Energy, Environment and Resources Programme Meeting Summary

The prospects of carbon dioxide removal in climate policymaking within the United States

The event was co-hosted by Chatham House and the Institute for Carbon Removal Law & Policy, American University

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10 St James's Square, London SW1Y 4LE T +44 (0)20 7957 5700 F +44 (0)20 7957 5710
www.chathamhouse.org

Introduction

In November 2019, Chatham House and the Institute for Carbon Removal Law & Policy at American University convened a meeting to discuss the prospects of carbon dioxide removal (CDR) and negative emissions technologies (NETs) in climate policymaking within the US. This one-day workshop considered possible deployment pathways of different NETs in the US and the current policy realities (and appropriate governance and finance mechanisms) for developing and deploying different CDR options given various geographical constraints and socio-environmental implications. The meeting was convened in California due to its incorporation of CDR options into state climate policymaking, well-developed research programmes in the public and private sector as well as its historical and contemporaneous de-facto role as a laboratory for progressive domestic climate policy.

This document is intended to serve as an aide-memoire for those who took part and to provide a general summary of discussions for those who did not. The ideas presented here are those of individual participants and it should not be assumed that every participant subscribes to all the observations and conclusions. The meeting was held under the Chatham House Rule.

The exigencies of, and progress towards, achieving CDR and NETs at scale

- There is growing scientific consensus that if Paris Agreement temperature targets are to be met then NETs will need to be dramatically scaled-up in the next few decades to enhance carbon sinks, alongside efforts to reduce carbon emissions. The scale and scope of the challenge requires urgent transformational change. The National Academy of Science recently concluded that, ‘If the goals for climate and economic growth are to be achieved, negative emissions technologies will likely need to play a large role in mitigating climate change by removing globally 10 $GtCO_2$ per year by mid-century and 20 $GtCO_2$ per year by century’s end.’[1] Some participants considered this to be a conservative estimate in spite of the fact that 20 $GtCO_2$ equates to the annual emissions of the US trucking, iron ore, cement, and pipeline industries combined. Nonetheless this need not be beyond the realms of possibility; 10 $GtCO_2$ per year was thought to be attainable with existing technologies.
- Within the portfolio of available CDR approaches, including nature-based solutions (NBS), bioenergy with carbon capture and storage (BECCS), direct air carbon capture and storage (DACCS), biochar, enhanced weathering, and various ocean-based approaches, there are a variety of social, environmental, political, economic, and technical constraints on near-term deployment. Many NBS and BECCS solutions are theoretically deployable immediately as they are not new technologies; yet they have still struggled to achieve traction and are not currently deployed at scale, suggesting non-technological barriers to adoption warrant detailed consideration if they are to be overcome.
- Economic factors influence the viability of different CDR approaches at various carbon prices – and framing CDR as a waste management solution requiring a ‘tipping fee’ for new and residual CO_2 emissions may focus more attention on the imperative of financing ongoing waste collection and secure waste disposal. This could be supported in part by a common carbon accounting framework so that communication of the potentials of each technology over various time frames were simplified and harmonized.
- Beyond narrow economic considerations, public support for NETs and other demand factors will be crucial in realizing the potential of NETs and attaining mid-century emissions targets.

[1] US National Academies of Sciences, Engineering and Medicine (2019), Negative Emissions Technologies and Reliable Sequestration: A Research Agenda (2019), https://www.nap.edu/catalog/25259/negative-emissions-technologies-and-reliable-sequestration-a-research-agenda

- The Green New Deal congressional resolution of 2019 has provided a recent framing for potential US CDR efforts. Many of the Green New Deal goals are compatible with carbon removal goals, e.g. achieving net-zero emissions by 2050 through a fair and just transition; creating millions of good, high-wage jobs; investing in infrastructure; securing health; and promoting justice and equity. Framing the contributions of CDR to society in these terms, as well as for their role in decarbonization, may aid the case for locally appropriate deployments of CDR solutions.
- As all solutions are place-based and will have localized impacts, there is considerable merit in expanding the scope of cost/benefit considerations to tangible impacts on, and co-benefits to, local communities. This could potentially change the perceived viability of different CDR approaches in different locations; promoting and realizing co-benefits will be crucial in achieving NETs' social licence to operate, and there is a strong case to be made for prioritizing projects located in communities economically reliant on fossil-fuel production, or which require rural revitalization, to aid with a just transition.
- Although there is potential moral hazard associated with an increasing focus on NETs (if this comes at the expense of accelerating emissions reductions), we no longer have the luxury of these being either/or solutions; sources must be scaled-down while sinks are simultaneously scaled-up with comparable rapidity. If the scale of removals required is realized, the CDR and NETs sector could become one of the largest industries in the US by the end of the century.
- No NET provides a silver bullet solution – biological, technological, and hybrid approaches will all be required to achieve the necessary volume of reductions while comporting with other objectives including sustainability and social equity, as will urgently reversing emissions from potential sinks.

The potentials and pitfalls of different approaches

- Both BECCS and DACCS are reliant on permanent geological storage, though they also offer the potential to utilize rather than sequester the carbon, such as in enhanced oil recovery (EOR) or in producing synfuels. While not net-negative, such usage offers potential bridging solutions, for example transitioning towards solutions co-optimized for EOR and CO_2 storage to eventually achieve dedicated CO_2 storage. The oil and gas industries have the requisite expertise to scale-up the geological storage options required by BECCS and DACCS, though if these NETs are perceived to be in the control of fossil energy companies this could potentially stymie their social acceptability, especially if public money is used, thereby subsidizing further oil extraction.
- While DACCS is commonly thought of as a land-sparing NET due to the small land footprint of plants and feedstocks (in contrast with the huge land requirements of BECCS feedstocks and some NBS) this ignores the potentially considerable renewable energy footprint that would be required to power DACCS plants at a meaningful scale. Thus, although likely to be lower than for some alternatives, DACCS aggregate land footprint should not be trivialized.
- Analysis of the economic potential of BECCS deployment in the US (commissioned by the US Department of Energy (DoE)), which took account of site suitability, feedstocks, logistics, and CCS costs, suggests that stover (crop residues) and switchgrass-based systems could be viable and net negative at carbon prices of approximately $100/tCO_2$. However, future efforts are required to further investigate regional feedstock availability (forest thinnings, wood from beetle-kill trees, etc.), and to determine opportunities to integrate CO_2 pipeline models, advanced feedstock logistics, and to maximize locational electricity price opportunities.
- Agriculture has a significant role to play, both in halting and reversing land conversion to agriculture, and in ensuring that remaining agricultural lands and practices maximize their sequestration potential. One approach being promoted under the US Department of Energy's

ARPA-E SMARTFARM[2] initiative is to increase the economic incentives for minimizing the carbon intensity of bioenergy feedstocks (including through practices that enhance soil carbon sequestration (SCS) and minimize N_2O emissions) by providing technology that permits connecting auditable field-level data on carbon intensity to biofuel carbon markets, creating new revenue streams for farmers.

- DoE have also identified opportunities to develop agricultural products with lower net emissions through sequestering carbon via CCS, such as during fermentation in corn ethanol production; although still net positive such approaches are part of the DoE Bioenergy Technologies Office's approach to creating a 'renewable carbon economy' by developing ways to substitute petroleum-based products with those derived from renewable biomass.
- Biochar and enhanced weathering (EW) approaches are also both highly relevant to the agricultural sector, especially given its responsibility for around a quarter of current emissions, many of which come from very diffuse sources and which are unlikely to be reduced to zero in gross terms. One estimate suggested that deploying EW on the 70 per cent of global croplands it is suited to could result in emissions reductions of 4 GtCO2 and improve food security through 20 per cent yield increases, as the rocks serve as fertilizer. Nonetheless, significant questions remain regarding the mining footprint of deployment on this scale and, as with all solutions reliant on changing land management practices, how to promote widespread adoption of best practices including through appropriate and viable long-term price signals.
- Biochar also benefits soil stability, water retention, and fertility, so has drought resiliency and food security co-benefits alongside carbon sequestration, especially on marginal lands and those infrequently harvested. Increasing uptake of biochar utilization will likely be as dependent on policy developments and incentivizing use in these allied areas as those in CDR arenas. For example, one promising application for biochar is as a livestock feed additive, which can reduce enteric fermentation emissions; however, this application is no longer approved by the US Food and Drug Administration. Nonetheless, several private carbon markets have begun to develop carbon accounting protocols and mechanisms for trading biochar-based sequestration credits.
- Nature-based solutions offer significant sequestration potentials on both natural and working lands. As the 2016 *US Mid-Century Strategy for Deep Decarbonization*[3] notes, 'the greater our ability to reduce emissions through lower-cost land sector options compared to CO_2 removal technologies and difficult-to-decarbonize sectors, the more we can reduce overall costs'. New analysis suggests that a $3 billion (7 per cent) addition to the current USDA federal budget could fund a carbon removal land management plan implementing all currently available nature-based solutions at around $12 per tonne. Nonetheless, precisely because many of these solutions are not readily monetizable, challenges persist in increasing their utilization among private actors; so delivering economic, ecological and social co-benefits will all be critical in scaling-up these activities. The window to implement these plans is relatively short-lived to meet mid-century decarbonization targets, especially as high inter-annual variability in nature-based sequestration and emissions (driven by fire, rainfall, and other ecosystem shocks) may be expected to increase, and ecosystem stores of carbon to decline, as the climate warms.
- A number of marine-based CO2 management approaches were also discussed, including increasing marine-based photosynthesis through aquaculture, direct ocean CO2 capture through aeration/degassing or electrochemical extraction, geochemical CO_2 consumption and storage, and ocean iron fertilization. While these merit further consideration, especially given the size of the

[2] Babson, D. (undated) SMARTFARM: Changing What's Possible For Agriculture, U.S. Department of Energy: Advanced Research Projects Agency – Energy, https://arpa-e.energy.gov/?q=news-item/smartfarm-changing-whats-possible-agriculture (accessed 28 Jan. 2020).
[3] The White House (2016), United States Mid-Century Strategy for Deep Decarbonization, https://unfccc.int/files/focus/long-term_strategies/application/pdf/mid_century_strategy_report-final_red.pdf (accessed 28 Jan. 2020).

ocean sink and the potential to alleviate land pressures from terrestrially-based CDR approaches, there are some large potential downside risks associated with many of these options, particularly those based on inorganic carbon storage. These include ocean acidification and trophic cascades that may materialize following resultant plankton proliferation, and leakage of oceanic carbon back into the atmosphere. As such, as with many CDR approaches, these require further research and development to ensure safety, and environmental and societal acceptability, and should only proceed once there is greater clarity on how R&D and application could be effectively regulated through current or future marine legislation.

The public sector role in fostering a responsible CDR roadmap

- Several challenges were discussed regarding appropriate policy, regulatory and carbon pricing approaches to facilitate an acceleration of appropriate CDR within the US, and whether these are most effectually and realistically implemented at supra-national, federal, or sub-national levels, where many state and city administrations are instigating more progressive measures. Regardless, there was reasonable consensus that some form of carbon pricing – for carbon both emitted and sequestered – would be necessary, but not sufficient. One suggestion was to require emissive entities to hold verifiable certificates of sequestration commensurate with the volume of their emissions to avoid further emissions taxes.
- There is a significant challenge ahead in achieving the co-ordination and alignment required between multiple policy domains (and at different scales) to successfully implement a portfolio of CDR approaches, as they cut across agricultural, environmental, water, energy, and climate policy jurisdictions (for example, ensuring that land and energy policies are synergistic).
- Given that a portfolio of CDR approaches will be required, and the suitability of each approach will vary geographically, there was a suggestion that all options should remain on the table and that it would be premature to pick winners on a NET-by-NET basis. Provided that each potential deployment is holistically evaluated against a broad and consistent risk-adjusted framework, including place-based social and environmental criteria, in addition to the attainable carbon balances, this could foster healthy competition among implementation approaches. Nonetheless, given the currently limited public investment in NET research and development, some early-stage prioritization of investments may be required to ensure optimal outcomes and to accelerate progress towards the more promising approaches. Historical precedent from the declining costs of solar photovoltaic panels suggests the price trajectory between first commercial deployment of a climate technology and reaching unsupported marketable prices is too shallow for NETs to make a meaningful contribution to emissions reductions on the required timescales. Some backing of perceived winners and risk of lock-in therefore may need to be accepted to accelerate cost reductions.
- Within the Californian context, Assembly Bill 32 (2006) provides the overarching emissions reductions framework, mandating emissions levels return to 1990 levels by 2020, and a further 80 per cent reduction by 2050. This has since been followed, in 2018, by Senate Bill 100, setting a state-wide requirement of 100 per cent carbon-free electricity by 2045 and Executive Order B-55-18 setting a target of economy-wide carbon neutrality by 2045. The carbon neutrality goal is being supported by state investment, and partnerships with other states and nations, in a healthy soils programme. This provides the first US climate finance investment (directed to farmers and demonstration projects in equal measure) in soil carbon sequestration. It has been followed-up by a 2019 draft climate strategy on natural and working lands, explicitly recognizing the role of the land sector in achieving California's carbon-neutrality ambitions.

Ways forward and remaining challenges

- Emerging from all this complexity are several challenges that are simple to describe but 'wicked' to solve.
  - First, common to all CDR approaches is the necessity of achieving meaningful volumes of carbon sequestration and storage once full life cycle emissions balances have been accounted for. These balances will vary considerably not just across approaches, but on a case-by-case basis, depending on the specific details of implementation.
  - Second, while the carbon balance is paramount to success, design and evaluation of CDR approaches cannot afford to be so parochial if social, environmental, and political risks are to be avoided, co-benefits are to be realized, and public acceptance is to be achieved.
  - Third, carbon dioxide removal is a system, more so than conventional abatement approaches, requiring expansive and uncommon engineering, scientific, policy, and political and geographic integrations and alignment.
  - Fourth, that there is no single silver-bullet CDR solution, which means there are inherent tensions in appropriately allocating research, development, deployment, and policy resources. On the one hand it is necessary to commit to furthering several CDR approaches that could constitute valuable components of successful CDR portfolios; on the other hand, unless the field of viable options to be taken forward is not narrowed somewhat, then dilution of resources and political will, among many CDR contenders could potentially hinder progress on the time scales required. Coalescing around a shortlist of the most promising options needs to occur rapidly, supported by a political economy analysis of the enablers and barriers to progress.

- At a fundamental level, greater understanding is still required about the availabilities, costs, and performances, of different CDR systems and technologies (and how these will evolve as systems mature); their aggregate potentials compared with the aggregate removal requirements; where the burdens and benefits will fall; how downside risks and unintended consequences can best be capped; and what an appropriate policy roadmap looks like, which approaches are included and excluded, and which existing policy frameworks (such as low carbon fuel standards) can be adapted and harmonized to foster progressive and risk-mitigated CDR implementations.