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The importance of radical transparency for responsible carbon dioxide removal

Christopher T. Reinhard & Noah J. Planavsky

Carbon removal is a strongly debated component of societal efforts to address anthropogenic climate disruption, in part because efforts to scale carbon removal could delay or substitute for efforts aimed at mitigating anthropogenic greenhouse gas emissions. Although there is no single solution to this problem, we argue here for radical transparency on the data behind carbon removal claims and the data required for evaluating the dollar-per-ton costs of various carbon removal pathways. Although this would represent a major shift from current practice, it has the potential to both minimize the deleterious impacts of carbon removal on near-term mitigation efforts and provide a foundation for ensuring that future carbon removal serves the public good.

It is well-accepted in the scientific community that reducing greenhouse gas emissions must be the foremost goal in climate mitigation efforts in the coming decades[1,2]. However, the notion that carbon removal must also be included in societal efforts to address anthropogenic climate disruption has garnered increasingly broad acceptance[3,4]. In most emission scenarios, even with rapid and aggressive reductions in anthropogenic greenhouse gas emissions carbon removal at the scale of multiple gigatonnes of CO_2 (Gt; 10^9 tonnes) per year by the end of the century is required in order to meet key climate goals[1,5]. Carbon removal is also a key component of numerous corporate strategies for achieving net-zero greenhouse gas emissions[6] and incorporating carbon removal into targeted hard-to-abate industries—such as agriculture and wastewater management — will likely be important for reducing net emissions from these sectors.

In addition, many integrated assessment pathways promote significant future CO_2 removal through durable approaches—in contrast to the reversible or temporary organic carbon storage which currently dominates voluntary carbon markets (e.g., forest management projects). However, durable carbon removal—broadly defined here as carbon removal with a permanence timescale of centuries to millennia—is estimated to currently supply < 0.003 $GtCO_2$ per year[7] in total. This large mismatch in scale and the potential profit to be made in scaling up carbon removal to meet projected demand has resulted in a significant increase in venture capital and philanthropic investment in a nascent durable carbon removal sector, along with significant public attention on carbon removal and voluntary carbon markets more broadly.

Efforts to scale carbon removal face several challenges. Some of these hurdles are largely technical – for example, scaling can be dependent on innovations in core carbon removal pathways and technologies, or can depend on the design of rigorous monitoring, reporting, and verification (MRV) frameworks. Others are largely technoeconomic, centering on the dollar-per-ton cost and resource use of different approaches. Still others are ethical or social, centering on the effects of ton-for-ton frameworks in the context of procedural and environmental justice[8,9], or whether carbon removal projects have a social license to move forward in a given context[10].

Here, we revisit the concern that claims about the prospect of widespread, low-cost carbon dioxide removal in the future might lead to mitigation deterrence. We use the term 'mitigation deterrence' to refer to a delay or substitution of greenhouse gas emissions mitigation induced by the prospect of offsetting carbon removal projects[11,12]. We argue that policies and practices fostering greater transparency in the data used to make carbon removal claims and information required for accurate dollar-per-ton cost estimates are a critical hedge against large-scale mitigation deterrence by emerging durable carbon removal activity.

Mitigation deterrence can be enacted in several ways. Here, we distinguish between contemporaneous substitution—in which current carbon removal projects are substituted for emissions mitigation activities that would otherwise occur now—and intertemporal substitution – in which current emissions mitigation activities remain unpursued due to the promise of future carbon removal. The dynamics of contemporaneous substitution are straightforward: when it is cheaper in dollar-per-ton terms to purchase carbon removal on a voluntary market than it is to mitigate emissions there will be economic pressure to purchase offsets to meet compulsory or voluntary climate goals. If carbon removal purchases are subsequently shown to be of dubious quality, a purchaser has been incentivized to delay their own mitigation efforts in a way that ultimately causes net harm to the global environment and human livelihoods. For example, a recent analysis of rainforest carbon credits found that roughly 90% of the claimed offsets of projects surveyed – equivalent to ~100 million tonnes of CO_2 (Mt; 10^6 tonnes) emitted – did not represent true emissions reductions[13–15]. This is not an isolated issue[16]. If these findings are robust, it is clear that contemporaneous substitution (and failure) has already occured in practice.

The dynamics of intertemporal substitution are somewhat different. In this case, the magnitude of the incentive to substitute at any given time horizon will be controlled largely by the relationship between: (1) discount rates—which quantify assumed long-term benefits of any mitigation action today; and (2) the anticipated levelized cost of a given carbon removal pathway relative to a forecasted abatement cost. The former is an area of political contestation, making it difficult to predict. The latter, however, can arguably be best understood through analysis of the deployment costs of carbon removal projects. Indeed, the pull toward intertemporal substitution will be set foremost by (presumed) knowledge of long-term cost trajectories, the ability to evaluate carbon removal claims, and the speed and volume

projections of pathways deployed at scale. However, opaque or unjustified claims of low cost or rapid learning rates could straightforwardly lead to mitigation deterrence through intertemporal substitution and failure[17]. Critically, evaluation of forecasted emissions mitigation, carbon removal, and environmental impacts over the next century from integrated assessment models (e.g., ref. [18]) will be strongly reliant on a robust understanding of the dollar-per-ton cost of emerging carbon removal pathways. In this light, publics having limited or no access to key information about carbon removal projects (such as deployment and monitoring costs) makes it more difficult to plan future climate mitigation efforts and set informed climate policies and goals.

More novel forms of carbon removal—for example, direct air capture and storage, enhanced weathering, or ocean alkalinity enhancement—are often proposed to be lower risk than forestry removals from a durability standpoint, but are currently much more expensive in dollar-per-ton terms[3,4]. In an idealized market-based system, the high price of these novel, more durable forms of carbon removal might countervail the potential for mitigation deterrence, because it will often be cheaper to mitigate emissions than it would be to purchase offsets from durable carbon removal pathways on a carbon market[2]. However, there will commonly be a direct scaling between the quality of offsets and dollar-per-ton cost in carbon removal pathways. This scaling will be impossible to assess without transparency in both the data used to make carbon removal claims and the all-in costs of removing a ton of CO_2. There is increasing acceptance that access to the data and methods behind carbon removal and reduction claims is essential (see, for instance, ref.[19]). However, we stress that transparency on both data/methods and cost can help to mitigate against perverse outcomes in early carbon market activity.

There will be significant pressure on suppliers to keep costs as low as possible whether in a voluntary, compliance, or hybrid market. In addition, deployment and scaling in novel carbon removal is currently being pursued almost exclusively by venture-backed, for-profit startups and major oil companies, which raises the possibility of predatory pricing[20] – a situation in which a carbon removal supplier prices its offsets below its own dollar-per-ton costs in order to outcompete rivals and increase market share. This includes outcompeting efforts that are community based (e.g., cooperative structures), which are less likely to be able to operate at significant losses. Venture-backed startups are clearly incentivized to consider this tactic in an unregulated market in which demand is growing exponentially and most existing market activity surrounds extremely cheap but high-risk land use offsets. Large oil companies – some of which are publicly framing carbon removal as providing social license to operate for many decades (e.g., ref. [21]) – may also be incentivized to pursue and promote carbon removal technologies at continued economic loss.

Unsubstantiated marketing claims about carbon removal volume and cost will often run counter to overall climate and societal goals. Therefore, we argue that robust understanding and open debate about current and future dollar-per-ton costs of claimed offsets produced by traditional and novel carbon removal pathways should be a regulated requirement as part of a push for more responsible scaling of carbon removal. At the individual, regional, and national level, decisions will be made in the coming decades regarding what greenhouse gas emissions are 'acceptable' and/or 'tolerable', and carbon removal is already a part of these discussions. Uncertain CDR practices have already entered political dialog at the highest levels—for instance, soil management practices that lack broad scientific consensus on their ability to sequester carbon[22] are featured in many of the Long-term Low Emission Development Strategies submitted to the United Nations Framework Convention on Climate Change (UNFCCC)[23]. These strategies must ultimately balance the costs and benefits of emissions mitigation against uncertain estimates of the potential and risks of CDR pathways. Academic technoeconomic assessments provide critical knowledge and can pinpoint key knowledge gaps[24–26], but a rigorous evaluation of cost and effectiveness will likely also require information from bottom-up deployment efforts that are under substantive unit-cost constraints.

There are multiple potential mechanisms for preventing or minimizing the impacts of contemporaneous or intertemporal substitution, and these can all be enacted in conjunction with greater overall transparency in CDR efforts[27]. Given that many prominent CDR pathways are still essentially unproven in the field at any scale, transparency in monitoring, reporting, and verification efforts, as stressed above, will be essential. Greater transparency could be pursued in parallel with a formal separation of carbon removal goals from emissions mitigation milestones[28], which would be a major step toward preventing mitigation deterrence in its own right[29]. A clear separation of removal and mitigation targets could help to augment the benefits of transparency by helping to foster a more coherent and open debate on the holistic value that should be placed on a given intervention—going beyond ton-for-ton frameworks to incorporate potential co-benefits for biodiversity and/or food security.

Regardless of hypothetical market structures, the simplest immediate path forward is for corporate and government purchasers of CDR to require full data and cost transparency for carbon removal projects that supply offsets to the voluntary market. These requirements must go beyond permissioned access to data that is controlled by project developers themselves and/or NGOs with incentives toward market growth. Further, the academic community and those committed to responsible carbon removal practice, whether suppliers, purchasers, land managers, or policy advocates, should avoid and speak out against "transparency washing" — the performative use of the language of transparency as a tool for obscuring intentional limitation of public access to data—in the carbon removal realm.

In sum, there is credible concern that carbon removal efforts will overpromise and under-deliver on removal volume, with clear potential for negative impacts on overall climate mitigation efforts. There is also a strong possibility of carbon removal suppliers overpromising and underdelivering on dollar-per-ton costs. Whether emerging through irrational optimism or as a short-term competitive strategy this could have a range of negative impacts, including mitigation deterrence, crowding out community-based frameworks for project development, and significant waste of time, resources, and talent in a critical juncture for the development and scaling of new, durable carbon removal approaches[30]. We argue that policy frameworks for supporting transparent and accurate evaluation of the dollar-per-ton cost of technically rigorous durable carbon removal must be a key piece of the overall effort to scale carbon removal in an effective and responsible way. In the near term, transformative corporate buyers of CDR and early government procurement programs can make an immediate impact by forcing full data and cost transparency in carbon removal efforts. This will be a major shift from current practice in voluntary carbon removal markets. However, a turn towards radical transparency will allow academic researchers, and governments to critically evaluate claims to scale for CDR technologies with the goal of spurring an effective transition to large-scale, regulatory carbon removal practices that serve the public good.

Data availability

No datasets were generated or analysed during the current study.

Christopher T. Reinhard[1] ✉ **& Noah J. Planavsky**[2] ✉
[1]School of Earth & Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA, USA. [2]Yale Center for Natural Carbon Capture, Yale University, New Haven, CT, USA.
✉e-mail: chris.reinhard@eas.gatech.edu; noah.planavsky@yale.edu

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Both authors conceptualized, wrote, and edited the manuscript.

Competing interests

CTR and NJP co-founded Lithos Carbon, a company engaged in commercial activity in the enhanced weathering sector, but have no ongoing financial or administrative ties to the company. NJP co-founded, and CTR serves as a Scientific Advisor for, CREW Carbon, a company engaged in commercial carbon removal activity in the wastewater treatment sector.

Additional information

Correspondence and requests for materials should be addressed to Christopher T. Reinhard or Noah J. Planavsky.