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The Role of Carbon Dioxide Removal in Net-zero Emissions Pledges

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Introduction

The Paris Agreement requires countries to undertake deep decarbonization efforts to reduce long-term temperature change to "*well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C*" (UNFCCC, 2015). Outlining how this could be achieved, Article 4.1 of the Agreement states that countries should "*aim to reach global peaking of greenhouse gas emissions as soon as possible...and to undertake rapid reductions thereafter…so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century*" implying that countries should strive to achieve net-zero emissions. In addition, the Intergovernmental Panel on Climate Change (IPCC) has concluded based on latest science that net global CO_2 emissions should reach zero by around 2050 to limit warming to 1.5 °C. Net CO_2 emissions should reach zero around 2070 to limit warming to 2 °C (IPCC, 2014, 2018). This net-zero framing has proven to be an effective organizing device for countries as they make their future emission reductions plans. It is a more tangible goal for an individual actor than the goal of limiting warming to a particular level, which depends on the actions of all actors. Indeed, an increasing number of countries – including major economies such as China – have announced net-zero emissions pledges generally consistent with the IPCC's guidelines for 1.5 °C (Climate Watch, 2020).

Previous studies that have assessed long-term national and international deep decarbonization scenarios suggest that achieving net-zero emissions will entail not only rapid decarbonization of energy, land, urban and infrastructure (including transport and buildings), and industrial systems, but also large-scale deployments of carbon dioxide removal (CDR) measures (Clarke et al., 2009; Clarke et al., 2014; DDPP, 2015; Fawcett et al., 2014; IPCC, 2018; Weyant and Kriegler, 2014). CDR measures discussed in the literature include surface-based measures such as enhancement of terrestrial CO_2 uptake through afforestation and reforestation, coastal blue carbon, increasing soil carbon through

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biochar application, and enhanced weathering, and subsurface-based measures that include storing atmospheric CO_2 in geological formations through technologies such as bioenergy in combination with carbon capture and storage (BECCS) and direct air capture (DAC) (IPCC, 2018; National Academies of Sciences Engineering and Medicine, 2019).

As the international community gears up to design net-zero emissions strategies, policymakers and analysts are faced with several open issues and questions about the role of CDR. We highlight three pertinent issues that have been discussed widely in the emissions mitigation literature, underscoring their importance in the context of net-zero emissions strategies. Foremost, there are questions about the scale of CDR measures required to achieve net-zero emissions and how that might affect the costs of emissions mitigation. Similarly, there are concerns about the possible and unintended consequences of large-scale deployment of CDR for other societal priorities such as the Sustainable Development Goals (SDGs) beyond climate (Fuhrman et al., 2020; Fuss et al., 2020; Roy et al., 2018). Furthermore, there are questions about where CDR will be undertaken around the world and what this might mean about emissions trading and the interpretation of country-level net-zero pledges. This perspective offers insights on the above issues and questions, and in doing so, contributes to the continuing debate on the role of CDR in deep decarbonization (Anderson and Peters, 2016; Fuss et al., 2018; Lenzi et al., 2018; Minx et al., 2018; Nemet et al., 2018; Williamson, 2016).

A zero-sum game: The scale of CDR deployment will affect the level of mitigation required in the energy system

Net zero emissions requires that emission sources—such as CO_2 emissions from the combustion of fossil fuels, land-use changes, and non-CO_2 emissions from agriculture and livestock, fossil fuel extraction, waste disposal, and refrigerants and chemicals – must be balanced by CDR measures. Hence, the scale of CDR could dictate the scale of emission reduction efforts required in the energy system (Figure 1) (The White House, 2016). The greater the scale of CDR, the lower is the pressure to reduce energy-system CO_2 emissions.

By extension, although the economic costs of reducing CO_2 emissions depend on various factors such as technology availability, technological change, renewable integration, and institutional factors, *ceteris paribus*, greater CDR deployment would imply lower costs of achieving net-zero pledges. By contrast, lower amounts of CDR would imply more rapid transformations of the energy system including measures to reduce demand which could be expensive (Clarke et al., 2014).

In this zero-sum game, non-CO_2 emissions take on a particularly important role since some non-CO_2 emissions – such as methane emissions from cattle due to enteric fermentation – are hard to reduce (Clark et al., 2020; Harmsen et al., 2019; Herrero et al., 2016). What confounds this zero-sum game further is that there is large uncertainty in the potential for CDR measures. For example, even though afforestation is a mature option with ample experience, the ability for terrestrial systems to absorb CO_2 at scales suggested by global decarbonization studies is uncertain (IPCC, 2019). Likewise, BECCS and DAC technologies are immature and remain expensive (Fuss et al., 2018).

Another key subtlety that could affect the scale of CDR is how net-zero is measured in the first place. Stabilization of radiative forcing and therefore global average temperature requires that net global CO_2 emissions be zero (IPCC, 2018). However, non-CO_2 emissions, and particularly methane need not be zero as their concentrations are related to emissions rates rather than cumulative emissions. While this is a subtlety at present, this could be important when societies are getting close to net-zero emissions.

CDR measures could create tradeoffs and synergies with societal priorities beyond climate

CDR measures could create varying degrees of synergies and tradeoffs with societal priorities other than climate (Figure 2) (Fuhrman et al., 2019; Fuhrman et al., 2020; Fuss et al., 2020; Roy et al., 2018). In general, CDR measures that restore or enhance natural processes tend to have greater synergies. For example, restoration of natural ecosystems and soil carbon sequestration could provide co-benefits such as improved biodiversity, soil quality, and local food security (IPCC, 2018). By contrast, CDR measures that require conversion of agricultural lands to either forest or bioenergy production such as afforestation and BECCS could create competition for land to grow crops resulting in higher crop prices, thus creating tradeoffs with societal priorities such as food security and hunger eradication (Calvin et al., 2014; Iyer et al., 2018; von Stechow et al., 2015; von Stechow et al., 2016). Synergies and tradeoffs of CDR with other societal priorities highlight the need for policymakers to incorporate governance mechanisms and regulations that would limit trade-offs and maximize synergies in net-zero strategies.

It’s all about location, location, location

Global decarbonization studies generally agree that that the timing of carbon neutrality can vary substantially across countries while global emissions reach zero by around mid-century (Clarke et al., 2014; Luderer et al., 2018; Rogelj et al., 2018a; Rogelj et al., 2018b; Schaeffer et al., 2020). The studies suggest that while all countries reduce emissions to close to zero around mid-century, the location of CDR is the fundamental determinant of when individual countries reach net zero. Countries endowed with substantial resources for CDR, for example, through afforestation or an abundance of geological storage, reach net zero first, moving into net negative emissions in order to allow for other countries without these CDR options to maintain positive emissions for some time into the future. In some of the above studies, some countries never reach zero this century, while others reach zero in or before 2040 and then provide CDR services to the rest of the world.

The role of CDR and its geographical dispersion implies that many countries without meaningful CDR options will be dependent on other countries to offset their residual emissions. That is, net-zero pledges may very well be based on trade and not on actual net zero within the country boundaries. While this raises fundamental questions about what is actually meant by net-zero pledges, it is not clear that countries have internalized this potential character of their pledges or communicated their need to work in collaboration with other countries to facilitate this balancing of sources and sinks.

In addition, this CDR-driven need for collaborative action raises the importance of emissions trading in facilitating global carbon neutrality. At present, discussions about Article 6 of the

Paris Agreement – which outlines options for emissions trading – often focus on near-term economic efficiency gains that might emerge from its implementation, and perhaps the ability to use those efficiency gains to achieve greater ambition. Yet, in the context of net-zero, the value of Article 6 and the trading that it implies may extend beyond modest economic efficiency gains and may prove to be a necessity, as countries without meaningful CDR capabilities will be unable to meet net-zero pledges within their boundaries.

More broadly, given the critical importance that CDR will play in achieving carbon neutrality both globally and, importantly, in individual countries, it will be important for the international community – that includes policymakers and analysts – to better understand when and where CDR might take place in the future. This understanding could be an important precursor for efforts to ensure equitable distribution of CDR responsibilities and formulate schemes for sharing the benefits of CDR across multiple countries (Fyson et al., 2020).

Concluding thoughts: Net-zero could set the stage for net-negative emissions

As countries design net-zero emissions strategies and evaluate the role of CDR in them, it is important to note that net-zero is very likely *en route* toward net-negative emissions – which global decarbonization studies highlight as being important to limit global temperature change to less than 2 °C and even more so to limit temperature change to less than 1.5 °C (Clarke et al., 2014; IPCC, 2018). The same studies also suggest that while net-zero could be achieved primarily with terrestrial CDR measures, it might be harder to achieve large net-negative emissions without engineered measures such as BECCS or DAC. Hence, establishing policies to incentivize R&D and deployment of more nascent CDR measures in the near-term as part of the net-zero emissions strategies could help bring down costs to enable net-negative emissions in the future.

Furthermore, the design of net-zero emissions strategies will require due considerations of how CDR activities are funded. So long as emissions are net-zero or above, CDR activities can be funded by the remaining emitting sectors. However, once emissions become net-negative, any tax revenues from emitting sectors would be less than the needed funds to subsidize CDR activities. If emission mitigation policies are largely non-price-based regulations – as is the case in many countries today, additional revenue might need to be generated to fund CDR activities.

Nevertheless, it may be difficult for policymakers to pre-commit to net-negative emission targets. A different suite of policies might be needed to incentivize net-negative emissions compared to the policies that can drive emissions to net zero. There is a clear need to focus today on policies that will drive the transition to net zero. Decisions about policies that could potentially deliver net-negative emissions may be best left for future generations.

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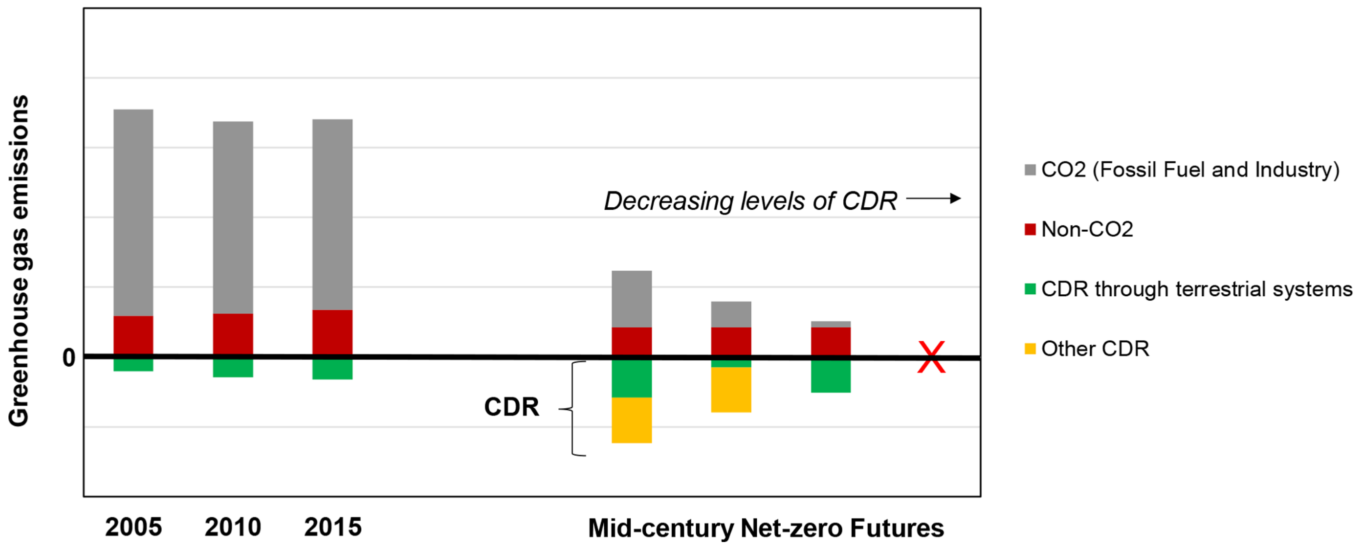

Figure 1:

Conceptual figure showing the implications of the scale of CDR in a zero-sum game. The greater the scale of CDR, the higher are CO_2 emissions from fossil fuels and industry. With very low levels of CDR, achieving net-zero could be infeasible (which is shown by an “X” in the figure) (The White House, 2016).

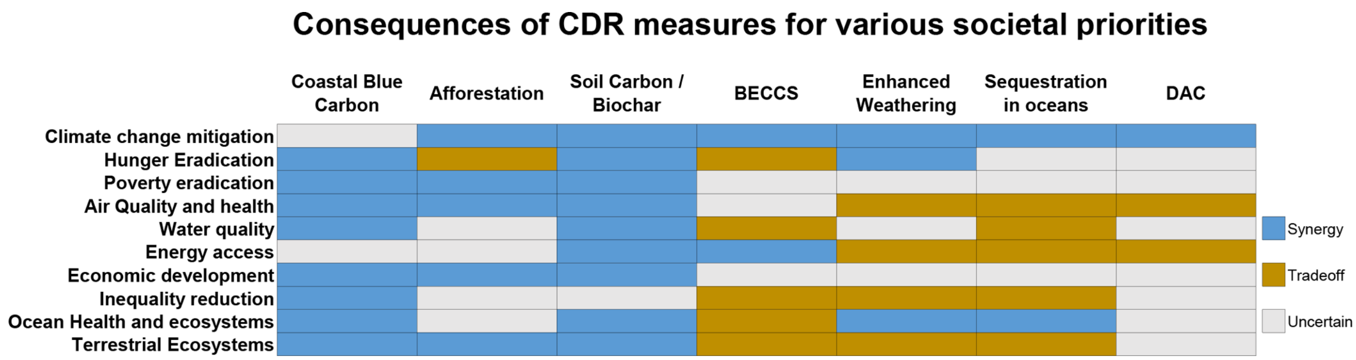

Figure 2:
Consequences of CDR measures for various societal priorities beyond climate (summarized based on a detailed assessment by Fuhrman et al. (2019)).