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The promise and risks of negative emissions in Africa

Global climate change mitigation efforts lag behind what is required to deliver the Paris Agreement goals. As a result, integrated assessment models mapping out pathways to limit greenhouse gas emissions (GHGs) and keep warming under 1.5 degrees C increasingly rely on 'negative emissions', or carbon removal. This has triggered greater efforts to determine what types of natural or engineered interventions can deliver these negative emissions, and where to target such interventions. Africa, with its abundant landmass and renewable energy potential, is increasingly being proposed as fertile ground for these efforts. While proponents highlight that developing negative emissions technologies presents opportunities for Africa to lead in the development of new industries that will be at the forefront of the green revolution, they often fail to cite the significant financial and human resources still needed to ascertain if these technologies are worth pursuing at scale, or explain why these resources should be channeled into negative emissions at the expense of other development efforts. Given Africa's minimal share of anthropogenic emissions, it should not bear the economic, environmental, and social risks of developing these technologies.

Why negative emissions?

Negative emissions technologies (NETs), sometimes referred to as carbon dioxide removal or CDR technologies, can result (directly or indirectly) in a net removal of carbon dioxide (CO_2) from the atmosphere. Recent interest in NETs has been spurred by scientific studies finding that global warming levels depend on the cumulative amount of CO_2 emissions in the atmosphere, irrespective of the timing of those emissions.[1] Therefore, global temperature rise can be limited, or reduced after overshooting a target such as 1.5°C, by removing CO_2 from the atmosphere in the future through engineered interventions. Because of this, NETs are increasingly discussed as a necessary tool for limiting average global temperature rise to 1.5°C by the end of the century, as outlined in the Paris Agreement. The Intergovernmental Panel on Climate Change (IPCC)'s Global Warming of 1.5°C report highlighted that all model pathways that delivered the Paris accord goals with no or limited overshoot of the temperature target use NETs to some extent to neutralize emissions from hard-to-mitigate sectors and correct the overshoot.[2] However, some researchers and policymakers remain skeptical about the technical feasibility, scalability, and social acceptability of these technologies because of their natural resource intensity (land, water, and energy use) and the financial incentives needed to deploy them at scale.[4,5,6,7,8]

Which solutions are the front runners?

Several natural and engineered processes have been proposed to realize negative emissions. These typically result in the storage of carbon in organic matter such as biomass, or geological reservoirs such as deep saline formations or depleted oil and gas fields. An overview of proposed NETs is provided in Table 1.

TABLE 1: Overview of main negative emissions technologies, and their estimated carbon removal potentials and costs.[9,10,11]

Technology	Description	Removal Potential by 2050 ($GtCO_2$/yr)	Cost (\$/tonne CO_2)	Physical limitations
Afforestation/ Reforestation	Planting new forests or restoring deforested land. Trees absorb CO_2 from the atmosphere as they grow and store it in organic matter.	3.6	5-50	• Removal not realized immediately as forests can take up to 10 years to reach maximum sequestration rate and the CO_2 absorption potential of trees subsequently decreases over time, meaning that the stock of woodland may need to be renewed to maintain a desirable rate of CO_2 absorption • Stored CO_2 is vulnerable to natural and human disturbances such as drought, pests, fires, and land-use change • Competition with agriculture and other sectors for land
Soil carbon sequestration	Improved land management practices to increase carbon retention in soils.	2.3-5.3	-12 - 100	• Need to coordinate action from a large number of actors (e.g., smallholder farmers) • Vulnerable to reversibility • Constant monitoring is needed even after storage occurs
Biochar	Charcoal produced by burning agricultural wastes in the	0.3-2	90-120	• Lack of field trials means side effects are largely unknown

	absence of oxygen, via pyrolysis. Biochar can serve as a soil additive to improve soil fertility and quality.			
Bioenergy with carbon capture and storage (BECCS)	Biomass absorbs CO_2 from the atmosphere as it grows. If burned for energy and the resulting CO_2 is sequestered geologically, it results in a net removal from the atmosphere.	0.5-5	100-200	• Land competition, distortion of food prices, biodiversity loss, and water stresses owing to large-scale biomass production • Biomass supply chain emissions could counter negative emissions • Upscaling requires building large infrastructure such as CO_2 transport and storage networks
Direct air carbon capture and storage (DACCS)	Using chemical sorbents to remove CO_2 from the atmosphere directly and storing it geologically.	0.5-5	100-300	• Large energy requirements given CO_2 has very low concentration in air • Some technologies are water-intensive • Upscaling requires building large infrastructure, such as CO_2 transport and storage networks.
Enhanced weathering	Accelerating the natural process of rock decomposition via chemical and physical processes such as grinding to increase reaction surface area. Rocks such as olivine,	2-4	50-200	• Large energy requirements for rock grinding • Uncertainties surrounding permanence of stored CO_2

	dunite, and basalt have the potential to sequester significant amounts of atmospheric CO_2.			
Ocean fertilization	Accelerating the ocean's natural absorption of CO_2 from the atmosphere through photosynthesis of phytoplankton by adding nutrients such as iron to increase plankton growth	Not viable because of impermanence of storage	2-457	• Uncertainty surrounding implications on marine ecosystems and food cycles • Increased ocean acidification

The technical and economic potential of each NET varies greatly because of the uncertainty surrounding their respective resource intensities (principally land, energy, and water), the permanence of the CO_2 stored, and their broader impacts on the ecosystems in which they are deployed. Additionally, the climate's response to negative emissions remains the subject of debate.[2,4] Integrating biomass-based NETs into GHG accounting frameworks remains difficult as land is both a source and sink of emissions, requiring constant monitoring and management. Additionally, reliance on internationally-traded biomass for NETs such as BECCS raises questions around which state actor gets credit for emissions reductions. Finally, the extent to which innovation can drive down initial cost estimates to the values highlighted in Table 1—which are significantly higher than costs of other mitigation or adaptation measures—is unknown, as many of these NETs are yet to be demonstrated and scaled. [3,4]Only afforestation/reforestation has been widely practiced globally. Although BECCS and DACCS have been demonstrated as technically feasible, acceptable policies and business models that enable commercial scale-up have not yet been determined.[5] NETs startups such as Carbon Engineering and Climeworks are receiving increasing attention and investment from venture capital, technology firms, and impact investors. Most notably, Stripe, in collaboration with other companies, has committed to purchasing $925M of permanent carbon removal by 2030 through an advanced market commitment funding mechanism that guarantees future demand for the startups. The remaining solutions are at the research and development stage, and commentators have emphasized that the risk posed by their unintended outcomes could outweigh the benefits or prevent negative emissions from being achieved.[6]

Biomass-based interventions (afforestation/reforestation, soil carbon sequestration, biochar, and BECCS) are typically geographically-constrained and limited by land-use competition for agriculture and urbanization.[7] In contrast, engineered NETs are predominantly energy-intensive, and utilizing fossil fuels in their development limits their effectiveness for carbon removal. For example, a study showed that BECCS could end up being a net-emitter of carbon over a plant's lifetime if carbon emissions incurred in the supply chain of the biomass feedstock (processing and transport activities, especially if internationally traded) are above certain thresholds.[5,8] Thus, low- or zero-carbon energy is necessary for the sustainable operation and scale-up of many NETs.[12] Consequently, Africa's vast landmass and renewable energy potential are increasingly making proponents of NETs consider the continent an optimal location for deploying these technologies.

The case for NETs in Africa

The IPCC's recent assessment reports have increasingly emphasized that negative emissions are unavoidable if net-zero emissions are to be achieved, despite reports acknowledging the risks. The scale of negative emissions needed to deliver the Paris Agreement ranges from a few gigatons per year as early as 2030, to 20 gigatons annually by the end of the century. There is broad consensus that countries with the highest levels of historical emissions are poorly positioned to realize NETs to this scale within their borders, or at least using indigenous resources.[3,8,12] Proponents including the United Nations Economic Commission Africa, have proposed NETs as a means to develop sustainable livelihoods and aid the achievement of the Sustainable Development Goals. They posit that making Africa a large 'sink' for carbon emissions will mitigate against climate change impacts to which it is uniquely vulnerable because of its geography and low adaptive capacity. Additionally, some NET methods such as afforestation/reforestation and soil carbon sequestration could restore natural ecosystems that have economic potential or cultural significance, improve soil quality, and boost crop yields.

NETs also potentially offer a unique value proposition that African economies and industries can capture. NETs domiciled in Africa can bring in much-needed revenue by producing surplus 'carbon credits' which can be sold to state and non-state actors that are lagging behind on their mitigation targets. There is also the opportunity for nascent and existing industries to support the delivery of these negative emissions, which could facilitate economic growth and employment. These industries include renewable energy, carbon transport and storage infrastructure, chemicals manufacturing, CO_2 production and utilization in niche markets such as carbonation of drinks, greenhouses, etc.

The challenges

While new avenues for innovation and development may appear promising, the path to realizing prosperity within the African context in the near-term would involve many trade-offs that could ultimately be counterproductive to economic growth.

- **Energy demand:** Given the large energy deficit in sub-Saharan Africa, and the already difficult political economy of delivering widespread energy access, it would be ill-advised to channel limited energy infrastructure or new investment into climate change mitigation efforts before improvements in energy access and service quality.[13] The only NET that is an energy-producer is BECCS, and large-scale bioenergy production and use has been controversial because of the land and water resource intensity of growing dedicated energy crops or forest biomass, and the impacts of the resulting land-use competition on food prices and other sectors of the economy.[7,14,15] Other NETs, such as enhanced weathering (which involves mining of rocks) and DACCS, would need to be accompanied by significant expansion in energy generation capacity to drive both processes.

- **Infrastructure:** The permanent sequestration of captured CO_2 is critical to achieving negative emissions. The NETs that have the greatest mitigation potential, BECCS and DACCS, require captured CO_2 to be transported in a supercritical state through pipelines into some form of geological storage. While some African countries have sparsely distributed hydrocarbon fields or sedimentary reservoirs purportedly suitable for CO_2 storage, only Algeria and Angola have conducted country assessments of storage potential.[16] In wealthy countries, government-supported national laboratories or agencies can typically conduct the necessary geological surveys to ascertain the integrity of geological reservoirs. However, the limited financial and technical capacities of corresponding African agencies mean this information is largely underdeveloped on the continent.

- **Technology risk and transfer:** Engagements on the research and development, deployment, and governance of NETs have largely excluded developing countries.[17] Thus, the risks, physical or otherwise, they might pose in the African context are largely unknown. Additionally, NET start-ups are predominantly funded by European or American government R&D spending and impact investors.[18] The technologies that they have developed remain largely proprietary, making it unlikely that there will be immediate technology transfer to indigenous African companies to ensure that the value creation to the financiers is retained.

- **Regulatory framework:** The effective operation of NETs requires regulatory frameworks that allow for the monitoring, reporting, and verification (MRV) of negative emissions. These include GHG inventory development, biomass certification standards, ecosystem monitoring, emissions standards for fuels and vehicles, and new carbon accounting mechanisms. A range of institutions have developed guidelines for MRV of carbon stocks and flows in different sectors. However, the technical expertise and costs involved in the adoption of these guidelines are likely to prove prohibitive for many African countries, at least in the near-term. Furthermore, the likely reliance on international supply chains and investment in developing NETs raises the question of who gets the credit for delivering negative emissions: the financier or the provider of the natural resources necessary?

- **Potential impacts on climate action:** Beyond the economic arguments, the ethical debates surrounding the development and deployment of NETs are yet to be resolved. Given the nascent nature of these technologies, could a reliance on their future availability weaken near-term mitigation ambition? Climate models relying too heavily on NETs could leave the world vulnerable to more dangerous levels of global warming, should these technologies not materialize at the scale or rate desired—the consequences of which will be disproportionately borne by African countries that have poor adaptive capacities. Furthermore, the encouragement of NETs fuels a narrative that we will always be able to limit cumulative GHG emissions and thus, climate change. This could have the unintended consequence of diminishing the importance of adaptation which is likely to be especially critical in Africa where climate change impacts on livelihoods are already being experienced. Finally, despite the extensive scientific literature available on NETs, the IPCC still highlights that "limits to our understanding of how the carbon cycle responds to net negative emissions increase the uncertainty about the effectiveness of CDR to decline temperatures after a peak."[2] Given the imminence of the climate crisis, are NETs a worthy risk in Africa?

Wealthy economies should shoulder the risk of developing and testing NETs

While NETs may eventually be depended upon to deliver deep decarbonization, there is currently significant uncertainty surrounding their feasibility, impacts, scalability, and ultimately their effectiveness for climate change mitigation. Advocating for the limited financial, technical, and institutional capacities of African countries to be channeled into developing these technologies domestically is, for the reasons stated above, presumptuous at best, and unfair at worst, as it shifts the conversation from more pressing sustainable development challenges such as poverty alleviation and improving energy access. It is important that we apply a lens of climate equity and justice in deciding which climate change mitigation solutions to propagate on the continent. Thus, wealthier countries should bear the responsibility of developing and testing NETs while Africa prioritizes proven development strategies.

Endnotes

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9. Data based on reviews conducted by the Royal Society and Fuss et al. [3], [4]. Authors' assessment of likely potentials and costs presented in the table.

10. For reference, only 21.5% of global GHG emissions are covered by carbon taxes or emissions trading schemes, and these tax rates vary significantly from <$1 to $140 per tonne of CO_2 [16]. 7% of global emissions are taxed at above $15 per tonne CO_2. Note that these taxes typically do not apply to all sectors of the economy or even all fuel types. Additionally, they serve as penalties for emissions but not remuneration for negative emissions, so they do not imply that a revenue stream for NETs is readily available in countries where a carbon tax exists.
11. A negative cost implies that it will result in cost savings.
12. International Energy Agency, "Direct Air Capture: A key technology for net zero," Paris, Apr. 2022. Accessed: Apr. 10, 2022. [Online]. Available: https://www.iea.org/reports/direct-air-capture-3
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