Over the past year, news of progress on negative emissions technology projects has increasingly been accompanied by a balancing, critical perspective on the challenges faced by the particular approach – such as the sustainability of biomass supplies for BECCS, the water and power requirements for DAC, and so forth.

While this more frequent criticism may be welcomed as evidence of the growing awareness of NETs across the climate concerned community, it also points to the challenge highlighted in Ralph Keeling’s 2009 paper *Triage in the Greenhouse*. Keeling noted that “The global environment will not be adequately protected by an approach that focuses exclusively on local environmental concerns,” and highlighted the need for an internationally agreed risk management framework to enable trade-offs to be made between the respective risks accompanying action and inaction – between the risk of local or regional damage arising from some mitigation action and the global benefits of taking action on climate restoration.

Risk assessment and management is a common theme in work on NETs including, in relation to marine approaches, the work of bodies such as the International Maritime Organization (i.e. the London Convention/Protocol and the work of the GESAMP expert group). But these efforts are typically focussed on a single or a narrow range of negative emissions approaches, and do not link to a consideration of the broader risks of climate change.

As Keeling also noted “Virtually all conceived actions for mitigation could become casualties of environmental protests unless broadly agreed frameworks can be established.”

Creating such a broader risk management framework, that bridges the gap between global climate change risks and those related to individual mitigation approaches, will be a critical enabler for large scale CDR deployment.

Keeling, Ralph F. "Triage in the greenhouse." Nature Geoscience 2, no. 12 (2009): 820-822.
**Research and development progress**

**Net-zero emission targets for major emitting countries consistent with the Paris Agreement**

Abstract: “Over 100 countries have set or are considering net-zero emissions or neutrality targets. However, most of the information on emissions neutrality (such as timing) is provided for the global level. Here, we look at national-level neutrality-years based on globally cost-effective 1.5°C and 2°C scenarios from integrated assessment models. These results indicate that domestic net zero greenhouse gas and CO$_2$ emissions in Brazil and the USA are reached a decade earlier than the global average, and in India and Indonesia later than global average. These results depend on choices like the accounting of land-use emissions. The results also show that carbon storage and afforestation capacity, income, share of non-CO$_2$ emissions, and transport sector emissions affect the variance in projected phase-out years across countries. We further compare these results to an alternative approach, using equity-based rules to establish target years. These results can inform policymakers on net-zero targets. van Soest, Heleen L., Michel GJ den Elzen, and Detlef P. van Vuuren. "Net-zero emission targets for major emitting countries consistent with the Paris Agreement." Nature Communications 12, no. 1 (2021): 1-9. Open access.

**Potential of Maritime Transport for Ocean Liming and Atmospheric CO$_2$ Removal**

Abstract: “Proposals to increase ocean alkalinity may make an important contribution to meeting climate change net emission targets, while also helping to ameliorate the effects of ocean acidification...In this study, the potential of discharging calcium hydroxide (slaked lime, SL) using existing maritime transport is evaluated, at the global scale and for the Mediterranean Sea... Based on maritime traffic data from the International Maritime Organization for bulk carriers and container ships, and assuming low discharge rates and 15% of the deadweight capacity dedicated for SL transport, the maximum SL potential discharge from all active vessels worldwide is estimated to be between 1.7 and 4.0 Gt/year. For the Mediterranean Sea.. a potential discharge of about 186 Mt/year is estimated. The discharge using a fleet of 1,000 new dedicated ships has also been discussed, with a potential distribution of 1.3 Gt/year. [T]he global potential of CO$_2$ removal from SL discharge by existing or new ships is estimated at several Gt/year, depending on the discharge rate...” Caserini, Stefano, Dario Paganò, Francesco Campo, Antonella Abbà, Serena De Marco, Davide Righi, Phil Renforth, and Mario Grosso. "Potential of maritime transport for ocean liming and atmospheric CO$_2$ removal." Frontiers in Climate 3 (2021): 22. Open access.

**Irrigation of biomass plantations may globally increase water stress more than climate change**

Abstract: “The majority of scenarios that meet the goals of the Paris agreements exceed sustainability and precautionary thresholds in land, biodiversity and BECCS potentials. Risks may be best avoided by demand-side driven rapid decarbonization and less land-intensive carbon dioxide removal technologies.” Creutzig, Felix, Karl-Heinz Erb, Helmut Haberl, Christian Hof, Carol Hunsberger, and Stephanie Roe. “Considering sustainability thresholds for BECCS in IPCC and biodiversity assessments” Global Change Biology – Bioenergy https://doi.org/10.1111/gcbb.12798. Open access.
Research and Development progress (cont’d) —————————

A New Perspective for Climate Change Mitigation—Introducing Carbon-Negative Hydrogen Production from Biomass with Carbon Capture and Storage (HyBECCS)

Abstract: “A key opportunity to replace fossil fuels across sectors is the use of renewable hydrogen. In this context, the main political and social push is currently on climate neutral hydrogen production through electrolysis using renewable electricity. Another climate neutral possibility that has recently gained importance is biohydrogen production from biogenic residual and waste materials. This paper introduces for the first time a novel concept for the production of hydrogen with net negative emissions. The derived concept combines biohydrogen production using biotechnological or thermochemical processes with carbon dioxide capture and storage. Various process combinations referred to this basic approach are defined as HyBECCS (Hydrogen Bioenergy with Carbon Capture and Storage) and described in this paper... For the production and use of carbon-negative hydrogen, a saving potential of 8.49–17.06 MtCO$_2$eq/a is estimated for the year 2030 in Germany. The production costs for carbon-negative hydrogen would have to be below 4.30 € per kg in a worst-case scenario and below 10.44 € in a best-case scenario in order to be competitive in Germany, taking into account hydrogen market forecasts.” Full, Johannes, Steffen Merseburg, Robert Miehe, and Alexander Sauer. "A New Perspective for Climate Change Mitigation—Introducing Carbon-Negative Hydrogen Production from Biomass with Carbon Capture and Storage (HyBECCS)." Sustainability 13, no. 7 (2021): 4026. Open access.

Carbon capture and biomass in industry: A techno-economic analysis and comparison of negative emission options

Abstract: “Meeting the Paris Agreement will most likely require the combination of CO$_2$ capture and biomass in the industrial sector, resulting in net negative emissions. CO$_2$ capture within the industry has been extensively investigated. However, biomass options have been poorly explored, with literature alluding to technical and economic barriers. In addition, a lack of consistency among studies makes comparing the performance of CO$_2$ capture and/or biomass use between studies and sectors difficult... Therefore, an integrated evaluation of the techno-economic performance regarding CO$_2$ capture and biomass use was performed for five energy-intensive industrial sub-sectors. Harmonization results indicate that CO$_2$ mitigation potentials vary for each sub-sector, resulting in reductions of 1.4–2.7 t CO$_2$/t steel (77%–149%), 0.7 t CO$_2$/t cement (92%), 0.2 t CO$_2$/t crude oil (68%), 1.9 t CO$_2$/t pulp (1663%–2548%), and 34.9 t CO$_2$/t H$_2$ (313%). Negative emissions can be reached in the steel, paper and H$_2$ sectors. Novel bio-based production routes might enable net negative emissions in the cement and (petro)chemical sectors as well...” Yang, F., J. C. Meerman, and A. P. C. Faaij. "Carbon capture and biomass in industry: A techno-economic analysis and comparison of negative emission options." Renewable and Sustainable Energy Reviews 144 (2021): 111028. Subscription required.

Considering sustainability thresholds for BECCS in IPCC and biodiversity assessments

Abstract: “The majority of scenarios that meet the goals of the Paris agreements exceed sustainability and precautionary thresholds in land, biodiversity and BECCS potentials. Risks may be best avoided by demand-side driven rapid decarbonization and less land-intensive carbon dioxide removal technologies.” Creutzig, Felix, Karl-Heinz Erb, Helmut Haberl, Christian Hof, Carol Hunsberger, and Stephanie Roe. "Considering sustainability thresholds for BECCS in IPCC and biodiversity assessments" Global Change Biology – Bioenergy (2021): 510-515. Open access.
Evolution patterns of bioenergy with carbon capture and storage (BECCS) from a science mapping perspective

Abstract: “As one of the most promising [negative emissions technologies], bioenergy with carbon capture and storage (BECCS) methods, which captures carbon dioxide (CO₂) emissions from bioenergy plants and then stores them in geological reservoirs, are being widely used in climate change scenarios. With the increased focus on mitigating solutions, several concerns have been raised regarding the deployment of BECCS. As no science mapping analyses of evolutionary BECCS patterns have yet been made, this study sought to determine these evolution patterns using a systematic analysis approach based on science mapping and visualization analyses. Under a longitudinal framework, the conceptual BECCS evolutionary track was determined using SciMAT to elucidate the structure and dynamic aspects of the associated scientific research. The co-word network and thematic evolutionary analysis revealed five main BECCS related themes...” Li, Meihui, Yi Lu, and Mengjiao Huang. "Evolution patterns of bioenergy with carbon capture and storage (BECCS) from a science mapping perspective." Science of The Total Environment 766 (2021): 144318. Subscription required.

A nature-based negative emissions technology able to remove atmospheric methane and other greenhouse gases

Abstract: “Fulfilling the Paris Climate Agreement requires reducing rapidly the new emissions of greenhouse gases (GHGs) to reach net zero by 2050. As some anthropogenic emissions cannot be zero, to compensate them it will be necessary to remove GHGs from the atmosphere. Among possible methods, the Iron Salt Aerosol (ISA) offers new possibilities, including removal of methane and several other GHGs, as well as carbon dioxide... ISA is different from the method known as Ocean Iron Fertilization and the differences are explained... Still larger laboratory trials, safety and environmental impact studies and global chemical computer modeling are necessary before ISA would be ready to be trialed. Desk and laboratory studies indicate low cost, easy deployment and efficacy, all of which can be validated by future small scale field trials, a step needed before, if successful, a possible implementation at a climate-relevant scale.” Ming, Tingzhen, Renaud de Richter, Franz Dietrich Oeste, Robert Tulip, and Sylvain Caillol. "A nature-based negative emissions technology able to remove atmospheric methane and other greenhouse gases." Atmospheric Pollution Research (2021). Subscription required.

Negative emissions using Mg sourced from desalination brine or natural evaporite deposits

Abstract: “We establish a profitable negative emissions technology that converts desalination brine or salt deposits into saleable products while concurrently mineralizing atmospheric CO₂ as Mg-carbonates. The process produces water, gypsum, salt, potash, aggregate, and hydrochloric acid with the ratios of products dependent on the brine or evaporite deposit composition. In addition to the negative emissions realized through direct removal of CO₂ from the atmosphere, the co-products drive out existing production methods resulting in CO₂ emissions reduction... We outline how extant equipment and technologies can be used to implement this process... Per tonne of total CO₂ reduction (mitigated + removed), the process operates at an energy consumption of 2.1 GJ/t-CO₂, falling to 1.1 GJ/t-CO₂ if the system is powered by renewable energy. Via Monte Carlo analysis using global price distributions, we find that even without including a price on CO₂ the process operates, on average, at a profit of 196 USD/t-CO₂ (total reduction).” Myers, Corey, and Takao Nakagaki. "Negative emissions using Mg sourced from desalination brine or natural evaporite deposits." Available at SSRN 3812220 (2021). Open access.
Research and Development progress (cont’d) —————————

Delivering carbon negative electricity, heat and hydrogen with BECCS – Comparing the options

Abstract: "Biomass can be converted into a range of different end-products; and when combined with carbon capture and storage (CCS), these processes can provide negative CO\textsubscript{2} emissions... The aim of this study is to comparatively assess a combination of BECCS pathways to identify the applications which offer the most valuable outcome, i.e. maximum CO\textsubscript{2} removal at minimum cost, ensuring that resources of sustainable biomass are utilised efficiently. Three bioenergy conversion pathways are evaluated in this study: (i) pulverised biomass-fired power plants which generate electricity (BECCS), (ii) biomass-fuelled combined heat and power plants (BE-CHP-CCS) which provide both heat and electricity, and (iii) biomass-derived hydrogen production with CCS (BHCCS). The design and optimisation of the BECCS supply chain network is evaluated using the Modelling and Optimisation of Negative Emissions Technology framework for the UK (MONET-UK). The results show that indigenous sources of biomass in the UK can remove up to 56 MtCO\textsubscript{2}/yr from the atmosphere without the need to import biomass..." Bui, Mai, Di Zhang, Mathilde Fajardy, and Niall Mac Dowell. "Delivering carbon negative electricity, heat and hydrogen with BECCS—Comparing the options." International Journal of Hydrogen Energy (2021).

Industrial biochar systems for atmospheric carbon removal: a review

Abstract: “In the context of climate change, there is an urgent need for rapid and efficient methods to capture and sequester carbon from the atmosphere. For instance, production, use and storage of biochar are highly carbon negative, resulting in an estimated sequestration of 0.3–2 Gt CO\textsubscript{2} year\textsuperscript{-1} by 2050. Yet, biochar production requires more knowledge on feedstocks, thermochemical conversion and end applications. Herein, we review the design and development of biochar systems, and we investigate the carbon removal industry. ... Carbon removal services via biochar are currently offered through robust marketplaces that require extensive certification, verification and monitoring, which adds an element of credibility and authenticity. ... Process optimization is imperative to produce an end product that meets application-specific requirements, environmental regulations and achieve ultimate stability for carbon sequestration purposes.” Fawzy, Samer, Ahmed I. Osman, Haiping Yang, John Doran, and David W. Rooney. "Industrial biochar systems for atmospheric carbon removal: a review." Environmental Chemistry Letters (2021): 1-33. Open access.

Alkalization Scenarios in the Mediterranean Sea for Efficient Removal of Atmospheric CO\textsubscript{2} and the Mitigation of Ocean Acidification

Abstract: “It is now widely recognized that in order to reach the target of limiting global warming to well below 2°C above pre-industrial levels ... cutting the carbon emissions even at an unprecedented pace will not be sufficient, but there is the need for development and implementation of active Carbon Dioxide Removal (CDR) strategies. This study [presents] an analysis of marine alkalization applied to the Mediterranean Sea taking into consideration the regional characteristics of the basin. We demonstrate that [this] approach allows to stabilize the mean surface pH at present day values and substantially increase the potential to counteract acidification relative to the alkalinity added, while the carbon uptake efficiency is only marginally reduced. Nevertheless, significant local alterations of the surface pH persist, calling for an investigation of the physiological and ecological implications of the extent of these alterations to the carbonate system...” Butenschön, Momme, Tomas Lovato, Simona Masina, Stefano Caserini, and Mario Grosso. "Alkalization scenarios in the Mediterranean Sea for efficient removal of atmospheric CO\textsubscript{2} and the mitigation of ocean acidification." Frontiers in Climate 3 (2021): 14. Open access.
**Research and Development progress (cont’d)**

**On the trade-offs and synergies between forest carbon sequestration and substitution**

Abstract: “Forest biomass can be used in two different ways to limit the growth of the atmospheric greenhouse gas (GHG) concentrations: (1) to provide negative emissions through sequestration of carbon into forests and harvested wood products or (2) to avoid GHG emissions through substitution of non-renewable raw materials with wood. We study the trade-offs and synergies between these strategies using three different Finnish national-level forest scenarios between 2015 and 2044 as examples. We demonstrate how GHG emissions change when wood harvest rates are increased... According to our results, an increase in harvest rates in Finland increased the total net GHG flow to the atmosphere virtually certainly or very likely, given the uncertainties and time frame considered. This was because the increased biomass-based CO$_2$ and other greenhouse gas emissions to the atmosphere together with decreased carbon sequestration into the forest were very likely higher than the avoided fossil-based CO$_2$ emissions...” Soimakallio, Sampo, Tuomo Kalliokoski, Aleksi Lehtonen, and Olli Salminen. "On the trade-offs and synergies between forest carbon sequestration and substitution." Mitigation and Adaptation Strategies for Global Change 26, no. 1 (2021): 1-17. Open access.

**Fuzzy optimization model for enhanced weathering networks using industrial waste**

Abstract: “Enhanced weathering is a negative emissions technology based on the accelerated weathering of alkaline minerals... Enhanced weathering has been demonstrated in proof-of-concept laboratory and field tests, but scale-up to a level that delivers significant CO2 removal is still an engineering challenge that requires a system-level perspective. Future enhanced weathering networks should be planned like industrial supply chains, taking into account constraints in the supply of alkaline minerals and the availability of land sinks. Optimization of such networks should also take into account techno-economic uncertainties that are inherent in any emerging technology. To fill this research gap, this work develops a fuzzy mixed-integer linear programming model for optimal planning of enhanced weathering networks... The use of the model is illustrated with two case studies. First, a pedagogical example is solved; then, the model is demonstrated for a realistic scenario which shows that 0.69% of Taiwan’s CO$_2$ emissions can be offset by the use of blast furnace slag for enhanced weathering.” Aviso, Kathleen B., Jui-Yuan Lee, Aristotle T. Ubando, and Raymond R. Tan. "Fuzzy optimization model for enhanced weathering networks using industrial waste." Clean Technologies and Environmental Policy (2021): 1-17. Subscription required.

**Industrial biochar systems for atmospheric carbon removal: a review**

Abstract: “In the context of climate change, there is an urgent need for rapid and efficient methods to capture and sequester carbon from the atmosphere. For instance, production, use and storage of biochar are highly carbon negative, resulting in an estimated sequestration of 0.3–2 Gt CO$_2$ year$^{-1}$ by 2050... Herein, we review the design and development of biochar systems, and we investigate the carbon removal industry. Carbon removal efforts are currently promoted via the voluntary market. The major commercialized technologies for offering atmospheric carbon removal are forestation, direct air carbon capture utilization and storage, soil carbon sequestration, wooden building elements and biochar, with corresponding fees ranging from 10 to 895 GBP (British pounds) per ton CO$_2$. Biochar fees range from 52 to 131 GBP per ton CO$_2$, which indicates that biochar production is a realistic strategy that can be deployed at large scale.” Fawzy, Samer, Ahmed I. Osman, Haiping Yang, John Doran, and David W. Rooney. "Industrial biochar systems for atmospheric carbon removal: a review." Environmental Chemistry Letters (2021): 1-33. Open access.
Research and Development progress (cont’d)

Life cycle assessment of carbon dioxide removal technologies: a critical review
Abstract: “A large number of prospective climate scenarios rely on Carbon Dioxide Removal (CDR) technologies to limit global warming below 2 °C. To date, however, a comprehensive understanding of the overall life-cycle environmental impacts of CDR technologies is missing. We present a critical review on conducted Life Cycle Assessments (LCAs) of a comprehensive set of CDR technologies: afforestation and reforestation, biochar, soil carbon sequestration, enhanced weathering, ocean fertilisation, bioenergy with carbon capture and storage, and direct air carbon capture and storage. One of the key observations is that emissions avoided due to substitution of certain processes (due to system expansion in LCA) can be easily misinterpreted as negative emissions, i.e. as carbon removal from the atmosphere. Based on the observed inconsistencies and shortcomings, we recommend to interpret available CDR LCA results with caution. [Six recommendations are made to] improve the understanding of environmental implications of CDR deployment. … We conclude that more comprehensive and rigorous LCAs are needed to help inform the design of CDR technology portfolios and to aid in anticipatory governance.” Terlouw, Tom, Christian Bauer, Lorenzo Rosa, and Marco Mazzotti. “Life Cycle Assessment of carbon dioxide removal technologies: A critical review.” Energy & Environmental Science (2021). Open access.

Projects and companies

Climeworks and Northern Lights to explore DAC in Norway
Climeworks and Northern Lights (recently incorporated as a joint venture company between Equinor, Total and Shell) have agreed to explore the development of a full-chain CDR project in Norway, including possible use of the Northern Lights facilities as part of new negative emission solutions, addressing the need of companies in non-industrial sectors to become carbon neutral and/or carbon negative.

C-Capture completes £8M funding round
C-Capture the Leeds, UK based company developing carbon capture technology based on proprietary a phenoxide based solvent announced the completion of an £8M funding round, supported by existing shareholders IP Group, Drax, and bp Ventures, with additional funding from the British Business Bank’s Future Fund. C-Capture recently completed a post-combustion capture pilot project at the Drax biomass fired power plant, and funding will contribute towards further development of this negative emissions technology (BECCS), which is expected to make a significant contribution towards the UK reaching its 2050 net zero.

Schlumberger New Energy, Chevron, and Microsoft Collaborate on 300 ktCO2/yr BECCS project
Schlumberger New Energy, Chevron Corporation, Microsoft and Clean Energy Systems announced plans to develop a BECCS project to produce carbon negative power in Mendota, California.

The BECCS plant will convert agricultural waste biomass into syngas (CO + H2) that will be combusted in oxygen to generate electricity, with more than 99% of the carbon from the process planned to be captured for deep geological storage. When completed, the plant is expected to remove about 300 ktCO2/yr, equivalent to the emissions from electricity use of more than 65,000 U.S. homes.
Carbon pricing and trading developments

The zero-emissions cost of energy: a policy concept
Abstract: “The energy sector generates over 70% of global greenhouse gas (GHG) emissions, but existing energy-climate policies do little to reduce GHG emissions to prevent climate change. We present a new carbon tax policy concept in which energy users would be taxed an amount equal to the cost of cleaning up the emissions that they create, wherein the tax revenues would be used to operate negative emissions technologies. The policy is based on applying the Zero-Emissions Cost metric to energy prices, which includes the “regular” cost of an energy source plus the cost of sequestering its emissions. Using the ZEC, 1) the energy sector would be emissions-neutral, 2) biofuels would be cheaper than petroleum fuels, and 3) renewable electricity would be cheaper than fossil-fuel electricity... The summary point of this commentary is to demonstrate a pathway to achieve net-zero GHG emissions from the US energy sector, and to contemplate the associated economic impacts on our society.” Beal, Colin M., and Carey W. King. “The zero-emissions cost of energy: a policy concept.” Progress in Energy (2021). Open access.

UK carbon trading system to launch in May
Summary: “The UK’s post-Brexit carbon trading scheme will launch in May, with the first auctions that replace its EU counterpart expected to attract strong interest from buyers. The UK emissions trading programme is a cornerstone of the government’s pledge to become a net-zero economy by 2050. It sets a limit on the volume of greenhouse gases that heavy polluters can emit and requires them to buy carbon credits, which can be traded, to cover their output. Companies such as power providers have been awaiting details on the UK scheme since the Brexit transition period concluded at the end of 2020... The UK ETS is designed to enable companies to cut emissions in a cost-effective way, make cleaner fuels more competitive and force industry to clean up its operations. It will become the main UK benchmark for the price of emissions following Brexit.” Subscription required.

Policy, governance and social license

A policy roadmap for negative emissions using direct air capture
Abstract: “Negative emission strategies are central to avoiding catastrophic climate change. Engineered solutions such as direct air capture are far from cost-competitive. As past low-carbon technology transitions suggest, this calls for policy and political strategies beyond carbon pricing. We adopt a policy sequencing perspective that identifies policies that could create niche markets, building political support for later widespread deployment of direct air capture. Climate leaders could pursue an “incentives + mandates” policy strategy targeted at the oil and gas industry. These early moves could create global spillovers for follower countries by reducing technology cost and facilitating knowledge transfer through global firms.” Meckling, Jonas, and Eric Biber. “A policy roadmap for negative emissions using direct air capture.” Nature Communications 12, 2051 (2021). Open access.

As Much as Possible, as Soon As Possible: Getting Negative About Emissions
Abstract: “This paper is a report on the viability, both technical and ethical, of negative emissions technologies (NETs) in climate change mitigation... Critics argue that we should not rely on the promise of future NETs because that could be taken as an excuse to avoid de-carbonization in the near term. The concern is genuine, but if the prima facie arguments for drawing down carbon as soon as possible are correct, ways must be found to counter the incentives to defer the immediate deployment of NETs and other forms of mitigation. A policy instrument is sketched which could help accomplish that task.” Peacock, Kent A. “As Much as Possible, as Soon As Possible: Getting Negative About Emissions." Ethics, Policy & Environment (2021). Subscription required.
**Undoing equivalence: Rethinking carbon accounting for just carbon removal**

Abstract: “Concerns are increasingly raised over the centrality of carbon removal in climate policy, particularly in the guise of ‘net-zero’ targets. Most significantly perhaps, treating emissions and removals as equivalent obscures emission reductions, resulting in ‘mitigation deterrence’. Yet the conflation of emission reductions and removals is only one among several implicit equivalences in carbon removal accounting. Here we examine three other forms – carbon, geographical and temporal equivalence - and discuss their implications for climate justice and the environmental risks with carbon removal. We conclude that ‘undoing’ these equivalences would further a just response to the climate crisis and tentatively explore what such undoing might look like in practice.” Carton, Wim, Jens Friis Lund, and Kate Dooley. "Undoing equivalence: Rethinking carbon accounting for just carbon removal." *Frontiers in Climate* (2021). Open access.

**Exploring cross-national public support for the use of enhanced weathering as a land-based carbon dioxide removal strategy**

Abstract: “This study explores how public attitudes across three countries influence support towards terrestrial enhanced weathering, whereby silicate minerals are applied to agricultural land to remove carbon dioxide from the atmosphere. An online survey was administered in Australia (N = 1000), the UK (N = 1000), and the USA (N = 1026) where there are ongoing field trials of this technique. Findings are similar across all three countries with many participants unfamiliar with enhanced weathering and unsure about supporting the use of enhanced weathering. Results show that positive affect is the main predictor for support of this technique, along with perceived benefits and level of concern about climate change. .. Overall, our findings show that it is imperative to continue to engage the public, thereby allowing their views to be incorporated as enhanced weathering technology develops over time.” Spence, Elspeth, Emily Cox, and Nick Pidgeon. “Exploring cross-national public support for the use of enhanced weathering as a land-based carbon dioxide removal strategy.” *Climatic Change* 165, 23 (2021). Open access.

**Carbon Dioxide Removal Policy in the Making: Assessing Developments in 9 OECD Cases**

Abstract: “The scientific literature on CDR governance and policy is still rather scarce, with empirical case studies and comparisons largely missing. Based on an analytical framework that draws on the multi-level perspective of sociotechnical transitions as well as existing work on CDR governance, we gathered and assessed empirical material until early 2021 from 9 Organization for Economic Co-operation and Development (OECD) cases: the EU and three of its Member States (Ireland, Germany, and Sweden), Norway, the United Kingdom, Australia, New Zealand, and the United States. Based on a synthesis of differences and commonalities, we propose a tripartite conceptual typology of the varieties of CDR policymaking: (1) incremental modification of existing national policy mixes, (2) early integration of CDR policy that treats emission reductions and removals as fungible, and (3) proactive CDR policy entrepreneurship with support for niche development. Although these types do not necessarily cover all dimensions relevant for CDR policy .. the conceptual typology might spur future comparative work as well as more fine-grained case-studies on established and emerging CDR policies.” Schenuit, Felix, Rebecca Colvin, Mathias Fridahl, et al. "Carbon Dioxide Removal policy in the making: Assessing developments in 9 OECD cases." *Frontiers in Climate* 3 (2021): 7. Open access.
On the permissibility (or otherwise) of negative emissions

Abstract: “Limiting dangerous climate change is now widely believed to require negative emissions (NETs), a prospect some believe to be unjust and unacceptably risky. While NETs are not risk-free, I argue that they could be part of minimally just responses to climate change. In doing so, I identify a dilemma between limiting warming to 1.5°C, which promises lower climate impacts but implies greater NETs risks, and 2°C, which requires less NETs but promises greater climate impacts. Finally, I consider what the case of NETs reveals about permissibility in the face of non-compliance with principles of climate justice.” Lenzi, Dominic. “On the Permissibility (or otherwise) of Negative Emissions.” Ethics, Policy & Environment (2021).

The biochar system in the EU: the pieces are falling into place, but key policy questions remain

Summary: “The biochar system presents itself as an exceptional negative emissions technology in that it can readily provide multiple public goods at relatively low cost, notably restoration of soil carbon and water conservation in addition to climate mitigation, as well as multiple private goods related to the use of biochar as a soil amendment and other possible uses. To realise this potential at scale, however, a holistic and coherent cross-sectoral policy approach is needed. So far, the lack of an enabling and supportive policy framework at the EU level and, consequently, low demand for biochar as a soil amendment, has been the main barrier to widespread diffusion of the biochar system. Such framework is now under construction, but its final configuration is still undefined. Which policy instruments should be used to reward greenhouse gas removals produced by the biochar system and other negative emissions technologies, is a question that should be addressed soon.” Verde, Stefano F., and David Chiaramonti. “The biochar system in the EU: the pieces are falling into place, but key policy questions remain.” (2021). European University Institute, Policy Briefs; 2021/08; Florence School of Regulation; Climate. Open access.

Reports and other publications

The Sabin Center for Climate Change Law publishes Volume 2 of The Law of Enhanced Weathering for Carbon Dioxide Removal

Summary: “Volume 2 of The Law of Enhanced Weathering for Carbon Dioxide Removal identifies existing legal requirements that could hinder the mining of silicate materials for use in enhanced weathering and recommends reforms that could facilitate such activity without comprising environmental and other outcomes. The paper also explores legal issues associated with sourcing mine tailings for use in enhanced weathering. As the paper explains, there is often significant uncertainty as who owns mine tailings, and restrictions on their transfer to third parties. Again, the paper recommends reforms to address these issues and facilitate the use of mine tailings in enhanced weathering.” The first volume in the series, published in September 2020, provided a detailed analysis of the international and U.S. legal frameworks governing enhanced weathering on land and in the oceans.

Carbon Dioxide Removal Primer

Summary: “This online resource provides the context and background on CDR to enable readers to begin applying themselves to the climate crisis. Written by dozens of authors, it offers a dialogue, rather than a rigid consensus, with open questions and insight into the needs of large-scale carbon dioxide removal. The primer reflects more than two years of thoughtful work and collaboration among dozens of authors, all experts in different areas of carbon dioxide removal. The effort spanned several workshops and an extensive period of writing, reading, and constructive feedback.” Wilcox, Jennifer, Ben Kolosz, and Jeremy Freeman (2021) CDR Primer. Open source.
A Carbon-Sucking Startup Has Been Paralyzed by Its CEO
Intro: “Global Thermostat, the New York-based company that created this green box, told reporters it would be able to suck about 4,000 tons of CO₂ out of the air per year. The company is one of just three around the world with direct-air capture technology that seems to have a shot at capturing carbon on a vast scale. Scientists say that to prevent catastrophic climate impacts, it might be necessary to draw as many as 10 billion tons of the gas from the air each year by 2050. But the promise of a few thousand tons removed, plus assurances about the potential for billions, was enough to generate excitement around Global Thermostat and its chief executive officer, Graciela Chichilnisky.”

NET Jobs: Founding Executive Director
Carbon Removal Advocacy Europe is seeking a UK-based founding Executive Director, to raise the ambition level for CDR in Europe and the UK, emphasising the region’s potential to become a global leader in scaling CDR to billions of tonnes per year. The successful applicant will become the face of CDR in the UK by engaging policy makers, NGOs, industry, and community leaders, and ensure that environmental justice and equity are key pillars in the UK’s CDR strategy. The deadline for applications is “mid-April”, 2021.

NET Jobs: Ocean-Based CDR Program Manager
Ocean Visions, the science and innovation organization with a mission is to identify, develop, demonstrate, and ultimately deploy equitable, durable, and scalable solutions to the ocean’s most pressing environmental challenges, is seeking a US-based Program Manager for ocean-based CDR. The successful applicant will plan, coordinate, and lead implementation of an important portion of Ocean Visions’ work to advance ocean-based CDR, the primary role being to help accelerate the development, testing, and evaluation of ocean-based CDR technologies and applications. The deadline for applications is 7 May, 2021.

NET Jobs: PhD Researcher - Intergenerational Democracy and Negative Emissions Technology
The University of Twente has an opening for a full-time, 4-year, fully-funded PhD project on Intergenerational Democracy and Negative Emissions Technology: Procedural Justice and Legitimacy for Future People in Climate Policy. Responding justly and feasibly to climate change will very likely require a large-scale effort to remove carbon dioxide from the atmosphere. Some of these technologies remain relatively uncontroversial, but many generate difficult tradeoffs or significant ethical concerns. And while many of these concerns have been the subject of rigorous study, questions of intergenerational justice in the context of NETs are relatively under-theorized.

The objective of this project is not merely to unearth and then elucidate these intergenerational issues—whether they be predicated upon storage, mitigation obstruction, or risk—but also to translate these concerns into a language that can be more effectively incorporated into policy-making models and deliberation. The deadline for applications is 26 May, 2021.