Governing large-scale carbon dioxide removal: are we ready? - an update

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C2G Carnegie Climate Governance Initiative

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CLIMATE ANALYTICS

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Summary

In 2015, Parties to the United Nations Framework Convention on Climate Change (UNFCCC) agreed to limit global temperature increase to well below 2°C above pre-industrial levels and to pursue efforts to limit the increase to 1.5°C. This goal is to be operationalised in part through achievement of a balance between anthropogenic emissions by sources and removals by sinks, as stated in Article 4 of the UNFCCC's Paris Agreement.

In 2018, the Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C (IPCC SR 1.5°C) warned that the impacts of warming at 2°C would be significantly worse than those at 1.5°C. This IPCC report also found that all pathways to achieve 1.5°C with limited or no overshoot, project the use of Carbon Dioxide Removal (CDR) in the order of 100–1000 GtCO2 over the 21st century.

In short, the IPCC SR 1.5°C bolsters the case for pursuing the lower end of the Paris Agreement's temperature goal and makes clear that it is no longer sufficient to reduce emissions alone — CO2 will also need to be removed from the atmosphere, on a scale never previously attempted.

Is the international community prepared for the implementation of CDR options at this unprecedented scale? Can the sustainability challenges, risks and trade-offs inherent in large-scale CDR efforts be managed? What governance tools would need to be in place to deploy CDR options at the levels the IPCC says are needed? Can provisions under the current climate change regime support implementation at scale, or will further provisions and incentives be needed?

This report aims to address these questions, recognising that some degree of reliance on CDR options is now inevitable to achieve the Paris Agreement's long-term temperature goal, as a direct result of the international community's delay in making the necessary transition to a low-carbon economy.

The top-line finding is that while a number of reporting rules and accounting practices are already in place with direct applicability to the implementation of CDR options, many governance gaps remain.

This report is intended to start a discussion focused on three key issues: how much CDR is needed to avoid or limit any overshoot of the 1.5°C temperature goal; are there governance mechanisms in place that can begin to address CDR at the necessary scale; and what governance gaps remain to be filled.

The scale of the CDR governance challenge is daunting. The good news, however, is that many of the governance systems needed to support the necessary acceleration in emission reductions under the Paris Agreement will also take us a good way toward filling the gaps needed to govern largescale CDR. Addressing large-scale CDR and reducing global emissions cannot be seen as separate activities; they are intimately related, both are needed and their governance goes hand in hand.

Key insights

1. The scale of CDR needed to limit global warming to 1.5°C depends on the speed of emissions reductions

According to IPCC SR 1.5°C, to avoid or limit any overshoot of the 1.5°C temperature goal, CO_2 emissions will need to be phased out almost entirely by 2050 while the "balance" cited in Article 4 would need to be reached by 2070.[1] Current levels of ambition in the Nationally Determined Contributions (NDCs) fall far short of what is needed.

The pace of global efforts in the near-term is therefore critical: the longer it takes to reduce emissions, the more large-scale CDR will be needed.

- Substantial amounts of CDR will likely be needed over the remainder of the 21st century even if NDCs are ratcheted up substantially, given insufficient global mitigation action to date;
- If the international community succeeds in ratcheting up NDCs only modestly, an extremely large contribution from CDR will be needed; if NDCs are ratcheted up only marginally, limiting temperature rise to well below 2°C and 1.5°C will be out of reach completely;
- A broad portfolio of CDR options will be required to satisfy the overall need for CDR, to avoid running into limitations inherent in any single CDR option;
- CDR activities and technologies will need to be rolled out sooner rather than later, as delay in deployment and hence capacity to rapidly scale-up a portfolio of options creates substantial future risk.

If Parties bring forward new and updated NDCs by 2020 that are substantially more ambitious in the reductions they deliver for 2030, this can reduce future reliance on CDR to a scale that may be economically feasible and avoid jeopardising sustainable development.

2. A number of existing provisions under the UNFCCC, Kyoto Protocol and Paris Agreement address governance aspects of Carbon Dioxide Removal

Provisions under the UNFCCC, Kyoto Protocol and Paris Agreement address the reporting and accounting of CO_2 removals. The IPCC has also provided guidance relevant to Bioenergy with Carbon Capture and Storage (BECCS) and substantial guidance on Carbon Capture and Storage (CCS). The development and application of a new rule set under the Paris Agreement provides a valuable, near-term opportunity to address a number of governance challenges and legacy issues that have not been adequately addressed through existing provisions, or that have arisen due to the scale of CDR that is now required.

For example, the presentation of consistent and comparable greenhouse gas (GHG) inventory data across all Parties, at an appropriate level of granularity in connection with CDR options employed, would help the international community assess the scale of removals underway and track progress toward the necessary "balance" between anthropogenic emissions and removals. Similarly, consistency in the presentation of NDC information, and consistency in reporting on progress in NDC implementation and achievement, would help project 2030 emission levels and aid in CDR planning. The adoption of robust land sector accounting rules and robust rules for the use of cooperative approaches under Article 6 would address historic and continuing concerns over environmental integrity in these two contexts. The presentation of separate targets for emission reductions and for removals within NDCs, and the presentation of a separate target for the land sector, would help ensure that emission reductions take place across all sectors, and avoid a situation in which land sector removals are used to delay a reduction in fossil fuel emissions.

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1 This applies to a 50% chance to limit warming to 1.5°C (median) or with a limited overshoot to 1.6°C, accounting for uncertainties in the climate system, non-CO2 greenhouse gases, aerosol pollutants and carbon cycle. Zero emissions would need to be achieved earlier for a 66% chance to limit warming to 1.5°C (a "likely" chance in IPCC terms). Further, the underlying energy-economic pathways show rapid global GHG emissions reductions from 2020 until the point of zero emissions, with the cumulative emissions until that point consistent with total cumulative emissions budgets, calculated using geophysical relationships. Obviously, if global emissions were not reduced and were growing, or kept constant at present-day levels, the emissions budget would be exhausted much earlier.

UNFCCC, Kyoto Protocol and Paris Agreement contexts		Selected provisions*	Key points
Existing provisions from which lessons can be learned	UNFCCC	• Annex I Reporting Guidelines (Decision 24/CP.19) • Non Annex I Reporting Guidelines (Decision 17/CP.8) • Biennial reporting and review guidelines for developed and developing countries (Decision 2/CP.17) • REDD+ (Decisions 1/CP.16, 2/CP.17, 12/CP.17, 9/CP.19, 10/CP.19, 11/CP.19, 12/CP.19)	Gaps and differences between UNFCCC and Kyoto Protocol provisions form a starting point for the Paris Agreement rule-book and highlight the need to move towards consistent and comparable GHG inventories and robust accounting rules for all Parties
	Kyoto Protocol	• Land use, land use change and forestry (Decisions 16/CMP.1, 17/CMP.1, 18/CMP.1) • Afforestation and reforestation under CDM and sink enhancement under JI (Decisions 5/CMP.1, 9/CMP.1, 13/CMP.1, 15/CMP.1) • CCS as CDM project activities (Decisions 10/CMP.7, 5/CMP.8) • The Cancun Agreements: Land use, land use change and forestry (Decision 2/CMP.6) • Second commitment period (Decisions 2/CMP.7, 1/CMP.8, 2/CMP.8, 5/CMP.8)	
Paris Agreement provisions to be built upon	Land sector	• Decision 1/CP.21 • Articles 4, 5, 13, 14 • Decision 4/CMA.1 • Decision 18/CMA.1	Robust reporting and accounting guidance for NDCs needed as part of an effective CDR governance architecture. This includes robust accounting rule for Article 6 transfers, land sector accounting rules and an effective Global Stocktake.
	Assessment of progress toward temperature goal / balance between emissions and removals	• Decision 1/CP.21 • Articles 2, 4, 13, 14 • Global Stocktake (Decision 19/CMA.1) • Transparency Framework (Decision 18/CMA.1) • Further Guidance in relation to the mitigation section of decision 1/CP.21 (Decision 4/CMA.1)	
	Transfers between Parties	• Decision 1/CP.21 • Articles 4, 6, 13	Robust accounting rules needed for Article 6 market-based transfers to avoid double counting, ensure environmental integrity and ensure transparency, including in governance.

Existing IPCC guidelines to be built upon	IPCC Guidelines relevant to A/R, CCS and BECCS	• Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories • IPCC Special Report on Land Use, Land-use Change and Forestry, 2000 • Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 2000 • IPCC Good Practice Guidance for Land Use, Land-use Change and Forestry, 2003 • IPCC Special Report on Carbon Capture and Storage, 2005 • 2006 IPCC Guidelines for National Greenhouse Gas Inventories • 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands • 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories • IPCC The Special Report on Climate Change and Land, 2019	Additional guidance is needed for reporting lifecycle emissions and removals from bioenergy (with and without CCS) and Direct Air Capture with Carbon Storage (DACCS).
* This listing is not intended to be inclusive, but rather to point to key decisions, provisions and documents.			

3. Despite existing provisions, many key governance gaps and challenges remain for large-scale CDR and will need to be addressed

While existing provisions and guidance under the UNFCCC, Kyoto Protocol and Paris Agreement already cover a number of governance issues related to CDR (as above), many key governance challenges remain. These gaps revolve around 4 key issues:

- The scale and speed of implementation required, and the associated challenges for research and development and for monitoring deployment.
- The substantial incentives that will be needed to scale-up potential CDR options, as sufficient incentives do not at present exist under the UNFCCC or other legal frameworks.
- The trade-offs between, and interactions with, a range of Sustainable Development Goals (SDGs) e.g., food security, water security, that may follow from large-scale implementation intended to achieve climate ends.
- The risks to the climate system and to the SDGs that will follow if CDR options are not implemented at the pace or scale required, if CDR is used inappropriately to compensate for continued fossil fuel emissions, or if large-scale reversals follow large-scale CDR efforts.

The report identifies ten particular areas with remaining governance challenges for the implementation of large-scale CDR:

- **Rapid pace of CDR scale-up required to limit warming to 1.5°C:** many potential CDR options are at a low level of technology readiness, and it may take decades to achieve widespread deployment for these options.
- **Responsibility and ethics of implementation:** to date there has been no clear assignment or acknowledgement of responsibility for development and deployment of CDR options among Parties to the UNFCCC and/or Paris Agreement.
- **Access to information needed to monitor progress:** a significant challenge that will arise once CDR starts to be deployed at scale is how best to monitor progress towards the goal of balancing emissions and removals.
- **Safeguards for sustainable development:** there are constraints on the sustainable potential of BECCS and Afforestation/Reforestation (A/R) due to limits on resource availability.
- **Challenges for measuring, reporting and verifying CO_2 removals:** measurement and

verification of the scale of removals from CDR presents substantial governance challenges, in particular in the context of terrestrial sinks.

- **Issues of storage, permanence, leakage and saturation:** a key criterion for successful CDR deployment is that carbon removals be durable. Potential CDR options that store carbon in geological reservoirs and terrestrial reservoirs have different degrees of "*permanence*".
- **Planning for and monitoring the biophysical effects of deployment:** for land-based CDR options, deployment can have biophysical impacts beyond CO_2 removal that require consideration.
- **Liability and redress:** Safeguards need to be put into place to address physical risks and accounting risks related to reversals of removals and storage.
- **Incentives for CDR deployment:** direct funding and economic incentives will be needed for the deployment of CDR at the pace and scale required to achieve the Paris Agreement's long-term temperature goal.
- **Public awareness and acceptance:** public awareness and acceptance of CDR will be important for its development and roll-out. At the broadest level, public acceptance of CDR as a concept is influenced by the ethics of pursuing CDR and the perceived risk of moral hazard.

4. Priority gaps on mitigation, information, accounting, knowledge and incentives can be addressed in the near-term, both inside and outside of the UNFCCC process

Certain priority areas for governance can be addressed in the near-term. These include **mitigation gaps, information gaps, accounting gaps, knowledge gaps, and incentive gaps**. Some can be addressed through the ongoing negotiating processes under the Paris Agreement, while others will require decisions and interventions outside the UNFCCC process.

Key governance challenges and gaps that can be addressed in the near-term:

Governance challenges and gaps	Entity or entities	Options for adressing them
1. Narrow the mitigation gap to reduce possible future reliance on CDR options	UN Secretary General UNFCCC Executive Secretary	• Maintain momentum from the IPCC SR 1.5°C by raising awareness of climate impacts and risks at low levels of temperature change • Encourage new and updated NDCs in this 5-year cycle, with far more ambitious emission reduction targets for 2025 and 2030 • Encourage communication of 2050 strategies, consistent with 1.5°C pathways • Encourage shift to economy-wide NDCs • Facilitate greater collaboration between treaty Secretariats • Encourage distinct land sector targets • Encourage targets for negative emissions
	Parties	• Enhance 2030 NDC ambition, to avoid extreme reliance on CDR options • Communicate 2050 Low Emission Strategies (LT-LEDS) including consideration of targets for negative emissions, options and needs • Evolve a common understanding of "net zero" (all sectors, all gases, no reliance on international units)

2. Improve inventory data and information management systems	IPCC	• Develop IPCC Guidance on biomass energy lifecycle emissions for inclusion in national emissions inventories • Develop IPCC Guidance on emission inventory and reporting for DACCS
	IGOs, NGOs, CSOs	• Explore how external datasets can be used to verify sectoral emissions data (e.g. through atmospheric measurements) • Support capacity building initiatives
	Parties	• Provide information necessary for clarity, transparency and understanding of existing NDCs in Decision 4/CMA.1 for first and subsequent NDCs • Shift to economy-wide NDCs • Apply common accounting rules in Decision 4/CMA.1 for first and subsequent NDCs • Present distinct land sector targets • Present negative emission targets • Adopt common GHG reporting formats that facilitate aggregation
3. Put in place robust accounting rules	Parties	• Move toward common accounting rules for the land sector (e.g. for Harvested Wood Products, Natural Disturbances) • Develop robust rules for Article 6 transfers under Article 6.2 and 6.4
	UNFCCC Executive Secretary	• Collaborate with International Maritime Organization (IMO), International Civil Aviation Organization (ICAO), Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) and Montreal Protocol to enable sharing of emissions data, to ensure no double counting of emission reductions and ensure work is not at cross-purposes
	IPCC	• Develop guidance on accounting for life cycle emissions involving multiple sectors and multiple countries
4. Create incentives to accelerate research, investment and implementation	Research community	• Develop policy packages to support accelerated deployment • Identify inexpensive no-regrets options for immediate implementation • Consider ways to share risks and responsibilities for research and development of less mature options (e.g. public / private partnerships, particularly where existing infrastructure and plans can be utilised)
	Parties	• Develop policy packages to support accelerated deployment • Provide direct financial and capacity building support for low cost no-regrets CDR options with known co-benefits (A/R, soil sequestration, ecosystem restoration) • Reserve market based cooperative approaches under Article 6.2 and 6.4 for reductions that are clearly permanent, additional and readily measurable and verifiable • Consider ways to share risks and responsibilities for research and development of less mature options (e.g. public / private partnerships, particularly where existing infrastructure and plans can be utilised) • Provide direct financial support for expensive CDR options

5. Engage the research community in scoping specific CDR options and necessary incentives	Research community	• Build scenarios around specific CDR options, value chains and their sustainability implications (e.g., BECCS linked to existing and new CCS sites, DACCS linked to renewable energy, other land- based options with sustainability benefits) • Research environmental aspects of CDR options and portfolios, including storage permanence and leakage • Support regional, bottom up studies to identify realistic, sustainable removal potential in given locations • Identify pathways for collaboration, cost-sharing and benefit sharing, as well as options for the allocation of responsibilities and liability
6. Improve public awareness of potential CDR options, risks and trade-offs in planning processes	IGOs, NGOs, CSOs	• Increase public awareness of co-benefits • Engage a wide range of stakeholders in planning processes • Identify areas or facilities with potential to accommodate large-scale CDR options • Establish a registry of CDR initiatives and projects, including information on scale and location • Provide information from external datasets to facilitate tracking of CDR deployment, e.g. on forest cover, clearing, natural disturbances, from satellite data
7. Improve international collaboration and cooperation	ICAO and IMO	• Data sharing and enhanced collaboration with UNFCCC • Develop long-term vision for zero emissions in their sectors
	IPCC	• Evaluate the implications of geophysical feedbacks and other issues for emission pathways and CDR needs consistent the Paris agreement long-term temperature goal, for inclusion in assessment reports that will inform the Global Stocktake
	Research community	• Emissions-reduction tracking initiatives: expand tracking of NDCs and current policies to include CDR deployment

Introduction

In 2015, Parties to the UN Framework Convention on Climate Change agreed to ***pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels***. The Parties adopted this goal in express recognition that "*climate change represents an urgent and potentially irreversible threat to human societies and the planet and thus requires the widest possible cooperation by all countries.*"[2] When adopting the agreement, Parties invited the Intergovernmental Panel on Climate Change to provide a special report in 2018 on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas (GHG) emission pathways.

This *Special Report on Global Warming of 1.5°C* (IPCC SR 1.5°C) has now been released. It is an eye-opening read for Heads of Government and policymakers around the world. The report makes absolutely clear that getting the world on a 1.5°C consistent pathway is necessary to avoid irreversible impacts of climate change on human, social, ecological and economic systems. It also makes clear that this effort will require unprecedented levels of mitigation ambition, international coordination, and international cooperation if we are to realise the deep reductions in global emissions needed. A key element of the mitigation requirements confirmed in the IPCC SR 1.5°C is the need for large-scale Carbon Dioxide Removal — or CDR. The longer it takes for truly ambitious mitigation action to get underway, the greater the need will be to turn to existing and proposed methods and technologies that would aim to remove CO_2 directly from the atmosphere, through biological and technological means — termed "*Carbon Dioxide Removal*" options.

This paper aims to help senior climate change negotiators and other relevant stakeholders better appreciate some of the current gaps in international governance that would need to be remedied for potential CDR options to contribute to 1.5°C-consistent pathways at the scale and pace required.

The term **Carbon Dioxide Removal (CDR)**[3] as used in this paper, follows the definition provided in the 2018 IPCC SR 1.5°C and its approved Summary for Policy Makers (SPM), reproduced below:

> "*Anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage, but excludes natural CO_2 uptake not directly caused by human activities*".

IPCC SR 1.5°C points to important sustainability and other concerns with CDR, but also shows some reliance on CDR options is now inevitable. All 1.5°C-compatible[4] model pathways considered by the

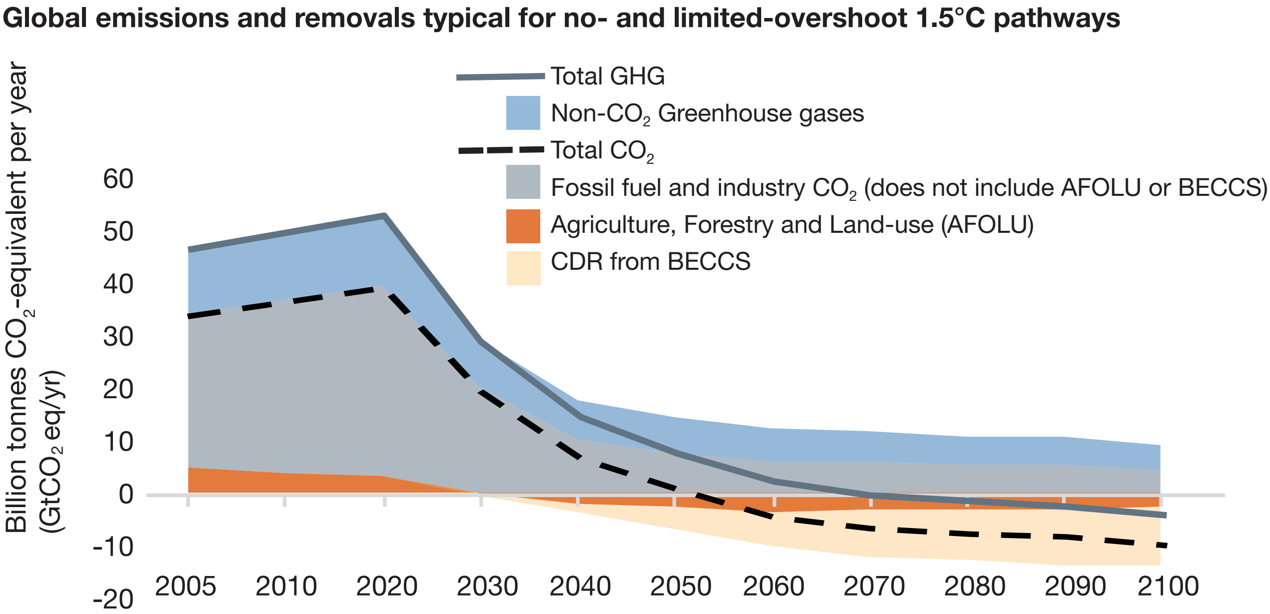
2 Decision 1/CP.21, preamble.

3 The IPCC SR 1.5°C definition of "anthropogenic removals" is the "withdrawal of GHGs from the atmosphere as a result of deliberate human activities. These include enhancing biological sinks of CO_2 and using chemical engineering to achieve long-term removal and storage. Carbon capture and storage (CCS) from industrial and energy-related sources, which alone does not remove CO_2 from the atmosphere, can reduce atmospheric CO_2 if it is combined with bioenergy production". Removals commonly refer to CO_2, as very little data and literature is available on anthropogenic removals of other GHGs (for an exception see Ming et al. 2016) the average global temperature will still increase during this century. A lot of research has been devoted to prevent and reduce the amount of carbon dioxide (CO_2).

4 Following the IPCC SR 1.5°C these are defined as pathways with no or limited overshoot of 1.5°C in that they give at least 50% probability based on current knowledge of limiting global warming to below 1.5°C ('no overshoot') and/or limit warming to below 1.6°C (maximum 0.1oC overshoot) and return to 1.5°C or below by 2100 ('limited-overshoot').

IPCC SR 1.5°C (see Figure 1) rely to varying degrees on a contribution from potential CDR options, though the extent of this reliance varies across pathways. CDR also plays a major role in the vast majority of scenarios that limit global temperature rise to 2°C.

Figure 1. Total global CO_2 and GHG emissions for 1.5°C-compatible pathways in IPCC Special Report on 1.5°C (IPCC SR1.5). These pathways typically require substantial levels of Carbon Dioxide Removal (CDR) to limit global warming to 1.5°C, both to compensate for limited mitigation action to date and to compensate for remaining CO_2 and non-CO_2 in sectors where the scientific literature shows reaching zero emissions will not be feasible. CDR is achieved in these pathways at a global level via Afforestation/Reforestation — leading to global CO_2 removals in the sector of Agriculture, Forestry and Land-Use (AFOLU) — as well as via BioEnergy combined with Carbon Capture and Storage (BECCS). All emissions and removals where calculated from the median emissions levels across the 46 pathways in the IPCC SR1.5 scenario database that are 1.5°C compatible and that reported data for all variables included here (Source: IPCC SR1.5 scenario database https://data.ene.iiasa.ac.at/iamc-1.5c-explorer, accessed 22 October, 2018)



A number of potential terrestrial CDR options have been identified (see Table 1), but these are at different stages of maturity and few examples currently exist of successful large-scale CDR operations, aside from Afforestation and Reforestation. The rapid scaling-up of large-scale CDR options is untested and will require international governance systems capable of addressing a range of sensitive issues and challenges, e.g., responsibility for funding and hosting possible CDR options; accounting, monitoring, reporting and verification of CDR; systems for managing, minimising and avoiding environmental and social impacts; systems to share benefits among actors and costs among beneficiaries; systems to manage future liability; and systems and models for international cooperation. Consideration needs to be given to geophysical, environmental, technological, economic, social-cultural and institutional enabling conditions. International cooperation can be expected to play a role, particularly in developing countries, in supporting and creating the necessary conditions for large-scale initiatives.

In this study we consider the potential scale and pace of CO_2 removals needed to meet the Paris Agreement goals, existing and emerging provisions under the UNFCCC rules and Paris Agreement governing anthropogenic CO_2 removals and then identify significant governance gaps and challenges at the international level that policymakers need to address as soon as possible. Framing considerations for identifying challenges include ensuring that scaling-up CDR measures are sustainable and can be governed equitably and effectively.

We will focus on three specific CDR options:

1) Afforestation and Reforestation (A/R)[5];

5 Although we specifically address Afforestation and Reforestation (A/R), large-scale land restoration would raise similar governance challenges at scale.

2) Bioenergy with Carbon Capture and Storage (BECCS); and
3) Direct Air Capture with Carbon Capture and Storage (DACCS).

We focus on these options due to their potential for low-cost up-scaling (A/R), their potential to create sustainability challenges at various level of governance (A/R, BECCS), their unique governance challenges in the context of transboundary transfers (BECCS, DACCS) and their need for investment and incentivisation to support commercialisation (BECCS, DACCS).

Table 1 below shows options identified in the scientific literature that achieve net Carbon Dioxide Removal and their definitions, as included in IPCC SR 1.5°C. Note that the scientific literature identifies a number of additional potential options for enhancing terrestrial sinks beyond those that are the focus of this paper, including ecosystem restoration (both on land and along coastlines), soil carbon sequestration and enhanced weathering. Table 1 below sets out options identified in the scientific literature that achieve net CDR together with their definitions, as included in IPCC SR 1.5°C. Some of these options are often low cost, and could be more rapidly deployed than technological CDR options such as BECCS and DACCS, although their potential falls far short of what is needed in terms of CDR. Many would raise similar governance challenges to A/R when deployed at large-scale (e.g., issues related to monitoring, reporting and verification, permanence) and they are not a specific focus of this report.

Table 1. Options identified in the scientific literature that achieve net Carbon Dioxide Removal, showing definitions as included in IPCC SR 1.5°C.[6] Note that this IPCC list is not an exhaustive list and other options exist, such as CDR by ecosystem restoration.

IPCC SR 1.5°C Glossary
Afforestation Planting of new forests on lands that historically have not contained forests.
Reforestation Planting of forests on lands that have previously contained forests but that have been converted to some other use.
Bioenergy with carbon dioxide capture and storage (BECCS) Carbon dioxide capture and storage (CCS) technology applied to a bioenergy facility.
Direct air carbon dioxide capture and storage (DACCS) Chemical process by which CO_2 is captured directly from the ambient air, with subsequent storage. Also known as direct air capture and storage (DACS).
Biochar Stable, carbon-rich material produced by heating biomass in an oxygen-limited environment. Biochar may be added to soils to improve soil functions and to reduce greenhouse gas emissions from biomass and soils, and for carbon sequestration.
Soil carbon sequestration (SCS) Land management changes which increase the soil organic carbon content, resulting in a net removal of CO_2 from the atmosphere.
Enhanced weathering Enhancing the removal of carbon dioxide from the atmosphere through dissolution of silicate and carbonate rocks by grinding these minerals to small particles and actively applying them to soils, coasts or oceans.

6 IPCC SR 1.5°C Glossary also includes a definition of ocean fertilisation. However, it is not included in the table here, since Chapter 4 in the IPCC SR 1.5°C notes that "*The London Protocol of the International Maritime Organization has asserted authority for regulation of ocean fertilisation (Strong et al. 2009), which is widely viewed as a, de facto moratorium "on commercial ocean fertilisation activities*". For completeness, the IPCC SR 1.5°C Glossary definition is "*Deliberate increase of nutrient supply to the near-surface ocean in order to enhance biological production through which additional carbon dioxide from the atmosphere is sequestered. This can be achieved by the addition of micro-nutrients or macro-nutrients. Ocean fertilisation is regulated by the London Protocol.*" Substantial doubt has also been raised by the scientific community in relation the efficacy of ocean fertilisation — see for example Williamson, P. et al., 2012. Lauderdale, J., et al., 2020

1) What scale of removals is needed to meet Paris Agreement goals?

In the Paris Agreement of 2015, the international community adopted an ambitious long-term temperature goal, resolving to strengthen the global response to the threat of climate change, by *"[h]olding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels."*[7] This goal is operationalised in Article 4.1 of the Paris Agreement inter alia via a global emissions pathway whose key parameters are to be determined based on the best available science:

> " *In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, to undertake rapid reductions … in accordance with best available science, to achieve a balance between anthropogenic emissions by sources and [anthropogenic] removals by sinks of greenhouse gases in the second half of this century, in the context of sustainable development and efforts to eradicate poverty*" (Art. 4.1).

With these Paris Agreement goals in place, attention has turned to how the required temperature limit and the emissions pathway required under Art. 4.1 can be operationalised, including defining how, and when this "balance" is to be achieved. The IPCC 1.5°C Report makes clear how rapidly reductions need to be achieved to avoid or limit any overshoot of the 1.5°C temperature limit — CO_2 emissions will need to be approximately halved by 2030, and reach zero, or lower, by 2050.[8] The report also shows that total GHG emissions will need to peak by around 2020 and be significantly below present levels by 2030 to reach zero by about 2070, thereby defining the timeframe within the second half of this century by which a balance has to be achieved.[9] As a consequence, systems will need to be found to generate "negative emissions" in connection with the basket of GHGs that contribute to global warming.[10] All emissions pathways in the literature show that some GHG emissions cannot be reduced to zero (e.g. remaining nitrous oxide and methane emissions from agriculture (Rogelj et al, 2018). Accordingly, the "balance" in Article 4 implies that some level of continuous anthropogenic CO_2 removal will be required to offset the residual GHG (CO_2 and/or non-CO_2) emissions that cannot be reduced below zero, in order to reach global net-zero GHG emissions.

7 See UNFCCC Decisions 10/CP.21 (adopting this goal under the Convention) and 1/CP.21, Annex (embedding this goal in Article 2.1 of the Paris Agreement).

8 IPCC SR 1.5°C, SPM-15, SPM-19.

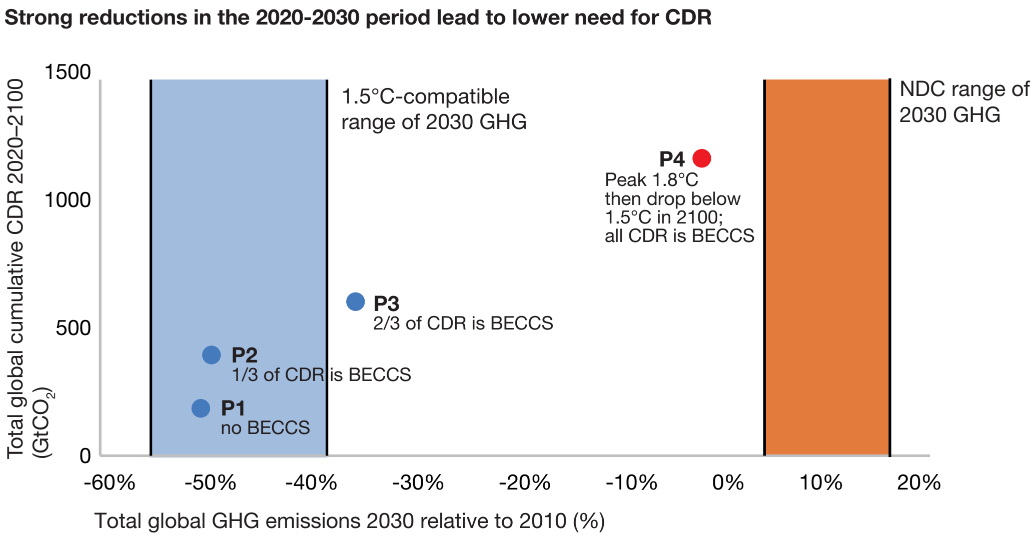
9 This applies to a 50% chance to limit warming to 1.5°C (median) or with a limited overshoot to 1.6°C, accounting for uncertainties in the climate system, non-CO_2 greenhouse gases, aerosol pollutants and carbon cycle. Zero emissions would need to be achieved earlier for a 66% chance to limit warming to 1.5°C (a "likely" chance in IPCC terms). Further, the underlying energy-economic pathways show rapid global GHG emissions reductions from 2020 until the point of zero emissions, with the cumulative emissions until that point consistent with total cumulative emissions budgets, calculated using geophysical relationships. Obviously, if global emissions were not reduced and were growing, or kept constant at present-day levels, the emissions budget would be exhausted much earlier.

10 In the background literature of emissions pathways, total greenhouse gas emissions are calculated as the GWP-100 weighted total of individual GHG emissions (see, e.g. IPCC AR5 WGIII).

In addition to the need for CDR to ensure the "*balance*" in Article 4.1, substantial efforts will be necessary to achieve the deep emissions reductions necessary to hold warming well below 2°C and limit it to 1.5°C. The slow pace of emissions reductions to date makes achievement of Article 2.1's long-term global temperature goal challenging. Indeed, most Paris Agreement-consistent emissions pathways[11] assessed in the recent IPCC SR 1.5°C exceed a warming level of 1.5°C above pre-industrial levels by a small amount (up to 0.1°C), before dropping down to below 1.5°C at the end of the century and typically reach around 1.3°C by 2100. All of these PA-consistent pathways rely on a contribution from potential CDR options, though the extent of this reliance varies across pathways, ranging from 100 to 1,000 $GtCO_2$ cumulatively over the 21st century.

The IPCC SR 1.5°C frames some of its considerations of feasibility and sustainability using four "*illustrative*" pathways (P1-P4), which are represented by dots in Figure 2. These four pathways vary greatly in their reliance on CDR options as a function of the global emissions reductions achieved by 2030. The global total GHG emissions reduction achieved by 2030 will of course be a prime indicator of the overall mitigation ambition level represented by NDCs (represented by the orange bar in Figure 2). There are no mitigation pathways in the scientific literature that reach the Paris Agreement goals from these NDC-consistent 2030 emissions levels[12]. Continuing the level of ambition represented by NDCs submitted so far would result in over 3°C warming by 2100, with temperatures continuing to rise into the next century[13], and hence currently submitted NDCs in aggregate fall far short of what is needed to reach the Paris Agreement goals. NDCs to 2030 need to be enhanced substantially by 2020 to bring expected global GHG emissions by 2030 down to levels represented by the P1-3 pathways in Figure 2.

Figure 2. Total global GHG emissions in 2030 and cumulative Carbon Dioxide Removal (CDR) in the four "illustrative" pathways (P1-P4) in IPCC SR 1.5°C. These pathways require increasing levels of CDR to limit global warming to 1.5°C as 2030 GHG emissions levels are higher — with increasing relative shares of total CDR supplied by Bioenergy with Carbon Capture and Storage (BECCS). Note the P1 pathway was developed specifically to limit global warming to 1.5°C without CCS (and hence without BECCS). P4 is labelled red to indicate that it is not consistent with limiting global warming to 1.5°C, as it exceeds 1.5°C around mid-century by as much as 0.3°C. (Source: IPCC SR 1.5°C SPM (2018); Rogelj et al. (2018 Supplementary Information; Grubler et al. (2018))



11 We define PA-compatible pathways here as those that are referred to in the IPCC SR 1.5°C with no or limited overshoot. See IPCC SR 1.5°C Box SPM 1: Core Concepts Central to this Special Report. The report also assessed pathways where global warming exceeds 1.5°C by as much as 0.4°C before reaching 1.5°C by 2100, which is typified as "high overshoot". Given their peak warming at 1.9°C, this is not considered to be "well below 2°C" and hence not considered here as consistent with the Paris Agreement aim. For a broader discussion of emissions scenarios in the context of the Paris Agreement, see Schleussner et al. (2016) and Rogelj et al. (2019).

12 *In extremis*, this would lock in substantial overshoot of the 1.5°C warming level and would lead to the requirement for much larger levels of CDR than presently seen in the cost optimal integrated assessment models, and which would exceed sustainability boundaries.

13 See https://climateactiontracker.org/global/cat-thermometer

While these "*illustrative pathways*" make it immediately clear that stronger global GHG emissions reductions by 2030 lead to a smaller need for CDR over the 21st century to achieve the long-term temperature goal, the need for CDR is still substantial. The P4 illustrative pathway relies on CDR at even larger scale than the other pathways to get back to 1.5°C by 2100, but is not consistent with limiting global warming to 1.5°C as it exceeds this limit around mid-century by as much as 0.3 °C.

The relationship between 2030 mitigation ambition and CDR reliance is an essential one to understand in considering the governance-related dimensions of CDR — the core subject of this briefing. Current NDCs are recognised as insufficient for consistency with the Paris Agreement's long-term temperature goal. At the same time, CDR options raise questions of social acceptability and environmental sustainability, food security and feasibility of large-scale deployment amongst other issues. If Parties bring forward new and updated NDCs by 2020 that are substantially more ambitious in the reductions they will deliver for 2030, this can reduce future reliance on CDR options that are untested at scale.

What is also clear from Figure 2 is that the relative contribution of different CDR options, approaches and technologies differs substantially between these four pathways, depending on GHG emission levels in 2030. The primary CDR options built into the underlying models that limit warming to 1.5°C are BECCS and A/R (IPCC SR 1.5°C SPM at C3.1). Both BECCS and A/R are explicitly represented at a process level in the models. This means various vegetation types and their carbon-cycle characteristics are resolved, as are the life-cycle emissions of harvest and decay, as well as uptake by re-growth and efficiency of bioenergy as a feedstock for power plants. As illustrated in Figure 2, not only does the total cumulative CDR reliance increase depending on the 2030 emissions level, but also the share of BECCS in total CDR and in absolute terms.

Historically, most existing model scenarios rely largely on BECCS and A/R for CDR (Köberle, 2019), because these options have been studied the most, considered to be the most plausible and estimated to be cost effective at scale. However, as a result of concerns over the sustainability of large-scale biomass energy, the CCS components of BECCS[14] and A/R deployment (see section 4), as well as growing research on other potential CDR and decarbonisation options, the scientific community is starting to build in other options, including additional land-based approaches. The next generation of modelling will undoubtedly include a wider range of options, both land-based and technology-based, to expand the portfolio of approaches available to meet climate targets and sustainability boundaries. For example, the declining cost of renewable energy technology and related technologies have led to a resurgence of interest in DACCS, which may have cost-effective applications in high penetration renewable energy systems[15]. Enhanced weathering has also received recent attention (Beerling et al., 2020).

For 1.5°C-compatible[16] pathways in IPCC SR 1.5°C, annual rates of BECCS deployment range from 0-1, 0-8, and 0-16 $GtCO_2$/yr in 2030, 2050 and 2100 respectively, while A/R ranges from 0-5, 1-11 and 1-5 $GtCO_2$/yr in those years (IPCC 2018). By mid-century, values at the upper end of these ranges exceed the assessed potential for BECCS of up to 5 $GtCO_2$/yr and for A/R of up to 3.6 $GtCO_2$/yr, if sustainability concerns and land-use priorities are accounted for (Fuss et al, 2018).

At the higher end, potential CDR numbers are comparable in magnitude to the present-day net CO_2 uptake by the global terrestrial biosphere (due to natural processes rather than direct human impacts) of around 11 $GtCO_2$/yr (average for 2007-2016 (Le Quéré et al. 2018); 11.5 $GtCO_2$ for 2009-2018 (Global Carbon Project 2019)). To place these numbers into the context of human-induced emissions, the current net emissions from land use, land use change and forestry are about 5.5 $GtCO_2$/yr (IPCC 2019); these emissions will have to be brought to zero and then reversed in the next 1-2 decades. This is an important illustration of the scale of the CDR governance task.

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14 Köberle, 2019 also discusses the reliance of many model scenarios on large amounts of BECCS, and how this relates to model assumptions and structure, including assumed discount rates and technology constraints. For a historical perspective on BECCS see: https://www.carbonbrief.org/beccs-the-story-of-climate-changes-saviour- technology

15 Recent studies indicate potential for DACCS at scale (Wohland et al. 2018, Voskian and Hatton (2019) and indicate that direct air capture costs may decrease substantially with commercialisation (Fasihi et al. 2019). See https://www.carbonbrief.org/combining-renewables-with-direct-air-capture-for-net-negative-emissions

16 Meaning Paris Agreement-consistent pathways such as P1-P3 — but not "high-overshoot" pathways, such as P4, which relies on higher levels of CDR.

Avoiding or limiting overshoot will be essential to minimise climate change impacts. High-overshoot pathways, such as the P4 pathway mentioned above, return warming to 1.5°C by 2100, but achieve this after an overshoot to as much as 1.8°C, which is clearly not "well below 2°C" as specified in Paris Agreement Article 2.1 and would be associated with climate risks, impacts and damages close to 2°C. These pathways are therefore not compatible with the Paris Agreement long-term temperature goal. Indeed, IPCC SR 1.5 SPM notes:

> "*Future climate-related risks depend on the rate, peak and duration of warming. In the aggregate they are larger if global warming exceeds 1.5°C before returning to that level by 2100 than if global warming gradually stabilises at 1.5°C, especially if the peak temperature is high (e.g., about 2°C) (high confidence).*"

We draw four key conclusions from this brief assessment:

1. Substantial amounts of CDR will likely be needed over the remainder of the 21st century even if NDCs are ratcheted up substantially, given insufficient global mitigation action to date.
2. An even more significant contribution from CDR would be needed if NDCs were only modestly ratcheted up; if NDCs were ratcheted up only marginally, limiting warming to 1.5°C without a substantial overshoot for an extended period of time may be out of reach completely.
3. A broad portfolio of CDR options would be required to meet the overall need for CDR, to avoid dependence on any single option that would have its own limitations at scale and/or insurmountable sustainability concerns at larger scale.
4. CDR activities and technologies will need to be rolled out sooner rather than later, as delay in deployment and hence capacity to rapidly scale-up a portfolio of options creates substantial future risk due to policy failure and the need to compensate for carbon cycle feedbacks such as melting permafrost (Comyn-Platt et al., 2018) or heat and drought induced loss of carbon from the terrestrial biosphere.

2) How do current provisions under the UNFCCC, Kyoto Protocol and Paris Agreement address removals?

International governance for CDR currently lies largely under the UNFCCC and its related processes. Decisions taken under the UNFCCC provide for the use of IPCC guidelines for the development of GHG inventories, IPCC guidelines in turn address reporting on anthropogenic removals in the land sector, and CCS in the energy sector. Decisions taken under the Kyoto Protocol for its two commitment periods (2008-2012 and 2013-2020) set out how removals in the land sector contribute to emission reduction targets ("accounting") for Parties with Kyoto targets.

However, these provisions were not designed for the scale of removals required for the Paris Agreement's long-term temperature goal, nor are they appropriate for all potential options for CDR. The adoption of the Paris Agreement and the release of the IPCC's SR 1.5°C brings new focus on the need for international governance of CDR that addresses the potential scale of CDR in fulfilling the objective of the Paris Agreement, and on existing governance gaps in global measuring, reporting and accounting systems.

The rules being developed under the Paris Agreement draw from the differing provisions related to removals under the UNFCCC and Kyoto Protocol, but also break new ground. It is useful to consider the legacy effects of these different rule sets, including the gaps they have created, for example, between developed and developing country inventory reporting of removals, as well as the particular challenges these rule sets have created, some of which have never been satisfactorily resolved (Carton et al, 2020). This section describes existing provisions under the UNFCCC, the Kyoto Protocol and the Paris Agreement, noting the existing challenges for assessing whether progress is being made toward a balance between anthropogenic emissions and removals, either at the country or collective level. It then very briefly identifies specific IPCC reporting guidance related to A/R, BECCS and CCS.

1. UNFCCC reporting on emissions and removals

The UNFCCC requires all Parties to *"[p]romote sustainable management, and promote and cooperate in the conservation and enhancement of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol, including biomass, forests and oceans, as well as other terrestrial, coastal and marine ecosystems"* (Art 4.1(d)). Each Party is required under Article 4 to regularly communicate a national inventory of anthropogenic ***emissions by sources*** and ***removals by sinks*** using comparable methodologies, and each Party reports its inventory both including the land sector and excluding the land sector. The UNFCCC places differentiated reporting obligations on developed countries, in recognition of their national capacities and circumstances.

Since 2015, developed countries ("*Annex I*" Parties) have been required to report their GHG inventories annually, using the **2006 IPCC Guidelines,** as well as ***the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories***, and the ***IPCC Good Practice Guidance for Land Use, Land-use Change and Forestry (GPG-LULUCF)***.[17] Emissions are reported on a gas by gas basis, on at least seven GHGs and families of gases, in tonnes of CO_2-equivalent

17 Decision 24/CP.19

emissions, applying 100-year global warming potential (GWP-100) values from the IPCC's Fourth Assessment Report.[18] Emissions and removals are allocated to different source and sink categories according to prescribed Common Reporting Format tables.[19] Emissions by sources are listed separately from removals by sinks, except in cases where it may be technically impossible to separate information on sources and sinks, for example, in some carbon pools reported under Land use, Land-use Change and Forestry (LULUCF). Reporting on the land sector under the Convention by Annex I Parties is "comprehensive", meaning that all categories of land use and all carbon pools are to be reported (Iversen et al., 2014).

Periodic Annex I Party National Communications, containing national GHG inventories and descriptions of adopted policies and measures, are supplemented by **Biennial Reports (BRs)**. In BRs Parties report on progress made in achieving their quantified economy-wide emission reduction targets under the Convention and provide emission projections for 2020 and 2030.[20] Parties are asked to state the role of LULUCF in their base year and target year (included or excluded), and whether the contribution of LULUCF is calculated using a ***land-based approach, activity-based approach or other specified approach***,[21] acknowledging the difference in accounting treatment applied by Parties under the Convention and those Convention Parties that are also Annex B Parties to the Protocol. National GHG Inventories and biennial reports are subject to technical reviews.

Developing countries ("*Non-Annex I Parties*"), in contrast, submit GHG inventories every four years,[22] and update these inventories every two years through **Biennial Update Reports (BURs)** which also include information on their mitigation actions.[23] Inventories are to be no older than four years prior to the year of submission, with more recent years submitted if available.[24] Least developed country Parties and small island developing States may submit BURs at their discretion.[25]

Developing country inventory updates use the IPCC's **1996 Guidelines** and ***GPG-LULUCF.*** Most developing countries use global warming potential (GWP) values from the IPCC's Second Assessment Report. Developing countries are encouraged to use tabular reporting formats for the land sector but are not required to produce information in an equivalent format as that for developed countries, or at a similar level of detail.[26] Those developing countries that aim to receive "***results-based finance***" for mitigation efforts related to Reducing Emissions from Deforestation and Forest Degradation and related measures (REDD+) apply specific REDD+ guidance, which addresses, among other issues, a range of sustainability concerns.[27] Unlike developed country inventories and BRs, which undergo a technical review, developing country inventories and BURs are subject to technical analysis.[28]

Differences in reporting and review obligations for developed and developing countries under the Convention have presented a fundamental challenge for any assessment of progress toward global goals. Inventory data still cannot be readily aggregated across all Parties due to a series of issues. These include: different reporting requirements for developed and developing country Parties; use of different IPCC reporting guidelines (2006 and 1996); application of different GWPs to the underlying GHG data reported; different frequency of inventory reporting; different treatment of the land sector by developed and developing countries (land-based v. activity based for Kyoto Parties); and the absence of common reporting format tables used by all Parties (Annex I Parties use Common Reporting Format software consistent with Annex I reporting guidelines and Kyoto land sector accounting rules; developing countries do not use this common software). The Paris Agreement's

18 Decision 24/CP.19, Annex III
19 Decision 24/CP.19, Annex II.
20 Decision 2/CP.17, Annex I.
21 Decision 19/CP.18, Annex, Table 2(d).
22 Decision 1/CP.16, para 59.
23 Decision 2/CP.17, Annex III.
24 Decision 2/CP.17, para 41.
25 Decision 2/CP.17.
26 Decision 2/CP.17.
27 See, e.g., Decisions 1/CP.16, 2/CP.17, 12/CP.17, 9/CP.19, 10/CP.19, 11/CP.19, 12/CP.19.
28 Decision 2/CP.17, Annex IV.

enhanced transparency framework aims to narrow this divide.

The absence of equivalent coverage and treatment for the land sector across different countries, as well as across other inventory categories, is a challenge to adequate governance of CDR measures globally. To understand the quantum of CDR planned and underway across the full range of sectors requires comparable levels of reporting, to enable country-based and aggregated assessments.

2. Kyoto Protocol provisions related to the land sector and CCS

Accounting rules have been negotiated for two Kyoto Protocol commitment periods, a first commitment period that ran from 2008-2012 and a second running from January 1, 2013 through December 31, 2020 (see decision 1/CMP.8 (the "Doha Amendment").

Reporting and accounting rules for the land sector

The Kyoto Protocol takes an "activity-based" approach to the land sector for Parties with quantified mitigation targets, as contrasted with the Convention's comprehensive "land-based" approach for developed country Parties.

Under the Protocol, Parties with quantified mitigation targets have agreed to reduce or limit their future emission levels relative to their base year emission levels over fixed commitment periods. In accounting for their targets, Parties are required to add to their sectoral emissions (from energy, industrial processes and solvent use, agriculture, waste) their net changes in emissions by sources and removals by sinks from direct human-induced land-use change and forestry activities, with these activities limited, under Article 3.3 of the Protocol, to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks in each commitment period. Under Article 3.4 of the Protocol, Parties were permitted to also elect to include net emissions and removals from certain additional "activities" — ***forest management, cropland management, grazing land management and revegetation*** — if they so chose in the first commitment period. This list was expanded in the second Kyoto commitment period (2013-2020) to make forest management a mandatory activity for accounting purposes, and to include wetlands drainage and rewetting as another activity which could be elected for accounting by Parties, in a move toward more inclusive coverage.[29]

In effect, Protocol Parties were given the flexibility to use net removals from mitigation efforts in the land sector to offset emissions in other sectors of their economies. Parties with net removals could issue "*removal units*" (RMUs) that they could use to offset emissions in other sectors for purposes of complying with their quantified targets. However, due to concerns with estimation uncertainties in the land sector, and concerns that net removals achieved in a given period might be re-emitted into the atmosphere, limits were placed on the amount of units that could be used for demonstrating compliance and Parties were prevented from carrying over surplus units to use against future quantified targets.[30] So while the Kyoto Protocol accounting system provided ***incentives*** to Parties to undertake activities in the land sector, these incentives did not aim to deliver net emission reductions and were also limited as a result of concerns around permanence, leakage and estimation uncertainties.

LULUCF accounting rules for the first commitment period were criticised among other things for not offering sufficient incentives in the forest sector, and for creating accounting loopholes that undermined environmental integrity by permitting asymmetric accounting — allowing Parties to choose to include only beneficial activities (Krug, 2018). In partial response, rules for the second commitment period made forest management accounting a mandatory activity.[31] To accommodate

29 *See Kyoto Protocol second commitment period User-friendly document Consolidated decisions from the second commitment period* 23 February 2016, available at https://unfccc.int/sites/default/files/kp_2nd_cp_userfriendly_doc_23feb2016_final_2.pdf

30 Kyoto Protocol Reference Manual (UNFCCC) at 98; Krug (2018).

31 See Decisions 1/CP.16 and 2/CMP.7, setting out accounting rules for the LULUCF sector for the KP second commitment period.

different national circumstances (such as harvesting cycles or legacy effects of previous management), Parties were permitted to propose "*forest management reference levels (FMRLs*)" against which they would compare their performance.[32] FMRLs were established using a variety of approaches, but all were subjected to technical review. While FMRLs provided an incentive structure for forest-based mitigation that had been lacking in the first commitment period, they also allowed some anthropogenic emissions included under these reference levels to go unaccounted towards national emissions targets.

Under the Protocol, Parties report and account for emissions and removals from carbon stocked in harvested wood products (HWPs), such as timber and fuelwood. Parties are permitted, under certain conditions, to exclude from accounting emissions from natural disturbances (e.g., provided they do not account for subsequent removals in the land they excluded from accounting due to natural disturbance), under the rationale that emissions from natural disturbances do not reflect human intervention. Under Protocol rules, emissions from HWPs are reported and accounted for by the producing country. Where HWPs are moved across borders between two Kyoto Protocol Parties with quantified emissions targets, imported HWPs are not accounted for by the importing country, to avoid double-counting.[33]

The asymmetric accounting possibilities created under the Kyoto Protocol, via the activity-based approach for land accounting, if allowed to propagate under the Paris Agreement, would create serious challenges for the adequate governance of CDR activities globally. Structural asymmetric accounting creates the possibility, and indeed the incentive, for Parties to count only beneficial activities (carbon storage) and omit activities that lead to CO_2 releases. Under the Kyoto Protocol architecture this can occur for a variety of reasons, including the choice of activities reported, the timing of this reporting, and the discounting of natural disturbance-induced carbon losses from managed land for which credits have already been accounted.

Project-based mechanisms under the Kyoto Protocol

The Kyoto Protocol established two project-based mechanisms that provided ***further incentives*** for investment in A/R and CCS. Parties were allowed to use units representing emissions reductions achieved in other Parties toward their own emission reduction targets under two Articles: Article 6, which addressed transfers between Parties with quantified, binding emission reduction commitments (Joint Implementation (JI)); and Article 12, which addressed transfers between Parties with targets and developing countries without targets, the Clean Development Mechanism (CDM). Specific accounting methodologies for A/R project activities and for CCS activities were developed to address the unique accounting challenges of these approaches and to provide environmental and social safeguards in these two contexts.

Few Joint Implementation A/R projects have been registered,[34] in part because removals associated with A/R activities are potentially non-permanent, and it was agreed that the units resulting from these projects would only be valid for a specific period of time. Similarly, emission removals associated with CDM LULUCF projects were recognised to be at risk of being re-emitted into the atmosphere at a future date. As a result, it was agreed that the units resulting from these projects would be valid only for a fixed period of time and would have to be replaced with other units prior expiry.[35]

No CCS projects have ever been approved under the CDM, despite procedures to manage a range of physical and accounting risks, including risks of seepage and liability.[36]

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32 See Decisions 2/CMP.6 and 2/CMP.7.

33 Decision 2/CMP.7, para 26-27.

34 See UNEP DTU CDM Pipeline, http://www.cdmpipeline.org/cdm-projects-type.htm#1, accessed September 11, 2020 (A/R projects in developing countries constituted 70 projects in total, 0.8% of registered CDM project activities and 0.8% of issued certified emission reductions (CERs). A/R and avoided deforestation projects in developed countries constituted 3 projects in total and 0.4% of JI project activities. See http://www.cdmpipeline.org/ji-projects.htm

35 See Kyoto Protocol Reference Manual, available at https://unfccc.int/resource/docs/publications/08_unfccc_kp_ref_manual.pdf

36 See Decision 10/CMP.7.

The lack of uptake for these project types has been linked to unambitious Kyoto targets, related low demand for the emission removal units generated by A/R activities and certified emission reductions under the CDM, and lower than expected carbon market prices, which have contributed to a lack of incentive for deployment (Dixon et al., 2013). Accounting concerns and methodological issues have also contributed (Carton et al., 2020). The methodologies developed for A/R and CCS under the Kyoto Protocol are considered to be robust and highlight some of the governance challenges identified in this report for CDR.

3. Paris Agreement provisions related to emissions and removals

The *Paris Agreement*, adopted in 2015, now requires all Parties to communicate their NDC every five years, setting out their planned domestic mitigation efforts. Each successive NDC is to represent a progression beyond the previous NDC and represent highest possible ambition.[37] Developed countries are expected to take the lead by undertaking economy-wide absolute emission reduction targets; developing countries are encouraged to move over time toward economy-wide emission reduction or limitation targets.

Article 4 of the Paris Agreement requires Parties then to pursue domestic mitigation measures, with the aim of achieving the objectives of their NDCs. In addition, Article 5 of the Agreement specifically provides that **Parties should take action to conserve and enhance, as appropriate, sinks and reservoirs of GHGs**.[38] Parties are encouraged to "implement and support, **including through results-based payments**", policy approaches and positive incentives for activities relating to reducing emissions from deforestation and forest degradation (REDD), and relating to the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.

Because Parties were given little guidance on how to present their intended NDCs before adoption of the Paris Agreement, NDCs address the land sector in many different ways. Nevertheless, as under the Kyoto Protocol, ***each Party is required to account for its NDC target (Art. 4.13)***. What remains challenging, however, is that the Agreement contains no defined rules on what aspects of LULUCF need to be accounted, how they should be accounted, or which methods are to be applied (Krug, 2018). Under the guidance agreed in Katowice in 2018, Parties are to provide information on the approaches and assumptions used to account for emissions and removals in their NDCs, but this guidance stops short of indicating which approaches should be used (Fyson & Jeffery, 2019).

Article 4.13 does provide that "*[i]n accounting for anthropogenic emissions and removals corresponding to their nationally determined contributions, Parties shall promote environmental integrity, transparency, accuracy, completeness, comparability and consistency, and ensure the avoidance of double counting,*" in accordance with guidance to be adopted by the Parties to the Paris Agreement. These so-called "TACCC" principles (transparency, accuracy, completeness, comparability and consistency) have already been defined in developed country reporting guidelines under the Convention. Paris Agreement Parties have also agreed to account for anthropogenic emissions and removals in accordance with methodologies and common metrics assessed by the IPCC and adopted by the Parties to the Paris Agreement.[39] Parties are to strive to include all categories of anthropogenic emissions or removals in their NDCs, and once a source, sink or activity is included, Parties must continue to include it. Accounting guidance will only be mandatory in the second NDC period, though it may be applied voluntarily to Parties' first NDCs.[40]
The Paris Agreement maintains a clear distinction between the ***reporting of Parties' GHG inventories*** — including removals — on the one hand, and ***accounting for Parties' NDCs*** on the other. This distinction is particularly important because NDC efforts are not necessarily co-extensive

37 Article 4.3.

38 The UNFCCC defines "sink" as "any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere"; "reservoir" is defined as "a component or components of the climate system where a greenhouse gas or a precursor of a greenhouse gas is stored."

39 See Decision 1/CP.21, para 32.

40 Decision 1/CP.21, para 32; Decision 4/CMA.1, para. 14.

with national GHG emissions inventories. Many developing country NDCs, for example, are not economy-wide. Many do not encompass all inventory sectors or align with these sectors, many do not cover all Kyoto gases, and many do not present absolute reductions relative to a base year (Herold et al., 2018). Different metrics have also been presented to calculate NDC climate impacts. Significantly, not all NDCs specify whether their land sector is included, or if it is, how emissions and removals from the land sector will be accounted (e.g., through a land-based approach, activity-based approach or other) (Herold et al., 2018), or what quantitative contribution the sector might make (Fyson & Jeffrey, 2019; Sato & Nojiri, 2019). So while reported GHG inventories are expected to give a comprehensive picture of a Party's emissions and removals, at present, for many Parties, the specific emissions and removals that must be accounted toward these NDC targets under Article 4.13 remain unclear and will not be co-extensive with emissions inventories. These aspects make it challenging to aggregate these planned efforts to determine their future impact on emissions and removals.

With respect to reporting, the Paris Agreement has moved away from the previously distinct sets of guidelines for developed and developing countries. The Parties have adopted common guidance for reporting and review as part of the Paris Agreement's "*Enhanced transparency framework*", with built-in flexibility to take into account Parties' different capacities.[41] This new framework will supersede the existing framework as of 2024.[42] As part of this enhanced transparency framework, all Parties are required to provide national inventory reports at least biennially (though they are to maintain at least the frequency and quality of their reporting under the Convention[43] — thus annual inventories must continue to be presented by developed country Parties), and all Parties are required to provide information necessary to track progress made in implementing and achieving their NDCs.[44] Submitted information will be subject to a ***technical expert review*** and each Party will participate in a multilateral process that considers its progress in implementing and achieving its NDC. *A Capacity Building Initiative for Transparency* will support developing countries in meeting enhanced transparency requirements.[45] ***A Global Stocktake*** every five years will assess the overall effect of Parties' NDCs as well as collective progress in the context of the Agreement's global temperature increase limitation goal, to inform the ambition of Parties' successive NDCs.

As under the Kyoto Protocol, Article 6 of the Paris Agreement provides opportunities for using mitigation outcomes achieved in other Parties toward Parties' NDCs. Article 6 may prove to be an important channel for support for technological CDR options over time.

Parties have been mandated by decision 1/CP.21 to develop guidance under Article 6.2 for ***cooperative approaches***" that involve the use of internationally transferred mitigation outcomes toward NDCs. This guidance shall, among other things, ensure that double counting is avoided on the basis of a "corresponding adjustment" between Parties to reflect the accounting impacts of these transfers.[46]

Parties are also mandated to develop rules, modalities and procedures for the mechanism established under Article 6.4, that will contribute to emission reductions in one Party that may be used by another Party to fulfil its NDC. This mechanism shall aim to deliver an "*overall mitigation in global emissions*" (OMGE), which has been described as moving beyond the zero-sum offsetting approaches of the Kyoto Protocol. This is likely to require an accounting adjustment by host Parties for the full reductions achieved through mitigation activities, paired with a percentage discount or cancellation of the resulting units (see Schneider et al., 2018; Schneider and Warnecke, 2019), though agreement on Article 6 rules has not yet been reached.

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41 Decision 18/CMA.1, preamble and Annex, para. 4

42 Decision 18/CMA.1 at para. 3.

43 Decision 1/CP.21, para 92; Decision 18/CMA.1, Annex, para. 4.

44 Article 13.7; Decision 18/CMA.1, Annex, Part III. It is notable that LDCs and SIDS may submit required information at their discretion, under 18/CMA.1, Annex, para. 11

45 Decision 1/CP.21, paras. 24-25; 18/CMA.1, preamble and para. 7.

46 Decision 1/CP.21, para 36.

4. Challenges for assessing progress towards the Paris Agreement long-term temperature goal

The Paris Agreement takes a step forward, moving to more regular inventory reporting by all Parties, accounting by all Parties and a process for the aggregation of GHG inventories and efforts across both developed and developing Parties (Mace, 2016). This aggregation of GHG inventories to the global scale, as well as aggregation of the effects of policies and NDCs, is critical to assessing progress towards the Paris Agreement's long-term temperature goal and critical for assessing whether GHG anthropogenic emissions and removals are progressing globally towards the balance needed by around 2070. Significant challenges nonetheless remain for aggregation at the country and collective levels:

- **Current NDCs are presented with different timeframes, use a range of reference years and apply different GWPs —** and there is no guidance yet in place for common timeframes or common features of future NDCs.
- **NDCs are not yet co-extensive with GHG inventories —** although all Parties are to move to economy-wide NDCs over time, many Parties' NDCs cover only a subset of their GHG emission profiles, NDC sectors may not map on to inventory sectors neatly, and NDCs often lack a clear articulation of their relationship with Parties' inventories.
- **Party inventories do not cover all gases within the scope of the Paris Agreement -** developing countries retain flexibility to report only a subset of gases, depending on their capacities.
- **GHG inventories do not cover all emissions within the scope of the Paris Agreement —** the Agreement implicitly covers emissions from international aviation and maritime transport, but systems are needed to ensure that these emissions are included in assessing progress toward Paris Agreement goals, and that the same emission reductions are not counted under multiple treaty processes, undermining treaty aims (e.g., counted in national GHG inventories under the Paris Agreement and also as offsets by aviation operators under International Civil Aviation Organization's (ICAO's) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), which aims to maintain international aviation emissions at 2020 levels).
- **There are no common accounting approaches for the land sector —** some NDCs do not address the land sector, or present un-quantified policies and measures in the land sector. Where the land sector is clearly included, it is not always apparent how Parties intend to account for land sector emissions and removals, Common accounting approaches for the land sector have yet to be agreed, and while the rulebook agreed in Katowice contains guidance for Parties to explain their accounting methods, it stops short of specifying common approaches that would increase comparability across countries and help to prevent double counting of removals.
- **Asymmetries in accounting persist —** in the absence of a requirement to present economy-wide NDCs, some developing countries have included in their NDCs activities or measures that are likely to result in emission reductions and removals, while omitting other activities that may result in emissions. Parties may also gain credit for removals that take place on "managed land", regardless of whether those removals were the direct result of human activity, while also being permitted to discount emissions from the same land if it is subject to 'natural disturbances (e.g., wildfires, infestation).
- **NDC accounting guidance will remain voluntary for the first NDC period —** though Parties are required to account for their NDC-related emissions and removals under Article 4.10.
- **Some reporting elements only become mandatory in the Biennial Transparency Reports that are required from 2024 –** or are only required for Parties' second NDCs, which for some Parties may not take effect until 2031.
- **Time lags in reporting and review —** all Parties are to present inventories with a latest reporting year no more than 2 years prior to the submission of their national inventory reports (NIRs); developing countries that need flexibility may provide inventory data for year X-3 from the year of submission. Incomplete inventory data for a given year may contribute to delays in aggregating inventory figures and efforts to plug gaps with external data may or may not be successful or accepted. Reviews of inventories and progress reports may also be delayed or become out of synch, due to the number of Parties involved.
- **'Emission balances' and 'structured summaries' —** tools have been identified for tracking

progress in the implementation and achievement of NDCs, but Parties have yet to agree on a format for these reporting tools. Parties have also been permitted to select their own indicators of progress, provided these indicators are relevant to their NDCs. These indicators may be either qualitative or quantitative.[47] As a result, these indicators may not in all instances provide information useful for quantification and aggregation.

- **Common reporting formats** — common formats and tables can facilitate calculation of progress toward net-zero emission levels at the national and international levels, but are not required of all Parties' inventories.
- **Capacity challenges** — many developing countries face capacity challenges in producing regular, reliable and complete GHG inventories; how the necessary flexibility will be built into the enhanced transparency framework has yet to be established.
- **Potential for double counting** — In the absence of robust accounting rules, potential exists for emission reductions to be counted by multiple Parties, multiple stakeholders, multiple programmes and possibly multiple treaty processes (for example, in offsets under Article 6, or in connection with ICAO's CORSIA).
- **2050 net-zero low emission strategies** — Parties have been invited to submit 2050 strategies by 2020, but few Parties have done so. These strategies can be an opportunity to present timeframes for the achievement of carbon neutrality and negative emission goals, while at the same time addressing sustainability and governance issues.

5. IPCC Guidelines relevant to A/R, CCS and BECCS

The IPCC provides the scientific authority for national GHG inventories under the Convention and reporting under the Kyoto Protocol and has a Task Force on National GHG Inventories for this purpose.[48] The IPCC has responded to reporting and accounting needs under the Convention and Kyoto Protocol through considerable guidance to support Parties in reporting on their land sector emissions and removals, as well as in reporting on CCS and bioenergy. See Table 2 below. However, guidance has not yet been provided for reporting net removals from DACCS or from other more novel forms of CDR, though some methodological work has begun on biochar.[49] IPCC guidance aims to support Parties in the production of more detailed and accurate GHG inventories, reflecting the best available science.

Beyond providing reporting guidance, the IPCC has assessed the available literature on CDR in its previous five assessment reports, in the IPCC SR 1.5°C and most recently in the IPCC *Special Report on Climate Change and Land* (IPCC, 2019). The IPCC has also started work on the *Sixth Assessment Reports*, which will include an assessment of information on potentials, governance, risks and impacts of GHG removal techniques, as well as a chapter on international cooperation that will cover "*transparency and accountability frameworks*".

This section provides a brief outline of existing IPCC guidance as well as the anticipated products from the ongoing Sixth Assessment Cycle that are relevant for CDR governance.

Afforestation / Reforestation and the land sector

As described above, under the Paris Agreement, all Parties will now be required to use the 2006 IPCC Guidelines for their first BTRs and importantly, each "shall use any subsequent version or refinement of the IPCC guidelines agreed upon by the [CMA].[50] Each Party is also "encouraged" to use the 2013 Wetlands Supplement.

The 2013 Wetlands Supplement fills gaps in the 2006 Guidelines, updating emission factors and covering inland organic soils and wetlands on mineral soils, coastal wetlands including mangrove forests, tidal marshes and seagrass meadows and constructed wetlands for wastewater treatment. This will create more consistency in land sector reporting.

47 Decision 18/CMA.1, Annex, para. 65.

48 https://www.ipcc-nggip.iges.or.jp

49 See IPCC 2019 Refinement

50 Decision 18/CMA.1, Annex, para. 20.

The IPCC SR 1.5°C includes a definition of CDR, which is helpful in addressing the challenge of distinguishing between anthropogenic and non-anthropogenic removals. This definition - set out in the introduction above - clearly states that CDR comprises *anthropogenic* activities, and does not include any indirect CO_2 uptake (for example, due to the higher CO_2 concentrations in the atmosphere) or any outgassing from ocean and terrestrial reservoirs, due to a decrease in these concentrations), although these indirect effects do have an impact on the amount of CDR required in modelled scenarios.[51]

The 2019 IPCC *Special Report on Climate Change and Land* (SRCCL) (IPCC, 2019) explores the mechanisms behind CO_2 removals in the terrestrial biosphere and provides an updated assessment of the role of land in meeting the Paris Agreement objectives. It includes a chapter on Land-Climate interactions (Chapter 2), which addresses the mitigation potential of a number of CDR options in $GtCO_2$/year (see Figure 2.24) as well as the potential biophysical impacts of land cover change on regional surface temperatures (through changes in water and energy exchange). Additionally, Chapter 6 assesses interlinkages between desertification, land degradation, food security and GHG fluxes, and speaks to a range of CDR options and integrated policy responses. Chapter 7 looks at risk management and decision-making in the context of sustainable development and includes a discussion of the risks associated with BECCS as well as existing policy instruments for land-based mitigation.

Carbon Capture and Storage

The Revised IPCC 1996 Guidelines, which are referenced in the Non-Annex I reporting guidelines and BUR guidelines, do not explicitly mention GHG storage, but allow for it to be addressed.[52] The 2006 IPCC Guidelines, which will now be used by all Parties to the Paris Agreement, explicitly cover carbon capture and storage in a dedicated chapter of the volume on energy.[53]

In 2005, the IPCC's Special Report on CCS considered whether CCS should be accounted for on the side of emissions, with CCS systems treated as ***mitigation options*** to reduce emissions to the atmosphere, or as ***sink enhancements*** by analogy to the treatment made to CO_2 removals by sinks in the LULUCF sector (Metz et al., 2005).[54] The first option was considered to offer transparency benefits, because it would enable emissions from captured CO_2 to be tracked through capture, transport, injection and storage, tracked from many sources and tracked across borders. It was also recognised that the second option would require new definitions not available in the UNFCCC or the framework for preparing inventories.[55]

As a result, under the IPCC 2006 Guidelines, emissions from industrial processes and energy that are captured may be reported as "*not emitted*", provided they are subsequently stored and subjected to long-term monitoring and reporting.[56] The 2006 Guidelines provide that captured emissions from industrial processes and energy should be allocated to the sector generating the CO_2, unless it can be shown that the captured CO_2 is stored in properly monitored geological storage sites to provide assurances over the permanence of storage. Where IPCC Guidance on monitoring is followed, captured and stored CO_2 may be reported as not emitted. The volume of CO_2 captured is reported as a memo item in the common reporting format (CRF) sectoral report on energy, but is not counted toward emission totals. Reporting on CO_2 capture is broken down into, "for domestic storage" and "for storage in other countries." Parties report on Table 1.C as information items the total amount captured for storage, total amount of imports for storage, total amount of exports for storage, total

51 For every tonne of CO_2 emitted by burning fossil fuels, about half ends up in the atmosphere, while the rest is distributed between the oceans and terrestrial biosphere. When CO_2 is removed from the atmosphere, this process goes into reverse: CO_2 concentrations in the atmosphere drop, causing some outgassing of CO_2 from the oceans and terrestrial biosphere (Jones et al., 2016). Hence the total CO_2 removed from the atmosphere will necessarily be less than the amount of CO_2 sequestered by CDR deployment. In modelled scenarios, the amount of CDR required takes into account the impact of outgassing (as well as changes in atmospheric CO_2 concentrations).

52 See 2006 Guidelines, Vol. 2, Chapter 5.

53 IPCC Special Report on CCS Chapter 9, at 366-67.

54 Id at 367.

55 Report to the IEAGHG — GHG Accounting for Bio CCS at 17, citing IPCC Vol. 1, Ch.1, p 1.6.

56 Recycled carbon dioxide (CO_2) for enhanced recovery is excluded from CO_2 transported or injected.

amount of CO_2 injected at storage sites, and total leakage from transport, injection and storage.[57]

Where a mixed fuel with both biogenic and fossil fuel origins is combusted, emissions are to be allocated, with the fossil fuel portion reported in the national emissions total and the biogenic portion reported as a memo item. Where CO_2 from biomass and CO_2 from fossil fuel emissions are combined for storage, no distinction is made between the two in accounting. Emissions and storage of both biogenic and fossil carbon will be estimated and reported as memo items in the sectoral report on energy.[58] In the case of re-release, both are counted in the same way, as tonnes emitted. In this way, the negative emissions that would otherwise have been recorded from BECCS upon storage are reversed from an accounting perspective upon re-release.

It is IPCC good practice to treat capture and storage on a per plant or facility basis. Project level guidance was made available in connection with the Kyoto CDM, by Decision 10/CMP.7, which addresses, among other things, site selection and characterisation of geological storage sites, risk and safety assessments, environmental and socio- economic impact assessments, monitoring requirements, and systems to account for net reversal of storage (non-permanence).

As there are no DACCS reporting guidelines, this could be a good area for IPCC engagement.

Biomass energy and CCS under current IPCC Guidelines

BECCS reporting is complicated by the fact that reporting and accounting implicate more than one sector in Parties' GHG emission inventories (e.g., LULUCF and energy, LULUCF and industrial processes, agriculture and energy) and different feedstocks have different carbon intensities when combusted.

The IPCC 2006 Guidelines affirmatively recognise negative emissions from BECCS, noting that "*Negative emissions may arise from the capture and compression system if CO_2 generated by biomass combustion is captured. This is a correct procedure and negative emissions should be reported as such.*"[59]

A zero emissions factor is applied to biomass combustion. As a result, emissions from biomass combustion are not counted toward energy sector emissions. The CRF tables currently used by developed countries for inventory reporting treat **CO_2 emissions from biomass** combustion as a memo item; these emissions are not counted toward energy sector emission totals.[60] The zero-emissions factor applied to biomass results from a set of assumptions that have been heavily critiqued: that emissions from biomass will be reported in the LULUCF sector at harvest, that biomass is produced in a sustainable manner, and that where biomass is harvested at an unsustainable rate, net CO_2 emissions will be reflected and reported for as a loss of biomass stocks in the LULUCF sector. These assumption may not be valid, for example, if combusted biomass originates in a country that reports land sector emissions using default emission factors (i.e., tier 1), that produce a less accurate estimate than use of country-specific emission factors, such that emissions at harvest are not fully reported.

Under the 2006 Guidelines, which will apply to all inventory reports submitted from 2024, biomass-related CO_2 emissions are to be reported under the LULUCF sector. While **reporting** by Parties is intended to be comprehensive, ***lifecycle accounting*** for biomass impacts may not be comprehensive if these countries fail to account for certain LULUCF activities, or if they source biomass from developing countries that do not provide inventory reports on their land sector emissions annually, or report using a tier 1 approach. Gaps in reporting raise the possibility that the GHG **benefits** of BECCS may count towards GHG commitments of some Parties, while the ***disbenefits of using more carbon intensive biomass*** in BECCS are not visible in reporting, where they should be eroding negative emissions. This mismatch has increasing significance in the context of large-scale BECCS.

57 See CRF Table 1 Sectoral Report on Energy, n. 1 and CRF Table 1.C Sectoral Background Data for Energy n. 4.

58 2006 IPCC Guidelines at Vol. 2, Ch. 5, 5-8.

59 Table 1, Sectoral Report for Energy, n. 1.

60 Table 1, Sectoral Report for Energy, n. 1.

The challenge of fully accounting for emissions from bioenergy is not specific to BECCS, but also applies to bioenergy without CCS and the challenges appear likely to be at a similar scale with or without the deployment of CCS coupled to bioenergy. The use of bioenergy has been assessed to be competitive enough to lead to large-scale deployment by 2100 even without any climate mitigation incentives, at a level of deployment comparable to levels reached in 1.5°C and 2°C compatible scenarios by 2050. Critically, this means that reporting and sustainability issues in relation to a growing share of bioenergy in the global energy mix are therefore not a problem unique to 1.5°C scenarios, and need to be addressed under any scenario, with or without CDR.

The IPCC's 2019 Refinement to the 2006 Guidelines includes a refinement to guidance for reporting emissions from harvested wood products used for energy generation (Chapter 12, section 12.5). This is relevant for BECCS reporting where the feedstocks are forest residues, depending on the reporting approach used, CO_2 emissions from bioenergy production could be reported in either the country of harvest or the country where the energy production takes place, while non-CO_2 emissions from bioenergy production are reported in the energy sector of the country where bioenergy production takes place (see table 12.5). As in previous guidance, the 2019 Refinement emphasizes that the use of different approaches to report emissions from harvested wood products by different countries can lead to emissions being double counted or not counted at all.

Table 2: Existing provisions

UNFCCC, Kyoto Protocol and Paris Agreement contexts		Selected provisions*	Key points
Existing provisions from which lessons can be learned	UNFCCC	• Annex I Reporting Guidelines (Decision 24/CP.19) • Non Annex I Reporting Guidelines (Decision 17/CP.8) • Biennial reporting and review guidelines for developed and developing countries (Decision 2/CP.17) • REDD+ (Decisions 1/CP.16, 2/CP.17, 12/CP.17, 9/CP.19, 10/CP.19, 11/CP.19, 12/CP.19)	Gaps and differences between UNFCCC and Kyoto Protocol provisions form a starting point for the Paris Agreement rule-book and highlight the need to move towards consistent and comparable GHG inventories and robust accounting rules for all Parties
	Kyoto Protocol	• Land use, land use change and forestry (Decisions 16/CMP.1, 17/CMP.1, 18/CMP.1) • Afforestation and reforestation under CDM and sink enhancement under JI (Decisions 5/CMP.1, 9/CMP.1, 13/CMP.1, 15/CMP.1) • CCS as CDM project activities (Decisions 10/CMP.7, 5/CMP.8) • The Cancun Agreements: Land use, land use change and forestry (Decision 2/CMP.6) • Second commitment period (Decisions 2/CMP.7, 1/CMP.8, 2/CMP.8, 5/CMP.8)	

Paris Agreement provisions to be built upon	Land sector	• Decision 1/CP.21 • Articles 4, 5, 13, 14 • Decision 4/CMA.1 • Decision 18/CMA.1	Robust reporting and accounting guidance for NDCs needed as part of an effective CDR governance architecture. This includes robust accounting rule for Article 6 transfers, land sector accounting rules and an effective Global Stocktake.
	Assessment of progress toward temperature goal / balance between emissions and removals	• Decision 1/CP.21 • Articles 2, 4, 13, 14 • Global Stocktake (Decision 19/CMA.1) • Transparency Framework (Decision 18/CMA.1) • Further Guidance in relation to the mitigation section of decision 1/CP.21 (Decision 4/CMA.1)	
	Transfers between Parties	• Decision 1/CP.21 • Articles 4, 6, 13	Robust accounting rules needed for Article 6 market-based transfers to avoid double counting, ensure environmental integrity and ensure transparency, including in governance.
Existing IPCC guidelines to be built upon	IPCC Guidelines relevant to A/R, CCS and BECCS	• Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories • IPCC Special Report on Land Use, Land-use Change and Forestry, 2000 • Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 2000 • IPCC Good Practice Guidance for Land Use, Land-use Change and Forestry, 2003 • IPCC Special Report on Carbon Capture and Storage, 2005 • 2006 IPCC Guidelines for National Greenhouse Gas Inventories • 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands • 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories • IPCC The Special Report on Climate Change and Land, 2019	Additional guidance is needed for reporting lifecycle emissions and removals from bioenergy (with and without CCS) and DACCS.
* This listing is not intended to be inclusive, but rather to point to key decisions, provisions and documents.			

3) What governance gaps and challenges exist for CDR at scale?

The central governance challenges for CDR stem from at least four key issues:

- The **scale and speed of implementation required,** and the associated challenges for research and development and for monitoring deployment;
- The **substantial incentives** that will be needed to scale-up potential CDR options, as sufficient incentives do not at present exist under the UNFCCC or other legal frameworks;
- The **trade-offs between, and interactions with, a range of SDGs** (e.g., food security, water security) that may follow from large-scale implementation intended to achieve climate ends; and
- The **risks to the climate system and to the SDGs that will follow if CDR options are not implemented at the pace or scale required,** or if large-scale reversals follow large-scale CDR efforts.

Existing provisions and guidance under the UNFCCC, Kyoto Protocol and Paris Agreement already cover a number of governance issues related to CDR (monitoring, reporting, verification of removals). However, a number of governance challenges remain, and some CDR options have received no specific attention under these frameworks or in the IPCC's reporting guidance (e.g., in what sector should CO_2 capture related to DACCS be reported?).

This section identifies t**en key governance challenges** for the implementation of large-scale CDR:

1. Rapid pace of CDR scale-up required to limit warming to 1.5°C
2. Responsibility and ethics of implementation
3. Access to information needed to monitor progress
4. Safeguards for sustainable development
5. Challenges for measuring, reporting and verifying CO_2 removals
6. Issues of storage: permanence, leakage and saturation
7. Planning for and monitoring the biophysical effects of deployment
8. Liability and redress
9. Incentives for CDR deployment
10. Public awareness and acceptance

1. Rapid pace of CDR scale-up required to limit warming to 1.5°C

By 2050 the median amount of CDR in 1.5°C compatible pathways is 7 $GtCO_2$/yr. This scale creates an imperative for a rapid transition from early stages of development to demonstration and deployment. In particular, the earlier deployment of afforestation or bioenergy has been shown to be beneficial in the long run for minimising the extent of land required for bioenergy deployment (Hanssen et al., 2020; IPCC 2019). However, many potential CDR options are at a low level of technology readiness, and it may take decades to achieve widespread deployment for these options (Lomax et al., 2015). Most literature to-date has focused on the start of the innovation process, rather than on demonstration and scale-up (Nemet et al. 2018). **Incentives are needed in the near-term for research and development, to boost learning-by-doing and advance less mature options to higher levels of maturity (Lomax et al. 2015).**

The **IPCC SR 1.5ºC** identifies at Table 4.13 a series of knowledge gaps and uncertainties that remain in connection with the scale of CDR required in 1.5°C consistent pathways (IPCC, 2018). These include assessments of environmental aspects for some CDR options; the need for bottom up regional studies on realistically available and sustainable removal potentials, taking into account social issues; issues of governance and public acceptance; impacts of large-scale CDR on the carbon cycle; potential to accelerate deployment and upscaling; and means of incentivisation (IPCC, 2018). The IPCC Special Report on Climate Change and Land (SR CCL) also notes significant gaps in knowledge exist when it comes to understanding the effectiveness of policy instruments and institutions related to land use management, forestry, agriculture and bioenergy (IPCC, 2019). Many of these challenges are expanded upon below.

2. Responsibility and ethics of implementation

The IPCC SR 1.5°C has laid out clearly that delaying mitigation now is not an option. The potential availability of CDR options in the future cannot be used to replace near-term inaction without exposing future generations to intolerable risks associated with both climate change impacts from substantially overshooting 1.5°C as well as the risks from very large-scale CDR (Kachi, et al. 2019, McLaren 2020, Shue, 2018). Instead, rapid near- term emissions reductions are needed across all sectors, and this mitigation effort needs to be complemented by the development and deployment of sustainable CDR options. Nevertheless, experiences from the Kyoto Protocol demonstrate that sinks have been used in the past to delay near-term mitigation (Carton et al., 2020). Moreover, the fact that some CDR will be needed, and that the total amount needed will depend on the degree of near-term mitigation, raises questions of distributional and intergenerational equity: who should shoulder the CDR burden, and how can the potential negative impacts associated with CDR deployment be reduced for current and future generations?

Parties to the Paris Agreement have not mentioned BECCS or other technological CDR options in their NDCs, and only a few (about 14) refer to CCS or to CO_2 transport and storage.[61] A number of NDCs do mention A/R activities or other forms of land restoration, pointing to the importance of these activities as mitigation options in the near-term. Several long-term strategies submitted by Parties to the UNFCCC process[62] or announced outside the process do include reference to the need for CDR or negative emissions, either explicitly, implicitly, in reference to Paris Agreement Article 4.1, or in reference to neutrality targets (Kachi, et al., 2019). However, these references do not address governance issues.

To date there has been no clear assignment or acknowledgement of responsibility for development and deployment of CDR options among Parties to the UNFCCC and/or Paris Agreement. The model pathways used to understand global CDR needs distribute CDR deployment in a cost-optimal manner, without tackling the question of who should pay for it. However, recent literature has highlighted the need for ethical considerations to be taken into account when developing mitigation scenarios (Carton et al. 2020; Lenzi et all, 2018; Minx et al., 2018) and two recent analyses have shown that using an equity-based burden-sharing system to share

61 See Paris Reality Check: https://www.pik-potsdam.de/primap-live/indcs-carbon-capture-and-storage/

62 https://unfccc.int/process/the-paris-agreement/long-term-strategies accessed 22 October, 2018.

responsibility for CDR yields a substantially different regional distribution from those provided in least-cost model pathways (Pozo et al 2020; Fyson et al. 2020). Such equity-based distributions can also shed light on how delaying emissions reductions in the near-term raises CDR burdens for future generations (Fyson et al. 2020).

Academics have suggested that unless researchers and policymakers start taking lessons from previous experience seriously (for example, from REDD+), it is the global South that is set to bear the brunt of the burden of land-based negative emissions or that will reap the least of its benefits, leading to local resentment and resistance and contributing to the undermining of global carbon removal ambitions (Carton et al. 2020).

Treaty overlap is also relevant to discussions of responsibility and ethics, as efforts to address climate impacts can result in yet another set of risks, impacts and related challenges. Other treaty processes do contain provisions relevant to CDR, and highlight the need for caution in particular contexts. The Convention on Biological Diversity (CBD), for example, addresses what it terms geoengineering, which it defines as including both solar radiation modification (SRM) and large-scale CDR.[63] In 2010 it invited governments to ensure that no climate-related geoengineering that may impact biodiversity takes place, until such time as appropriate controls and regulatory mechanisms are in place and associated risks and impacts have been fully considered.[64] This caution was renewed following adoption of the Paris Agreement, with the CBD citing an incomplete basis for global regulation and the need for more transdisciplinary research into impacts on biodiversity, ecosystem functions and services, socio-economic, cultural and ethical issues, and regulatory options (CBD, 2012, 2016). Similarly, the London Protocol, which aims to prevent marine pollution by the dumping of wastes and other matter, has asserted its authority over regulation of ocean fertilisation, with this assertion of authority widely viewed as a de facto moratorium on commercial ocean fertilisation activities (IPCC, 2018 at 346; LP 2013).

Another element of responsibility becomes relevant once CDR options are deployed — responsibility for ensuring that removals are verifiable and that information on these removals is publicly accessible (see liability and redress section below).

3. Access to information for monitoring progress

The Paris Agreement's transparency framework takes a step forward from the UNFCCC and Kyoto Protocol, moving to more regular inventory reporting by all Parties, accounting requirements applicable to all Parties, and a process for the aggregation of GHG inventories and NDC efforts across all Parties under Article 14's Global Stocktake (Mace 2016). However, tracking progress toward the required balance between emissions and removals will require more reliable GHG inventories and greater clarity on what planned NDCs will deliver.

Substantial gaps remain in many developing countries' GHG inventories, which often do not cover all categories of emissions, use default emissions factors rather than country specific emission factors, and may be years out of date. These inventory gaps will become particularly problematic where cross-border transfers of bioenergy feedstocks are involved.

Even if complete inventories could be provided, the reporting rules that have been agreed thus far

63 Definitions of geoengineering differ, and the IPCC refrains from using the term (IPCC, 2018). Under the CBD, geoengineering includes solar radiation management as well as large-scale CDR. There are good reasons for keeping CDR and SRM distinct, see e.g. https://climateanalytics.org/publications/2016/why-negative-co2-emission-technologies-should-not-be-classified-as-geoengineering/. For example, unlike SRM, CDR options address the problem of increased CO_2 concentrations.

64 See CBP COP 10 Decision X/33 (Parties have been invited to "ensure that, in the absence of science based, global, transparent and effective control and regulatory mechanisms for geo-engineering, and in accordance with the precautionary approach and Article 14 of the Convention, that no climate-related geo-engineering activities** that may affect biodiversity take place, until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts, with the exception of small scale scientific research studies…")

are not structured to collect information in a manner that separates anthropogenic emissions and removals neatly, such that they can feed into an assessment of where and whether progress toward a balance between emissions and removals is being made.

In addition, although Parties currently report emissions and removals following IPCC guidelines (e.g., for the land sector and CCS), **reporting guidelines do not require a sufficient level of detail from Parties to facilitate an estimate of the total contribution of BECCS, DACCS or other CDR options to negative emissions**. For example, in the context of CCS there is no requirement for the separate reporting of biogenic emission sources, fossil fuel emission sources, and removals from DAC that are injected for storage. This may make it challenging to identify what CDR activities are in place, where they are located, and the extent of their contributions. It may also make the creation of incentives under Article 6 for BECCS and DACCS more challenging.

Projecting the effect of NDCs on future emission levels is complicated by the fact that current NDCs are so diverse, and in many cases so ambiguous or limited in scope, that it is difficult to translate these NDCs into absolute planned emission reductions. Parties' current NDCs also have been presented with different timeframes (e.g., 2025, 2030) and with reductions relative to a range of different reference years and baselines. Most NDCs are not yet economy-wide and not all are quantified or quantifiable. Some NDCs do not address the land sector at all, or put forward unquantified policies and measures in the land sector. As a result, the contribution of the land sector to globally aggregated NDCs is so uncertain that it is not clear whether LULUCF activities will form a net source or a net sink in 2030 (Fyson & Jeffery, 2019). To the extent that NDC accounting rules have been agreed, they remain voluntary for the first NDC period, which for some Parties runs through 2030. These accounting rules also provide little detail on how LULUCF emissions and removals are to be accounted. This creates considerable uncertainty in how Parties will track progress towards net-zero at the national level.

At the global level, the Paris Agreement's **Global Stocktake** will assess collective progress towards the net-zero goal using a set of agreed inputs. While the Stocktake will use information from NDCs and GHG inventories to compare progress with emissions pathways consistent with limiting global warming to 1.5°C (as described in IPCC SR 1.5°C), inventory gaps, asymmetries in accounting and uncertainties in NDC coverage may distort this picture.

Fully symmetric reporting and accounting will be needed between countries that are involved in the transfer of mitigation outcomes to ensure environmental integrity. However, the issue of symmetric accounting also relates more broadly to any transfers between countries (e.g., transfers of biomass between countries destined for BECCS). Where transfers take place between countries, robust international guidance and accounting rules will be needed to address environmental integrity, avoid double counting and provide transparency.

4. Safeguards for sustainable development

The sustainable potential of BECCS and A/R is constrained by limits on resource availability (land, water, nutrients) that, if exceeded, would negatively impact sustainable development. For example, large-scale deployment has potential to create risks for food production, biodiversity and social cohesion by driving up land demand, and lead to the over-use of water and nutrient resources. At the same time, in some contexts deployment at smaller scales could lead to local environmental and social benefits, such as improved soil quality and water management, biodiversity conservation and income generation. Other land-based options such as **ecosystem restoration and soil carbon sequestration could also have substantial benefits for sustainable development** (IPCC, 2019).

Both the negative and positive impacts of most CDR options would be largely determined by the **scale, context and implementation strategy used** (Fuss et al., 2018; IPCC, 2018). This is why a portfolio of CDR options, spreading the negative emissions burden across different CDR options, would likely be more effective at achieving a given amount of CDR sustainably than a focus on one or two options. But the size and composition of a potential CDR portfolio that is beneficial for sustainability at the local, national or regional level in one context may look very different to a sustainable portfolio elsewhere (Hansson et al. 2019) and this mapping and consideration has yet to be done at the appropriate scale in real-world contexts.

The potential implications of a CDR portfolio on resource availability and sustainable development also **requires consideration of other drivers of land-use change, including land-based options for reducing emissions**. For example, land availability for CDR options is sensitive to improvements in crops yields, changes in demand for livestock products, changes in the intensity of livestock production and competition with other land uses, all of which depend on socioeconomic conditions and policy choices. The substitution of fossil fuel-based liquid fuels with biofuels (without CCS)[65] is an obvious example of a mitigation activity that might compete for land with land-intensive CDR activities. Even scenarios less reliant on BECCS use large amounts of bioenergy production for emissions abatement, which has implications for resource use and sustainability.

Managing the interactions between CDR deployment, other land-uses and sustainable development will require strong governance in a number of areas, guided by **research into the sustainability of different CDR portfolios at the relevant level (e.g., local, regional, national),** to explore potential interactions between CDR options (for example, competition for land or other resources), and to better understand the synergies and trade-offs between CDR deployment and sustainable development goals.

Safeguards will need to be tailored to prevent adverse impacts of potential CDR options on sustainable development at local, regional and global scales. Mechanisms will also be needed to **monitor negative and positive impacts** in an open and transparent manner, in order to allow for public participation and access to information and ensure that CDR deployment does not lead to adverse outcomes.

5. Challenges for measuring, reporting and verifying CO_2 removals

Measurement and verification of the scale of removals from CDR presents substantial governance challenges, in particular in the context of land-based CDR. Uncertainties in reported land sector mitigation actions are very high (Grassi et al., 2017; Rogelj et al., 2017), particularly in developing countries where measurement and monitoring capacities are often limited. In addition to uncertainties in CO_2 fluxes, methane emissions from tropical forests may be underestimated (IPCC, 2019 at 159; Welch et al., 2019).

In the case of bioenergy production, land-use emissions vary considerably between different geographies and different feedstocks, and also depend on the time horizon chosen for measuring net emissions (Daioglou et al. 2017; Hanssen et al. 2020). For example, recent research has shown that over much of global land area, purpose grown bioenergy crops for BECCS electricity generation would actually have a positive emissions factor when assessed over a timeframe of 30 years; in other words, BECCS can lead to net emissions in the short term, only providing true negative emissions when deployed over much longer time frames (~80 years) (Hanssen et al 2020). These uncertainties and variabilities present substantial challenges for anticipating, tracking and reporting overall progress, for designing results-based incentives to reward success in augmenting carbon stocks, and for the design of market-based approaches that can function credibly in the sector.

The estimation and verification of life cycle emissions presents an additional challenge, in particular for land-based options involving multi-sector and/or multi-national supply chains. For example, estimating net removals for a BECCS project lifecycle (and even net emissions from bioenergy systems in the absence of CCS) would require consideration of emissions and removals due to land-use change and emissions due to the transport, processing and conversion of biomass to bioenergy, which are reported under different IPCC categories. The IPCC 2006 guidelines recommend reporting emissions where the activity took place **(sector-based accounting),** which for bioenergy means reporting emissions in the land sector at harvest rather than in the energy sector at combustion. This approach was designed to avoid double counting but makes it difficult to track the net effect of projects and flows, and difficult to assess the total net removals achieved through

65 Note that only bioenergy combined with CCS can be considered as a form of CDR.

BECCS[66] (Peters & Geden, 2017).

Tracking flows and assessing total net removals will be particularly challenging when feedstocks are transported across national borders and emissions and removals from different stages of a project's life cycle are reported in different countries. For such supply chains, the assumption of a zero emissions factor for biomass in energy sector reporting can be contested if reporting capacities differ between the countries involved. The assumptions underlying this approach – that emissions from biomass harvesting will be reported in the LULUCF sector, and that biomass is produced in a sustainable manner – may not always be valid. For example, if combusted biomass originates in a country that reports land sector emissions using default emission factors rather than country-specific emission factors, emissions at harvest may not be accurately reported.

For some potential CDR options a key challenge is the identification of value chains with the greatest overall climate benefit. For example, the net effect of BECCS (and possibly also DACCS) for removing CO_2 is dependent on the context and timeframe of deployment, and this can lead to investment uncertainty and public acceptability challenges (Nemet et al. 2018). While there are existing certification schemes and frameworks for tracing the origins of biomass and assessing its sustainability, they tend to be regionally focused (e.g. the EU's Renewable Energy Directive, which includes provisions for preventing indirect land-use change) or are voluntary (e.g. the Roundtable on Sustainable Biomaterials).

Distinguishing anthropogenic emissions and removals. The aim of balancing emissions and removals relates to anthropogenic (human-induced) emissions and removals. However, for terrestrial sinks it can be very difficult to distinguish between anthropogenic and non-anthropogenic removals because the same area of land can be simultaneously influenced by both human and natural factors. The IPCC[67] has developed guidance for using emissions / removals on managed land[68] as a proxy for anthropogenic carbon flows, but countries differ in how they apply this tool (Ogle et al., 2018), and other datasets (e.g. FAO and global models) use different methods (Grassi et al., 2018; Pongratz et al., 2014). There is a discrepancy in global anthropogenic net land-use emissions of about 4 $GtCO_2$ yr−1 between global models and aggregated national GHG inventories reported under the UNFCCC (Grassi et al. 2018). This makes it difficult to compare historic and anticipated reductions in LULUCF emissions with the mitigation pathways assessed by the IPCC. Further work is needed to develop more robust and accurate methods for distinguishing anthropogenic emissions and removals from indirect and natural fluxes. A clear, universally applied definition of what constitutes an anthropogenic removal from the atmosphere would be necessary for reconciling different datasets and to enable the assessment of whether progress is being made in achieving a balance between anthropogenic emissions and removals.

Another substantial challenge is to ensure that NDCs are met through verifiable anthropogenic actions, rather than historical legacy effects. Some land sector carbon flows are the result of previous activities, age effects and inter-annual variability; under the Kyoto Protocol, accounting rules are used to ensure that only emissions reductions or removals that result from a change in policies or activities are counted towards targets. Accounting rules for LULUCF will be needed to ensure that only anthropogenic efforts are accounted under the Paris Agreement. Where forest reference levels are used, transparent assumptions and verification will be required to ensure that baselines are well-founded.

66 Note that this is also a challenge for bioenergy deployment without CCS.

67 See the IPCC 2006 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Agriculture, Forestry and Other Land Use, available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

68 Defined as: "Managed land is land where human interventions and practices have been applied to perform production, ecological or social functions". https://www.ipcc-nggip.iges.or.jp/public/mtdocs/pdfiles/0905_MLP_Report.pdf

6. Issues of storage: permanence, leakage and saturation

A key criterion for successful CDR deployment is that carbon removals are durable. Potential CDR options that store carbon in geological reservoirs and terrestrial reservoirs have different degrees of "***permanence***". Once CO_2 is captured in a geological reservoir, storage can be considered to be long-term (IPCC (2018) and Fuss et al., 2018). The risk of significant leakage is relatively low, and research has looked into enhancing monitoring, verification and leak detection for geological storage (Fuss et al., 2018). However, ***for biological sequestration in soils and plants there is a considerable risk that sinks will be reversed through land management decisions or natural disturbances***. This risk is likely to increase over time, as climate change impacts are projected to exacerbate droughts, forest fires and other potential drivers of non-permanence (Ciais et al., 2013; Griscom et al., 2017; P. Smith et al., 2014, Anderegg et al., 2020).

Worryingly, the IPCC's recent special reports have found that many coastal and terrestrial ecosystems would experience high to very high risks of climate change impacts if warming levels reach 3°C, as currently projected under current government pledges (IPCC, 2018; IPCC, 2019; IPCC, 2019b). Nature-based solutions (NBS) that involve the restoration of such ecosystems can enhance their resilience to climate change impacts, but their efficacy for removing CO_2 durably will be severely limited if warming levels are not kept to 1.5°C. Any strategy that involves relying on these options for CDR must therefore also include deep emission reductions that are strictly compatible with limiting warming to 1.5°C.

Mechanisms for protecting and enhancing the resilience of terrestrial sinks and stores of carbon, and for compensating for (and insuring against) releases, will be essential for reducing the risk of sink reversal or loss of CO_2 from CO_2 storage reservoirs at both national and international levels. The issue of permanence is also important in the context of storage in products: the IPCC SR 1.5°C definition of CDR includes activities that durably store CO_2 in ***products***. Here as well, mechanisms may be needed to monitor durability or to account for re-release over time.

Land-intensive CDR options are also subject to the risk of leakage. A/R or reduction in deforestation in one location can trigger increased deforestation and/or degradation or harvesting in another, cancelling out the overall benefits of carbon storage and forest restoration or protection. This dynamic can occur in connection with many mitigation actions in the land sector. There are existing governance mechanisms for addressing leakage in regional contexts, but their effectiveness has been questioned (IPCC, 2018).

Storage limits and saturation also limit removals. All CDR options have a limit to their maximum pace of deployment; for example, for BECCS and DACCS there will be physical limits to the amount of CO_2 that can be stored in a given geological reservoir (IPCC, 2018), though other factors (such as cost) may also prove to be a limiting factor. For biological sinks and related activities (e.g., A/R, soil sequestration) there is a limit to how much carbon can be removed from the atmosphere. Once a biological system reaches a state of "near" equilibrium it reduces its ability to remove carbon (Houghton et al., 2015). At least one recent study has indicated that the intact tropical carbon sink has already peaked; this saturation has significance for policies to stabilise the climate (Hubau et al., 2020). Anthropogenic warming has also set in motion a positive feedback loop with soil carbon; this soil-climate feedback will reduce the magnitude of the maximum sequestration potential of soils by an uncertain amount (Amundson & Beiardeau, 2018).

Therefore, while in the near-term there is a substantial potential for rapidly scaling-up activities that enhance terrestrial sinks, the role of such activities may decline over the longer-term. Focus would shift to preserving terrestrial stocks, and if further removals were needed then other forms of CDR would need to be identified. At present, storage limits and saturation are not a limiting factor, but these issues would need to be taken into account when planning long-term CDR deployment (Nemet et al., 2018), and could be further examined in the coming decades.

7. Planning for and monitoring the biophysical effects of deployment

The deployment of land-based CDR options can have biophysical impacts beyond CO_2 removal that require consideration. Large-scale changes in how the land surface is used can change the reflectivity (albedo) of the Earth, which in turn affects how much of the sun's radiation heats the Earth and how much is reflected back into space. Large-scale land-use changes for BECCS, A/R or biochar deployment could lead to such an albedo effect, depending on the location and type of land used. For example, replacing grasslands with forests at high latitudes darkens the land surface, reducing albedo and leading to warming (Smith, 2016; Smith et al., 2015). Local water and heat fluxes can also be affected through changes in evapotranspiration and the surface roughness of the land (IPCC, 2019).

These various effects can counteract each other, and there is currently limited understanding of the net biophysical effect of bioenergy plantations or large-scale afforestation in different contexts. However, observational data shows that the darkening of the land surface through increasing tree cover at high latitudes can lead to local warming (IPCC, 2019 at 179), while in the tropics the higher evapotranspiration rate would lead to local cooling (Duveiller et al., 2018). Large scale afforestation would also modify the planetary albedo and thus slightly increase global mean temperature - although this effect would be much less significant than the carbon sequestration benefits (Winckler et al., 2019).

The consequences of local land-use changes in one region for the climate in other regions remains uncertain, although current understanding suggests that changes in plant transpiration in one location can have consequences for regions located downwind (Zemp et al., 2017).

Appropriate regulations or safeguards will need to be put in place to prevent any large-scale CDR deployment that might negatively impact local or global climate. On the other hand, in cases where biophysical effects can lead to adaptation benefits (e.g. through increased rainfall or protection against erosion during heavy rainfall events), guidance or incentives may also be needed to ensure that in the design of CDR activities these **local or global climate benefits are realised**. A number of NDCs do include forest-based activities in the adaptation components of their current NDCs, indicating an openness to projects with co-benefits.

8. Liability and redress

Safeguards also need to be put into place to address physical risks and accounting risks related to reversals of removals and storage. Lessons can be learned from the Kyoto Protocol rules relating to land sector removals, e.g., RMUs and temporary Certified Emission Reductions (CERs) and rules establishing a framework for accounting for CCS as CDM project activities (described in section 3 above).

Kyoto Protocol land sector accounting rules explicitly take impermanence and the possibility of reversals into account, establishing removal units that cannot be carried forward to a subsequent commitment period, and tradable units from A/R CDM projects that are only temporary and must be replaced upon expiration.

Modalities and procedures for CCS as CDM project activities address both liability, in connection with physical leakage or seepage, and responsibility for accounting for net reversals.[69] Under those rules, The CCS rules also contain obligations for addressing **non-permanence** (any net reversal of storage) and for the **transfer of liability** from project participants to the host Party once site

69 See Decision 10/CMP.7, Modalities and procedures for carbon dioxide capture and storage in geological formations as clean development mechanism project activities. "Liability" is defined as "the legal responsibility arising from the CCS project activity or the relevant geological storage site, with the exception of the obligations arising from a net reversal of storage …, but including all obligations related to the operation of the storage site (e.g., monitoring, remedial measures, etc.) to compensate for or remedy any significant damages, including damage to the environment, such as ecosystem damage, other material damages or personal injury".

monitoring has terminated. Host Parties are required to have a legal framework in place to address liability and to provide redress to affected entities, individuals and communities for damage, including environmental damage and damage to ecosystems, from CCS project activities.

9. Incentives for CDR deployment

Currently there are only very weak policy incentives in place for CDR, which will not be sufficient to deliver CDR at the pace and scale required for the Paris Agreement's long-term temperature goal (Nemet et al., 2018).

The absence of government regulatory support or a carbon price high enough to force through investments are well-known factors limiting the take-off of carbon removal. (Carton, et al.. 2020). To achieve the pace of upscaling anticipated in modelled scenarios, policy packages will be needed in the near-term so that those CDR options that are already mature or being demonstrated can be deployed as soon as possible. Policies will likely need to evolve as more CDR options become available (Lomax et al., 2015), and coordination across multiple policy domains (climate, energy, agriculture, water, forestry, environment, among others) will be needed so that CDR portfolios can be implemented effectively (Brack & King, 2020).

Further research is needed to improve understanding of how to incentivise early deployment, develop niche markets, and scale-up and maintain CDR activities (IPCC SR 1.5°C). Incentives will be difficult to fashion where CDR options are expensive or involve multiple players (as is the case for BECCS and DACCS in particular, but also for other options). For both BECCS and A/R, the design of incentives is particularly sensitive, because large-scale or poorly implemented deployment can be anticipated to entail trade-offs, with impacts on food security, biodiversity and fresh water supply (Hansson et al., 2019). Conversely, where benefits of a specific CDR option for sustainable development are identified — such as flood control or improved soil quality in the case of ecosystem restoration, or job creation for deploying and monitoring CDR — this could also provide an incentive for deployment.

Poorly designed incentives can also lead to poor outcomes for carbon removal, for example, where payments for afforestation perversely result in the replacement of more carbon rich and biodiverse land cover with plantations (Heilmayr et al., 2020). Incentives will also be challenging to design for BECCS where bioenergy feedstocks are exported from a developing country for combustion and CCS in an industrialised country (Lomax, et al., 2015; Nemet et al., 2018, Peters and Geden, 2017): both countries should be incentivised to ensure that the biomass production is sustainable, and that the overall supply chain has a benefit for the climate.

Lessons may be learned from other technologies that have already made the journey to commercialisation (Nemet et al., 2018). However, challenges will continue in the longer-term, even after commercialisation. Once country emissions begin to go net negative, further incentives will be needed to drive ongoing negative emissions.

10. Public awareness and acceptance

Public awareness and public acceptance will be important for the development and large-scale deployment of various CDR options. CDR deployment will take place in very real political, social, economic and cultural contexts and making space for public discussion and debate will be essential, Social and cultural challenges for deployment can rival physical and technical challenges (Amundson & Biardeau, 2018; Carton et al., 2020).

At the broadest level, public acceptance of CDR as a concept is influenced by ethical implications and the perceived risk of moral hazard (e.g., where and how is CDR to be pursued, who is responsible, who benefits and who bears what burdens, and whether the availability of CDR inappropriately takes pressure off emissions reductions activities) (McLaren, et al. 2016; Carton, et al, 2020; Climate Assembly UK, 2020). At the more local level, public acceptance depends on whether users of a CDR measure and those exposed to its risks and benefits see value in it (Nemet et al., 2018).

Research on public perceptions in the UK and USA has found that, when discussed in the context of climate change urgency, CDR is seen as a response that is too slow, and that neither addresses the root cause of climate change, nor fits with a vision of a more sustainable future (Cox et al. 2019). The IPCC SR 1.5°C shows that any known model pathways consistent with 1.5°C require ***CDR in addition*** to a rapid drop in emissions, accelerated transitions in all sectors, and a phase-out of coal power generation by mid-century. Raising public awareness of these findings and emphasising that CDR does not and cannot offer a 'get out of jail free' card may help address concerns that CDR is being presented as a convenient way to protect the status quo, or to undermine ambitious climate change action by those most responsible (see, e.g., Carton et al., 2020; The Royal Society and Royal Academy of Engineering, 2018). This may enhance public acceptance.

Discussions on negative emissions, in particular discussions on A/R, BECCS and on issues around accounting for removals, have important parallels to earlier discussions on carbon sequestration and carbon sinks and important lessons need to be drawn about public engagement from previous controversies, successes and failures in these areas (Carton et al., 2020). Scientific and methodological choices, such as what counts as negative emissions and what assumptions underlie the choice of particular technologies and carbon accounting approaches, need to be exposed and made accountable to public debate (Carton et al, 2020).

It can be expected that the potential negative side effects of large-scale CDR deployment will create challenges for public acceptance. Nemet et al., (2018). BECCS faces a double challenge: both bioenergy and CCS suffer from a **limited level of public acceptance** (IPCC, 2018 at 343). Public concerns related to BECCS and DACCS have included sustainability, CO_2 leakage, mitigation deterrence and perceptions of tampering with nature (see, e.g, Climate Assembly UK, 2020; Wolske, 2019), among others[70]. As people gain familiarity with BECCS, the combination of CCS with bioenergy or direct air capture, rather than with fossil fuels, may make the option more acceptable (Nemet et al., 2018; Wallquist et al., 2012). However, at the local level, the need to transport large quantities of biomass and to install CO_2 pipelines may also affect acceptability. Soil carbon sequestration and biochar offer potential co-benefits for farmers which may increase their acceptance if these co-benefits can be made known, but the challenges of stakeholder engagement, even in wealthy countries, should not be underestimated (Amundson & Biardeau, 2018).

In general, there is **little existing research on the public acceptance of most CDR options** (Nemet et al., 2018), even though public acceptance may present a considerable barrier to deployment. Researchers and policy makers will need to consider how best to raise awareness of the risks and benefits of particular CDR options and portfolios of options in engaging with the public at local, national and international levels (Wolske et al., 2019). For this, a range of academic disciplines are relevant, including the social sciences, to enable inclusive and open discussions and questioning of actor-specific interests, and to identify a wide range of possible options and solutions (Carton et al, 2020).

4) What governance gaps and challenges could be addressed as a matter of priority?

A number of governance gaps, if addressed now, can help support informed decision-making on the necessary scale and portfolio of CDR options and lay the groundwork for upscaling relevant options. These governance gaps include the substantial gap in mitigation ambition, informational gaps, accounting gaps, research gaps, and incentive gaps.

We have identified priorities based on their significance for CDR scale and planning, their implications for Party accountability, and their near-term achievability. These priorities include:

- addressing the current 2030 mitigation gap to reduce the necessity for reliance on large-scale CDR options;
- improving inventory data and information management systems to improve accountability and support the tracking and assessment of aggregate CDR efforts;
- putting in place robust accounting rules to avoid double counting, including for the land sector;
- refining reporting and accounting rules for projects involving international transfers related to CCS and BECCS;
- creating incentives to support CDR research, investment and implementation;
- developing scenarios and value chains for specific CDR options and combinations of options; enhancing public awareness, and
- supporting the development of legal and planning frameworks at the national and international levels that can address large-scale CDR options.

Some of these elements may be addressed by policymakers and negotiators through the ongoing negotiating processes under the Paris Agreement; others will require decisions and interventions outside the UNFCCC process. We summarise these policy responses in Table 3 and suggest an allocation of possible responsibility for driving these efforts.

1. Narrow the mitigation gap to reduce possible future reliance on CDR options

Enhance mitigation ambition to 1.5°C-consistent emissions pathways - As explained in section 2 above, 2030 emission levels are a key indicator of the degree to which reliance on CDR will be necessary to meet Paris Agreement goals. Any acceleration of mitigation efforts will help reduce reliance on CDR. Paris Agreement Parties have been requested to bring forward new and updated NDCs by 2020 and these efforts need to move Parties onto a 1.5°C-consistent emissions pathway. Commitments by all Parties to raise the ambition of their NDCs in this current five-year cycle would help narrow the existing emissions gap and reduce future dependence on levels of CDR that might otherwise prove difficult or impossible to scale up in the necessary timeframe, or that may have substantial implications for sustainability (e.g., food security, resource availability, biodiversity, land tenure, social cohesion).

Adopt economy-wide NDCs - All Parties have been encouraged to move toward economy-wide NDCs. The adoption of economy-wide NDCs by a wider number of developing country Parties would facilitate consideration of the widest possible array of mitigation initiatives. As discussed in section 3 above, while developed countries have presented economy-wide NDCs, many developing countries currently have NDCs that cover only a subset of their inventory sectors. Developing countries could be encouraged to move to economy-wide emissions reduction or limitation targets in their new and updated NDCs.

Encourage distinct emission reduction targets for the land sector - Not all NDCs include mitigation efforts for the land sector. The establishment of distinct land sector targets within NDCs and within long term strategies will help clarify the planned contribution of the land sector (Fyson & Jeffery, 2019). Separate targets would also discourage the use of land sector removals to offset emissions in other sectors, in recognition that reductions are needed from all sectors to achieve the 1.5°C goal, and that carbon flows in the land sector are inherently more uncertain than those in other sectors (Crusius, 2020, Kachi et al, 2019, Jeffery et al. 2020).

Communicate 2050 long-term low GHG emission development strategies (LT-LEDS) -[71] Policymakers have been requested to communicate LT-LEDS by 2020. Policymakers should be encouraged to present 2050 strategies that are 1.5°C-consistent, aim to phase out CO_2 by 2050, aim to achieve a balance between emissions and removals, and aim to achieve net negative emissions later in the century. As mentioned in section 4, above, a number of the countries that have communicated 2050 strategies have begun to consider the role of CDR in these strategies.

Evolve a common understanding of "Net zero"- The balance to be achieved between emissions by sources and removals by sinks of GHGs can be read as both a collective and an individual Party goal. Because many different expressions of this goal seem to be in circulation, it will be important to evolve a shared understanding -- that achieving this balance over time at the national level (net-zero emissions) requires consideration of all gases and sectors, excludes reliance on international offsets, and needs to be accomplished through both rapid emissions reductions and the scaling-up of CDR.

Encourage targets for negative emissions – The explicit setting of distinct targets for emission reductions and for negative emissions has also been proposed as a way to ensure that negative emissions are used to supplement mitigation policy and emission reductions, rather than to replace these efforts or to allow increased emissions from other sectors (McLaren et al., 2019; Fyson & Jeffery, 2019; Jeffery et al. 2020). A number of NDCs already do contain targets for net removals (Herold & Böttcher 2018), and distinct targets warrant consideration in the context of future NDCs and LT-LEDS (von Hirschhausen, Herold & Oei 2012; Honegger, Michaelowa and Poralla 2019).

The UN Secretary-General is uniquely placed, using positive momentum from the IPCC SR 1.5°C, and deadlines set in 1/CP.21, to encourage more ambitious NDCs and the communication of LEDS - This effort will be aided by more recent research on countries' potential physical and financial losses due to a lack of climate action (Geiges et al. 2020; Wei et al, 2020) and recent science on accelerating climate impacts (IPCC, 2019b). In particular, raising awareness of the limits of NBS for removing carbon under higher levels of warming is important for enhancing understanding of why both urgent mitigation and CDR options development is needed

The UN Secretary-General and the UNFCCC Executive Secretary might also use this opportunity to **sensitise policymakers and the public** to the scale of the CDR implementation challenge if transformative mitigation action is delayed. Greater near-term mitigation efforts may be encouraged if the many sustainability and governance challenges inherent in large-scale reliance on potential CDR are made known, as most CDR options are currently of limited availability, high cost, resource intensive and/or unproven at scale. Improved understanding of who could be held responsible for deploying CDR – and how expensive this might be – if near-term mitigation efforts are not sufficient may also help in this regard (Fyson et al., 2020).

2. Improve inventory data and information management systems

Move toward a common format in the communication of new and updated NDCs - If Parties independently communicate their new and updated NDCs in a structure that responds directly to the Paris Agreement's new guidance on information necessary for clarity, transparency and understanding of NDCs and its new accounting guidance (Decision 4/CMA.1, Annexes I and II), this can facilitate the tracking of global progress towards a balance of anthropogenic emissions and removals. These rules are only mandatory for application to second NDCs, but expedited application

71 Decision 1/CP.21, para. 35

by Parties to their first NDCs would bring greater clarity to the contribution of the land sector, clarify accounting approaches, data sources and assumptions, and help quantify the mitigation effect of Parties' planned efforts in advance of the 2023 Global Stocktake. This is particularly important for those NDCs that are not currently quantified or quantifiable.

Develop reporting systems for CDR under the Paris Agreement – ongoing negotiations on the common reporting tables that Parties will use to electronically report their GHG inventories, emissions projections and progress toward NDC achievement should consider how best to enable the tracking of CDR. For example, these tables could provide for the reporting of gross emissions and removals separately. GHG inventories could also be designed to enable detailed reporting on CDR initiatives. Inviting more granular and geo-referenced reporting with respect to A/R, BECCS, DACCS and other CDR options as best practice will help track the uptake and support the scaling up of these options. This would also enable the separate tracking of CCS used in combination with fossil fuel combustion (which does not contribute to CDR) from CCS used for BECCS and DACCS. Greater clarity on how / where removals from DACCS should be reported in GHG inventories (for example, in which sector) would also be helpful.

Build developing country reporting capacity - the substantial gaps remaining in many developing country inventories will become increasingly problematic in reporting on CDR options that involve the land sector or multi-national supply chains, such as BECCS. Many developing countries will need support to implement data collection and information systems, and systems for measuring, monitoring and reporting inventory information. Improved inventories, in turn, will support forward planning and facilitate assessment of progress toward net-zero emissions.

Encourage input from external sources to supplement and verify data – Intergovernmental organisations (IGOs), non-governmental organisations (NGOs), scientific institutions and civil society organisations can help fill data gaps and support greater accountability and transparency by providing external checks on UNFCCC inventory data and progress in NDC implementation. This might include: data from the IMO and ICAO related to the use of international bunker fuels and the use of CORSIA offsets, Montreal Protocol data related to GHGs, including Hydrofluorocarbons (HFCs); land cover and land use data from the Food and Agriculture Organization (FAO) and other satellite-derived datasets (e.g. Ceccherini et al. (2020), Global Forest Watch); and London Protocol data related to sub-seabed storage. Key data sets should remain in public domain, and cyber security concerns should be recognised. Moving towards a common definition of anthropogenic emissions and removals would also be helpful, to allow these different datasets to be compared.

3. Put in place robust accounting rules for the land sector and for Article 6 transfers

Move toward common accounting rules for the land sector – over time, a consistent approach for incorporating the land sector into NDCs will be essential to support robust accounting. In addition, because some land sector carbon flows are the result of previous activities, age effects and inter-annual variability, rules are needed for the establishment of baselines and reference levels, for accounting for impermanence and leakage, and for reporting on harvested wood products (HWP), natural disturbances, and the identification of managed land. While some flexibility will have to be provided in recognition of Parties' different circumstances and starting points, a common rule set will support transparency, consistency and comparability, avoid double counting, minimize the risk of asymmetric accounting, and ensure net removals are anthropogenic. Limits and safeguards under these rules could be designed to limit Parties' use of removals from the land sector to offset emissions in other sectors, recognising that land sector removals cannot be assumed to adequately compensate for continued emissions in other sectors (Carton et al., 2020)

Address the risk of reversals – Accounting systems will need to adequately address the risk of CDR reversals, in the context of both terrestrial sinks (for which reversal risks are substantial) and geological carbon storage (for which reversal risks are much lower, but still exist in the longer term). Lessons from the Kyoto Protocol related to A/R and CCS may be useful in informing the development of such systems as they directly address issues of impermanence.

Develop guidance on accounting for life cycle emissions involving multiple sectors and multiple countries – Lifecycle emissions are a challenge for land-based CDR options involving multi-sector and/or multi-national supply chains. Guidance for accounting lifecycle emissions should consider the risks of countries within a supply chain lacking emissions reporting capacities. The need to track progress at the global level should also be taken into account: the current lack of a common approach for accounting emissions from HWPs used for energy means that emissions from bioenergy feedstocks that cross borders for BECCS could go unaccounted – leading to an overstatement of negative emissions.

Develop robust accounting rules for transfers under Article 6 – Article 6 requires that Parties transferring mitigation outcomes make what are termed 'corresponding adjustments' to their NDC-related emission balances, with one Party making an addition and the other a subtraction, reflecting respectively the transfer and use of these outcomes toward NDCs. Corresponding adjustments aim to avoid the double counting or use of the same outcomes by multiple Parties. If outcomes related to BECCS and DACCS are to be transferable under Article 6, systems will need to be in place to ensure that the underlying outcomes have themselves been fully accounted, and accounted in a symmetric manner where multiple Parties are involved, to ensure environmental integrity.

Consider excluding or limiting the use of international transfers of mitigation outcomes sourced from A/R and other biological removals (e.g., from soil sequestration, ecosystem restoration) toward NDCs – in view of their recognised environmental integrity challenges (difficulties in setting accurate baselines, impermanence, leakage and related difficulties for monitoring, reporting, verification and accounting) and the social, cultural and economic concerns these removals raise in the context of a market-based system that runs the risk of favouring least cost removals and that requires the transfer of their ownership. Fundamentally, biological removals are not equivalent to permanent reductions achieved through reductions in fossil fuel emissions and any 'assumed commensurability' or equivalence has been thoroughly challenged, together with the substantial issues of ethics and intergenerational equity that follow (Carton, et. al. 2020; Jeffery et al., 2020; Kachi et al., 2019).

4. Create incentives to accelerate research, investment and implementation

Develop policy packages that enable mature CDR options or those in the development stage to be deployed as soon as possible – A raft of policy options could drive CDR deployment. These include direct regulation (e.g., a requirement that fossil fuel companies deploy or finance CDR), economic incentives, subsidies for deployment, government support to reduce investment risks, direct funding of CDR options, or the adaptation of existing policy mechanisms (e.g. use of agricultural policy to incentivise soil carbon sequestration or biochar) (Lomax et al 2015; Nemet et al. 2018). Domestic emission trading systems can also create important incentives through pricing signals, in a regulatory environment that contains sustainable development safeguards for large scale projects, including impact assessments and enforceable systems to monitor, track and address reversals.

Provide direct financial and capacity building support for low cost no-regrets CDR options with known co-benefits (e.g., A/R, soil carbon sequestration, ecosystem restoration) – Simply increasing public awareness of the co-benefits of some CDR options may be sufficient to overcome barriers to deployment in some contexts. In other contexts, for example in developing countries, direct financial support and capacity building can help overcome barriers. Financial support through results-based payments (e.g. from the Green Climate Fund for REDD), or through international voluntary carbon market programmes that have no expectation of transferable emission reduction credits, can allow for the test driving of positive, no-regrets CDR initiatives in interested developing countries, while at the same time building up capacity for monitoring, reporting and verifying carbon stocks. This can help address questions over whether land-based programmes can be successful in protecting environmental integrity over the long-term (Carton et al., 2020).

Reserve market-based cooperative approaches under Article 6 for reductions that are clearly permanent, additional and readily measurable and verifiable. Market-based transfers are most appropriate where the mitigation outcomes transferred clearly represent permanent, additional, and readily verifiable emission reductions and where robust accounting systems are in place. Accordingly, negative emission technologies involving geological sinks are more suited to international approaches than those involving biological sinks (i.e., DACCS rather than A/R). Article 6 transfers require the relinquishing of rights by host countries to use the emission reductions achieved toward their own NDCs. For this reason, while the land sector offers least-cost mitigation opportunities in many developing countries, it may not be equitable to create incentives for the transfer of these reductions, leaving developing countries with relatively more expensive domestic mitigation options, new accounting challenges and long-term reversal risks that few are institutionally prepared to address.

Prioritise CDR measures with positive outcomes for sustainable development, biodiversity and climate change adaptation. The sustainable development co-benefits of specific CDR options can provide incentives and/or additional rationales for funding or deployment, provided regulations and safeguards are in place to prevent any large-scale CDR deployment that might negatively impact local communities, biodiversity, food and water security, and even climate. Over the longer term, a comprehensive approach to land-use policy that integrates all types and drivers of land-use change to minimise emissions, maximise removals and avoid negative impacts will be necessary (Daioglou et al., 2020, Dooley et al. 2020).

Support consideration of ways to share risks and responsibilities for research and development of less mature options equitably – a number of governments and companies are already funding innovation in carbon removal technologies, but different national circumstances and cumulative emission profiles offer opportunities for an equitable division of responsibility in accelerating CDR upscaling. Open discussion among governments, companies and other non-state actors on how risks and responsibility can be shared equitably may accelerate the commercialisation of promising CDR options (Fyson et al. 2020).

Provide direct financial support for expensive CDR options - BECCS and DACCS are relatively more expensive CDR options. For BECCS, further incentives may not be needed on the demand side, where bioenergy is already economic for commercial use and importing countries benefit by being able to record negative emissions (BECCS). But there may be a need to incentivise inputs for BECCS on the supply side. Direct support or subsidisation of the development and commercialisation of BECCS and DACCS will likely be needed to drive emissions below zero at the international level.

5. Engage the research community in scoping specific CDR options and necessary incentives

The necessary scaling up of CDR options will be facilitated by efforts from the research community to build scenarios around specific CDR options, their associated value chains and their sustainability implications (e.g., BECCS linked to existing and new CCS sites, DACCS linked to renewable energy). This applies equally to those options that have not yet seen widespread consideration in model-based analysis.

Research initiatives might include:

- Modelling specific CDR options and portfolios of options at scale, to identify linkages between potential options and implications for the SDGs;
- Performing bottom-up studies at the local or regional level to identify sustainable potentials, potential socio-economic impacts, and governance needs;
- Identifying potential locations for implementation of large-scale CDR initiatives, in view of related sustainability concerns;
- Identifying potential near-term and niche options that could be rapidly and sustainably expanded
- Identifying measures capable of incentivising different CDR portfolios in different settings;
- Piloting projects through public/private partnerships that can employ existing plans and infrastructure (e.g., CCS storage facilities);

- Identifying pathways for collaboration, cooperation, cost sharing and benefit sharing, as well as options for the allocation of responsibilities and liability;
- Identifying safeguards that can prevent adverse impacts of potential CDR options on sustainable development at local, regional and global scales;
- Identifying mechanisms to monitor negative and positive impacts in an open and transparent manner, in order to allow for public access to information and accountability;
- And, public awareness and acceptance surveys of identified CDR options.

Where research reveals low cost options that have clear co-benefits (e.g., soil carbon enhancement, erosion prevention, habitat restoration, income generation) and that can be immediately deployed at large-scale (taking into consideration relative maturity, known trade-offs, sustainability challenges, cumulative impacts and interactions between CDR options), these options can be targeted for early implementation.

Focused research on the range of contexts in which different potential CDR activities might be sustainably deployed will bring more clarity on how much each option could contribute to future CDR needs. In the case of BECCS, for example, niche options for bioenergy deployment at the local level may have a greater likelihood of achieving synergies with sustainable development (IPCC, 2018; IPCC, 2019), but the feasibility of combining such small-scale operations with CCS would depend on costs, supply chain and infrastructure requirements.

6. Improve public awareness of potential CDR options, risks and trade-offs in planning processes

Engage a wide range of stakeholders in planning processes – Reliance on CDR options to meet Paris Agreement goals will be inevitable, even if 2030 NDCs improve dramatically. Engaging a wide range of stakeholders in planning processes for NDCs and LT-LEDS can help reinforce the need for urgent emission reductions and enhanced removals to achieve Paris goals. Citizen assemblies can increase public awareness of cost, risks, uncertainties, sustainability challenges and trade-offs associated with various CDR options at different scales, consider the potential role of these options in delivering net-zero targets, and open the door to consideration of other solutions (e.g., lifestyle changes) (Carton et al, 2020. Ghambir & Tavoni; UK Climate Assembly).

Identify areas or facilities with potential to accommodate large-scale CDR options – Land use and land sector planning documents at various levels (local, regional, national) might consider land set asides for A/R, recognising standards for sustainability and the need to protect communities from land grabs (The Royal Society and Royal Academy of Engineering, 2018).

Establish a registry of CDR initiatives and projects - IGOs or NGOs might be invited to **develop a registry** of ongoing existing BECCS, CCS, DACCS initiatives and projects to track deployment of negative emission technologies in tonnes removed and sequestered, to increase public awareness and track transparency related issues (e.g., their funding sources, whether they are being used to compensate for emissions, and whether sustainable development is being adequately safeguarded).

Increase public awareness of co-benefits - increasing awareness of the co-benefits of A/R, soil carbon sequestration and ecosystem restoration may assist in mobilising investment and improving public acceptance.

7. Improve international collaboration and cooperation

Enhance collaboration between international treaty bodies: Enhancing collaboration in connection with the measurement, monitoring, reporting and management of emissions and removals, and on issues related to responsibility and liability in connection with CDR options, can help treaty bodies (CBD, UNFCCC, MP, London Protocol, ICAO, IMO, FAO, WMO) avoid working at cross-purposes. It will also help maintain and improve the information base needed to support sound policy-making. For example, while the UNFCCC process generates GHG inventory data, as noted above, this data suffers from gaps and consistency challenges. **IGOs, NGOs and other civil society organisations (CSOs) can help fill gaps and support greater accountability and transparency by supplementing and verifying UNFCCC GHG inventory data and information on emission flows**, thereby contributing to a fuller understanding of emissions and removals in country contexts and in aggregate. This collaboration could be supported by the UN Secretary General working with the UNFCCC Executive Secretary.

Develop mutually-reinforcing research agendas – Collaboration can help target support to research, development and commercialisation of prioritised CDR options, and to research initiatives that solicit stakeholder input and reflect local community concerns and needs regarding sustainability. As consensus grows on optimal mixes of CDR options and physical locations for the implementation of these options, international collaboration and cooperation can help identify the most effective incentives for deployment and mobilise resources to support this deployment.

Conclusion

The issue of CDR presents the global community with a dilemma. On the one hand, the science is clear that a substantial scale of CDR will be needed to limit warming to 1.5°C, and CDR deployment will be needed soon in order to reach such a scale in the coming decades. On the other hand, CDR is not 'a get out of jail free' card, and the global community has an interest in ensuring that its ultimate deployment and use are as low as feasibly possible. Deployment of CDR at scale, whether it is based on the land sector, on biomass energy with CCS, or on new approaches such as DACCS, will have serious challenges in the sustainability domain. Use of CDR should never be used as an excuse to postpone early reductions, or particularly to delay the necessary fossil fuel phase out

2030 targets must be improved dramatically, if they are not, the international community will need to rely heavily on CDR options that are as yet unproven at scale, to meet the Paris Agreement's 1.5°C temperature limit. Even with improvements in current policies and NDCs, significant, if not substantial, CDR will be needed to meet the Paris agreement's long-term temperature goal. The next decade really is critical — emissions levels in 2030 will determine the scale of CDR options that may be needed. If Parties bring forward new and updated NDCs by 2020 that are substantially more ambitious in the reductions they deliver for 2030, this can reduce future reliance on CDR to a scale that may be economically feasible and avoid jeopardising sustainable development.

More work is needed to develop an appropriate portfolio of CDR approaches that can maximise synergies with sustainable development and minimise trade-offs. Investment is needed for research and for commercialisation of promising technologies, and this work is really just beginning.

This report shows that the global community is far from ready to provide incentives for the deployment of CDR, and that there are many gaps in the governance systems that will be needed to manage CDR at scale. In this report, we have begun to ask questions such as:

- Is the international community prepared for the implementation of large-scale CDR options?
- Can the sustainability challenges, risks and trade-offs inherent in large-scale CDR efforts be managed?
- What governance tools need to be in place for an urgent development and upscaling of possible CDR options?
- Can current provisions under the climate change regime support implementation at scale or are further provisions and incentives needed?

Some biological options, such as A/R, and other land management activities, are available at relatively low cost and provide positive co-benefits: these approaches should be pursued as soon as possible. As the scale of these activities grow there will need to be an important strengthening of governance.

To ramp up CDR to the scale needed will require substantial lead time, planning and resources, and governance tools to ensure that CDR can be deployed sustainably, and that progress in achieving net-zero — and ultimately net negative emissions — can be monitored effectively.

In this report we identify key priority governance challenges and gaps at the international level for the development and potential deployment of CDR at a scale consistent with the Paris Agreement goals. These gaps include mitigation gaps, information gaps, accounting gaps, knowledge gaps, and incentive gaps, some of which can be addressed under the ongoing negotiating processes under the Paris Agreement, while others will require decisions and interventions outside the UNFCCC process.

The table below summarises the key governance challenges and gaps that can be addressed in the near-term, priority responses for addressing them, and who could be involved.

Table 3: Key governance challenges identified in this report, and options for addressing them

Governance challenges and gaps	Entity or entities	Options for adressing them
1. Narrow the mitigation gap to reduce possible future reliance on CDR options	UN Secretary General UNFCCC Executive Secretary	• Maintain momentum from the IPCC SR 1.5°C by raising awareness of climate impacts and risks at low levels of temperature change • Encourage new and updated NDCs in this 5-year cycle, with far more ambitious emission reduction targets for 2025 and 2030 • Encourage communication of 2050 strategies, consistent with 1.5°C pathways • Encourage shift to economy-wide NDCs • Facilitate greater collaboration between treaty Secretariats • Encourage distinct land sector targets • Encourage targets for negative emissions
	Parties	• Enhance 2030 NDC ambition, to avoid extreme reliance on CDR options • Communicate 2050 Low Emission Strategies (LT-LEDS) including consideration of targets for negative emissions, options and needs • Evolve a common understanding of "net zero" (all sectors, all gases, no reliance on international units)

2. Improve inventory data and information management systems	IPCC	• Develop IPCC Guidance on biomass energy lifecycle emissions for inclusion in national emissions inventories • Develop IPCC Guidance on emission inventory and reporting for DACCS
	IGOs, NGOs, CSOs	• Explore how external datasets can be used to verify sectoral emissions data (e.g. through atmospheric measurements) • Support capacity building initiatives
	Parties	• Provide information necessary for clarity, transparency and understanding of existing NDCs in Decision 4/CMA.1 for first and subsequent NDCs • Shift to economy-wide NDCs • Apply common accounting rules in Decision 4/CMA.1 for first and subsequent NDCs • Present distinct land sector targets • Present negative emission targets • Adopt common GHG reporting formats that facilitate aggregation
3. Put in place robust accounting rules	Parties	• Move toward common accounting rules for the land sector (e.g. for Harvested Wood Products, Natural Disturbances) • Develop robust rules for Article 6 transfers under Article 6.2 and 6.4
	UNFCCC Executive Secretary	• Collaborate with IMO, ICAO, CORSIA and Montreal Protocol to enable sharing of emissions data, to ensure no double counting of emission reductions and ensure work is not at cross-purposes
	IPCC	• Develop guidance on accounting for life cycle emissions involving multiple sectors and multiple countries

4. Create incentives to accelerate research, investment and implementation	Research community	• Develop policy packages to support accelerated deployment • Identify inexpensive no-regrets options for immediate implementation • Consider ways to share risks and responsibilities for research and development of less mature options (e.g., public / private partnerships, particularly where existing infrastructure and plans can be utilised)
	Parties	• Develop policy packages to support accelerated deployment • Provide direct financial and capacity building support for low cost no-regrets CDR options with known co-benefits (A/R, soil sequestration, ecosystem restoration) • Reserve market based cooperative approaches under Article 6.2 and 6.4 for reductions that are clearly permanent, additional and readily measurable and verifiable • Consider ways to share risks and responsibilities for research and development of less mature options (e.g., public / private partnerships, particularly where existing infrastructure and plans can be utilised) • Provide direct financial support for expensive CDR options
5. Engage the research community in scoping specific CDR options and necessary incentives	Research community	• Build scenarios around specific CDR options, value chains and their sustainability implications (e.g., BECCS linked to existing and new CCS sites, DACCS linked to renewable energy, other land-based options with sustainability benefits) • Research environmental aspects of CDR options and portfolios, including storage permanence and leakage • Support regional, bottom up studies to identify realistic, sustainable removal potential in given locations • Identify pathways for collaboration, cost-sharing and benefit sharing, as well as options for the allocation of responsibilities and liability

6. Improve public awareness of potential CDR options, risks and trade-offs in planning processes	IGOs, NGOs, CSOs	• Increase public awareness of co-benefits • Engage a wide range of stakeholders in planning processes • Identify areas or facilities with potential to accommodate large-scale CDR options • Establish a registry of CDR initiatives and projects, including information on scale and location • Provide information from external datasets to facilitate tracking of CDR deployment, e.g. on forest cover, clearing, natural disturbances, from satellite data
7. Improve international collaboration and cooperation	ICAO and IMO	• Enhance data sharing and collaboration with UNFCCC Develop long-term vision for zero emissions in all sectors
	IPCC	• Evaluate the implications of geophysical feedbacks and other issues for emission pathways and CDR needs consistent the Paris agreement long-term temperature goal, for inclusion in assessment reports that will inform the Global Stocktake
	Research community	• Emissions-reduction tracking initiatives : expand tracking of NDCs and current policies to include CDR deployment

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