calvin et al., 2023, p. 21). The IPCC had already reached a similar conclusion in 2005, concluding that "for well-selected, designed and managed geological storage sites, the vast majority of the CO_2 will gradually be immobilized by various trapping mechanisms and, in that case, could be retained for up to millions of years. Because of these mechanisms, storage could become more secure over longer timeframes (Carbon Capture and Storage Special Report, Intergovernmental Panel on Climate Change, 2005, p. 14).

An innovative study, published in December 2022, uses a new methodology (with a numerical transport model) to assess the possibility of basin-wide CO_2 leakage where billions of tonnes of CO_2 are injected underground in aquifers with caprocks. It finds that even in the worst-case scenario, where rocks present a large number of fractures, the CO_2 would be contained deep in the subsurface for millions of years (see Ivi et al., 2022).

26 For a review of certification issues applicable to CO_2 storage, see Shabanek and Heidug (2023).

27 DACCS is considered to be the most promising carbon removal technology, based on a recent scientific study led by ENGIE that assesses

A neutral balance would ultimately be reached between the carbon stored and the carbon emitted or embodied.

The regulatory framework designed by the Club would provide certainty for all participants, including from the private sector, as well as deal with issues such as liability or any legal issues between countries and stakeholders that are members of the Club and that are engaging in CSU trading. The actual organizational framework of the Club would be modeled on that of the Secretariat of an international organization.[28]

Conclusion: a Storage Climate Club as a new multilateral climate organization

The recent multiplicity of bilateral or minilateral initiatives reflects the realization that the urgency of the climate change challenge requires that bold action by a select group of key countries be taken.[29]

A Storage Climate Club would however not simply be a loose alliance of "enthusiastic" countries or a Club in the sense of a group of countries intent on pushing forward an agenda, but would represent a new international organization, structured and organized as such (i.e., with headquarters, member countries, a Secretariat, etc.), that could sit under the Clean Energy Ministerial (CEM).

The Club would be financed by member country and stakeholder contributions and would aim to become gradually more inclusive of new members from emerging economies and developing countries. Currently, the maximum rate of storage achieved globally is largely controlled by deployment in six key regions, the United States, Canada, China, the United Kingdom, the European Union and the Middle East, in order of decreasing impact. Some of these key players could form the core members of the Club.

This however raises the question of who would make the rules and regulations of the Club with regard to other potential member countries and stakeholders, as well as the key issue of how to bring domestic MRVs in line with international standards. Social acceptance of geological storage of CO_2 will also remain a critical point, as well as the ability of other developing countries with storage potential to realistically be able to "catch-up" with key incumbent players given technical, institutional and economic uncertainties.[30] A Climate Storage Club will moreover require the mobilization of political will from its core members and will have to demonstrate its ability to provide traction for other members and stakeholders.

Achieving clarity on the mission and objectives of the Club from the outstart will be particularly fundamental in such a context. However, a Storage Climate Club is a necessity given the rate of deployment needed for CCS to help meet climate objectives, while the development of interconnected carbon markets worldwide provide geological storage of CO_2 for the first time with a sustainable, credible business model.

The geopolitics of CCS are very complex.[31] However, given the global influence of key players in the geological storage of CO_2 sector and CCS, including in Europe[32] and across the Middle East and Asia, a Storage Climate Club could realistically be established that could be a means to keep climate diplomacy and multilateralism active in the context of retreat by the United States from climate-related Agreements and tensions related to tariffs, in particular with China and the EU.

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the quality of 16 carbon removal technologies available today according to ESG score and sequestration timescale (see Mertens et al., 2024).

28 This would include (a) a decision-making body made up of member countries and private sector members (b) an administrative body (c) sub-administrative bodies (CSU Accounting Body, MRV Assessment Body) (d) technical committees and working groups (emissions data, monitoring reports, verification and validation, scientific committees, applicability of third-party standards and methodologies, etc.).

29 Such as the Climate Club for industry decarbonization established in 2023 (ClimateClimate Club, Global Matchmaking Platform, 2023).

30 See Alcalde et al. (2025).

31 This is exemplified by the Trump Administration's recent announcement (31 May 2025) of its decision to cancel $3.7 billion worth of clean energy grants, of which the majority concerned carbon capture and storage (see Muir, 2025).

For an analysis of the geopolitics of CCS (see Ansari et al., 2024).

32 The drive toward geological storage of CO_2 in Europe is illustrated by the European Union's recent decision that oil and gas companies collectively participate in developing and reserving at least 50 million tonnes of annual CO_2 storage capacity by 2030, as established in its Net-Zero Industry Act that entered into force in June 2024. By 2030, the Act seeks to create a Union market for CO_2 storage services, see Official Journal of the European Union (2024).

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