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Carbon dioxide removal: Five principles for a science-based, sustainable, and feasible approach

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The UN Secretary General's Climate Ambition Summit on September 20 is an important moment for climate ambition and accountability in the run-up to COP28, where countries are expected to deliver a clear signal on how they will course correct climate action to keep the Paris Agreement's collective goal of limiting temperature rise to 1.5°C. While the [Summit's agenda](#)—on the three 'acceleration tracks' of ambition, credibility, and implementation—is comprehensive, an area with less focus so far is guidance on Carbon Dioxide Removal (CDR) use to address the 'net' in net-zero commitments. This blog post highlights 5 principles to help guide a science-based, sustainable, and feasible approach to CDR, which aligns with the broader mitigation action needed to keep to the 1.5°C limit and reverse biodiversity loss.

The ‘Integrity Matters’ report, [released](#) by the UNSG-mandated High-Level Expert Group at COP27 and acting as a ‘north star’ underpinning next week’s Climate Action Summit, only mentions CDR briefly¹. CDR has also not yet become a strong focus in the net-zero ‘accountability’ norm-setting space that has emerged since COP26.² Yet CDR, which has shot up in prominence in the past year (with significant [private sector](#) and [public investment](#), emerging [national governance](#), and a growing focus in the international policy space) requires further scrutiny in advance of COP28 and beyond, as a variety of current developments point to the growing risk that rather than play the limited—but key—role we need it for to get to net-zero and beyond, CDR be (mis)used to distract or delay from the deep emission cuts that are primordial to keep the 1.5°C limit (and even 2°C).

To increase accountability to ‘true’ net-zero, and help ensure CDR is approached in a science-based manner that aligns with the broader mitigation action needed to keep the Paris Agreement goals, the following 5 key principles are a useful place to start.

1. Deep emission reductions first

[The IPCC 6th Assessment Synthesis Report](#) released earlier this year [clearly underscores](#) that to keep the 1.5°C with no to limited overshoot, CO₂ emissions need to be reduced by 48% by 2030, and 99% by 2050 (alongside significant reductions of other GHG emissions), and that whether we can keep the 1.5°C (and even 2°C) depends primarily on whether countries and non-state actors can deliver deep emission cuts by the end of this decisive decade. Because the scale of emissions reductions is so large, and CDR will take decades to scale up, CDR cannot replace or offset emission cuts needed to keep 1.5°C. This has led scientists to caution that CDR is “[not a current climate solution](#)” and call to reframe the narrative on what its true role can be.

Yet there is significant evidence that some CDR developments are at risk of replacing or delaying deep emission cuts. One example is how the oil and gas industry is eyeing Direct Air Carbon Capture and Storage (DACCS) as [a ‘lifeline’, and license to continue and expand fossil fuel production well through the 21st century](#). In August, [Occidental Petroleum purchased the leading DAC company Carbon Engineering for \\$1.1 billion](#), which will create DAC plants that can not only be used as CDR (by geologically storing the captured CO₂), but also for ‘enhanced oil recovery’ (i.e., continued fossil fuel production) and synthetic fuels. Further, the Biden administration [announced that nearly half of the \\$1.1 billion earmarked to DAC \(via the US’ 2021 bipartisan Infrastructure Act\) would be disbursed to Occidental Petroleum](#) for the construction of the largest DACCS plant (built by Carbon Engineering). Such an approach to CDR stands in stark contradiction with the IPCC indication that to keep the 1.5°C (or even 2°C), fossil fuel use needs to strongly decline in coming decades, and the [IEA’s finding that keeping the 1.5°C requires halting new fossil fuel expansion](#).

2. The realistic and sustainable supply of CDR is limited

The 2019 [IPCC Special Report on Climate Change and Land](#) already made clear that very large-scale deployment of land-based CDR such as afforestation—planting trees where there were none historically—and bioenergy with carbon capture and storage (BECCS) would have severe negative impacts on food security and biodiversity loss. The [IPCC-IPBES Co-Sponsored Workshop Report on Biodiversity and Climate Change](#) and other recent [science](#) suggests that sustainable deployment of land-based CDR is even more significantly limited. Further, while the land footprint of a ‘technological’ CDR method such as DACCS is small, its scale-up remains limited by high costs, and the very large renewable energy it requires, at a time when significant renewable energy scale-up needs to be first prioritised to decarbonise electricity and sectors such as industry, and to provide electricity access to those [770 million people](#) still lacking it around the globe.

Yet countries and companies are already over-depending on CDR deployment in coming decades (primarily land-based CDR) to reach their net-zero goals. The [Land Gap Report's](#) analysis of Nationally Determined Contributions and Long-Term Strategies revealed States are collectively banking on allocating 1.2 billion hectares of land by 2060 to land-based CDR, an area almost equivalent to the current global cropland. This raises both major feasibility questions, and concerns that if deployed, it would add a major land-use change pressure at a time when halting and reversing biodiversity loss and [achieving the Kunming-Montreal Global Biodiversity Framework goals](#) requires instead unprecedented ecosystem conservation.

3. Residual Only

The IPCC is clear that to keep the 1.5°C goal, residual emissions—i.e., those that remain at the point of net-zero—are very limited: by 2050, only 15% of current total GHG emissions (~1% of current CO₂ emissions). This means 'residual emissions' need to be minimised, and clearly defined as those truly 'hard-to-abate' emissions that are too difficult or yet impossible to fully eliminate: for example, in sectors such as agriculture or heavy industry.

Yet a look at States' Long-Term Strategies reveals that many are envisaging mid-century residual emissions significantly larger than what the IPCC states is compatible with the 1.5°C: [developed countries are planning their residual emissions in 2050 to be on average 18% of current GHG emissions](#)—without yet addressing the equity claims developing countries will likely make to have larger residual emissions—and [G20 countries \(which account for ~80% of global emissions\) 20-30% of current emissions](#). This is the other side of the coin of the over-dependence of CDR highlighted above.

4. Overshoot Reduction

The IPCC Synthesis Report finds that delayed emission cuts to date make temperature rise to 1.5°C temperature almost inevitable, even though staying at that limit is still within our reach with deep, urgent, and sustained emission cuts. Were temperatures to 'overshoot' above 1.5°C, theoretically CDR deployed at a larger scale than the remaining residual emissions could bring temperature back down—taking us from a 'net-zero' to a 'net-negative' emissions state.

Yet the Synthesis Report is clear overshoot should be limited to the strict minimum as it brings with it major irreversible impacts (e.g., sea level rise) and some major unknown risks (e.g., [breaching tipping points](#)). Further, deploying CDR at such large scale to counterbalance high overshoot would be highly challenging and likely compromised by the limited sustainable and feasible CDR supply.

5. Ensuring high integrity and sustainable implementation of CDR

A key challenge States and the international climate community will face in the coming months and years is how to scale up CDR in a way that truly supplements, rather than *substitutes* and *distracts* from the deep emission cuts that are the key priority.

This requires good CDR governance, which takes as starting point the priority of deep emission cuts, and should then also, at the very least:

- *Separate out emission reduction and CDR targets in upcoming net-zero target, minimising CDR to realistic and sustainable scales:* Separate targets are expected to be a feature in the European Union's upcoming 2040

climate target, and should also be set at COP28 as an expectation for Parties' 2025 updated NDCs.

- *Provide clarity about what truly is CDR, and what is instead emission reductions:* This requires (1) being clear that Carbon Capture and Storage or Use (CCS/CCU) are not CDR –because they capture fossil CO₂ from fossil fuels at point source (e.g., factories and power plants) rather than remove CO₂ from the atmosphere³ – and should be kept separate in policymaking (making it key to scrutinise 'carbon management' initiatives such as the Carbon Management Challenge that seek to address these different practices under a same umbrella), and (2) distinguishing activities which store carbon for short time periods (e.g., decades, such as soil carbon sequestration) from CDR with longer permanence (centuries to millennia–e.g., ecosystem restoration, CDR with geological storage, enhanced weathering).
- *Ground 'nature-based' CDR in sound ecosystem science:* Prioritising ecosystem restoration activities (e.g., natural forest regeneration, etc.) is key: they represent a one-time opportunity to restore the degraded land sink, with high carbon capture capacity, important biodiversity and adaptation co-benefits (although sustainability and feasibility limits exist). Monoculture tree-planting (e.g., afforestation) in turn, does not meet the UNEA 'Nature-Based' definition, and raises concerns of negative impacts on food security and biodiversity.
- *Minimise deployment of CDR methods with land-use change, establish safeguards for land-based CDR:* Grounding land-based CDR in existing governance schemes such as the UN Committee on World Food Security's voluntary guidelines on land tenure can help serve as a safeguard to reach climate goals without hampering other major sustainable development priorities (food security, employment and income, biodiversity protection).
- *Ensure CDR credits in carbon markets are not used to offset current emissions but rather to counterbalance truly residual emissions:* Both the CDR inclusion in Article 6.4 (for adoption at COP28), and the EU's Carbon Removal Certification Framework (for finalisation in 2024) present risks of enabling offsetting, and hence deterring deep emission cuts.

Significant work will be needed to ensure CDR helps keep us within—not lead us further away from—the 1.5°C limit: COP28, emerging national legislation, and the 'net-zero accountability' norm-setting community are key opportunities to make this become reality.

¹ The HLEG 'Integrity Matters' report refers to CDR four times: it states that 'residual emissions' (which it does not further define) need to be counterbalanced by CDR for an entity to claim a net zero state, and calls for: (1) CDR credits to be used only for unabated emissions beyond net zero pathways or counterbalancing residual emissions; (2) market integrity on CDR credits; and (3) entities to explain in their transition plans if and why they need CDR.

² For example, the UNFCCC Climate Champions' Race to Zero has not yet developed clear guidance on CDR use by their members (yet the 2022 Race to Zero Criteria Consultation's Expert Group on 'Offsetting, carbon removals and responsible communication of claims' recommended this be an area for deeper discussion). The Science Based Targets initiative so far only touches briefly on CDR, although more detailed guidance is set to be released later this year.

³ CCS and CCU are emissions reductions technologies (the most expensive identified by the IPCC Synthesis Report for the energy system). CCS/CCU capture fossil-fuel CO₂ at 'point source' (e.g., from factories and power plants) and: CCS stores the CO₂ in geological reservoirs: if effectively implemented, CCS can reduce most (although usually not all) of the CO₂ emissions released by the point-source into the atmosphere. CCS-related technologies can be an important part of a CDR process (e.g., Direct Air Carbon Capture and Storage - DACCS). CCU utilises the CO₂ (e.g., producing synthetic fuels, chemicals, cement, and plastics) yet usually without leading to long-term CO₂ storage, but rather to delayed emissions: