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A Mechanism for CCS in the Post-Paris Era:

Piloting Results-Based Finance and Supply Side Policy Under Article 6

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About KAPSARC

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Key Points

This paper explores opportunities to establish a transformative new support mechanism for deploying carbon capture and geological storage (CCS) consistent with the Paris Agreement's bottom-up and flexible architecture. Our proposal sets out a vision for structured cooperation between Parties based around the creation of a new, technology-specific, transferable asset class or unit: a carbon storage unit (CSU).

Collective action for CCS could be mobilized through a 'club' of voluntary cooperation, aligned with Article 6.1 and Article 6.2 of the Paris Agreement, drawing membership from countries wishing to collaborate on CCS as part of their contribution to achieving the Paris Agreement's goals.

Actions of the CCS club would be unified by a CCS-specific technology mechanism involving a new dedicated unit, a CSU. Rather than being measured as an avoided emission, emission reduction or emission removal per se, a CSU would represent a verified record of a tonne of carbon dioxide (CO_2) or carbon securely stored/sequestered in a geological reservoir. This would allow CSUs to function as a complementary and supplementary incentive alongside carbon pricing policies aimed at reducing emissions, without any risk of double counting.

Demand for CSUs would be created in a pilot phase through results-based climate finance (RBCF). CCS club members would pledge to procure CSUs as part of their nationally determined contribution (NDC) target and establish a fund that enters into forward contracts to purchase CSUs from CO_2 storers in operational CCS projects. The exact price, volume and timeframe for contracted CSUs would be determined on a case-by-case basis, according to project-specific circumstances and club priorities.

Two layers of finance would be created: a CSU price and a carbon price. A double incentive would help address past challenges of deploying CCS. These challenges include, principally, the inability of carbon pricing alone to support emergent low-carbon technologies like CCS, and the lack of a price signal for storing CO_2, which has hampered commercial transactions of physical CO_2 between capturers and storers in the absence of utilization.

Several options exist for transitioning away from RBCF into mechanisms that create systematic demand for CSUs over the longer term. One such option would be to introduce a CSU obligation on countries or companies, linked to their levels of fossil fuel supply or use. The obligation could be increased over time, aligned to the remaining atmospheric carbon budget and the achievement of a net-zero emissions outcome.

The proposed mechanism offers a pathway toward smarter supply-side climate policy based on creating value for depositing carbon into a variety of planetary stocks other than the atmosphere.

Summary

The Paris Agreement presents profound challenges and new opportunities for the design of the world's future energy system. On entry into force in 2016, the Agreement committed ratifying Parties to new targets for limiting the global average temperature increase and to the balancing of greenhouse gas (GHG) emissions and removals in the second half of this century, or a 'net-zero' emissions outcome. The Agreement expects all Parties to pledge ambitious plans and strategies for meeting its goals in the form of increasingly ambitious nationally determined contributions (NDCs), departing from the 'top-down, two-track,' architecture of the Kyoto Protocol. Countries may voluntarily cooperate to meet or exceed their NDC targets using the Agreement's Article 6 'mechanisms.'

Meeting the Paris goals requires the accelerated deployment of a portfolio of low-carbon technologies that collectively stabilize atmospheric GHG concentrations at or below 450 parts per million (ppm) carbon dioxide CO_2-equivalent (CO_2e). Technologies involving carbon capture and geological storage (CCS) are consistently seen as a critical part of this portfolio. Sustaining global temperature increases to below 2°C above pre-industrial levels approximates to restricting the remaining atmospheric carbon budget to 800-900 gigatonnes (Gt) of CO_2. At current emission rates, this budget will be used up sometime around mid-century. Thereafter, net-zero emissions would require either phasing-out fossil fuel use or using CCS and other sink enhancements to maintain a steady-state climate. This puts into stark relief the crucial relevance of CCS for countries and companies highly dependent on fossil fuel extraction, supply and use.

Against this backdrop, this paper outlines a pathway for aligning countries around CCS as a critical technology for meeting the Paris goals, based on a structured form of voluntary cooperation that could drive new ways to support deployment, that transcends experiences of the past. The paper also outlines longer-term strategic issues associated with progressing along such a pathway.

For CCS to find a place in the Paris Agreement process, countries must firstly make commitments in their NDCs to support and use the technology. However, only a handful of countries have so far pledged contributions in these contexts, although many more exhibit patterns of high emissions intensity and national policies that infer carbon-dependent development pathways. This inconsistency suggests that CCS has been overlooked as a credible mitigation option by many countries, a point noted by several observers. The technology is probably relevant for around 50-60 states at present rather than all 195 Parties to the Agreement, pointing to a need for 'bottom-up' flexible cooperation that aligns countries around such a common interest.

We propose that a CCS 'club' be established as a means of voluntary cooperation in accordance with Article 6. It would draw its membership from countries with high dependency on fossil fuel production and use that wish to include CCS as a prominent part of their NDCs and as a means of differentiated contributions based on a common interest: the pursuit of cleaner fossil fuels. The primary goal of the club would be the deployment of CCS by pooling finance and technical resources. The club could also include non-state actors with interests aligned to its goals.

To be effective, any CCS club would require a unifying technology-specific mechanism that differentiates it from other mitigation technologies

and acts as a conduit through which to aggregate, channel and disburse the finances of club members to project activities. We propose to base this upon a new tradable asset class specific to CCS: a carbon sequestration or carbon storage unit (CSU) that represents a verified tonne of CO_2 or carbon securely stored or sequestered in a geological reservoir.

CSUs would have no intrinsic emission reduction or removal value but would instead provide a verified record of carbon stock addition to the geosphere. As such, CSUs could complement and supplement emissions reduction-based policy instruments. Creating value under emission-based policies in parallel would require the corresponding avoided emissions to be calculated according to GHG accounting rules, such as allocation and baseline determination methods, applicable for a given carbon pricing scheme in a particular jurisdiction. This value would be supplemented by the CSU to create a double incentive for CCS, but without posing the risk of double counting.

This approach addresses two key challenges of the past: the inability of carbon pricing alone to support emergent, climate-critical technologies like CCS and the lack of value for CO_2 storage to drive commercial transactions of physical CO_2 between capturers and storers, absent of utilization. A price signal for CO_2 storage also creates an incentive for industries with relevant sub-surface technical skills and know-how to seek opportunities to build investment grade CCS project chains.

We propose piloting the approach using results-based climate finance (RBCF) to create demand for CSUs in the near term. In practice, CCS club members would pledge to procure CSUs in their NDCs and establish a fund that – using RBCF – enters into forward contracts to purchase CSUs from CO_2 storage operators at an agreed price, volume and timeframe. Exact terms would be determined on a case-by-case basis according to factors such as the size of the fund, technical details of particular projects, and the availability of additional layers of finance and incentives.

Over the longer term, RBCF could transition to a mechanism that creates systematic demand for CSUs. One option would be to disband the CCS club, with CSU purchases becoming part of mainstream NDC pledges. Another option would be for fossil fuel extractors or suppliers to make voluntary pledges or take on an obligation – for example, via a low carbon fuel standard – to surrender an amount of CSUs proportional to the amount of carbon they extract from the geosphere. Over time the pledge or obligation could be increased in line with the goal of achieving a net-zero outcome. Alternatively, either CSUs or carbon pricing alone could be used as a single incentive to promote CCS, depending on experiences gained from piloting.

We consider several near-term factors that could influence the implementation of the concept. One risk is the present fixation of stakeholders on creating a globalized carbon market under the Paris Agreement. Early drafts of Article 6 rules suggest negotiators are taking a narrow interpretation of voluntary cooperation, based primarily on building a club of networked carbon markets under Article 6.2, rather than exploring new forms of market mechanisms to drive transformative collective climate action. Although not necessarily mutually exclusive outcomes, the pursuit of a global carbon market does not have to be at the cost of shutting down other avenues for cooperation.

A second risk is acceptance. Strategies being pursued by the oil and gas sector suggest alignment

with our proposed concept. Several companies and the alliance of companies under the Oil and Gas Climate Initiative have established funds to invest in both geosequestration and biosequestration as core components of their corporate climate change strategies.

The approach outlined in this paper has the potential to create a pathway toward smarter supply-side climate policy built around carbon stock accounting and the creation of a broad set of sequestration units covering CCS, direct air capture and nature-based solutions (biosequestration). Collectively, this can create value for depositing carbon into a variety of non-atmospheric carbon stocks and complement policies focused on penalizing flows of carbon into the atmosphere.

Introduction

The Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCCC) presents profound challenges and new opportunities for the design of the world's future energy system. On entry into force in 2016, it committed ratifying Parties to hold the increase in the global average temperature to well below 2-degrees Celsius (°C) above pre-industrial levels and pursue efforts to limit the increase to 1.5°C. It also committed Parties to achieving a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases (GHGs) in the second half of this century, i.e., a net-zero emissions future. Meeting these ambitious goals requires accelerated deployment of a portfolio of low-carbon technologies that deliver deep reductions in emissions, and enhance removals by sinks, to collectively stabilize atmospheric greenhouse gas (GHG) concentrations at or below 450 parts per million (ppm) carbon dioxide (CO_2)-equivalent (CO_2e).

Technologies involving CO_2 capture and geological storage (CCS), with or without use or utilization, are consistently seen as a critical part of a 450 ppm stabilization pathway.[1] The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5; IPCC 2014) showed that many integrated assessment models are unable to achieve atmospheric GHG concentrations of 450 ppm CO_2e by 2100 if limitations exist on the availability of key technologies including CCS. The International Energy Agency's (IEA) 2°C (2DS) temperature limitation scenario indicates that CCS could contribute to 14% of emission reduction efforts by 2060 (IEA 2017), capturing and storing 400-500 megatonnes (Mt) of CO_2 annually by 2025 and reaching around 6 gigatonnes (Gt) of CO_2 stored annually in 2050 (IEA, 2016; IEA, 2017). By the middle of this century, cumulative CO_2 stored could reach around 100 $GtCO_2$, delivered from a variety of sources, including more than 800 gigwatts (GW) from fossil fuel power plants and almost 30 $GtCO_2$ from industry (IEA 2016). This equates to the deployment over the next 50 years of several hundred to several thousand CCS projects worldwide.

The importance of CCS comes into sharper focus when viewed from a carbon budget perspective. Emissions pathways consistent with 450 ppm and a 2-in-3 chance of limiting the global temperature increase to within the Paris goals approximate to restricting further additions to the atmosphere by between 550 and 900 $GtCO_2$ (budget range 325-1180 $GtCO_2$; Allen et al. 2009a; Meinhausen 2009; IPCC 2014; Millar et al. 2017; IPCC 2018).[2] At current emission rates this point will be reached by around 2040 or deferred until 2050 to 2075 at the latest under 1.5°C and 2°C mitigation pathways, respectively, if enhanced mitigation actions start promptly (IPCC 2018). Thereafter, anthropogenic emissions and removals will have to remain in balance in perpetuity, or at net-zero, to avoid further dangerous interference with the climate system. This means either phasing-out fossil fuels or using CCS or CO_2 removal (CDR) technologies and other sink enhancements to maintain a steady-state climate (Haszeldine 2016). It is fair to say, therefore, that CCS is an important tool for the 21st century's energy transition, as foreseen in the Paris Agreement. By the same token, discussions around 'unburnable carbon' and the possibility of stranded fossil fuel assets (Carbon Tracker Initiative 2011; McGlade and Ekins 2015) place in sharp relief the crucial relevance of the technology for countries and companies highly dependent on fossil fuel extraction, supply and use.[3] Consequently, near-term efforts to foster the technology are vital in ensuring its availability for widespread deployment by mid-century and for maintaining the legitimacy of fossil fuels over the long term.

Introduction

The Paris Agreement expects all Party countries to undertake and communicate plans and strategies for meeting their goals every five years in the form of increasingly ambitious nationally determined contributions (NDCs), representing a departure from the top-down, two-track, architecture of the Kyoto Protocol. Countries may also cooperate to meet or exceed the level of ambition set out in their NDCs using various mechanisms outlined in Article 6 of the Agreement. In another departure from the Kyoto Protocol policy architecture, cooperation is focused more on country-driven, bottom-up processes for working together (Streck et al. 2017), the spirit of which seems to open up opportunities to explore new avenues for flexible forms of collaboration among countries to deliver mitigation outcomes, in particular where they align around common interests.

Given the new opportunities presented in the post-Paris era, this paper outlines a pathway for aligning countries around CCS technologies as a critical tool for meeting the Agreement's goals. The paper also sets out a vision for how a structured form of cooperation could drive new ways of supporting CCS deployment, and the longer-term strategic aspects of progressing along such a pathway.

The paper starts by reviewing the current state of play for CCS ahead of the Agreement's implementation. We then assess how renewed commitments to develop and deploy CCS can be driven by NDCs under Article 4 of the Agreement, before discussing options for a new platform through which cooperation among Parties could be made consistent with Article 6. The fourth part of the paper considers the opportunity presented to unify cooperative actions based around a mechanism that systematically supports CCS deployment, consistent with Article 6.2, Article 6.4 and domestic policies and measures aimed at driving GHG emission reductions. In the final section, we consider near-term issues for operationalizing the approach set out in the paper and its potential strategic implications.

The paper draws upon the knowledge of experts who were closely involved in the evolution of CCS in the Kyoto Protocol process to articulate a starting point for action. Concepts outlined herein also revisit ideas put forward by various authors over the past decade or so and will be further refined and reshaped through wider consultations with Parties and other interested stakeholders.

Setting the Scene: CCS Status Leading Into the Post-Paris Era

It is almost 15 years since Parties to the UNFCCC considered CCS for the first time, acknowledging that, based on the findings of the IPCC Special Report on Carbon Dioxide Capture and Storage (SRCCS; IPCC 2005), CCS technology is one option, within a portfolio of options, to stabilize atmospheric GHG concentrations (UNFCCC, 2005). Agreement of the 2006 IPCC Guidelines on National Greenhouse Gas Inventories (IPCC, 2006) took developments a step further by providing a basis upon which countries could monitor and report emission reductions from CCS. Since 2015, Annex I Parties have been obliged to follow these guidelines (UNFCCC, 2014). Norway and Canada now report emission reductions from active CCS projects in their in National Inventory Reports (NIRs). In 2011, agreement of modalities and procedures for CCS as clean development mechanism project activities also set out de facto guidelines and safeguards under which CCS projects could generate certifiable emission reductions in developing countries. In combination, these provide valuable 'readiness' elements for a new approach to CCS under the Paris Agreement.

The entry into force of the Kyoto Protocol coincided with the publication of the IPCC SRCCS in 2005, precipitating a wave of political commitments and multilateral initiatives aimed at supporting CCS deployment (IEA 2016; SBC Energy Institute 2016; Haszeldine 2016; Lipponen et al. 2017).

Key milestones included the European Union (EU) vision for 12 large-scale CCS projects by 2015 (Council of Ministers 2007), the commitment by G8 countries to support the deployment of 20 large-scale CCS demonstration projects globally by 2010 (G8 2008), and the launch of several multilateral government-led groups to support these goals. These groups included the Carbon Sequestration Leadership Forum (CSLF), the Major Economies Forum on Energy and Climate (MEF), the Asia Pacific Partnership on Clean Development and Climate (APP), the Clean Energy Ministerial (CEM) and the Global CCS Institute (GCCSI).

At that time, more than 40 large-scale CCS facilities were under consideration across Australia, Canada, China, Europe, the United Arab Emirates (UAE) and the United States (U.S.), put forward by a range of well-capitalized corporations including BP, Enel, Endesa, Peabody Energy, Royal Dutch Shell, RWE, Shenhua Group, Statoil (Equinor) and Vattenfall (MIT CC&ST 2016). In parallel, a range of enabling legislation was enacted in Australia, Canada, Europe and the U.S. to support CCS deployment. Agreement of monitoring guidelines for CCS under the EU's emissions trading scheme (ETS), enactment of the 45Q sequestration tax credit in the U.S., the passing of Alberta's Specified Gas Emitters Regulation in Canada and agreement of the aforementioned modalities and procedures for CCS under the Kyoto Protocol's clean development mechanism (CDM) offered a carbon price signal for deploying CCS across many parts of the world. These were complemented by new regulations for geological storage sites designed to ensure that injected CO_2 remains isolated from the atmosphere indefinitely.

But early momentum was followed by slow decline. A combination of the weak outcome of the Copenhagen Climate Conference in 2009, a deepening of the financial crisis in 2011, and the collapse of the carbon price in the EU's Emissions Trading System (ETS) and Clean Development Mechanism (CDM) in 2012 led to many project cancellations and government funding cutbacks (IEA 2016; Lipponen et al. 2017). Interest in CCS was also tempered by public concern and resistance in some countries, such as Germany, where CCS is limited by law to demonstration projects only, and in the Netherlands, where the Barendrecht project was cancelled as a result of concerns raised by residents living close to the planned storage site. To date, the reality of CCS implementation has not matched the early ambition. At time of writing 18 large-scale integrated CCS projects are operating globally, three-quarters of which involve CO_2-enhanced oil recovery (EOR) and five of which were built before the turn of the century (Global CCS Institute 2018). The high-water mark for dedicated government CCS funding was reached around 2010 (Lipponen et al., 2017) and looks unlikely to return any time soon. Recent deployment has been supported primarily by CO_2 demand in EOR operations (e.g., Petra Nova) and/or large grants and long-term fixed income investments (e.g., Quest). In some cases, the support provided has only vague relationships with climate policy and carbon pricing. A lack of broad global commitment to the technology has provoked a sense of 'buyer's remorse' among some government backers.[4]

Nonetheless, several significant milestones have been reached. The opening of the Boundary Dam and Petra Nova CCS projects in North America has proved the viability of large-scale CO_2 capture on grid-connected fossil-fuel fired power plants. The In Salah (Algeria), Santos Basin (Brazil), Abu Dhabi National Oil Company (United Arab Emirates), Uthmaniyah (Saudi Arabia), and Jilin (China) projects show that CCS is possible in emerging economies. More than 30 million tonnes of anthropogenic CO_2 is being captured and injected into geological reservoirs each year with no signs of leaks. In addition, there has been a large body of enabling 'readiness' work and knowledge-sharing, such as under the CSLF, the World Bank's CCS Capacity Building Trust Fund, the GCCSI, and many other bilateral and regional initiatives. The last two examples include initiatives between the EU and China, the U.S. and China, Australia and China, activities in southern Africa, Southeast Asia, Mexico and Brazil. Reasons exist, therefore, for CCS protagonists to remain positive.

The flexibility of the Paris Agreement and the renewed enthusiasm for climate action it has generated provide the basis for a new phase of concerted efforts around CCS. These efforts should go beyond experiences of the past and be underpinned by stable governance and accountable mechanisms that systematically support the technology toward deployment levels commensurate with meeting the Agreement's ambitious goals.

As work continues to operationalize the Paris Agreement's rules, it is timely to consider what a new approach to CCS might involve. In the first instance, any new mechanism for CCS should be guided by the specific characteristics and needs of the technology and lessons from the past. Key issues associated with mobilizing CCS deployment include:

1. CCS is an expensive mitigation technology that will benefit from greater deployment to drive cost reductions. While CCS remains economically feasible in some circumstances, it is not commercially replicable on a widespread basis.

2. Current climate policies and measures do not adequately value the role of CCS as an option for avoiding dangerous climate change. Emergent technologies such as CCS need dedicated support policies to guide them from demonstration to technical maturity (Krahé et al. 2012). The extensive literature reviewing experiences from the EU ETS, for example, consistently shows that carbon pricing has been effective in driving short-run, marginal, investment actions but has so far failed to offer a sufficiently stringent, predictable and stable long-run price signal to drive systematic investment into innovative low carbon technologies (see for example: Neuhoff 2011; European Commission 2015; Rogge 2016; Marcatonnini et al. 2017; Carbon Pricing Leadership Coalition 2017).

3. CCS is a chain of technologies, each of which is proven but which together pose challenges for integration. The division of risks and knowledge between different parties across the process chain also presents challenges for creating investment grade project packages.

4. Cooperation is essential. Because CCS costs relate solely to reducing CO_2 emissions rather than other co-benefits, utilization options excepted, capturing and storing CO_2 in isolation offers first-mover disadvantages for both countries and corporations. Multilateral climate action is therefore important in managing financial and economic risks for public and private investors.

Any new climate actions targeted at CCS must start with the objective of facilitating deployment, something that carbon pricing alone cannot solve. A technology-specific approach will help overcome market failures seen for CCS technology innovation, accelerate learnings that lead to cost reductions, and address commercial gaps in the business of moving CO_2 molecules between sources, shippers and sinks. It must include strong elements of cooperation and knowledge-sharing in order to share costs and benefits, and to dilute the effects of first-mover disadvantage.

The Starting Point for Action: Nationally Determined Contributions

Key factors driving climate action in the post-Paris world are the pledges made by Party countries in their NDCs. Every five years each ratifying Party must prepare and communicate an NDC describing its intended domestic mitigation (and adaptation) contributions, with each successive NDC representing a progression from the previous. When considered collectively, the pledges in NDCs determine whether the world is on track to meet the Agreement's goals. Starting in 2023 and continuing every five years thereafter, governments will take stock of implementation in order to assess collective progress, a process known as the global stock take (GST). [5] The cycle of pledges (NDCs) and reviews (GSTs) is designed to act as a ratchet for increasingly ambitious climate actions.

For CCS to find a place in the Paris Agreement process, countries will need to make commitments to support and use the technology. So far only 10 first NDCs or intended NDCs (iNDCs) submitted by Parties refer to the use of CCS, while a further 31 just mention it as a source sector to be monitored under their NDC (PIK 2019a). Of the first group, only Saudi Arabia and South Africa make quantified forward-looking statements on deployment contributions, while the eight other NDCs contain loose statements regarding the potential of CCS. This compares to 145 NDCs that refer to renewable energy, with 109 citing specific renewable energy targets (IRENA 2017), and 148 and 157 NDCs that refer to agriculture and land use, land use change, and forestry (LULUCF) respectively (FAO 2016). Several countries that have historically been strong supporters of CCS, or which are members of groups focused on the technology, are notable for excluding any mention of CCS in their NDCs (Table 1).

The variability of coverage, and the absence of explicit mention of CCS by some Parties are, to an extent, understandable. Notwithstanding the urgency of action recently asserted by the IPCC (IPCC 2018), current pledges represent only the first cycle of the NDC process and the guidance on offer regarding format and information disclosure is limited. It is fair to suggest that clearer commitments from Parties may be forthcoming once universal guidance is available. Another factor at play may be a lack of knowledge about the mitigation potential of CCS at a national level, which may deter countries from noting its role in meeting long-term domestic mitigation targets among other low carbon technologies. A third factor is that some countries may fear the risk of overplaying their hand: the inherently introspective and semi-binding nature of NDCs means a mere mention of a technology may imply its near-term use as a domestic mitigation action, a risk which becomes particularly acute when considering the requirement to make more ambitious pledges in the next NDC cycle. Countries with limited or no experience of CCS technology are therefore unlikely to commit to its use today without a clearer idea of the available support for the technology. The use of conditional pledges may partially overcome this issue, at least for developing countries, but would still be subject to the provisos

Table 1. CCS in first NDCs and iNDCs.

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

Notes: * 28 member state countries at time of writing. 1 = Member country of 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: KAPSARC.

of financial and technical assistance. All of these factors are reasonable excuses for not seeing a wider role for CCS in the current NDC portfolio.

On the other hand, critics of the pledge-and-review approach will perceive the current miscellany of NDCs as being indicative of the inherent weaknesses in a bottom-up driven process. They can assert with some confidence that today's NDCs indicate the tendency for such a process to become a race to the bottom rather than to the top. Analyses by research groups such as Climate Action Tracker clearly highlight the shortcomings of currently pledged actions relative to the goals of the Paris Agreement.

In respect of CCS in particular, the NDC process offers countries the latitude to refer to abstract single number long-term 'decarbonization' ambitions, without necessarily providing details on how they intend to reconcile this with current patterns of high energy and industrial emissions, and national policies that infer carbon dependent development pathways. This is, in essence, a license to free-ride in the near term. This type of 'policy myopia' has been noted or implied for CCS technologies (for example: Allen 2012; Carbon Capture Project 2018; Záboji 2018). A key challenge for the Paris Agreement process is whether it can be effectively policed to avoid the short-termism apparent in NDCs today and ultimately whether it can drive ambitious efforts as required under the Agreement's Article 3. In short, the process must seek to establish a race to the top, not to the bottom.

One signpost that can help drive ambition in NDCs is clarity around the provision of finance and support for technology innovation and deployment.

The absence of a clear pathway for financing and deploying CCS over the short to medium term will likely drive unambitious NDCs and thereby reinforce conservative positions on this and other low-carbon technologies. Near-term policy actions should therefore seek to present clearer frameworks for using CCS within the contexts of the Paris Agreement to elicit more realistic and ambitious pledges from countries. This might also strengthen the effectiveness of the Paris Agreement by encouraging progressive ambition and broader participation. Over the medium term, quantified and measurable pledges regarding CCS, either domestically, multilaterally, or both, could increase the chance of significant deployment.

However, CCS is not a technology relevant to all 195 signatory Parties to the Paris Agreement, at least not in the short to medium term. The least developed countries, most small island developing states, and countries with limited fossil fuel resources or use, have little interest in CCS. As noted in Table 1, there are some 50 to 60 states for which the technology has near-term relevance. The flexibility structures of the Paris Agreement are therefore useful starting points through which countries with a common interest in CCS can cooperate.

Coordinating Collective Action: Establishing a CCS Club

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. To encourage participation, club membership bestows exclusive benefits and privileges. In its broadest sense, the club concept has been tried in practice with mixed results. Under Tony Blair's presidency of the G8 in 2005, the United Kingdom (U.K.) government adopted the view that the G8 could act to drive ambitious climate action in parallel with and complementary to the UNFCCC and Kyoto Protocol processes. However, the U.S. preferred to focus on technology rather than emissions targets (Peichert and Meyer-Ohlendorf 2008). The U.K.'s efforts precipitated a wave of technology-focused dialogue forums as outlined previously (e.g., the MEF, APP, CEM), but did little to help establish binding emission reduction agreements, either outside or within the UNFCCC. Today, however, the Paris Agreement enshrines the concept of climate clubs and explicitly seeks to facilitate their use within its bottom-up driven framework, as envisaged under Articles 6.1 and 6.2. Thus, new forms of climate clubs acting within the broader auspices of the UNFCCC are likely to be a feature of the post-Paris world.

The Paris Agreement's nationally-driven pledge process seeks to enhance actions by Parties through voluntary cooperation. This is widely interpreted as an option to form climate clubs. Article 6.1 refers to the option for some Parties to pursue voluntary cooperation in pursuit of NDCs to allow for higher ambition in their mitigation and adaptation actions, while Article 6.2 refers to voluntary cooperative approaches that involve the use of internationally transferred mitigation outcomes (ITMOs) toward NDCs. Voluntary cooperation represents a departure from the centralized Kyoto Protocol architecture and offers latitude for Parties with common interests to coordinate actions in parallel with, but inside and/or outside the direct purview of the mainstream UNFCCC political process. Club members may also exchange fungible units (ITMOs) that can be counted toward the meeting of NDC targets.

Climate clubs can take a variety of forms. Hovi et al. (2016) define a climate club simply as a group of countries smaller than all UNFCCC Parties that aims to cooperate on one or more climate change-related activity. Definitions vary, however, and tend to be fluid depending on their degree of adherence to economic theory. Recent literature tends to frame climate clubs under the Paris Agreement primarily in terms of a 'club,' or 'clubs,' of networked carbon markets that offer improved trade terms as an excludable benefit and as a means to deter free-riding (Marcu 2016; World Bank 2016; Hawkins 2016; Keohane 2017).

A climate club in the broadest sense may also be united by other interests, including specific activities and technologies. The coalition of countries focused on establishing approaches and finance for reducing emissions from deforestation and forest degradation (REDD+) may be viewed as a form of activity-specific quasi-climate club operating partly within the UNFCCC process. Other examples include the Renewables Club formed by Germany and nine other countries in 2013 or the Powering Past Coal Alliance launched by Canada and the U.K. at the Bonn (Fiji) Climate Conference in 2017.

A CCS club is a viable possibility under the Paris Agreement. Members could be drawn from countries wishing to cooperate on the technology as part of their NDC, a means of differentiated contributions based on a common interest: the pursuit of cleaner fossil fuels. The primary purpose of such a club must be to pool finance and technical resources from an enthusiastic group that is willing to include CCS deployment as a prominent part of its climate mitigation strategies, both domestically and via plurilateral processes. Such a club would not necessarily need to include all relevant Parties in the first instance, but should be an enthusiastic group with the motive, the technical interest and financial capability to deploy CCS. Membership could increase over time, based on demonstrated benefits drawn from early experiences with the technology.

A key issue for establishing a CCS club is to make a clear case for member benefits: it must differentiate from, but also complement, other CCS-focused clubs that are already operating outside the auspices of the UNFCCC (e.g., CSLF, CEM, IEA Greenhouse Gas R&D Programme, GCCSI). These clubs primarily focus on research and development cooperation and tend to operate as dialogue forums (Weischer et al. 2012; Andresen 2014), rather than as platforms through which to drive ambition and finance technology deployment. In terms of the Paris Agreement, these types of actions may be best reserved for activities under Article 10 (Technology Mechanism).

For a CCS club to have relevance to Article 6.2 or even to Article 6.4 of the Paris Agreement it must be focused on supporting deployment that drives deeper ambition and creates measurable and verifiable outcomes, transferable or otherwise, that can be counted toward achieving NDCs. Design of a CCS club can draw upon lessons from REDD+ to sustain its relevance and focus. Unlike currently operating CCS clubs, REDD+ is making substantial progress toward implementing an activity-specific mechanism that generates outcomes which are directly compatible with the international policy architecture under the Paris Agreement.[6]

CCS is an expensive technology. For this reason, a club focused on finance and deployment is unlikely to offer directly equitable benefits for all members in the first instance. Rather, it must act to share the costs of CCS deployment across members to reduce first mover disadvantage. Benefits of membership should therefore be seen in a broader context: countries heavily dependent on the supply and/or use of fossil fuels need widespread deployment of CCS technology to sustain the relevance of their products and energy infrastructure in the post-Paris era. This common interest must be the primary motivator for participation in a CCS club. Other residual benefits of club membership may also include:

Offering an additional means to achieve NDC targets. This may not necessarily be based solely on emission reduction type ITMOs, but also on other forms of measurable contributions. These might include the provision of climate finance and technology commensurate with national strategic priorities, and the acquisition of an alternative type of non-emission reduction (or "non-GHG") asset class or unit specific to CCS, as discussed later in the paper.

Increased participation and higher ambition. Offering a clear pathway to CCS deployment may provide opportunities for those Parties with high levels of fossil fuel use to support the technology. And those lacking domestic CO_2 storage capacity, to support CCS as part of their contribution the Paris goals.

Technology learnings and cost reductions. Experiences drawn from club membership could be used to generate benefits for the future domestic deployment of CCS. For some countries, club membership could also create opportunities for domestic industries and service providers.

Efficiency and price discovery. There is no single price for CCS but rather a spectrum of costs that vary according to the emission source and geological setting. Overseas opportunities may be cheaper than domestic opportunities. For example, capture and storage of CO_2 vented from natural gas sweetening operations is significantly cheaper than CCS at fossil fuel-fired power plants. Deployment at these types of low cost, 'early opportunity,' emission sources reduces the overall cost of CCS deployment, supports price discovery, and creates infrastructure for connecting other CO_2 sources in future.

A further important aspect to consider for a CCS club is the involvement of non-state actors, in particular the private sector. The scholarly literature on climate clubs has tended to focus on country-level participation and has not considered the role of corporations. This is usually because the primary good of a climate club is considered to be the non-excludable benefit of emission reductions, which has limited relevance for companies. The private sector tends to be viewed as the agent for change, driven by government principals acting within a climate club.

A technology-oriented club as described could, however, benefit from direct private sector membership for several reasons. First, the fossil fuel industry has interests directly aligned to the objective of a CCS club, as described. Second, it has significant capital to help co-fund activities. Third, it has the technical know-how and the physical asset base that may be utilized for deployment. Fourth, the transboundary nature of their operations offers a potentially powerful lever through which to expand club membership, for example, in circumstances where candidate projects are located in non-member jurisdictions. Moreover, to be sustainable over the long term, the private sector must be tasked with delivering widespread rollout of the technology, as described elsewhere in this paper.

For a CCS club to have sustained relevance, it should have a unifying mechanism that differentiates it from other mitigation technologies and actions and that serves as a conduit through which to aggregate, channel and disburse the finances of club members to CCS project activities. The design options for such a mechanism are discussed in the following section.

Unifying Actions: A CCS Mechanism

Technology clubs focused on CCS have been in existence for some time, albeit with limited impact on deployment. The primary difference of a CCS club established pursuant to Article 6.1 and Article 6.2 of the Paris Agreement is that it should focus on actions that support the overall goal of the Paris Agreement and thus deliver measurable outcomes that can be counted in NDCs. The general mechanisms emerging under Article 6.2 and Article 6.4 of the Paris Agreement may be able to support this objective, although it is questionable whether these alone would offer a price signal sufficient to incentivize CCS investment given its current level of maturity. Historical precedent suggests it is unlikely. For this reason, a dedicated mechanism that leverages complementary and supplementary finance will be key to unlocking the mitigation potential of CCS. Given that mechanisms under the Paris Agreement are still taking shape, it is timely to consider possibilities for a specific CCS mechanism to enter into the process.

Committed global government financial support for CCS technology reached a high of over $30 billion in 2010, although only around 10% was ever mobilized, and levels have since dwindled (Lipponen et al. 2017). A club of voluntary cooperation under the Paris Agreement has the potential to drive new commitments to fill the current funding gap, create new channels through which climate finance can flow, and also support cost-sharing that helps de-risk investments for governments and corporations. History has shown that countries, regions and companies independently pursuing CCS deployment has proved challenging: Alberta has developed buyer's remorse, Australia and Europe have been reluctant to spend the funds committed to the technology, and all privately financed CCS projects have failed where EOR is not an option.

A range of CCS-specific financing mechanisms have been mooted on several occasions, primarily at a national or regional level (e.g., European Commission 2013; WBCSD 2015; PAG 2016). Today, however, the only dedicated and systematic funding mechanism for CCS is the 45Q sequestration tax credit in the U.S. Moving into the post-Paris era, a new type of mechanism that can bring together cooperative action is urgently needed if CCS is to fulfil its potentially widespread contribution to a net-zero emissions future. Several options exist through which to establish a globally-relevant support mechanism for CCS.

A basic option is to create a fund made up of contributions and replenishments from CCS club members. The fund would support CCS deployment through a mixture of grants and/or soft loans. It could potentially provide some 'readiness' type activities,where required, in certain jurisdictions and could operate either with or without the creation and acquisition of emission reduction-based ITMOs from funded activities i.e., respectively, as a non-market mechanism under Article 6.8 or as a transfer-based financing arrangement under Articles 6.2 and/or 6.4 of the Paris Agreement.

The main problem with this approach is that it offers little that is new in terms of the Paris Agreement architecture or goals, provides little certainty over deployment and does not offer any clear long-term incentive for private sector investment. The World Bank and Asian Development Bank CCS Capacity Building Trust Funds, sponsored by the U.K. and Norway, have operated similarly since 2009, focusing on developing countries, while the CSLF has operated similar capacity-building funds. The EU also established its NER300 fund in 2011 to support CCS and other technologies. Although these efforts have been effective in raising awareness of and driving knowledge development for CCS, they have so far struggled to mobilize deployment.

Any new mechanism for CCS should therefore demonstrate several significant and transformative features that address the barriers that have previously prevented CCS deployment and have clear relevance to the Paris Agreement architecture. Desirable features of a new mechanism include for it to be:

> **Widely applicable to a range of countries and circumstances.** Given the challenges faced by CCS deployment in all parts of the world, a new CCS mechanism would benefit from being widely available to all interested Parties to the Paris Agreement. This need not necessarily involve establishing a single price signal for all, but rather a variable mechanism that can be tailored to specific national circumstances, individual project costs and the availability of other sources of finance and revenue.

> **Cognizant of the current maturity of CCS technologies.** As noted previously, carbon pricing alone is unlikely to be sufficient to incentivize significant investment in CCS over at least the next decade. CCS needs an additional layer of finance that reflects its present level of technical maturity, addresses the shortcomings of carbon pricing policies, and effectively values its long-term contribution to climate change mitigation goals.

> **Compatible with the Paris Agreement architecture, mechanisms and goals.** A new layer of finance for CCS should be additional and complementary to the incoming system of NDCs and ITMOs, as well as having the ability to dovetail with national or regional carbon pricing schemes and other incentive programs that include CCS. This would allow the mechanism to drive deeper ambition than can be achieved through a common price signal for all types of CO_2 emissions abatement technologies alone.

> **Able to address commercial barriers to CCS deployment.** Carbon pricing only offers an incentive for CO_2 emitters, whereas a lesson learned from the past decade or so is that viable markets for CCS work best when a price signal is offered both to emitters and storers of CO_2, as is the case with, for example, EOR. A price signal for emitters and storers provides the basis for structuring commercial transactions around the transfer of physical CO_2 between parties across a CCS process chain and creates an incentive for industries with relevant subsurface technical skills and know-how to seek viable geological storage sites.

> **Able to create a pathway to systematic long-term support for CCS.** The additional operating cost of CCS means that secure, sustained and stable ongoing revenue support throughout its lifetime is necessary in order to unlock investment. This has largely been lacking in most jurisdictions to date. Furthermore, the widespread longer-term roll-out of the technology requires a structured and stable policy environment that establishes clear incentives and sustainable mechanisms for finance in a net-zero emissions world.

Creating a specific asset class: a carbon storage unit

The creation of a new tradable asset class specific to CCS – a carbon sequestration or storage unit (CSU) – is, in our opinion, a mechanism that can fulfil all of the desirable features described previously. A CSU would represent a verified tonne of CO_2 securely stored or sequestered in a geological reservoir. Although the concept of a storage credit or storage certificate is not new (Allen et al. 2009b; European Commission 2013; WBCSD 2015; PAG 2016; Haszeldine 2016; Haszeldine et al. 2018; Element Energy 2018), previous proponents have focused either on end-game options without considering transitional approaches, or on challenges posed by trying to dovetail the approach with existing carbon pricing mechanisms. Our proposed approach overcomes these challenges by proposing that CSUs operate as a mechanism that complements and supplements existing emission control policies and measures.

Allen et al. (2009b) were early proponents of the storage crediting idea. They proposed a novel but straightforward concept, the 'sequestered adequate fraction extracted' (SAFE), involving the placement of a global mandate on all fossil fuel producers to sequester an amount of carbon corresponding to the amount of carbon they extract from the geosphere. The 'adequate fraction' is recalculated over time, according to cumulative emissions. Over time the remaining atmospheric carbon budget is taken up by CO_2 emissions and the adequate fraction eventually reaches 100%, meaning a sustained balance is maintained thereafter between carbon extraction and carbon sequestration. A useful insight from the work of Allen and his colleagues is that a net-zero emissions outcome can be equally framed as a carbon stock management challenge as much as an emissions control and removals (or carbon flow management) problem. Allen et al. suggested that such a reframing may be more palatable than focusing efforts on reducing carbon emissions, with the implications of restricted consumption and constrained economic development.

A similar concept was proposed by the U.K. Parliamentary Advisory Group (PAG) on CCS (PAG 2016) and Haszeldine (2016), albeit focused on certificates of storage implemented at a national (U.K.) or regional (European) level. The European Commission (2013) also briefly considered policy options for what it termed CCS certificates, based on placing an obligation to acquire and surrender such certificates either on EU-based power generators, in a similar way as applied in a renewables obligation scheme, or on fuel suppliers based on embedded carbon, i.e., the fossil carbon content of products supplied, as per Allen et al., the PAG and Haszeldine. One of the implementation issues identified was the need to withdraw an equivalent number of EU Allowances from the EU ETS. Eventually, following consultations, the European Commission decided to proceed with direct funding through the NER300, an approach that has so far failed to deliver any large-scale CCS projects in Europe.

The World Business Council for Sustainable Development (WBCSD), under the auspices of its 2015 Low Carbon Technology Partnerships initiative (LCTPi), published a series of papers on low carbon technologies in the run-up to the Paris Climate Conference. The LCTPi paper on CCS proposed creating "a new fit-for-purpose funding mechanism" based upon a zero emission credit (ZEC) awarded for each tonne of CO_2 (tCO_2) stored by a CCS project operator (WBCSD 2015). It proposed that ZECs would in the first instance be purchased by a zero emissions credit development fund (ZDF) to drive early demand, rather than starting as a direct obligation. In the long term, the WBCSD proposed that ZECs would transition to an emitter obligation scheme in the same way as proposed by the European Commission (2013), rather than as a supplier obligation, as proposed by Allen et al., the PAG and Haszeldine.

The WBCSD's proposal has now been adopted by the Oil and Gas Climate Initiative (OGCI), which recently sponsored a study involving a detailed review of CCS policy options. The study included what was termed a CCS obligation approach (Element Energy 2018). In contrast to Allen et al. (2009b), Haszeldine (2016) and the WBCSD (2015), its authors concluded that a CCS obligation would present administrative complexity, be unsuitable for application at the global level, and make little difference whether placed on emitters or suppliers. We do not agree with these conclusions, but rather support those of Allen et al., Haszeldine and the WBCSD.

Drawing on the proposals described above, we propose two key modifications that can help shape the viability and applicability of the CSU approach for the post-Paris era and fulfil the necessary transformative features described previously.

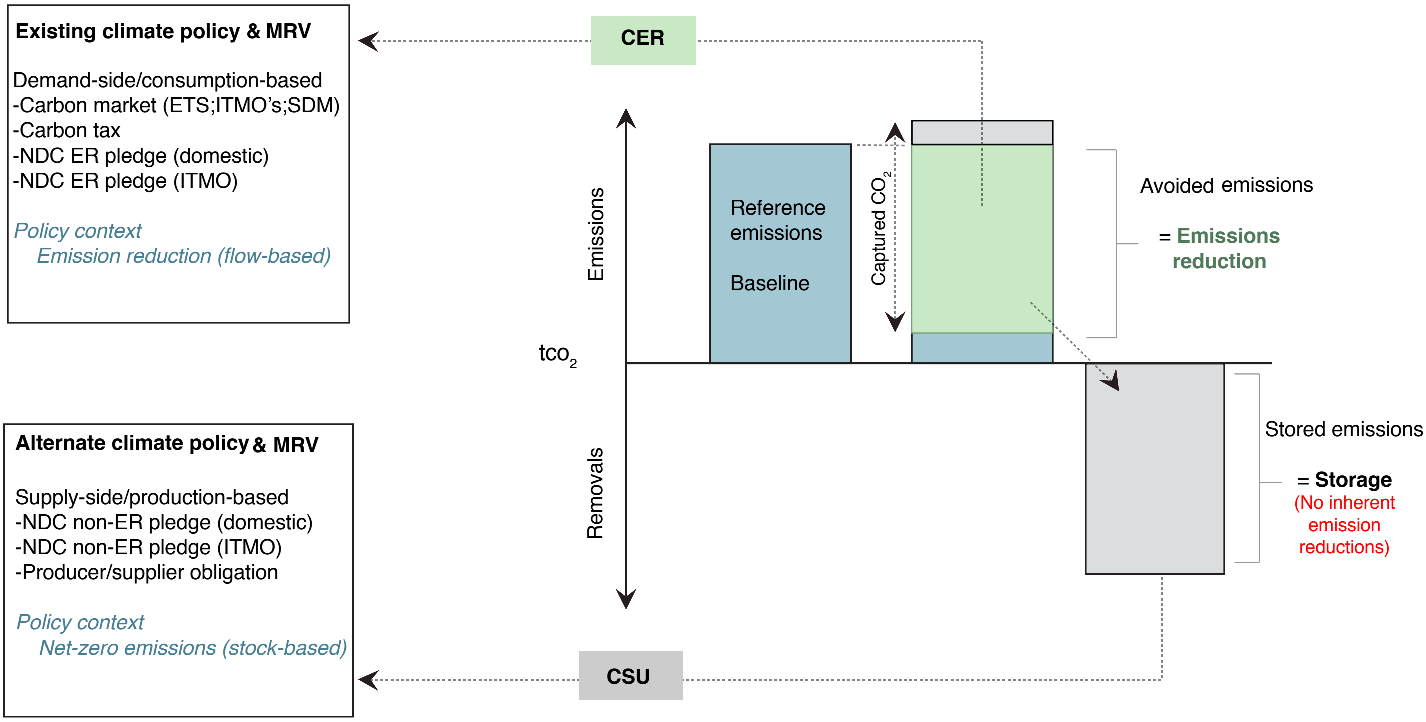
First, earlier studies have tended to make the implicit assumption that storage credits, CCS certificates, or ZECs directly replace carbon pricing as a means to support CCS deployment, or they have assumed that there is a need to link storage credits to carbon pricing instruments through an adjustment of tonnes CO_2 stored to tonnes CO_2 avoided. In our view, a CSU does not need to be a replacement for carbon pricing, but would rather act as a complementary and supplementary means of blending finance from both carbon emissions pricing and storage crediting.

The key to understanding how these approaches can function in parallel is to appreciate that a CSU asset would not represent an emissions reduction, removal or avoided value, but merely a tonne of carbon or CO_2 stored. In other words, it would be a verified record of a carbon stock addition to the geosphere. For CSUs to have currency as an emission reduction activity, the corresponding avoided emissions or emissions reduction amount would need to be calculated according to GHG accounting rules, such as allocation and baseline determination methods, applicable to a given carbon pricing scheme in a particular jurisdiction. This value would be supplemented by the CSU value. Although this produces a double incentive for CCS, it does not affect environmental integrity nor pose a risk of double counting. The CSU itself cannot be counted toward an emission reduction target without measuring the corresponding quantum of emission reductions. The relationship between the two asset classes or units is shown in Figure 1.

Second, with the exception of WBCSD (2015), the literature has also tended to presuppose, largely as a consequence of the first assumption, that no transitional situation can exist between carbon emissions pricing and carbon storage crediting. The tendency has been to focus on the end-game, such as a supplier or emitter obligation, without considering that intermediate steps are likely necessary to reach it. There are a number of problems with this assumption, however, notwithstanding the benefits of creating a double price signal.

The deep-rooted attachment to emission reduction controls and carbon flow accounting in today's climate policy framework means that an immediate switch to supply-side policies and stock-based accounting would likely be problematic. To have

Figure 1. Relationship between emission reduction units and proposed carbon storage units (CSUs).



Key: CER = Carbon emission reduction; 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 = Emissions reduction.

Source: Authors' research.

relevance under the Paris Agreement, CCS activities must also continue to be measured in terms of emission reductions in order to be counted accordingly when making NDC pledges and measuring progress toward achieving NDC emission reduction targets. There is also a need to acknowledge the current technical maturity of CCS. Uncertainties remain regarding its widespread technical feasibility and costs, which mean mandating its use today is premature without further operational experience. In the first instance, a CSU can best act as a complementary measure within existing frameworks.

Consequently, a transitional piloting phase of implementation will be required. Action today via a pilot program can pave the way toward alternative, supply-side, carbon stock-based regulation and accounting for climate policy, while still complementing demand-side, emissions flow-based regulation and accounting measures currently in place, such as national, regional or global carbon taxes, cap-and-trade ETSs and project-based crediting. Moreover, a transitional period offers several benefits that help to support CCS deployment over the near term, not least the opportunity to blend sources of climate finance.

The top half of Figure 1 shows how a carbon emission reduction (CER) unit is typically calculated and valued for a CCS activity, based on tCO_2 emissions avoided. The type of CER unit generated would be compatible with a range of existing climate policies, for example, NDC pledges and carbon pricing schemes such as project-based crediting, ETSs and carbon taxes. The lower half of Figure 1 shows how carbon storage can be counted as a removal without any emissions reduction value. It is recorded only as an addition to the geological carbon stock, not as an emissions reduction per se. The absence of an explicit emissions reduction value in a CSU means that the unit generated only has relevance to supply-side policies pertaining to the management and accounting of carbon stocks. In other words, it can only operate as a direct offset against the removal of carbon from geological stock – hence as a supplier, not an emitter, obligation.

We do not see the viability of CSUs functioning as a demand-side, emitter-based obligation, as considered by the European Commission (2013) and the WBCSD (2015). This is primarily because of the variable disconnect between tonnes of CO_2 stored and tonnes of CO_2 avoided by CCS (Figure 1). The two should always be reconciled to ensure and maintain fair treatment, environmental integrity and compatibility with policies measured in terms of emissions reduced. Placing the obligation on emitters also loses the price signal for storage and thereby also removes the incentive for action by CO_2 storers.

Creating near-term demand

Without an immediate obligation for any entity to acquire CSUs, there is an obvious need to create an alternate source of demand during a pilot phase to give CSUs value today. This is where the CCS club can play its role. Rather than providing finance in the form of either grants or soft loans with uncertain outcomes, as might be the case under non-market-based approaches under Article 6.8 of the Paris Agreement, CCS club members would make pledges in their NDCs to procure CSUs, with or without defined volume commitments, and contribute finance to a fund that offtakes such units from active CCS projects. This is similar to the role proposed for a ZDF by the WBCSD (2015).

A pledge to procure CSUs in an NDC would represent financial and technological contributions toward CCS deployment with the implicit co-benefit of emission reductions. This concept has parallels with other types of non-GHG targets evident in some NDCs today. These include megawatts (MW) of installed renewable energy capacity, gains in energy efficiency for certain sectors or appliances, or land area targets for afforestation (PIK 2019b), i.e., forms of contribution and mitigation outcome expressed in terms other than emissions or removals per se, for example, MWs of renewable energy deployed or square kilometers of newly-forested land. Hood et al. (2014) categorized such “non-GHG” mitigation contributions as “Type II” or “Type III” covering “non-GHG goals or actions with short-term impacts on GHG emissions” and “actions that promote long-term transformations to low-carbon economies,” respectively (Hood et al. 2014, 13). The CSU proposed in this paper would resemble a Type III mitigation contribution under this scheme. An advantage of adopting a ‘proxy’ measure approach to GHG mitigation is that it decouples finance and technology support from emission reductions or removals achieved, thereby allowing for dual layers of climate finance to flow from different sources – domestic, international, or both. A further benefit of such a scheme is that it leaves countries with options in terms of either retaining the emission reductions co-benefits that arise and counting them toward domestic NDC targets or selling them as emission reduction ITMOs for use by other countries in meeting their NDC targets. Consequently, it can act as complementary support for domestic or international carbon pricing policies and mechanisms focused on incentivizing emission reductions.

A CSU is similar to a renewable energy certificate: a technology-specific mechanism that, when coupled with the placement of a renewables obligation on electricity generators, subsidizes renewable power in a complementary way to explicit carbon pricing in the power sector. A partially analogous example is the international Global Energy Transfer Feed-in Tariff (GET FiT) scheme, where donors pay a per kilowatthour (kWh) premium for renewable energies, thereby providing a supplemental layer of financial support over and above national regulated renewable feed-in tariffs.

The most obvious modality by which a CCS club could procure CSUs in a piloting phase is through a results-based climate finance (RBCF) approach, an established method used in other areas of climate policy. For example, the Warsaw Framework on REDD+ (WFR) sets out a basis for using RBCF to support REDD+ activities, with the World Bank's Forestry Carbon Partnership Facility (FCPF) and the Green Climate Fund's (GCF) Pilot program for REDD+ results-based payments, among others, developing a practical application. The World Bank's Transformative Carbon Asset Facility (TCAF), which purchases certified emission reduction (CERs) from legacy CDM projects, is also piloting RBCF. RBCF involves providing, ex post, flows of finance from a centralized fund to procure quantified emission reduction or removal units in situations where other sources of demand for the particular unit or asset class do not exist. Such situations include those where the unit cannot be used or where demand is lacking in a market-based mechanism such as a carbon tax or ETS. This would be the situation facing CSUs in a transitional period.

In practice, the CCS club, or rather its fund trustee and operational entity, would act as the fund principal that, ex ante, makes forward commitments to purchase CSUs from a CCS project developer for a set price and volume over an agreed timeframe via a CSU purchase agreement. The club would subsequently procure the verified CSUs from the operator at the contracted rate after project implementation and then disburse them to club members for cancellation against NDC targets. The purchase agreement could be used by developers alongside other instruments to collateralize debt where project finance is required. The exact price, volume and timeframe for contracted CSUs would have to be determined on a case-by-case basis, according to several factors. Such factors would include the size of the fund, technical details and costs of particular projects, the availability of additional layers of revenue or incentives (including carbon pricing), the provision of other sources of finance, and any other priorities that the CCS club deemed appropriate (e.g., specific project types and geographies). In this way a variable fee, volume and timeframe can be determined according to funders' priorities and developers' circumstances. Such flexibility would help the fund to use its resources more efficiently.

Using RBCF to procure CSUs rather than emission reduction units has other advantages. Climate finance for CCS can be mobilized without the 'corresponding adjustments' needed for transfers of emission reduction ITMOs, as would apply under a transfer-based financing arrangement.[9] Parties lacking geological storage potential or facing high costs and/or public acceptance issues for CCS domestically could also seek to procure CSUs as a means to support the technology and help legitimize the continued domestic use of fossil fuels. However, CSUs would not offset the domestic use of fossil fuels unless emission reduction-based ITMOs were procured alongside the CSUs. Over the longer term, a migration from

RBCF to a pledge or obligation-driven approach would mean that CSU purchase would become mandatory for these countries, or its fossil fuel suppliers, as described below.

Establishing longer-term systematic demand

Depending on the success of the pilot phase using RBCF, the CCS club would need to consider whether to establish mechanisms that create systematic demand for CSUs or whether to dissolve the CCS club and scheme and rely solely on carbon pricing to incentivize CCS deployment.

Options for the former include countries making consistent pledges to procure CSUs as part of their NDCs, perhaps linked to their fossil fuel extraction or use. In practice, the pledge could be passed on to domestic fossil fuel suppliers as a mandatory obligation using national policies and measures, for example, through the introduction or modification of a 'low-carbon' or 'renewable fuel standard.' Alternatively, fossil fuel extractors or suppliers could make voluntary pledges to procure and cancel CSUs commensurate with their levels of extraction or supply: an approach that could provide a basis for marketing and promoting 'decarbonized' fuel products.

Dissolving the scheme and relying solely on carbon pricing could also be viable should carbon prices reach levels sufficient to sustain both operational CCS projects and incentivize new investment. Removing CSUs would, however, eliminate the price signal on offer to CO_2 storage developers, which could hamper further commercial deployment of the technology, especially in greenfield locations (tie-ins to existing CCS infrastructure may still be feasible with carbon prices alone).

CCS club rules could include a requirement for periodic review and evaluation. The review would establish a fixed and informed basis for assessing options to drive systematic demand for CSU units or their dissolution, based on experiences gained in the pilot phase.

Benefits of the proposed approach

The approach described above has several benefits that can address near- and long-term CCS deployment challenges:

1. **Creating an additional source of revenue for CCS deployment**. A double incentive can help close the gap between the cost of CCS deployment and the price signal typically on offer in carbon pricing schemes around the world. Moreover, variable pricing through an RBCF format enables an adaptable approach to different circumstances.

2. **Creating a price signal for CO_2 storage alongside CO_2 capture.** Both emitters and storers will be incentivized to find CCS project opportunities. This, in turn, supports commercial transactions between emitters and storers based on physical transfers of CO_2 across a CCS process chain. An absence of storage value has been an impediment to commercial CCS deployment and physical CO_2 price formation in jurisdictions without utilization opportunities.

3. **Supporting price discovery for CCS.** There is significant variability of, and uncertainty about, the widespread technical viabilities and costs of CCS in different sectors and geographies. Using RBCF in a pilot phase should improve understanding of CCS costs in different situations and environments as a result of a variable pricing mechanism.

4. **Creating new ways to value sink enhancements and other types of carbon removal technologies.** Achieving a net-zero emissions future without entirely phasing out fossil fuel use relies on the widespread use of carbon sequestration technologies. A CSU introduces a new type of tradable asset class that quantifies, values and confirms activities undertaken to enhance sequestration without a need to express these as emission reductions or removals. This is useful for considering a new broader asset class or set of asset classes that create value for all forms of sequestration activities, including direct air capture, forestry, land-based carbon or wetlands ('blue carbon'). Such a group of assets could be applied as offsets against carbon production and supply activities and help move further upstream toward zero emissions through policy actions focused on carbon stock management.

Some near-term actions that could legitimize and operationalize the approach are discussed in the following section.

Moving Forward: Near Term Actions to Drive the Approach

The idea of CSUs needs to be tested for its compatibility with international mechanisms evolving under the Paris Agreement and the likelihood of wider acceptance and levels of interest among key stakeholders before it can be operationalized. Experiences from REDD+ suggest that rules and modalities for a club and its fund can be established fairly quickly if there is widespread support for the idea. For example, the WFR agreed by UNFCCC Parties in 2013 included a mandate for the GCF to mobilize the results-based payments approach, resulting in the launch of its "pilot programme for REDD" some four years later. This suggests that several years of preparatory work are needed in order to build entirely new mechanisms. However, mobilizing funds for REDD+ has proved more difficult. To date, no REDD+ emission reduction units have been generated and FCPF and GCF funds so far remain unused for the purchase of such assets. Legal, regulatory and methodological issues are, in principle, less complex for CCS than for REDD+, which suggests that establishing and mobilizing CCS could be more rapid than for REDD+. Concerns over reference emission levels are not an issue: reference emissions can be calculated according to accounting methods and the rules of the relevant carbon pricing scheme; safeguards are less onerous and precedents exist; and, accounting and measurement, reporting and verification (MRV) rules have already been established by the IPCC in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) and in the modalities and procedures for CCS under the CDM.

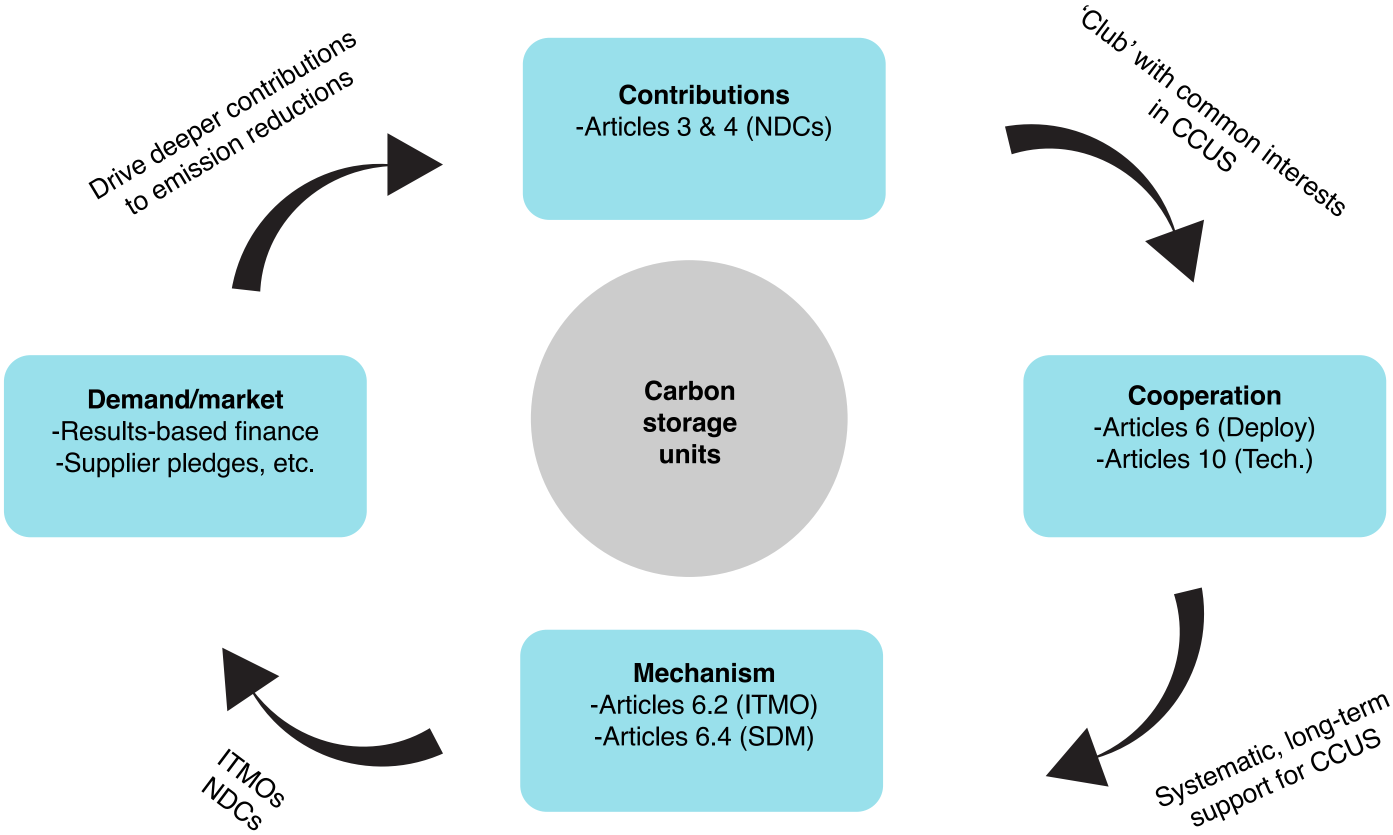
A CCS club with a fund dedicated to the purchase of a new asset class for CCS, the CSU, with linkages to NDC targets could offer a way of piloting support for CCS in the post-Paris era. It also presents options to transition it to a systematic support mechanism over the longer term. The approach could drive deeper ambition by countries and address tendencies to overlook the role of CCS in NDCs. Such an approach could also offer innovative ways to move climate policy upstream, into the supply-side of fossil fuels. Figure 2 presents a summary of the proposed framework and linkages.

However, putting the proposal into practice might lead to uncertainties that require further assessment. While none of these issues can be resolved without wider consultations and further crystallization of the Paris Agreement rulebook, some initial observations can be made.

Compatibility with the Paris Agreement

The approach outlined in the previous sections presupposes the flexibility and spirit of the Paris Agreement to accommodate new ideas and seek out new forms of market mechanisms. The rulebook which operationalizes the Agreement's requirements was mostly agreed at the Katowice

Figure 2. A possible virtuous circle for driving deeper ambition in the Paris Agreement through a dedicated support mechanism for CCS.



Key: CER = Carbon emission reduction; 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 = Emissions reduction.

Source: Authors' research and design.

Climate Conference, the 24th Conference of Parties to the UNFCCC (COP24), held in December 2018. However, Parties failed to reach consensus on the specific rules governing Article 6. As a result, uncertainty persists regarding how voluntary cooperation, and market- and non-market mechanisms consistent with Article 6 will work in practice. The topic has been carried over by Parties for further work through 2019 with a plan to conclude negotiations at COP25, scheduled for November 2019. Consequently, opportunities remain for potential CCS club members to provide input into the process during 2019. The success of this process will, however, partly depend on two key factors.

The first is the willingness of negotiators and other key stakeholders to use the opportunity and flexibility presented by Article 6 of the Paris Agreement to seek out transformative new forms of cooperation with new types of market mechanisms that can unlock greater ambition. In our view, a broad interpretation of Article 6 offers the possibility to promote greater flows of finance for low carbon technologies between Parties, transcending past experiences. There is a tendency, however, for negotiators to be fixated by emissions and emissions trading (the 'club' of networked carbon markets described previously) as the only meaningful form of voluntary cooperation between Parties. Forth (2018) recently noted this phenomenon and suggested that "there is a conservative bias in favor of historical experiences [and] an underlying motivation to be satisfied with recreating a CDM-like situation under the Paris Agreement [that could] obstruct serious negotiations on new market mechanisms," (Forth 2018, 6). The Agreement offers sufficient latitude for Article 6 rules to be novel and/or to rebuild Kyoto Protocol-style market architecture in a slightly different format. That is not to say that these are mutually exclusive outcomes, nor that the architecture for a global carbon market is not a legitimate activity, but rather that its pursuit should not come at the cost of shutting down other novel avenues for cooperation. Some draft rules presented in the lead-up to COP24 betrayed the aforementioned fixation on the global emission trading market while others – such as the potentially wide definition and scope of ITMOs – seemingly implied greater flexibility. The prevalence of the described tendencies and 'historical biases' could impair the potential for the mechanism proposed herein to achieve wider traction, indicating the benefits of wide consultation and information-sharing in the lead up to COP25.

The second factor is the capacity of the Financial Mechanisms of the Paris Agreement to accommodate new modes of cooperative action and financial flows among a select group (club) of Parties. Presently the two Financial Mechanisms of the Paris Agreement – the GCF and the Global Environment Facility – support only one-way flows of climate finance, from developed to developing countries. This runs contrary to the proposed RBCF format that would involve providing differential levels of financial flows to projects located anywhere in the world. We feel that this approach offers a better fit with the challenges that CCS deployment faces globally as it can tailor financial support to national circumstances, priorities and locally-available layers of co-financing. Also, neither fund offers the possibility of acting as a fund trustee on behalf of a group of contributors. Consequently, housing the fund of a CCS club in either facility would make it subject to the facilities' standard governance procedures, including in the case of the GCF its 24-member political-appointee board. This hampers the capacity of a club to make decisions independent from the wider political interests of all Parties to the UNFCCC and the Paris Agreement. An exception to GCF rules may be warranted in circumstances where it can unlock wider capabilities of the Paris Agreement to support the deployment of innovative climate technologies and solutions.

Alternative fund trustees include the World Bank Group, a multi-institution structure, bilateral development banks and private banks, all of which face potential issues. For example, the World Bank supports development only in low- and middle-income countries and has committed to finance no more upstream oil and gas after 2019.[10] It is unclear whether this commitment also encompasses CCS. Given this uncertainty, further consultation and analyses are needed to identify a suitable host for a CCS club fund.

Broader acceptance

Although the idea of using supply-side policy to support CCS deployment was proposed 10 years ago (Allen et al. 2009), it has received only limited attention since then. This is mostly a consequence of adopting a 'polluter/emitter pays' principle to climate change policy design, thus focusing attention on the users, rather than the suppliers, of fossil fuels. The UNFCCC, Kyoto Protocol and Paris Agreement all focus targets, compliance and GHG accounting rules on monitoring and regulating carbon flows rather than carbon stocks. Even though activities that increase biological sequestration are recognized as removals by sink enhancements, net removals are essentially counted as emission reductions in GHG accounting and compliance systems. LULUCF activities resulting in emission reduction units (ERUs) under Joint Implementation of the Kyoto Protocol, and temporary or long-term CER units for afforestation and reforestation project activities under the CDM, were treated as emission reductions for Kyoto compliance purposes. The emission reduction concept is deeply entrenched and pervasive, and with good reason: flow-based emissions policy is far more equitable as it penalizes the widespread use of fossil fuels rather than focusing on the limited group of countries that produce and export more carbon than they emit domestically.

The infancy of the Paris Agreement, and its flexibility, does, however, offer an opportunity to change direction by at least a degree or two. Ongoing discussions on issues such as non-emission reductions, or “non-GHG,” NDC targets and ITMOs leave open the possibility of shifting part of the dialogue toward carbon stock-based accounting and supply-side policies. This need not mean an immediate wholesale shift but as a possible complementary and supplementary way of enhancing climate action alongside demand side policies – what Lazarus and van Asselt (2018, 4) refer to as a “widening of the mitigation cost curve.” However, proposals along the lines of Allen et al. (2009) and others such as Ajani et al. (2012), continue to be tempered by the historical tendency to focus on controlling carbon flows rather than stocks, a tendency that will inevitably take some time to change.

The interest in, and body of literature on, supply-side climate policy is growing but is generally dismissive of CCS. Analysts have instead focused on direct regulatory interventions such as moratoria on fossil fuel exploration and development (or lending for such activities), shareholder-driven approaches to curtail fossil fuel investments based on stranded asset risk (such as divestment and climate-related financial disclosure) and grass-roots climate activism to prevent fossil fuel projects. However, given the huge task of delivering an equitable and orderly energy transition in the next 50 years aligned to net-zero emissions, these seem to be blunt instruments that lead only to binary outcomes. The consideration of mechanisms that support the decarbonization of fossil fuels as another means of achieving the same result seems to be sorely lacking, posing a risk to the ultimate goal of the Paris Agreement.

For this reason, we consider it appropriate to present an alternate and complementary way forward for ‘smarter’ supply-side policies. The simplicity, in terms of design and implementation, of basing this path forward around carbon stock regulation and its focus on cumulative emissions and carbon budgets that lead to a net-zero outcome, holds some appeal. It also creates the opportunity of placing significant new value on carbon sequestration activities and could provide the building blocks of a commercial geological carbon storage industry.

But when framed in these contexts, it should not be assumed that the potential benefits of the approach outlined in this paper will start and end with the fossil fuel industry. A new storage or sequestration asset class affords possibilities to significantly increase demand for a host of sequestration activities alongside geosequestration – achieving a net-zero emissions future will not be possible using CCS alone. Thus, the evolution of a CSU asset class based on tonnes sequestered presents the possibility of new and perhaps unexpected alliances forming between the fossil fuel industry, the direct air capture industry, and the biosequestration sector, such as forestry and agriculture conservancy groups. A new approach to CCS has the potential to increase the value of biosequestration and investments into such activities.

Willingness to participate

The idea of a global technology innovation fund or funds has been mooted in the past (Newell 2008) and ideas have been outlined regarding how to leverage contributions (Barrett 2003). However, these concepts have yet to gain wider support. For example, the Paris Agreement's Technology Mechanism presently provides only small-scale technical assistance grants to help countries with absorptive capacity and implementation, rather than sponsoring hardware deployment. The GCF will be the main channel for financing technology deployment under the Paris Agreement, with the attendant issues for the proposed club and mechanism described previously.

On the other hand, the private sector is showing signs of unilateral and collective action, suggesting that the concept could be taking hold in industry at least. For example, Shell's recent 'Sky' scenario – the most optimistic of three – outlined a net-zero emissions future by 2070 where CCS, CDR and biosequestration collectively remove almost 20 $GtCO_2$ per year from the atmosphere (Shell Global 2018). Shell CEO Bert van Beurden has publicly backed the idea, recently referring to the need for both CCS and mass reforestation, equal in scale to the Amazon rainforest, to meet global warming targets (Vaughan 2018).

Norwegian oil and renewable power company Equinor (formerly Statoil) recently announced its intention to invest in REDD+ at a level corresponding to emissions from its 'volumes' from operated production in areas where there is no price on CO_2. In 2017 this reportedly amounted to slightly below one million tCO_2 (Equinor 2018). This new strategy is additional to the company's ongoing focus on developing and deploying CCS technology in partnership with the Norwegian government and industry.

Moreover, the OGCI established a joint investment fund in November 2016, of over $1 billion, to develop and accelerate the commercial deployment of innovative low emissions technologies over the next 10 years. The group's 'circular carbon model,' which will drive the fund's investment strategy, is based on combining geological sequestration, carbon utilization and 'nature based solutions' to limit warming to 2^oC. Alongside an obvious commitment to CCS, the OGCI is also clearly assessing opportunities to expand its areas of operation into natural carbon sinks. Given that many of its members have close ties to governments, including key Parties in the UNFCCC negotiations – such as Brazil, China, Mexico, Norway and Saudi Arabia – its strategies and actions have significant potential to influence international climate policy under the Paris Agreement.

Given all of the above, it may be that the potential of supply-side climate policy and stock-based accounting will be realized in the post-Paris era.

Conclusion

The Paris Agreement provides significant latitude for new approaches to climate action. It offers opportunities, by way of Article 6, for groups with common interests to act independently of the wider and often conflicting interests of the majority. It also offers new ways to drive climate action, including through non-emission reduction-related measures and targets that result in mitigation co-benefits. This enables a consideration of alternative approaches to climate policy and incentive mechanisms, including technology-oriented mechanisms and 'smarter' supply-side policies based around carbon stock accounting.

This paper proposes the establishment of a carbon storage unit (CSU) as an asset class that can work effectively under these conditions. A CSU would act as a verified record of carbon sequestered or stored, a measure which, although implied, is entirely decoupled from an emission reduction measure and price signal. This new proposition captures the potential of the Paris Agreement to seek out alternative policy approaches and other types of climate benefits. Many previous assessments of 'CCS certificates' or 'storage certificates' have grappled with the problem of how to reconcile such units with emissions reductions, taking account of the energy penalty effects of CO_2 capture. Uncoupling the emissions reduction value from other proxy metrics, such as tCO_2 stored, overcomes this problem. CSUs also offer the possibility of establishing a secondary price signal for CCS developers that could help the technology through its current nascent status and into a mature lower cost climate solution. Furthermore, CSUs would give a price signal to CO_2 storers, alongside CO_2 emitters, that would for the first time drive commercial transactions and price formation for physical transfers of CO_2 between emitters and storers where utilization is not viable. In practice, the proposed mechanism bears similarities to a renewable energy certificate that, when coupled with a renewables obligation on electricity generators, subsidizes renewable power in a complementary and supplementary way to any explicit carbon pricing in the power sector.

The proposed CSU could open up valuable possibilities around stock-based accounting, which has worth when considering that the fundamental goal of the Paris Agreement is to balance the emissions of GHGs by sources and removals by sinks. A net-zero emissions outcome can also effectively be achieved by matching carbon stock removals such as fossil fuel extraction and wood harvesting, with carbon stock additions such as CCS and geosequestration, plant growth and biosequestration. The proposed unit, the CSU, provides the basis for such a regulatory system over the long term when coupled with a carbon-based supplier pledge or obligation. It also opens up the possibility of establishing lasting linkages between technology-based sequestration such as CCS and CDR, and nature-based sink enhancements, such as agriculture, forestry, land-use, REDD+ and wetlands ('blue carbon'). This creates the potential to unlock the value and increase the prices of nature-based solutions, and, ultimately, to catalyze a possible price convergence for a host of sequestration assets.

Long-term carbon reduction strategies being explored by the oil and gas industry bear a resemblance to the solution proposed in this paper. The proposed new CSU unit could, therefore, have some traction with these actors and provide them with stronger incentives to start delivering large-scale climate actions and meaningful ways of decarbonizing fossil fuels.

Such a policy framework, if implemented correctly, could finally offer genuine incentives to deposit carbon in a variety of planetary carbon stocks other than the atmosphere.

Endnotes

[1] This report uses the term CCS throughout, although it is used in the context of both pure geological storage and/or geological storage including utilization.

[2] Determining historical, current and future cumulative emissions and remaining atmospheric carbon budgets is a complex branch of climate science. Variations in estimates arise due to differing assumptions regarding e.g., total emissions to date since 1750, the target warming limitation (1.5ºC or 2ºC), the probability of attaining it (50% or 66%), emissions of non-CO_2 greenhouse gases, positive and negative system feedbacks arising from increased warming, absorptive capacity of the oceans, and choice of modelling approach used e.g. Earth system models (ESMs), combined ESM and observational data, or integrated assessment models (IAMs). These uncertainties have led to recent criticism of the use of carbon budgets to influence climate policy design (Peters, 2018; Geden, 2018). The range of 550-900 $GtCO_2$ presented here is based on the carbon budget for 1.5ºC given in IPCC (2018) and the range in Table TS.1 of the Technical Summary of AR5, WGIII (IPCC, 2014) for a 66% chance of staying within 2ºC of warming. The range in parenthesis is drawn from the same Table and recent literature concerning assessments of a 1.5ºC temperature increase limitation. It is considered illustrative for policy interpretation purposes, rather than as any definitive view on the matter.

[3] This paper refers only to fossil fuel producers, although the term can equally be extended to include cement producers which, through the extraction and calcination of limestone, also remove carbon from geological stock and transfer it to atmospheric stock.

[4] In December 2014, the late Jim Prentice, the then premier of Alberta, announced that "Alberta has done more than its fair share at this point in terms of very significant public investments in CCS [and] if you take the investments that we've made as Albertans and compare them on a global basis, it's 10% of all the money invested worldwide in large-scale CCS projects […] This is a very sizeable investment of taxpayers' money and prudence dictates that we should ensure that we begin to see some commercial viability to these investments". He then put Alberta's CCS program on hold, aside from the already financed projects, namely the Quest and Sturgeon Refinery projects. See Financial Post newspaper, Dec. 15, 2014.

[5] Nearly all Parties have already submitted interim intended nationally determined contributions (iNDCs) and some have submitted First NDCs. A stock-take of these, named the 'Talanoa Dialogue' was concluded in December 2018 at the Katowice Climate Conference, noting that, inter alia, more ambitious near-term climate action, greater use of technology and bold leadership is needed ('Talanoa Call for Action': joint statement by the Presidents of COP23 and COP24, 12/12/2018).

[6] Results-based payments for REDD+ are explicitly included in the Paris Agreement, Article 5.

[7] The Australian contribution, of US$2.4 million, to the funds put forward by the Global CCS Institute are in the process of being withdrawn.

[8] The NER300 is a fund established by the European Commission for directly supporting projects demonstrating environmentally safe CCS and innovative renewable energy technologies on a commercial-scale within the European Union over the period 2013-2020. The fund of 2.1 billion euros was raised from the sale of 300 million surplus EU Allowances in the new entrant reserve of the EU's greenhouse gas emission trading scheme, hence the name 'NER300' (the new entrant reserve is the unallocated reserve of EU allowances available for new installations built in the EU during the trading period). Problems with the scheme have left around 440 million euros undisbursed.

[9] Corresponding adjustments are referred to in Decision 1/CP.21, (para. 37) in relation to Article 6.2 of the Paris Agreement and the need to avoid double counting of emission reduction activities. Where an ITMO transaction occurs, the corresponding adjustment involves subtracting emissions from acquiring countries' greenhouse gas inventory and adding them back to the transferring countries' greenhouse gas inventory. Questions remain as to whether the corresponding adjustment should relate only to sectors covered by a country's NDC, or to all sectors (regardless of whether it is included in an NDC or not), the latter being necessary to avoid incentivizing countries to limit the sectoral coverage of their NDCs.

[10] At the One Planet summit in December 2017, World Bank Group President Jim Yong Kim announced that the bank would no longer finance upstream oil and gas after 2019, except in exceptional circumstances, where consideration will be given to financing upstream gas in the poorest countries where there is a clear benefit in terms of energy access for the poor and the project fits within the countries' Paris Agreement commitments.

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Notes

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About the Project

This study is part of a project examining opportunities for Saudi Arabia to apply Carbon Capture, Utilization and Storage technologies (CCUS) in an increasingly carbon-constrained world and the role that CCUS could play in the Saudi economy. The project assesses policy options and analyzes related regulatory and commercial issues affecting the development and deployment of CCUS.

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