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Implementing Carbon Capture and Storage Technologies: A call to action

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Takeaways

Without exception, a survey of mitigation scenarios describing pathways towards net zero emissions in line with the temperature stabilization targets of the Paris Agreement shows that CCUS and removals are a necessary part of the equation across all scenarios. In line with the nationally determined approach of the Paris Agreement, different countries will pursue different strategies toward decarbonization, reflecting their vastly divergent domestic circumstances. Across all countries, CCUS and removals will be critical for the achievement of net zero emissions.

Two distinct approaches can be identified:

- Addressing residual and life cycle emissions: countries that are able to focus on reducing their direct emissions, for instance by substituting fossil fuel combustion with renewable energy technologies, will still face residual emissions – including the lifecycle emissions of clean technologies – which will need to be compensated through deployment of CCUS and removals.
- Addressing direct emissions from combustion: countries may opt for continued use of emissive technologies in line with their domestic resource endowment and economic and social priorities and will then have to rely more heavily on CCUS and – given inefficiencies in CCUS technologies – removals to achieve net zero emissions.

In each case, CCUS and removals need to hence be available options. The global energy transition is urgent, and important, and requires engagement by all, including the deployment of all available options. Curtailing the availability at scale and affordability of CCUS and removals not only risks collective failure to achieve the internationally agreed temperature stabilization targets but would also impose an unequal burden on different countries based on their respective domestic circumstances.

If all options are to be on the table, however, they also need to secure the necessary technical and political support. Until recently, CCUS and removal technologies have not benefitted from the same political and technical support as other options, especially renewable energy solutions. Both the imperative of decarbonization and the nationally determined nature of the Paris Agreement require that the principle of technology neutrality – which has lately been neglected – be restored to the center of the discussion.

To remain an option, this technology and approach will need to receive increased political support, both at the national and regional level, such as in the EU, as well as at the international level. Much remains to be done in this respect, highlighting the urgency of prompt action. The next major opportunity to accelerate the exploration and deployment of CCUS will present itself at the 28th Session of the Conference of the Parties to the UNFCCC (COP28) in Dubai, United Arab Emirates, in December 2023. A political signal at the COP through a political declaration, in the cover decision, or through another mechanism, would be of great value to accelerate the availability of CCUS and removals, including in terms of public opinion and debate.

Practical solutions that can help with the implementation of CCUS and removals are likewise essential if these options are to play the critical role ascribed to them in all mitigation scenarios. Because of the uneven geographic distribution of CCUS and removal capacities, testing the regulatory framework and infrastructure for international cooperation – especially using Article 6 of the Paris Agreement – will be important, underscoring the importance of prompt adoption of methodological guidance on removals under Article 6.4. Consideration can also be given to the formation, within the framework of the Paris Agreement or outside of it, of coalitions of countries or "clubs" that can advance CCUS and removals, for instance through piloting activities.

Providing solutions to address risks and inefficiencies specific to CCUS and removals is important and needs to be done by creating the appropriate international governance and instruments. Removals have an inherent long-term nature which needs to be matched by the appropriate regulatory safeguards. Assignment of liability associated with removals to an existing or newly created international institution with a significant balance sheet can address such risks.

Ultimately, ensuring the availability of all options, including CCUS and removals, to address climate change and meet the objective of the Paris Agreement is a matter of managing and hedging risk, because no single solution offers a panacea.

1 Background

The Paris Agreement is the first universal, legally binding climate treaty. It aims at limiting the increase of global average temperature well below 2°C and pursuing efforts to stay within 1.5°C, adapting to climate change and enhancing communities' resilience to this change-related impacts, and, finally, securing the means of implementation (MOIs): finance, technology, and capacity building to enable climate action in developing countries UNFCCC, "Paris Agreement.".

While stabilization of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system was the overarching objective of the United Nations Framework Convention on Climate Change (UNFCCC), it already mentioned adaptation and MOIs. Several important provisions in the Paris Agreement that also form part of its objectives reflect further elaboration of these elements.

First is climate neutrality, which is also often referred to as the global goal of achieving net zero emissions. This means global peaking as soon as possible, followed by rapid reductions in greenhouse gas emissions leading to the global balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases to be achieved in the second half of this century, as set out in Article 4 of the Paris Agreement.

Second, low-emission development strategies are recognized as the universal approach to be deployed by all the Parties to the agreement. They are obliged to communicate their strategies, so their efforts are transparently presented to the world.

Third, carbon dioxide removals (CDRs), through the enhancement of carbon sinks and reservoirs of greenhouse gases, are recognized through Article 5 of the Paris Agreement. The well-being of forests and other natural sinks is one of the acknowledged prerequisites for carbon neutrality. This is why so much attention has been attached to stopping deforestation worldwide, with strong political commitment by Heads of State and Governments. Unfortunately, actual success with halting or reversing deforestation has not been as forthcoming despite international efforts. This underscores the case for an increased focus on removals at the next session of the Conference of the Parties to the UNFCCC (COP) and the Conference of the Parties serving as the Meeting of the Parties to the Paris Agreement (CMA), and beyond.

Fourth, cooperation and the widest possible participation of all parties and non-parties in every kind of climate change-related effort. Article 6 of the Paris Agreement focuses on international cooperation as an important means of reaching the global net zero goal and was seen at the Paris COP as a key in the use of CDR to reach net zero emissions globally. Also, for the first time, an international treaty recognized the role of local governments and municipalities, businesses, as well as other stakeholders, along with the benefits of societal dialogue. Last but not least, indigenous peoples, women, youth, farmers, and other constituencies are no longer silent observers of the implementation process. They play a very important role and are represented in the global climate debate.

1.1 Fundamental concepts and building blocks

The Paris Agreement must be implemented in a way that respects the national sovereignty of each of the Parties and does not lead to imposing external pressures. Therefore, the nationally determined nature of contributions, with each individual Party contributing to the collective achievement of the global goals, was instrumental in unlocking the entire climate debate. Countries undertake a sovereign decision-making process to set their targets, the scope for action, and the necessary conditions and time needed to achieve progression in mitigating their impacts and adapting to climate change. In plain English, Parties will contribute as much as they can, in the manner that they choose, and report transparently to the international community. They communicate their Nationally Determined Contributions, the NDCs, which – together with transparency – are the bedrock of the approach chosen with the Paris Agreement.

One of the fundamental consequences flowing from the concept of NDCs in the Paris Agreement is that countries will choose to balance their use of different approaches, including CDR, as part of their overall implementation strategy. Focusing overwhelmingly on one approach only, and neglecting others, will lead to a lack of diversification and an inherent technological and political risk, should any one option not deliver as expected.

In its recent Sixth Assessment Report (AR6), the Intergovernmental Panel on Climate Change (IPCC) clearly indicated that the menu of possible mitigation actions includes: emission reduction at sources (for instance energy generation or land use, e.g. deforestation), renewable energy generation, energy efficiency, emission removals both through nature-based solutions and technology-based carbon capture and storage (CCS) or utilization (CCU), and direct capture from the ambient air (DAC) IPCC, "Climate Change 2022: Mitigation.".[1]

The Global Stocktake (GST)[2] is a non-coercive assessment of progress towards achieving the purpose of the Paris Agreement and its specific targets. Achievements to date, public expectations, scientific analysis, economic reality, and results of global efforts will all be discussed as part of the GST. Publicly available outcomes of the GST will help to update and enhance actions to be undertaken by the Parties. The first-ever GST shall be undertaken by the CMA at this year's COP28 in Dubai, United Arab Emirates.

Cooperation and engagement of as many stakeholders as possible is one of the keys to a successful implementation of the Paris Agreement. The mechanisms that incentivize various forms of cooperation are another important building block of the Agreement. They help to maximize the results of joint actions of partner countries and offer market opportunities for businesses. They also help to invest in and use the latest innovative technologies and systemic solutions in developing countries.

The Paris Agreement does not restrict the usage of any technology. Its purpose must be achieved, in other words, GHG emissions must peak and then rapidly decline. Carbon stocks must be enhanced so that sinks (both natural and technological) can remove CO_2 from the

[1] See, specifically, Sections 12.3 and 14.4.5 of IPCC "Climate Change 2021: Physical Science." and Chapter 7 of IPCC IPCC, "Climate Change 2022: Mitigation." for mitigation through agriculture, forestry, and land use.

[2] Article 14 of the Paris Agreement.

ambient air and achieve a balance between emissions and removals by the end of this century. None of the actions can affect the eradication of poverty or the ability of nations to further develop in a sustainable manner.

1.2 Increasing urgency

At COP21, Parties requested a report from the IPCC that would analyze the consequences of temperature increase above 1.5°C. According to the Special Report published in 2018, such an increase could result in momentous economic losses, and lead to mass migration of large numbers of people from the most affected areas IPCC, "Global Warming of 1.5°C.".

AR6 of the IPCCC recently concluded with the Synthesis Report adopted in March 2023 (IPCC 2023), is also very clear. A statement by the Chair of the IPCC made just before the adoption of the report reads: *"It provides world governments with a robust list of options to improve ways to adapt to and prevent climate change. It is up to each government to determine which options to pursue, but the Synthesis Report makes it very clear that inaction is no longer an option."*

This statement resonates very well with the COP27 outcome, in particular, Paragraph 13 of Decision 1/CP.27 on the Sharm el-Sheikh Implementation Plan, which addresses the urgency of action following scientific advice and the principles of the Paris Agreement.[3] The recent IPCC report defines *"unabated fossil fuels"* as *"produced and used without interventions that substantially reduce the amount of GHG emitted throughout the life cycle; for example, capturing 90% or more CO_2 from power plants, or 50–80% of fugitive methane emissions from energy supply"* (IPCC 2022).

1.3 One size does not fit all

The climate debate, which in many jurisdictions takes place as much through the media as it does in intergovernmental fora, is increasingly focused on threats, damages, and all the other negative consequences of climate change. There are also many stakeholders – such as businesses, trade unions, and economists – who point out that climate action undertaken in diverse economies in different regions must not follow a single approach that would replicate the same pattern for actions all over the world.

Just transition, adaptation, and making sovereign choices regarding energy sources along with cultural and geographic circumstances must be considered when planning actions. According to Article 3(4) of the UNFCCC, the national circumstances of the Parties should be recognized as well as *"their right to promote sustainable development [...], taking into account that economic development is essential for adopting measures to address climate change."*

[3] Decision 1. CP/27, para. 13: "Calls upon Parties to accelerate the development, deployment and dissemination of technologies, and the adoption of policies, to transition towards low-emission energy systems, including by rapidly scaling up the deployment of clean power generation and energy efficiency measures, including accelerating efforts towards the phasedown of unabated coal power and phase-out of inefficient fossil fuel subsidies, while providing targeted support to the poorest and most vulnerable in line with national circumstances and recognizing the need for support towards a just transition."

1.4 CCUS and the Paris Agreement

The Agreement does not make any direct reference to any specific technology. However, it calls on countries to undertake ambitious efforts to reduce GHG emissions and notes the importance of "sinks and reservoirs" in achieving this goal. Carbon capture and utilization or storage (CCU/CCS, jointly CCUS) is one such sink that can help mitigate emissions and/or remove CO_2 from the atmosphere.

Moreover, CCUS can promote cooperation and encourage the use of market-based mechanisms, such as carbon trading and offsetting. CCUS projects can generate carbon credits and offer additional financial incentives for their deployment.

In AR6, the IPCC lists CCS in the context of energy generation and supply. "Net zero CO_2 energy systems entail: a substantial reduction in overall fossil fuel use, minimal use of unabated fossil fuels, and use of Carbon Capture and Storage in the remaining fossil fuel systems" (IPCC 2023, 70). CCU and CCS will also be essential for keeping alive certain industries. In the majority of cases, reductions along the value chain will need to be achieved (IPCC 2023, 71).

2 Scenarios for emissions neutrality: why CCUS and removals are essential

The importance of the accelerated deployment of CCUS and removal technologies is backed by all major mitigation scenarios describing pathways towards emissions neutrality in line with the temperature stabilization targets of the Paris Agreement, including those outlined by the IPCC, the International Energy Agency (IEA), the Energy Transition Commission (ETC), as well as scenarios from the private sectors, each of which is presented in greater detail below.

This section also considers the evolving energy mix under these scenarios, which highlight the continued use of fossil energy sources – in varying degrees – projected under all the foregoing scenarios. Finally, it discusses the economic implications of CCUS and removals as a technology option for climate change mitigation, including technology cost and availability, under these scenarios, as well as the contribution that removals can and must make to reach the goals of the Paris Agreement.

2.1 CCUS and removals in global scenarios

Despite differences in the specific assumptions and outcomes, virtually all scenarios for emissions neutrality and achievement of the 1.5°C and 2°C temperature targets agreed in the Paris Agreement anticipate that cumulative emissions by 2050 will exceed the "carbon budget" consistent with these targets, and therefore envision the substantial deployment of CCUS and carbon removal technologies. Of particular importance are the scenarios published by the IPCC and the IEA, two intergovernmental entities whose reports enjoy a high degree of credibility and authority in the international community. Additionally, this section considers scenarios outlined by bp, an energy company, and the Energy Transition Commission, a civil society organization, to broaden the set of perspectives and reflected backgrounds.

2.1.1 Intergovernmental Panel on Climate Change (IPCC)

The IPCC, established in 1988 as an intergovernmental body by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), undertakes systematic reviews of the state of scientific knowledge on anthropogenic climate change and periodically compiles assessment reports for policymakers and the general public. The latest such assessment, AR6, was released in three working group contributions starting in 2021, and a synthesis report was made available in 2023. In the contribution by Working Group III on mitigation, the IPCC assessed a wide range of modeled global emission pathways and scenarios from the literature, including 1202 scenarios with projected global warming outcomes using climate emulators reflecting a wide range of modeling approaches (IPCC 2022).

From this larger set, the IPCC selected Illustrative Mitigation Pathways (IMPs) to illustrate a range of different mitigation strategies that would be consistent with different warming levels.

These illustrate pathways that achieve deep and rapid emissions reductions through different combinations of mitigation strategies, differing in terms of their focus and placing greater emphasis on renewables, deployment of CDR that results in net negative global emissions, and efficient resource use as well as shifts in consumption patterns globally.

In modeled pathways that limit warming to 1.5°C with a greater than 50% probability and no or limited overshoot, global net zero CO_2 emissions are reached in the early 2050s, and in modeled pathways that limit warming to 2°C with a greater than 67% probability, global net zero CO_2 emissions are reached around the early 2070s. Many of these pathways continue to achieve net negative CO_2 emissions after the point of net zero (IPCC 2022).

All global modeled pathways that limit warming to either 1.5°C or 2°C assume some continued use of fossil fuels (see Section 2.2), and deployment of CCS or CDR methods to counterbalance residual GHG emissions. Also, by mid-century, almost all electricity is supplied from zero- or low-carbon sources, including fossil fuels with CCS. Methods and levels of CDR deployment in globally modeled mitigation pathways vary depending on assumptions about costs, availability, and constraints (see Section 2.3).

Modeled pathways that report CDR and that limit warming to 1.5°C with a greater than 50% probability and no or limited overshoot assume global cumulative CDR use from 2020 to 2100 of 30–780 $GtCO_2$ from bioenergy with carbon dioxide capture and storage (BECCS) and of 0–310 $GtCO_2$ from direct air carbon dioxide capture and storage (DACCS), respectively. Total cumulative net negative CO_2 emissions including CDR deployment across all options represented in these modelled pathways are 20–660 $GtCO_2$. In modelled pathways that limit warming to 2°C with a greater than 67% probability, global cumulative CDR between 2020 and 2100 from BECCS and DACCS is 170–650 $GtCO_2$ and 0–250 $GtCO_2$ respectively, with total cumulative net negative CO_2 emissions of around 0–290 $GtCO_2$ (IPCC 2022).

2.1.2 International Energy Agency (IEA)

The IEA is an intergovernmental organization established in 1974 under the framework of the Organisation for Economic Co-operation and Development (OECD), and mandated with providing policy recommendations, analysis, and data on the global energy sector. It currently has 31 member countries, 3 accession countries, and 11 association countries, but its scope is broader, encompassing analysis, roadmaps, policy reviews, and detailed data on more than 150 countries. While its initial creation was motivated by concerns about conventional energy supply, it has recently shifted its focus on the transition to renewable energy and net zero emissions.

Aside from its annual flagship publication, the World Energy Outlook (WEO) on global energy projections and analysis, the IEA has recently published the first comprehensive pathway for the global energy sector to reach net zero emissions by 2050. With this 2021 special report, Net Zero by 2050, the IEA introduced a Net Zero Emissions (NZE) scenario that describes a transition to net zero emissions by 2050 while maintaining secure and affordable energy supplies, extending energy access, and encouraging robust economic growth (IEA 2021).

This report acknowledges the importance of CCUS in achieving net zero CO_2 emissions by tackling emissions from existing assets, providing a way to address emissions from some of the most challenging sectors, including a cost-effective pathway to scale up low-carbon hydrogen production rapidly, and allowing for CO_2 removal from the atmosphere through BECCS and DACCS. Initially, capture volumes in the NZE scenario increase marginally from current levels of around 40 Mt of CO_2 per year, but there is a rapid expansion over the following 25 years due to increasing policy success. By 2030, 1.6 Gt of CO_2 per year is captured globally, rising to 7.6 Gt of CO_2 in 2050 (IEA 2021).

2.1.3 Corporate: bp

Bp p.l.c., a British multinational oil and gas company headquartered in London, is a vertically integrated company operating in all areas of the oil and gas industry, including exploration and extraction, refining, distribution and marketing, power generation, and trading. Since 2011, it has annually published an Energy Outlook that makes projections of future energy trends. Its latest installment, Energy Outlook 2023, is focused on three main scenarios: “Accelerated”, “Net Zero” and “New Momentum”, which span a wide range of possible outcomes and explore the possible implications of different judgments and assumptions concerning the nature of the energy transition and the uncertainties around those judgments (bp 2023).

The “Accelerated” and “Net zero” scenarios explore how different elements of the energy system might change in order to achieve a substantial reduction in carbon emissions, with GHG emissions falling by around 75% by 2050 in the “Accelerated” and by 95% in the “Net Zero” scenario. By contrast, the “New Momentum” scenario is designed to capture the broad trajectory along which the global energy system is currently traveling, with GHG emissions peaking in the 2020s and falling to around 30% below 2019 levels by 2050 (bp 2023).

The Energy Outlook 2023 acknowledges that CCUS plays a central role in supporting the transition to a low-carbon energy system by capturing industrial process emissions, acting as a source of carbon dioxide removal, and abating emissions from the use of fossil fuels. In the Accelerated and Net Zero scenarios, the projected use of CCUS reaches between 4-6 $GtCO_2$ by 2050, compared to 1 $GtCO_2$ in the New Momentum scenario. Around 15% of CCUS in 2050 is used to capture and store non-energy process emissions from cement production, 10-

20% is BECCS, and the rest is utilized to abate emissions from the use of natural gas and coal (bp 2023).

The Energy Outlook 2023 also discusses the importance of removals to achieve deep and rapid decarbonization, describing the main technological options – including BECCS, natural climate solutions (NCS), and DACCS – but limits itself to replicating the scenarios included in the IPCC AR6, without projecting CDR uptake based on its own scenarios.

2.1.4 Energy Transitions Commission (ETC)

The ETC is an international think tank created in 2015 and based in London that is based on a coalition of currently 60 commissioners drawn from a range of organizations – energy producers, energy-intensive industries, technology providers, finance players, and environmental NGOs – which operate across developed and developing countries and play different roles in the energy transition. It develops transition roadmaps laying out how to reach net-zero emissions, as well as recommendations and tools to inform the implementation of those roadmaps.

In its 2022 report Mind the Gap: How Carbon Dioxide Removals Must Complement Deep Decarbonisation to Keep 1.5°C Alive, the ETC states that even the most ambitious possible reduction in gross emissions will almost certainly result in cumulative CO_2 emissions between now and 2050 exceeding the "carbon budget" consistent with a 1.5°C climate objective, and will not be able to reduce gross emissions to absolute zero by 2050, with a low level of CO_2, N_2O and CH_4 residual emissions likely continuing beyond mid-century (ETC 2022).

In addition to dramatic decarbonization to meet the 1.5°C climate objective, the Mind the Gap report therefore concludes that a significant volume of CDR will therefore be required, with ETC scenarios suggesting a need for at least 70-225 Gt CO_2 of cumulative removals by 2050 to neutralize the impact of the likely carbon budget overshoot ahead of mid-century, and about 3-5 Gt CO_2 per year to neutralize continuing residual emissions after mid-century of both CO_2 and N_2O. Additional removals may be necessary according to the report to generate sufficient net negative emissions in the second half of the century to reverse the effects of an overshoot of the cumulative budget (ETC 2022).

2.2 Energy mix in global scenarios

As indicated in the previous section, even scenarios that achieve net zero emissions by mid-century and offer a high probability of remaining within the 1.5°C and 2°C temperature stabilization targets of the Paris Agreement assume continued use of fossil fuels, underscoring the importance of CCUS and CDR technologies.

In its AR6 report, the IPCC underscores that, while global fossil fuel use will need to decline substantially by 2050 to limit warming to 2°C, and by 2030 to limit warming to 1.5°C, it still anticipates that fossil energy will provide 59% to 69% of primary energy in 2030 and 25% to 40% primary energy in 2050 in scenarios limiting warming to 1.5°C with a 50% or greater probability and that it provides 71% to 75% of primary energy in 2030 and 41% to 57% primary energy in 2050 in scenarios limiting warming to 2°C. The timelines for reducing the production and usage of fossil fuel vary across coal, oil, and gas due to their differing carbon intensities and uses (IPCC 2022).

Similarly, in the NZE scenario introduced with its 2021 special report Net Zero by 2050, for instance, the IEA projects large reductions in the use of fossil fuels, which fall from 80% of the total energy supply in 2020 to just over 20% in 2050 (IEA 2021). However, it assumes that significant amounts will still be used in producing non-energy goods where the carbon is embodied in the product, such as plastics, in plants with CCUS, and in sectors where emissions are especially hard to abate, such as heavy industry and long-distance transport. Accordingly, all remaining emissions in 2050 have to be offset by negative emissions elsewhere.

Different scenarios are informed by varying assumptions on the relative decline in the use of coal, oil, and natural gas, with coal generally seeing the fastest decline. For instance, the IEA projects that coal use would see an average annual decline of 7% each year from 2020 to 2050, whereas oil demand would experience an annual average decline of more than 4% from 2020 to 2050, and natural gas would only see an annual average decline of under 3% from 2020 to 2050. Coal demand declines by 90% to less than 600 Mtce in 2050, oil declines by 75% to 24 mb/d, and natural gas declines by 55% to 1 750 bcm. Overall, declining demand in developed economies is initially offset by a substantial increase in energy demand in emerging markets and developing economies, where economic and population growth is fastest and where there are fewer net zero pledges (IEA 2021).

Finally, BP in its Energy Outlook 2023 estimates that fossil fuels used at the final point of energy use will decline from a share of around 65% in 2019 to 20% to 50% by 2050 across all three scenarios: “Accelerated”, “Net Zero” and “New Momentum”. Within hydrocarbons, the share of coal falls particularly sharply as the world increasingly shifts to the use of electricity and low-carbon hydrogen in industry, as does the share of oil, driven primarily by the falling use of oil in road transport (bp 2023).

2.3 CCUS and removals: technology cost and storage capacities

Future deployment rates of CCUS and removals will not be primarily determined by the projected needs to achieve net zero emissions and remain within the 1.5°C and 2°C temperature stabilization targets of the Paris Agreement, but by technology availability, cost, and CO_2 storage capacities. According to the estimate presented by the ETC in its 2022 Mind the Gap report, costs for NCS approaches begin relatively low in a range of US$5 to US$50 per tonne but rise over time, whereas the costs of engineered removal technologies such as DACCS initially begin at around US$300-600 per tonne but fall to around $100 over time (ETC 2022).

To support the anticipated growth in removals, the Mind the Gap report projects that annual CDR payments could exceed US$200 billion per year by 2030, a substantial increase on the estimated less than US$10 billion of funding flowing into these sectors today. By 2050, the cumulative funding needs for investments in removals are estimated at around US$15 trillion by 2050, equivalent to around 0.25% of the projected global GDP (ETC 2022).

While there remains thus a substantial investment shortfall that will require a massive scaling up of funding to close, physical storage capacities for sequestered CO_2 should not pose a relevant constraint in the near and medium term. According to the IPCC AR6, global storage capacity is estimated to be on the order of 1000 Gt CO_2, exceeding the estimated storage requirements to limit average global temperature increase to 1.5°C, although regional availability varies (IPCC 2022). Likewise, the IEA in its Net Zero by 2050 special report estimates that global geological storage capacity is considerably above what is necessary to store the cumulative CO_2 captured and stored in its NZE scenario (IEA 2021).

As described in greater detail in Section 3.2.3, national or regional assessments of storage capacities confirm these global estimates. Potential storage capacities in different regions, for instance, have been estimated to amount to approximately 130 $GtCO_2$ in Canada (IEA 2022a), 170 $GtCO_2$ in the region of the Gulf Cooperation Council (GCC) countries (AFRY & GaffneyCline 2022), 150 $GtCO_2$ in South Africa (Council of Geoscience 2010), and between 2,600 and 22,000 $GtCO_2$ in the U.S. (CRS 2022).

2.4 Residual emissions and the importance of removals

As becomes evident from the scenarios described in the foregoing sections, no pathway to decarbonization can entirely obviate the need for removals.

Two distinct approaches can be identified:

- Addressing residual and life cycle emissions: countries that are able to focus on reducing their direct emissions, for instance by substituting fossil fuel combustion with renewable energy technologies, will still face residual emissions – including the lifecycle emissions of clean technologies – which will need to be compensated through deployment of CCUS and removals.
- Addressing direct emissions from combustion: countries may opt for continued use of emissive technologies in line with their domestic resource endowment and economic and social priorities and will then have to rely more heavily on CCUS and – given inefficiencies in CCUS technologies – removals to achieve net zero emissions.

While all credible projections of the global energy mix still anticipate a continued role for fossil fuels over the longer term (see Section 2.2 below), even where direct emissions from fossil fuel combustion and industrial processes can be reduced through substitution with low- or zero-emission technologies the lifecycle emissions from production of those technologies will still need to be mitigated.

In its review of lifecycle emissions from solar PV technology, for instance, the IPCC affirmed a considerable range of estimates for the lifecycle emissions of that technology, from 9 to 250 gCO_2 per kWh of electricity generated (IPCC 2022). Other renewable energy technologies as well as storage technologies also have non-trivial lifecycle emissions (NREL 2021). Likewise, CCUS technologies generate lifecycle emissions that will require recourse to removals.

Currently, however, the actual deployment of removals is estimated to be about 2 $GtCO_2$ per year for conventional approaches on land, primarily via afforestation, reforestation, and management of existing forests, with only a minuscule fraction, 0.002 $GtCO_2$ per year, resulting from technological approaches such as BECCS and DACCS (Smith et al. 2023). Yet despite growing policy interest and investment levels, no country so far has pledged to scale technological removals by 2030 as part of their NDC, and few countries have so far published proposals for upscaling technological removals by 2050.

Hence, removals – and in particular novel technological CDR approaches – merit particular consideration in efforts to ensure the future availability at scale of all significant mitigation options.

3 National approaches: what is driving the choice of deploying CCUS?

Interest in and deployment of CCUS, whether directly at the stack or through other means such as DACCS, is unevenly distributed between jurisdictions. A good understanding of what drives positions regarding CCUS in each jurisdiction is an important element in ensuring that this approach plays an important role in addressing the net-zero objective of the Paris Agreement. Not all countries will, or can be expected to, adopt CCS to the same degree in their toolbox of measures towards reaching their Paris Agreement commitments.

It would seem that a number of factors would logically influence the role that CCUS plays in a jurisdiction, including, but not limited to, the natural endowment in terms of energy sources, level of development, level of emissions, geology favorable to storage, public perceptions and acceptance, and so on.

One important factor that also needs to be considered is the general approach to addressing the climate challenge, whether it is more ideological and fixated on one specific technology, or pragmatic, open to a diversity of solutions, and accepting technology neutrality as a fundamental principle.

Any analysis of these issues will need to focus on jurisdictions where there is sufficient diversity between the factors referred to above.

3.1 State of play: national approaches

Although CCUS has only recently seen an uptick in real and concrete interest, the technology has been around since the 1970s, when it was introduced to improve oil recovery and enhance domestic hydrocarbon production. In the 1990s, it became a technology broadly associated with efforts to decarbonize the power sector and industry.

An instructive example is provided by the United States (U.S.), which is among the first countries to apply CCUS, initially for enhanced oil recovery and more recently as a technology to reduce emissions.

It has long relied on incentives such as the Windfall Profits Tax, which dated back to the 1980s and provided a tax exemption for oil producers relying on enhanced oil recovery (EOR) technologies (96th Congress 1980; repealed by 100th Congress 1988). However, the 45Q credit, which was initially introduced in 2008 and reinforced in 2018, is among the first CCS-specific policies implemented in the country (116th Congress 2020).

Recently, new legislative initiatives during the 117th Congress, including the Infrastructure Investment and Jobs Act (IIAJA) and the Inflation Reduction Act (IRA), have dramatically increased the incentives for the deployment of CCUS and DACCS technologies, extending and increasing the existing 45Q tax credit and appropriating additional funds for specific research and deployment activities (117th Congress 2021; 117th Congress 2022).

Because of its long history in CCUS, the U.S. is also the country with the largest number of projects – with 13 working facilities by 2022 – and hosts the oldest project, the Terrel Natural Gas Processing Plant, which started operations in 1972 (Global CCS Institute 2022).

Nevertheless, despite CCUS being recognized as an essential technology to achieve climate neutrality by all major mitigation scenarios, the U.S. makes no reference to this technology in its NDC, even as it pledges to achieve net-zero emissions no later than 2050 and covers CDR technologies in its scope. CCUS is instead mentioned in the country's long-term strategy, in which CO_2 storage is conceived as essential to decarbonize the U.S.' electric power sector, the second-largest producer of emissions in the nation, and as a zero-carbon industrial innovation (United States 2021). However, the Administration of President Joseph R. Biden has recently introduced new efforts to achieve climate neutrality, such as the COP28 Carbon Management Challenge, which aims at partnering with other countries to accelerate the deployment of this technology (White House 2023).

Australia was also an early leader in CCUS, at least in terms of policy implementation. Indeed, even if the only commercial-scale CO_2 injection project (at the Gorgon site), was only implemented in 2019, the government has been providing funding to accelerate the development and demonstration of the technology through the Carbon Capture and Storage Flagships (CCS Flagships) Program established in 2009. Legislation has also been updated more recently, with the launch of new programs and funds such as the Carbon Capture, Use and Storage Development Fund in 2020 and the Carbon Capture, Use and Storage (CCUS) Hubs and Technologies Program in 2021, among others, to support research, development, deployment, and commercialization of CCUS technologies (Commonwealth of Australia 2021).

In its long-term strategy, Australia also describes how its international (bilateral) partnership will help it achieve its climate neutrality target by fostering a technology-led approach to reduce emissions. With regard to CCUS, the Low Emissions Technology Partnership with Japan and the Australia-UK Partnership in Low Emissions Solutions seem to be of strategic importance, as they involve the export of hydrogen to Japan and cooperation on research and development of carbon capture, use, and storage technology, respectively.

While the U.S. and Australia were each early adopters in their own right, other countries already have considered CCUS for some time. Brazil, for instance, began manifesting greater interest in these activities after the discovery of significant offshore oil deposits, with the first project on Brazilian territory becoming operational in 2011 for oil recovery purposes (Global CCS Institute 2022).

Brazil does not currently have any specific policies or legislation in place to encourage the deployment of CCUS, neither in its NDC nor in its national framework. The government is only now discussing a bill to establish a legal framework for the economic development of CCS activities in geological reservoirs such as oil wells, saline aquifers, and coal beds.[4]

For other countries, such as India and South Africa, CCUS represents a more recent interest. In these jurisdictions, CCUS technologies were not originally seen as a priority as they have been associated with enhanced oil recovery, and these countries did not possess significant oil deposits. Likewise, these countries did not have any international GHG mitigation obligations, but now they have pledged net-zero targets by 2050 for South Africa and by 2070 for India in their respective NDCs.

In its long-term strategy, the government of India explains the reasons behind its chosen approach. The technology was not seen as a viable economic option, and only pilot projects could be considered until recently. Research is being conducted in India through the creation of two centers of excellence – namely the National Centre of Excellence in Carbon Capture and Utilization (NCoE-CCU) at the Indian Institute of Technology (IIT), Bombay, and the National Centre in Carbon Capture and Utilization (NCCCU) at the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bengaluru – with the objective of creating networks among stakeholders to foster innovation and project initiatives (India, n.d.).

In February 2023, India's Ministry of Environment, Forest and Climate Change announced the approval of the final list of activities to be considered for the trading of carbon credits under Article 6.2 of the Paris Agreement, and that list included CCUS as an eligible activity (India 2023).

South Africa displayed early efforts on R&D on CCUS. The South African Council for Geoscience, for instance, has been working on CCUS since 1993 and embarked on the country's CCUS program in 2004. Still, less activity is evident in terms of actual deployment.

Even countries where the technology had been previously used due to earlier experience in the oil industry, such as the Kingdom of Saudi Arabia (KSA) and Canada, did not start intense implementation of CCUS projects until the middle of the last decade.

KSA has committed to reducing, avoiding, and removing GHG emissions by 278 million tons of CO_2eq by 2030 from 2019 levels in its NDC, and announced a net-zero pledge by 2060 at COP26. It aims to achieve these targets through an approach launched in 2021 that has been labeled the Circular Carbon Economy (CCE), which rests on four Rs: reduce, recycle, reuse, and remove for the management of CO_2. It covers all applications of CCUS, including both engineered removals – such as DACCS – and nature-based solutions, such as carbon sinks through mangrove forests (Saudi Arabia, n.d.).

In addition to this pledge, the government has recently announced a target of capturing 44 million tons a year by 2035. This is supported by establishing a hub in Jubail with a storage capacity of up to 9 million tons a year by 2027 (Arab News 2023) through a joint development agreement between Saudi Aramco and SLB and Linde (Reuters 2022). However, KSA does not currently have any CCUS regulations in place, despite there already being one running project that focuses on storage: Aramco's Uthmaniyah demonstration project.

[4] Projeto de Lei n° 1425, de 2022. Available at https://www25.senado.leg.br/web/atividade/materias/-/materia/153342.

The first CCUS project in Canada, and the world's first commercial-scale, post-combustion CCS project on a coal-fired power plant, is the Boundary Dam Carbon Capture and Storage Project, which was launched in 2014 in Saskatchewan to reduce emissions from the related coal-fired power station that produces electricity. It was followed by the Quest Carbon Capture and Storage facility in 2015, operated by Shell Canada.

CCUS activities in Canada have initially been regulated and implemented at the provincial level, especially in the hydrocarbon-producing provinces of Alberta and Saskatchewan. Constituting this regulatory framework in Alberta are, for instance, the Carbon Capture and Storage Funding Act, the Carbon Capture and Storage Funding Regulation (funding for education and assessment), and the Carbon Sequestration Tenure Regulation, among others (Alberta, n.d.). CCUS is also covered under the Technology Innovation and Emissions Reduction Implementation Act (TIER), which is Alberta's carbon pricing system (McKenzie and MacDougall 2023).

In 2021, the Government of Saskatchewan announced in its CCUS priorities the intention to advance private sector investments in the technology, while it introduced a set of other policies in the oil sector that apply to CCUS projects, such as the Petroleum Innovation Incentive (SPII), the Oil and Gas Processing Investment Incentive (OGPII), and the Oil Infrastructure Investment Program (OIIP).

Meanwhile, to reach its net-zero target by 2050, Canada's federal government recognized the contribution that CCUS can make to reducing emissions by announcing the introduction of a federal investment tax credit for capture and storage projects, estimated by the federal government to reach $8.6 billion by 2030, which is currently under discussion.

Across the Atlantic, in Europe, there is still a strong debate on the role of CCUS and DACCS, but it is also becoming clear that CCUS is becoming more central in terms of policy development. Several recent policy initiatives – outlined below – underscore that observation. It is also important to highlight that, in the EU, implementation occurs at the Member State level, with significant differences between countries.

In effect, the first European CCUS projects were implemented in Hungary and Norway: the Mol Szank Field CO_2 EOR project in 1992, and the Sleipner CO_2 Storage project in 1996, respectively. Still, these did not herald a surge in broader implementation, and progress was further stymied by the 2007 financial crisis and the long period of low allowance prices under the EU Emissions Trading System (EU ETS) (CCUS ZEN, n.d.). Also, different Member States have chosen different approaches depending on several factors.

Only a few projects were then developed in the 2000s, such as the Cryocap project for blue hydrogen in France in 2015 and the Orca project in Iceland in 2021, among others. Many are under development or are in the stage of starting operations only starting next year or later (IOGP 2022). The only exception to this trend is represented by the United Kingdom: in the country, the oil company bp implemented the Decarbonised Fuels Project, known as DF1, in 2006 based at the Peterhead Power Plant to manufacture hydrogen and generate 'carbon-free' electricity as a demonstration project (House of Commons 2006).

By contrast, the EU has focused on a regulatory approach with the introduction of the CCS Directive in 2009, which provides an incentive for installations covered under the EU ETS Directive to store CO_2, by not requiring the surrender of allowances when CO_2 is captured at the stack (European Parliament and Council 2009). Further incentives are being proposed in the Net-Zero Industry Act presented in March 2023, which lists CCUS as a strategic technology that can benefit from faster permitting times and easier access to funding and benefits in public procurement procedures, while putting in place a target of achieving an annual injection capacity of at least 50 million tonnes of CO_2 by 2030 (European Commission 2023). Moreover, the Carbon Removal Certification Framework, put forward in November 2022, shows that removals and storage are increasingly targeted for incorporation under the EU legal framework (European Commission 2022b).

3.2 Factors contributing to country use of CCS

Countries have very different energy matrices and rely on different industrial sectors while having divergent potentials for renewable or low-carbon energy and CO_2 storage capacity. Their attitude towards CCUS is correlated to all these factors.

3.2.1 Energy matrix

Understandably, countries that have significant exposure to carbon-intensive industries and power generation will have a higher interest in CCUS as a solution. Lower levels of potential for renewable energy, such as solar, wind, and hydropower, are also likely to be a factor in the level of interest in using CCUS to lower the GHG emissions intensity of energy generation and industrial output.

This is true for countries such as India, where the government has stated in its long-term strategy that fossil fuels, including coal, will remain fundamental in the foreseeable future to meet the energy security needs of the country (India 2022). Indeed, India's consumption of fossil fuel was about 65% of its total energy mix in 2020, while renewable energy originating from wind, solar and hydropower accounted for less than 10% (IEA, n.d. e). Nevertheless, the government of India committed to achieving about 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030 in its updated NDC, for instance by promoting hydropower obligations along with renewable power obligations, as explained in the long-term strategy.

Similarly, South Africa is one of the world's largest coal consumers thanks to its vast coal reserves. More than 70% of South Africa's energy consumption relies on coal as a primary source, while less than 5% originated from hydropower, solar, and wind in 2020 (IEA, n.d. g). Such capacity is expected to double across the Sub-Saharan region from 2022 to 2027, with South Africa, along with Ethiopia, Tanzania, Angola, and Kenya, forecast to add more than 60% of the renewable capacity additions (IEA 2022b).

Canada relies on fossil fuels, which accounted for 76.5% of its total energy supply in 2020, despite it being the fourth-largest producer of hydropower in the world (IEA 2022a), covering about 10% of its energy consumption (IEA, n.d. c). Reliance on renewable energy is also expected to increase since the federal government wants to achieve a net-zero electricity grid by 2035, as stated in Canada's long-term strategy. Nevertheless, reliance on oil, for instance, remains high, peaking at almost 40% of the energy supply in 2020 (IEA, n.d. c).

Also, Brazil is a country with a high rate of renewable energy in its energy matrix, which is 44.7% in 2021. Hydropower accounted for 11% of the total internal energy supply, sugarcane biomass 16.4%, biomass and vegetal coal 8.7%, while other sources accounted for 8.7%. Wind, solar, biomass, and biodiesel are increasing as well (epe, 2022). However, fossil fuels still play an important role by covering close to 40% of the country's energy supply (IEA, n.d. b), but the share of renewables is expected to increase steeply in upcoming years thanks to the booming market for solar photovoltaic energy and the considerable pipeline of utility-scale wind and solar projects (IEA, 2022b).

Most other jurisdictions, such as Australia, the EU, KSA, and the U.S., continued to see reliance on fossil fuel sources including coal, natural gas, and oil, for more than 50% of their energy mixes in 2020 (IEA, n.d. a; IEA, n.d. d; IEA, n.d. f; IEA, n.d. h).

Still, these jurisdictions are also increasing their reliance on renewable energy sources. For example, Australia is installing solar, wind, and other renewable technologies at an accelerated rate to have more than half of its electricity generated by renewable sources by 2030 (Commonwealth of Australia 2021). But also, the U.S. recognizes the need to increase the deployment of zero-emission technologies in their long-term strategy (United States 2021).

In the revision of the Renewable Energy Directive, the EU has proposed to increase the current target for the share of renewable energy sources in the EU's energy mix from 32% to at least 40% by 2030 (European Commission, n.d.). The EU is also aiming at becoming independent from Russian fossil fuel imports through the REPowerEU plan, introduced in May 2022: it aims at scaling up the use of renewable energy in power generation, industry, and buildings, and increasing the previous deployment target to 45% by 2030 (European Commission 2022a).

In contrast to the other jurisdictions above, the KSA has, so far, only relied to a minor extent on renewable energy, which accounted for only 0.5% of total electricity generating capacity in 2019. Nevertheless, the country plans to achieve a share of 45-50% of renewables in the national energy mix of the power sector by 2030, by applying the National Renewable Energy Program (Saudi Arabia 2022).

3.2.2 Economic activities

Countries that are major fossil fuel producers and/or have a large manufacturing base in carbon-intensive products, such as steel, cement, aluminum, and coal, are more likely to consider the use of CCUS to maintain their industrial base while discharging their commitments under the Paris Agreement. For these countries, CCUS is not merely a potential option, but likely an essential technology that has to be integrated into the toolbox used towards net-zero targets. A recent study conducted by KOBiZE has shown that the EU will still need to remove 4% of its emissions to achieve 90% of emissions reductions[5] in ambitious scenarios, and the percentage

[5] The remaining 10% of emissions reduction is assumed to be achieved by compensation through, for example, the LULUCF sector.

is even higher in the other scenarios (Pyrka et al. 2023). Also, the Sky scenario prepared by Shell shows that 330 million tonnes of CO_2 emissions need to be captured through CCS by 2050 in the EU[6].

In addition to this, many countries are expanding their production of hydrogen. An example is Australia, which envisions CCS in its pathway to produce hydrogen using natural gas or coal while envisioning its coal and gas export industries continuing beyond 2050 to meet export demand while supporting jobs and regional communities (Commonwealth of Australia 2021).

Other countries, such as KSA, rely significantly on fossil fuel revenues to drive the transition. Oil production, processing, and export are the primary economic activities in terms of income resources (Saudi Arabia 2021), while the country aims to become a world-leading producer and exporter of hydrogen by 2030 (Saudi Arabia 2022). In this case, they will rely essentially on the Circular Carbon Economy program, which includes CCUS as a relevant negative emissions technology (NET). Moreover, countries in the Gulf, including the United Arab Emirates (UAE) and Qatar, can facilitate the creation of a cross-border hub as they can enable an economy of scale for CCUS thanks to the knowledge of local stakeholders (OGCI 2021).

Similar economic concerns apply to Brazil, Canada, the USA, and the EU, which have a strong GHG-intensive industrial base and will need to rely on CCUS to reach their net zero pledges. Some countries, such as Brazil, face a very low cost of oil extraction, which may further increase the demand to use CCUS to decarbonize energy sector activities (CEBRI-BMA 2022).

Canada is fostering research on CCUS to lower the emissions from sectors such as upstream crude oil production while aiming at reducing emissions from other sectors through the production, for instance, of CCUS-based hydrogen (IEA 2022a). The government is also supporting the development and commercialization of this technology for industrial applications, such as cement production, by allocating financial resources to projects through the Strategic Innovation Fund – Net Zero Accelerator (Canada 2022).

While contending with a very different energy resource endowment, the EU also needs to find a strategy to reduce CO_2 emissions from energy-intensive industry processes – which reached 351 million tons in 2020 (Statista 2023)[7] – to achieve a climate-neutral economy by 2050. According to the World Bank, the manufacturing sector[8] contributed about 15% of GDP value added in 2021 (World Bank, n.d.).

In its long-term strategy, the U.S. likewise highlighted that CCUS is one of the key tools to decarbonize the country's industrial emissions from the production of cement, chemicals, iron, and steel (United States 2021) and other parts of the manufacturing sector, which contributed 10% to GDP in 2021 (World Bank, n.d.).

Similarly, South Africa has vast coal reserves; phasing out coal will negatively affect communities that rely on this industry for their livelihood (Council of Geoscience 2022).

[6] For details, see the "The numbers behind Sky" file available at https://www.shell.com/energy-and-innovation/the-energy-future/scenarios/what-are-the-previous-shell-scenarios/shell-scenario-sky.html, last accessed on 4 May 2023.

[7] This data also includes emissions from Iceland and the United Kingdom.

[8] The manufacturing sector refers to industries belonging to ISIC divisions 15-37, which also include other sectors in addition to cement, chemicals, iron, and steel.

Indeed, mining represents the main industry for four out of nine of South Africa's provinces, namely Limpopo, Mpumalanga, North West, and the Northern Cape, representing between 20% and 30% of economic output in each in 2016 (South Africa Gateway 2021).

Lastly, India is a heavily coal-reliant country, where the fuel mainly supplies its power and industrial sectors. Collectively, these two sectors constitute around 60% of the total country's emissions with a total of 1600 Mt of CO_2 emissions in 2020, a number that is projected to increase to 2300 Mt annually by 2030 (NITI Aayog 2022). Faced with technological barriers to mitigate emissions in these sectors, particularly in the industry sector, the Government of India has identified CCUS as a critical and effective contributor to halving its CO_2 emissions by 2050 and in enabling the hydrogen economy in India (NITI Aayog 2022).

3.2.3 Storage capacity availability

The natural endowment with storage capacity can be an important driver for the deployment of CCUS technology: the larger the national storage capacity of a country, the higher the potential opportunities that can be reaped from exploiting it. That explains why many of the countries that are already using CCUS also have large storage capacities.

Examples include Australia, where the national combined storage capacity at four key locations has been estimated to exceed 20 billion tonnes (Commonwealth of Australia 2021), Canada, which can count on over 130 billion tonnes (IEA 2022a), and the U.S., whose estimated storage capacity ranges between about 2.6 trillion and 22 trillion metric tons of CO_2 (CRS 2022). In particular, the last two countries have a history of implementation of this technology. South Africa also conducted a study to understand its storage capacity in 2010, discovering that its theoretical capacity is 150 Gt, of which around 98% is located offshore (Council of Geoscience 2010). KSA is also believed to have some storage capacity, especially in the eastern part of the country (OGCI 2021), while the entire region of the Gulf Cooperation Council (GCC) countries is estimated to have a potential storage capacity of around 170Gt of CO_2 (AFRY & GaffneyCline 2022).

By contrast, other jurisdictions such as the EU, India, and Brazil have limited data on their CO_2 storage capacity or a limited number of storage sites, hampering the deployment of the technology. When looking at Europe, storage capacity appears to be rather localized, as most of the capacity is found in northern Europe – specifically in the North Sea area, for instance in the Netherlands, Norway, Denmark, and the UK – and varies depending on the type of storage site – such as storage reservoirs, hydrocarbon fields, and saline aquifers – with data on other European regions overall lacking (Anthonsen and Christensen 2021).

3.2.4 Public sentiment and acceptance

Public sentiment and public acceptance of CCUS are important factors in how countries will adopt the technology and the overall approach. It is affected, among other factors, by the 'not in my backyard' (NIMBY) phenomenon as well as the negative attitude that many stakeholders, especially environmental advocacy groups in civil society, have vis-à-vis CCUS, portraying it not only as unsafe and untested but also as a distraction from 'doing the right thing' by slowing down the energy transition and imperiling the global net zero target of the Paris Agreement. Insufficient understanding of the urgency and clarity of options also play an important role in shaping public opinion.

Those are the reasons why only recently a change in public opinion has begun taking shape – especially in countries where environmental activism has played an important role in policy formation – leading to greater, albeit in many ways reluctant, acceptance of CCUS. As the energy crisis and associated energy costs have impacted households, and as the ambitious goals of the Paris Agreement and the economic and financial challenges of their achievement have become more visible, with implementation measures directly affecting the population, previously unpopular options such as CCUS have regained social license.

That is not to say that differentiation in this domain does not continue to exist between countries. The message and the messenger – including the trust afforded the messenger – are important factors, as well as trust in government institutions. Governments such as Denmark have invested considerable and sustained effort in fostering public acceptance of CCUS, and that effort is now yielding dividends. Where trust in governments is high and there is a political will to engage by the government, it seems to make a difference.

4 A call to action: what needs to be done now?

As highlighted earlier in this report, different countries possess different circumstances, each with their own history and economic development, social priorities, geopolitical interests, and natural resource endowments, all of which influence how they will contribute to the objectives of the Paris Agreement and achieve climate neutrality. Likewise, previous sections have underscored that no one approach to mitigation can solve the climate challenge on its own. Leveraging all approaches – including CCUS and removals – simultaneously, in varying combinations depending on the unique domestic circumstances in each country, is therefore essential to accelerate progress on the agreed path towards decarbonization.

Doing so reflects the decentralized spirit of the Paris Agreement, which requires each country to freely choose its preferred approach to meeting its NDCs. The Paris Agreement further recognizes that international cooperation is critical in achieving its objectives, including cooperation under Article 6. This highlights that while not all countries are equally endowed with opportunities for CCUS and removals, international cooperation under Article 6 provides the pathway to share in these opportunities.

A number of stakeholders may therefore be interested in joining the efforts to enhance removals and potentially also use cooperative approaches, including local governments and cities, businesses, as well as various international institutions, which may be the first to start implementation of balancing emissions sources with sinks. In the following subsections, we set out a call for action on CCUS and removals that follows a twofold process within and outside the UNFCCC in the run-up to COP28 and beyond.

4.1 Within the UNFCCC: High-Level Political Dialogue and Potential Outcomes

The UNFCCC multilateral negotiations have evolved from focusing purely on the legal outcomes of COPs discussed and agreed upon among countries' delegates, with the observer community having no recognized role and being strictly separated from the official work of the Parties.

This has evolved into a combination of many formal and informal thematic streams unfolding in parallel to the formal negotiations and contributing to the final decisions adopted by the three governing bodies of the UNFCCC, the Kyoto Protocol, and the Paris Agreement – that is, the COP, CMP, and CMA.

Recent climate summits have seen increasing efforts to include language in the "cover decision" reflecting international consensus on global priorities. This has led to the growing use of the cover decision as a vehicle to promote political preferences identified by specific Parties or groups of Parties. We, therefore, urge, at a minimum, acknowledgment of the critical role of CCUS and removals in the cover decision adopted at COP28, ideally coupled with a roadmap for enhanced cooperation on R&D and deployment of these mitigation options.

Being Party-driven is a precondition of the successful conclusion of any UNFCCC decision taken by all the Parties in a formal process. It entails that every decision, COP declaration or work program needs to be transparently presented, thoroughly discussed, and amended by Parties if needed. This raises a significant bar for the adoption of a formal decision, but when it eventually reaches the stage of adoption, it is owned by the entire membership.

Still, while legal outcomes continue to remain the main delivery of the UN climate summits, they are not the only vehicle to advance CCUS and removals within the UNFCCC process.

Political declarations, statements, and roundtables have become another important measure of the success of each conference. They are considered a reflection of the diplomatic skills and determination of every COP president. Legal outcomes may be too complex to successfully communicate and shape public opinion. The same applies to technical decisions: only climate specialists can nowadays understand what is included in the substance of such decisions.

The UNFCCC rules of procedure require reaching a consensus by all Parties (no-objection principle) when making any decision. There are no such restrictions in the case of adopting political declarations, which are only signed by those willing to do so. Some declarations are even agreed upon among a more diverse membership with both Parties and non-Parties becoming part of them. It is also relatively easy to present them to the public to shape public opinion.

There is precedent in the history of the UNFCCC for such initiatives that have eventually informed COP/CMP/CMA decisions. In particular, the experiences from negotiating response measures, agriculture, REDD+, etc., offer relevant examples. The introduction of the concept of an INDC at COP 19 Warsaw is another useful example. In all such cases, COP decisions were preceded by extensive informal efforts, including bilateral and multilateral consultations, workshops, seminars, rounds of submissions, etc.

A high-level political dialogue on the role of CCUS and removals could be initiated by the COP28 Presidency or High-Level Climate Champion to assess the topic from a broader perspective, collect diverse views, determine possible landing zones, and give political guidance to the negotiators, thereby also helping provide a sense of the possible form (cover decision or informal political declaration) that the initiative could take at COP 28. Such a high level of political dialogue would respond to the Cover Decision 1/CP.27 on the Sharm el-Sheikh Implementation Plan, and notably its point 13 of the Mitigation chapter:

> "*The Conference of the Parties:*
>
> 13. *Calls* upon Parties to accelerate the development, deployment, and dissemination of technologies, and the adoption of policies, to transition towards low-emission energy systems, including by rapidly scaling up the deployment of clean power generation and energy efficiency measures, including accelerating efforts towards the phasedown of unabated coal power and phase-out of inefficient fossil fuel subsidies, while providing targeted support to the poorest and most vulnerable in line with national circumstances and recognizing the need for support towards a just transition."

Finally, the Paris Agreement has empowered observers to play a more significant role in the formal UNFCCC process. Annual COPs are no longer intergovernmental meetings only. A large number of participants from all possible stakeholder groups now play an important role in shaping the conference, and the accompanying program of presentations, seminars, forums, exhibitions, media events etc. The work of the High-Level Climate Champions and the Marrakech Partnership, for instance, brings together cities, businesses, trade organizations, scientists, UN agencies, and so forth around climate action.

In any of the foregoing activities, transparency and inclusivity need to be ensured. Relevant events could be held in multiple locations to facilitate easier access for developing countries' representatives and other stakeholders. Regional Climate Weeks as well as Climate Weeks organised by cities and international organisations offer excellent opportunities to include presentations of the initiative during the Thematic Days of the COP.

4.2 Outside the UNFCCC: Towards a Carbon Removal Alliance

In addition to the foregoing activities within or in the context of the formal negotiations ahead of and during COP28, efforts to recognize the role and accelerate the deployment of CCUS and removals can also be taken outside the UNFCCC process. Such efforts can promote informal and voluntary cooperation between states that are interested in actively engaging in pilot activities, accelerating the development and commercialization of removal technologies through research, development, and financial support, coordinating on rules and standards, and learning from and exchanging best practices.

Drawbacks of traditional multilateral negotiations, including large participation with often diverse priorities and interests, cumbersome diplomatic procedures, and the default requirement of unanimous decision-making, can be avoided in settings with more limited participation of like-minded countries engaging outside the UNFCCC process. Because only countries with an existing interest in advancing cooperation will choose to participate, such an alliance, coalition, or partnership approach can activate the greater alignment of views to advance more rapidly and adapt more dynamically to evolving circumstances. In doing so, it leverages the advantages of a "climate club", a cooperative format that has elicited much recent discussion.

Existing initiatives, such as the Glasgow Breakthrough Agenda, provide a growing body of experience and observational insight into the possible ways such a carbon removal alliance could be structured and operationalized outside the UNFCCC process to build momentum and foster support, catalyze concrete action, and ensure a durable and continuously visible platform for cooperation. While past initiatives such as the Global Methane Pledge have been able to garner considerable attention and yield initial successes, they also offer cautionary lessons about the perceived transparency, accountability, and legitimacy of informal channels of cooperation, all of which should influence the design of a CCUS and removals alliance to secure broad support.

Some of the design options that will need to be weighed, along with their respective advantages and disadvantages and trade-offs, include:

- **The degree and intensity of cooperation:** should a carbon removal alliance be conceptualized as a normative platform to foster dialogue and advance a broader normative agenda; a bargaining platform to facilitate and progress formal negotiations; or as a transformational alliance to define commitments and exercise governance functions?
- **Scope of participation:** should participation in a carbon removal alliance be limited to like-minded states, or also integrate non-state actors such as private sector companies, trade associations, and civil society organizations? Should it be an open alliance, or a closed alliance with limited, or invitation-only participation? Should it allow observers?
- **Scope of activities:** should the carbon removal alliance focus on technology innovation and R&D, deployment activities and project piloting, collection and disbursement of financial support, capacity building, and training, carbon sequestration commitments or targets, creation of a market for carbon sequestration units (CSUs), or all of the above?
- **Governance:** should the governance of a carbon removal alliance include a decision-making body, a standing secretariat, and technical committees or working groups? What rules of procedure should such governance follow? What options exist to resource any standing bodies, such as voluntary participant contributions, a mandatory annual membership fee, or levies imposed on profitable activities (such as CSU transactions)?

To obtain greater clarity of the respective merits and trade-offs of alternative options, an initiative to enhance recognition and deployment of CCUS and removals outside the UNFCCC can survey existing case studies, identify and systematically map design choices and their observed implications, and formulate alternative design scenarios evaluated against a matrix of relevant criteria that will provide guidance for the further steps of outlining a specific roadmap for the conceptual design and step-by-step process of establishing a carbon removal alliance in time for its launch during COP28, followed by scaling up and full operationalization over the following year.

Table 1. Countries' climate targets in their NDCs and LTS and number of CCUS projects (April 2023).

Country	Net-zero targets	Interim targets	N. of CCUS projects[9]
Australia	▪ Net-zero by 2050.	▪ 43% of GHG emissions reduction by 2030 from to 2005 levels.	▪ 3 projects.
Brazil	▪ Net-zero by 2050.	▪ 37% of GHG emissions reduction by 2025 from 2005 levels. ▪ 50% of GHG emissions reduction by 2030 from 2005 levels.	▪ 1 project.
Canada	▪ Net-zero by 2050.	▪ 40-45% of GHG emissions reduction by 2030 compared to 2005 levels.	▪ 9 projects.
European Union	▪ Net-zero by 2050.	▪ At least 55% of GHG emissions reduction by 2030 from 1990 levels.	▪ 31 projects.[10]
India	▪ Net-zero by 2070.	▪ 45% of GDP's emissions intensity reduction by 2030 from 2005 levels.	▪ None.
Kingdom of Saudi Arabia	▪ Net-zero by 2060.	▪ Reducing and avoiding GHG emissions by 278 million tons of CO2eq annually by 2030 from 2019 levels.	▪ 1 project.
South Africa	▪ Net-zero by 2050.	▪ A reduction of annual GHG emissions in a range from 350–420 MtCO2e by 2030.	▪ None.
United States of America	▪ Net-zero by 2050.	▪ 50-52% of GHG emissions reduction by 2030 from 2005 levels.	▪ 62 projects

[9] This category includes projects that are in operational, in construction and in advance development and that are applied at any facility industry as classified by the Global CCS Institute. For more information, refer to Global CCS Institute, 2022.
[10] This number includes projects in the EEA and in the UK as well.

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