Climate Technology

Dyrehaugen Web Notebook

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Climate Change

The issue of Climate Change is treated across several web notebooks:

- Climate System (github) (geek) (loc)
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- Climate Impacts (github) (geek) (loc)
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You are now visiting the **Climate Technology** Web Notebook.

> **Climate is someone else's Weather**
>
> **Climate Crisis and Economic Development are one and the same problem**

The neoliberal solution to climate change is to hope that somehow it will become profitable to save the planet. This will not work.

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Climate Technology

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CDR Controversies

Anderson

Who is responsible for cleaning up CO2 from the atmosphere?

Various methods of carbon dioxide removal (CDR) are being pursued in response to the climate crisis, but they are mostly not proven at scale. Climate experts are divided over whether CDR is a necessary requirement or a dangerous distraction from limiting emissions. In this Viewpoint, six experts offer their views on the CDR debate.

CDR started appearing in mainstream emission scenarios in the late 2000s and has become a dominant element of most mitigation scenarios consistent with the Paris Agreement's temperature goals. Initially, CDR was dependent on the assumed success of CCS applied to bioenergy (termed BECCS). Although there was much promise for CCS in the 2000s, including an IPCC Special Report in 2005, the technology has not yet lived up to its hope, despite lofty policy ambitions. CCS and most CDR methods are a complex set of technologies that have proved difficult to deploy at scale in real-world contexts. The repeated failure of CCS and CDR to deliver as promised has led many to question their feasibility, particularly at scale.

CDR terminology can be confusing as it combines two very different methods: restoring natural carbon sinks, such as forests, soils or oceans, and investing in unproven technologies, like BECCS, DACCS or enhanced weathering.

CDR has long been identified as a potential 'dangerous distraction' owing to its widespread deployment in emission scenarios but not in reality.

Given that the entire mitigation agenda is predicated on CDR working at scale, and if CDR does not work at the scale intended, then the world will go more rapidly into carbon debt and be locked into a higher-temperature pathway. A more risk-averse approach that uses only a modest scale of CDR would require greater near-term emission reductions that avoid going into carbon debt.

Enormous volumes of CDR are built into implausible mitigation scenarios for the second half of the century, generating a false sense of optimism that we can still meet ambitious temperature goals, even though global emissions are still not declining.

CDR in scenarios are effectively masking insufficient political action.

The main (IAM) modelling groups might work quite objectively, but they do so within deeply subjective political boundaries. Their low carbon futures are locked into tech-dominated versions of the present with no changes to core political elements or values of society in relation to fairness, or distribution of resources or power.

Tight political criteria, combined with very small carbon budgets, force all mitigation scenarios assessed by the IPCC to include increasingly extreme levels of CDR.

Restoration of natural carbon sinks should certainly not be used to justify any additional industrial or fossil fuel emissions. Speculative and largely unavailable CDR technologies are very different because they would require setting up entirely new industrial infrastructures at a large scale.

There is already about 2 billion tonnes of CDR occurring on land.

Big polluters and fossil fuel companies are promoting technological CDR as a cover-up for expanding their business.

The IPCC's Working Group III report highlights the dangers of overreliance of governments on these unproven technologies. Unfortunately, these warnings are downplayed in the heavily negotiated IPCC Summary for Policymakers. They are buried under an array of models and pathways that rely on precisely such technologies, that project continued use of fossil fuels for decades and that overwhelmingly assume that the world will go beyond 1.5 °C for decades or longer — with surprisingly little attention paid to the human and environmental consequences such assumptions entail.

The major IAM modelling groups have inadvertently done the bidding of both Big Oil and those deeply wedded to the obscene asymmetry in responsibility for emissions. Since the early 2000s, these models have increasingly normalized many hundreds of billions of tonnes of CDR as a means of maintaining the political status quo and seriously delaying the need to phase out fossil fuels.

0.3 trillion tonnes of CO2 since the Paris Agreement in 2015.

An alliance has arisen between failed (and failing) political leadership and complicit IAM modelling of the community's escalating dependence on CDR to reconcile the irreconcilable of delivering on the Paris Agreement 1.5 °C to 2 °C commitments without rocking the political boat.

As the climate is heating up, extreme weather events are becoming more frequent and we are approaching various tipping points; we risk losing the sink capacity of various ecosystems.

Industrial-scale ‘carbon farming’ to produce carbon credits is a false and dangerous promise.

It is not possible to say which CDR methods are most promising because, so far, all have failed to deploy at any meaningful scale.

It is possible to postulate theoretical pros and cons of each CDR method, but without sufficient deployment, they remain theoretical. Even afforestation and reforestation have limits, not only in terms of land competition but also in resilience to a changing climate and verifying how much carbon dioxide is removed over extended periods.

BECCS has little to no worthwhile potential, for multiple reasons. DACCS and some carefully applied nature-based solutions could have a useful role in GHG mitigation but should in no way be assumed to compensate for any fossil fuel emissions.

Important to keep a strong focus on CDR methods with characteristic timescales of storage beyond 100 years, like biochar, enhanced mineral weathering or DACCS.

CDR methods range widely regarding their climate mitigation potential, technology readiness level (TRL) and expected price range. Conventional CDR methods like afforestation, reforestation, soil carbon sequestration and peatland restoration have the highest TRL levels but do not offer long-term durability for CO2 storage. DACCS, BECCS and biochar are much more novel methods that offer strong mitigation potential and high durability and are not too far behind in terms of TRL.

The main problem is that international policymakers are implicitly relying on remarkably high volumes of CDR to help fix trajectories that already indicate a 1.5 °C overshoot, without necessarily knowing much about CDR or taking responsibility for the expected overshoot

Incorporating CDR in global scenarios is not slowing down emission reduction efforts, but it is hiding the impact of increasing global emissions and sparing climate policymakers the embarrassment of admitting that always staying under 1.5 °C is no longer achievable. But with the advent of national net-zero emission targets, the level of political scrutiny becomes higher, and it is easier to keep expectations about future national CDR levels in check.

Once governments start splitting their net-zero emission targets into emission reductions and carbon removal components, we can expect healthy national debates on the assumed trajectories, not only regarding CDR but also regarding the types and volumes of residual emissions.

Scaling up CDR could delay reducing emissions. Policymakers can address this risk by establishing separate climate targets for emission reductions and CDR.

We should cut emissions from our energy system assuming CDR will not work at scale.

Scaling these novel CDR technologies will require dedicated innovation policies.

Durability of different CDR methods are ranging from a few decades to thousands of years.It is crucial to guarantee that any residual emissions of fossil carbon are balanced by storage on the same millennial timescale

Setting up biochar production is relatively fast, hence, the reason biochar carbon removal has become the leading novel CDR method to deliver tonnes of carbon removed today. Building DACCS and BECCS plants is a longer and more complex undertaking that takes several years. Therefore, very different policy mixes and sequences must emerge to scale the vast ecosystem of CDR methods.

For direct air capture, low-carbon energy and cost are the main limitations. For biomass with carbon removal and storage, biomass and land are limitations. Other techniques face limitations in terms of land or in terms of robust schemes for monitoring and verification. The most relevant limitations will probably be social rather than technological.

There is the naive assumption that a few pilot schemes with chequered technical histories can unproblematically be rolled out at a planetary scale.

Global rates of CCS deployment are far below those in modelled pathways.

Anderson (2023) Controversies of carbon dioxide removal

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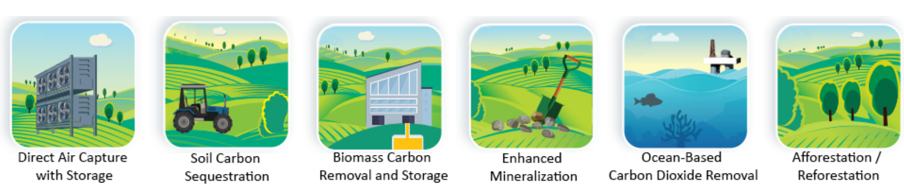
CDR - Carbon Dioxide Removal

CDR terminology can be confusing as it combines two very different methods: restoring natural carbon sinks, such as forests, soils or oceans, and investing in unproven technologies, like BECCS, DACCS or enhanced weathering.

Carbon dioxide removal (CDR) encompasses various deliberate human approaches that can remove CO2 from the atmosphere and store it in oceanic, terrestrial or geological reservoirs over climate-relevant timescales of decades to millennia. These approaches include schemes such as reforestation, afforestation, iron fertilisation, ocean alkalinity enhancement, enhanced rock weathering, bioenergy with carbon capture and storage (BECCS) and direct air capture and storage (DACCS). CDR is distinct from methods aimed at preventing new emissions at point sources, such as carbon capture and storage (CCS) at fossil power plants or cement works, as these prevention methods are classed as emission reduction strategies.

CDR focuses on removing CO2 that is already in the atmosphere or in the upper ocean, and permanently storing it for centuries or longer.



Office of Fossil Energy and Carbon Management (2023) Carbon Negative Shot

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Afforestation

Stevens

Afforesting grassy systems for carbon gain using flammable plantation trees could shift the fire regime from lower intensity grass-fuelled fires to high-intensity crown fires. Future changes in climate will worsen this. We highlight the fire risk of trees planted for carbon and costs of fire protection using African examples.

Tree planting projects in previously open ecosystems using non-native flammable species such as pines and eucalypts should not be allowed to begin, or continue, unless the projections for future plantation management, and especially fire protection, have been planned and suitable funding models developed. Without adequate funding, and the skills and technology to protect plantations far into the future, investment in tree planting has a high probability of going up in smoke while adding more carbon to the atmosphere as the trees burn.

Well-planned and executed commercial and state forestry programmes can contribute significantly to national economies. But afforestation of grassy ecosystems with highly flammable non-native plantation trees has long-term costs far exceeding initial planting costs. These costs and consequences of tree planting as 'Natural Climate Solutions' to global change need careful scrutiny by those committing their land to major land transformation. Targeting deforested and denuded formerly forest areas offers considerable scope for carbon sequestration and restoration with native species in parts of Africa and South America [14]. However to reduce the risk of inappropriate NBS, it also demands revision of the historical misclassification of African grassy ecosystems which has resulted in large-scale inappropriate 'forest' restoration.

Stevens (2023) A trillion trees: carbon capture or fuelling fires?

5.1 Planting Trees

Anderson

The carbon budgets provided by the IPCC already rely on a massive shift away from deforestation and a programme of forestry management, reforestation and some afforestation. So caution needs to be applied to ensure these options are not double counted.

Trees are not a secure carbon sink, as situations such as fire, land use practices, fuel shortages or pest movements can release the carbon back into the atmosphere. Finally, whilst there is immediate popular appeal to planting trees as a store of carbon, in practice, trees need to be considered as part of a rich ecosystem, including their impact on soil carbon cycling.

Anderson (2023) Controversies of carbon dioxide removal

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BECCS - Bioenergy with Carbon Capture and Storage

Burning plants and burying the carbon

Anderson

Biomass carbon removal and storage involves using biomass (such as algae, municipal waste, agricultural or forest residues) to remove CO2 from the atmosphere and store it underground or in products. It looks promising in many areas but is very context-dependent. There are a number of methods that deserve more research, including ocean alkalinity enhancement, enhanced rock weathering and agrigenomic ideas such as engineering plants for enhanced carbon sequestration or microbe-based carbon capture soil amendments. It is early to assess the scalability of all these approaches, and much of the scalability depends on culture and policy. The IPCC assesses that moderate-to-large future mitigation potentials are estimated for direct air carbon capture and sequestration, enhanced weathering and ocean-based CDR methods, with medium evidence and medium agreement.

As an engineer with a background in design and construction in the petrochemical industry, I feel a streak of professional shame when, in 2023, the pinnacle of engineering prowess is burning plants and burying the carbon (termed BECCS).

There are many reasons for this shame, but key amongst these is the *very low energy density of plants.* Add this to the inefficiencies in thermal electricity generation and *nation-sized areas of land needed to be put aside to deliver the volumes of BECCS assumed* in the IAM models. Yet, with very few exceptions, it is such an unsustainable and yesteryear approach to current problems that the IAM modelling groups evoke on a huge planetary scale. So, for me, and on so many levels, **BECCS is a blunder of monumental proportions** and illustrates just how low we are prepared to stoop to get the carbon molecules to add up in models.

Anderson (2023) Controversies of carbon dioxide removal

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DACCS

Anderson

DACCS typically relies on renewable energy to flow air over a catalyst, where the CO2 is captured before being stripped from the catalyst and subsequently stored. Despite its engineering appeal, it is still a fledgling technology and with very little scope to deliver real carbon reductions within the tight 1.5 °C–2 °C timelines. Moreover, as it stands today, in almost all nations, electricity, the key power source for DACCS, is under 20% of 'final energy consumption', and only a relatively small fraction of that is from low carbon generation. A triage approach to how we use what low-carbon energy supply we have would very likely see DACCS a long way down the priority order.

Anderson (2023) Controversies of carbon dioxide removal

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Wildfire technology

> If wildfires were a country, they'd be ranked No. 4, behind China, the U.S. and India in terms of carbon emissions.

Wesoff

The growing urgency of this issue has given rise to a category of startups called "firetech," a technology ecosystem that aims to confront the threat of wildfires and restore the health of the world's forests.

For much of the twentieth century, U.S. fire-management strategy focused on total suppression rather than nature-aligned regenerative management. As a result, the country is home to a backlog of denser, fuel-heavy forests that are dangerously prone to catastrophic wildfires, especially in this warmer, drier era. Beneficial fire in the form of strategic controlled burns can reduce the amount of fuel sources available to a fire while preventing the growth of invasive species, which are often less fire-tolerant.

Prescribed burns not only decrease wildfire risk and bestow ecological benefits — they are also more cost-effective than other types of fuel management, such as manually or mechanically removing leaf litter and downed woody material.

Although prescribed burns have been used for thousands of years, a new crop of startups claim they are improving on the techniques used to plan, carry out and control managed fires.

Nebraska-based Drone Amplified aims to replace the human-piloted helicopters that are now used for aerial ignition by using drones to drop golf-ball-sized incendiary spheres to set off prescribed burns. The drones are also equipped with surveillance equipment to monitor the fires as they run their course or to detect naturally occurring and other types of fires.

Vegetation-management startups are attacking the problem of tree-thinning and fuel removal with innovations in sensors, software and carbon sequestration.

Delos develops wildfire risk models for insurers and underwriters, and ClimUp provides actionable risk and mitigation data — providing insights at the structure level for almost any property. Finally, Kettle is modeling fire risk to optimize its role as an underwriter for insurers.

Wesoff (2023) A new wave of startups is tackling a huge emissions source: wildfires

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Fuel defossilisation

Floating farms of solar fuel leaves

McKie

Automated floating factories that manufacture green versions of petrol or diesel could soon be in operation thanks to pioneering work at the University of Cambridge. The revolutionary system would produce a net-zero fuel that would burn without creating fossil-derived emissions of carbon dioxide, say researchers.

The Cambridge project is based on a floating artificial leaf which has been developed at the university and which can turn sunlight, water and carbon dioxide into synthetic fuel. The group believe these thin, flexible devices could one day be exploited on a industrial scale.

Carpets of artificial leaves that would float on lakes and river estuaries, and use sunlight to convert water and carbon dioxide into the components of petrol and other fuels. “The crucial point is that we are not decarbonising the economy through techniques like these,” Reisner said. “Carbon is still a key component. What we are doing is to ‘defossilise’ the economy. We will no longer be burning ancient sources of carbon – coal, oil and gas – and adding greenhouse gases to the atmosphere, a process that is doing so much damage at present.”

The artificial leaf created at Cambridge takes its inspiration from plants, which use photosynthesis to create food. An early prototype consisted of chemical light absorbers and catalysts that turned carbon dioxide and water into a mixture of carbon monoxide and hydrogen. This combination is known industrially as syngas and it is an intermediary in the production of many chemicals and fuels.

Floated on water, the artificial leaf produces hydrogen and carbon monoxide.

McKie (2023) Floating factories of artificial leaves could make green fuel for jets and ships

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Cement decarbonisation

SCM = supplementary cementing materials

Lobet

> "Our dream is to decarbonize cement, and we want to do it as fast as possible"

The chemical reaction at the heart of today's cement-manufacturing process is a major reason why the production of this essential building material accounts for an estimated 7 percent of global carbon dioxide emissions from energy and industrial sources.

But a small group of tech entrepreneurs says they've found a better way. Cody Finke, co-founder and CEO of Brimstone Energy, is one of them.

Today, producers use limestone, a common rock, as the basis of cement. They mine it, grind it and then heat it up to temperatures roughly a quarter as hot as the surface of the sun. This drives carbon dioxide out of the rock and into the atmosphere.

Limestone is a form of calcium carbonate, a chemical compound with the formula $CaCO_3$, made up of three main elements: calcium, carbon and oxygen. Extracting the calcium and oxygen needed for cement leaves behind the single carbon atom and two oxygen atoms — CO_2. **Fifty to 65 percent of the CO_2 emissions from cement production result from the fact that the source rock is limestone**, not from heating cement kilns to high temperatures.

Brimstone's alternative recipe **swaps out this limestone for calcium silicate rocks**, which are also very common. The silicates contain the same calcium oxide, commonly known as lime. But "there is…no CO_2 in the rock,"

Using an alternative source rock also allows Brimstone to lower the kiln temperatures — another way the company can reduce CO_2 emissions. Typical cement production requires temperatures of approximately 900 degrees Celsius for one key part of the process and 1,450 degrees Celsius for the other. Brimstone's process, in contrast, requires temperatures above 500ºC for only 20 percent of its heat energy.

Because of these lower temperature requirements, Brimstone can use electric kilns for most of its process instead of kilns fired by coal, petroleum coke or natural gas. For now, the company still expects to burn a fossil fuel for the hottest 20 percent of its process or use hydrogen if it's available. It's possible to electrify the entire process, Finke said; it's just uneconomical to do so today.

Lobet (2021) Changing up the recipe to make low-carbon cement

St. John

"There are a lot of novel technologies out there that work, and work fine. But they're not scalable, they're not commercially viable — and usually it's because the feedstock is not available in full volume, or not available where it's needed."
"There are a lot of novel technologies out there that work, and work fine. But they're not scalable, they're not commercially viable — and usually it's because the feedstock is not available in full volume, or not available where it's needed."

Cement and concrete production are responsible for 8 percent of human-caused carbon dioxide emissions worldwide, and novel SCMs like Terra's offer one path to reducing that massive carbon footprint. SCMs lower emissions from concrete production because they reduce reliance on Portland cement — by far the most common type of cement made today and also the driver of concrete's carbon impact. The production of Portland cement requires super-high temperatures that are achieved by burning fossil fuels, and the carbon-rich limestone used in its production also leaks CO_2 into the air.

Major cement and concrete companies such as Cemex and Holcim already use millions of tons of SCMs today, mostly fly ash from coal plants and slag from steel mills, both to reduce their concrete's carbon footprint and to strengthen the material. But the same climate imperatives that are pushing the cement industry to cut its carbon emissions are also driving the closure of coal plants and steel blast furnaces, making these components less ubiquitous and more expensive to get.

Terra CO_2's SCM, by contrast, is made from a variety of silicate rocks, including granite, basalt, alluvial sand and gravel, glacial flood gravel and clay-sand mixtures. Silica rock for the most part doesn't have any embodied CO_2." That's in contrast to limestone, the primary ingredient of Portland cement, which "by weight is about 50 percent embodied CO_2" — carbon that's released into the atmosphere when it's processed into clinker, the precursor to Portland cement.

Terra CO_2 puts these rocks into a reactor that heats them to their melting point, yielding glassy powders that can replace 25 to 40 percent of the Portland cement needed for different mixes of concrete. The company estimates that every ton of cement replaced by Terra's SCM results in 70 percent lower carbon-dioxide emissions compared to pure Portland cement.

CarbonCure, a Canadian startup that injects carbon dioxide captured from other emitting sources into concrete, which both strengthens the concrete and stores the carbon, preventing it from entering the atmosphere. This practice can reduce the carbon footprint of concrete by roughly 5 to 15 percent, and it is relatively simple to integrate into how concrete is produced today.

Low-carbon SCMs tend to be the next step for cement-makers trying to cut their carbon emissions.

Fly ash is already supply-distressed now. By the end of the decade, it's going to go away. And blast furnace slag is going away as well.

Cement makers such as Heidelberg Materials and Hoffman Green Cement Technologies are pursuing one SCM option known as calcined clays. This material is widely available in Asia and Africa, but not as much in North America and Europe, making it less suitable for those markets.

Other approaches that promise a completely zero-carbon replacement for Portland cement are in a more experimental phase and would require retooling the cement industry to bring to scale. Some examples include startups such as Sublime Systems and Chement, which are developing electrochemical processes to replace the high-heat methods used to make cement. More esoteric concepts include using living organisms to "grow" cement.

St. John (2023) Terra CO_2 says its Texas factory will cut carbon and cost from cement

St. John

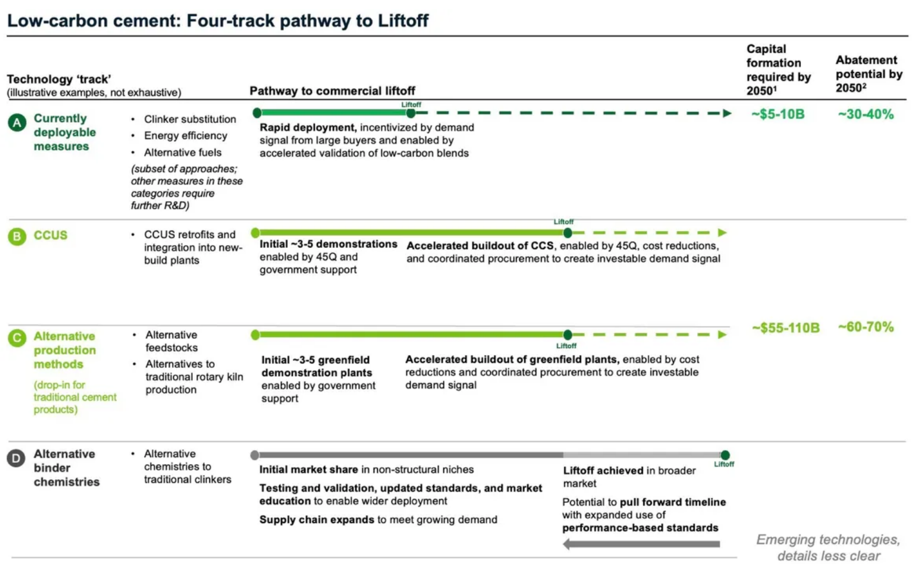
Holcim has managed to chip away at its emissions in recent years: Its 2022 annual report cited a 21 percent reduction in carbon emissions per unit of net sales from direct production and electricity consumption compared to the year before. The company has made progress largely because of a shift to lower-carbon cement and concrete products that reduce its use of clinker, the precursor material for cement, and by far the most emissions-intensive part of the industry. Crucially, costs have actually dropped along with emissions.

But not every solution to cement's climate problem will present companies with such a clear-cut economic calculus. And while the U.S. Department of Energy estimates that more than a third of the industry's emissions can be jettisoned using established technologies and processes like clinker substitution, the remainder of the solutions have yet to come into full focus.

Most uncertain of all is the pathway to eliminating what are called "process emissions," which account for the majority of cement's climate problem.

Process emissions are an unavoidable part of cement-making's status quo. The core input of ordinary Portland cement — the product that makes up the vast majority of cement made today — is limestone, a mineral that's about half calcium and half carbon and oxygen by chemical composition. When that limestone is converted to calcium oxide, the immediate precursor to clinker, the CO_2 trapped inside the mineral is released into the atmosphere.

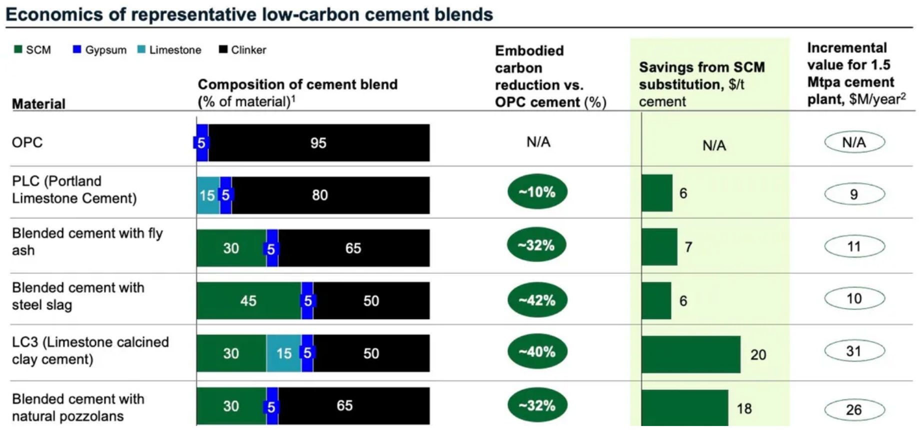
Eliminating these emissions means either finding novel, emissions-free ways to create ordinary Portland cement or a safe structural equivalent, or figuring out how to economically use carbon capture, utilization and sequestration (CCUS) technology to keep the CO_2 generated from the manufacturing process from entering the atmosphere. Though plenty of startups, companies and researchers are hard at work on both methods, neither has, at this point, proven to be workable at the necessary scale.



The science and economics of cement substitution

The math is fairly simple on clinker substitution: The greater the amount of clinker that's substituted with another material, the lower the carbon footprint per ton of cement that results.

By far the most widely adopted substitute is "Portland limestone cement," which replaces up to 15 percent of clinker with ground-up limestone. Because that ground-up limestone hasn't been processed in a way that releases its embedded carbon dioxide, this variety of cement yields an average 8 percent reduction in emissions-intensity compared to ordinary Portland cement.



A long list of supplementary cementing materials that can displace clinker and make up 30 to 45 percent of a cement mix. By far the most commonly used today are fly ash from coal plants and slag from steel mills.

The key to deploying clinker substitution at scale and keeping the economics positive are moving toward what we call next-generation substitutes. One promising "next-gen" substitute is calcined clays, a form of naturally occurring minerals.

Other next-gen supplementary cementing materials (SCMs) involve commonly available calcium silicate rock such as basalt, gabbro and other minerals. Because these rocks contain no carbon, they can be processed without releasing CO_2.

New cements, new processes — a steeper path to progress

Reducing clinker use and working lower-carbon SCMs into cement mixes can have a major impact now — but outright replacing or revamping the production of ordinary Portland cement is what the industry needs to eventually reckon with.

There are dozens of startups and university and government research projects working to come up with alternatives to ordinary Portland cement. Some are even engaged in pilot-scale demonstrations. But none have yet been embraced by the cement industry as a viable option for revamping a single integrated cement manufacturing plant.

The challenge is that the chemistry of cement and concrete — the mix of cement and rocks, gravel and other materials that harden into forms and slabs — is incredibly complex.

While Portland cement is well understood, "there are still fundamental debates among scientists" on the nature of the chemical reactions that yield better or worse forms of concrete from different types of cement for use in different applications.

Meanwhile, the industry has become more fragmented in recent years, moving from large centralized cement manufacturing to a more diverse lineup of smaller ready-mix and precast concrete operations that serve a multitude of end users. Each party in this chain relies on being able to secure consistent supplies and types of products for different needs, with an array of different standards that are difficult to alter to allow for new products to get to market.

The original patent for ordinary Portland cement was issued in 1824, giving the world nearly 200 years to understand its fundamental material properties.

Fortera's alternative cement is based on technology first developed back in the 2000s to mimic the process that leads to growth in coral reefs, but it's just one of many contenders. Others include geopolymer chemistries like Cemex's Vertua low-carbon concrete, magnesium oxides derived from magnesium silicate chemistries developed more than a decade ago by now-defunct U.K.-based startup Novacem, and the belite-ye'elimite-ferrite clinker being developed by Holcim.

Some methods for reinventing cement aim to forgo the high-temperature kilns altogether in favor of electrochemical processes. Sublime Systems and Chement are developing ways to use electrolyzers, like those used to make hydrogen from electricity and water, to dissolve and then extract the precursor compounds that make up cement.

There's only a relatively small fraction of the cement market that can be replaced by alternative cements — "maybe at most 25 percent of the cement market," according to Cody Finke, CEO of Brimstone, whose company is making a product that's structurally and chemically identical to Portland cement. "We want to decarbonize the whole cement industry."

It's a worthwhile approach, but one that also remains far from guaranteed. Brimstone, the only startup to win industry approval that its alternative process results in ordinary Portland cement.

St. John (2023) To decarbonize cement, the industry needs a full transformation

Gallucci (2023) 6 innovative startups that are kicking CO2 out of cement and concrete

11

Carbon Casting (Graphyte)

Osaka

Now, a start-up says it has discovered a deceptively simple way to take CO2 from the atmosphere and store it for thousands of years. It involves making bricks out of smushed pieces of plants. And it could be a game changer for the growing industry working to pull carbon from the air.

Graphyte, a new company incubated by Bill Gates's investment group Breakthrough Energy Ventures, announced Monday that it has created a method for turning bits of wood chips and rice hulls into low-cost, dehydrated chunks of plant matter. Those blocks of carbon-laden plant matter — which look a bit like shoe-box sized Lego blocks — can then be buried deep underground for hundreds of years.

The approach, the company claims, could store CO2 for around $100 a ton, a number long considered a milestone for affordably removing carbon dioxide from the air.

Graphyte's approach uses the power of plants and trees to photosynthesize and pull carbon dioxide from the air. While trees and plants are excellent at carbon capture, they don't store that carbon for very long — when a plant burns or decays, its stored carbon comes spilling back out into the air and soil.

Graphyte plans to avoid that decomposition by taking plant waste from timber harvesters and farmers and drying it thoroughly, removing all the microbes that could cause it to decompose and release greenhouse gases. Then, in a process that they call "carbon casting," it will compress the waste and wrap it into Lego-like bricks, for easier storage about 10 feet underground. The company says that with the right monitoring systems, the blocks can stay there for a thousand years.

Graphyte is planning to build its first project in Pine Bluff, Ark., and the company hopes to sequester its first carbon for a customer in 2024.

Osaka (2023) The Lego-like way to get CO2 out of the atmosphere

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Marine CDR

Doney

A variety of ways to capture and store CO2 from the ocean have been suggested. For example, marine CDR may include altering the chemical composition of sea water so that the ocean absorbs more CO2 from the atmosphere; using electrochemical techniques to remove dissolved CO2 from seawater and then storing that CO2 underground; or adding nutrients such as iron to areas of the ocean to encourage the growth of microscopic plankton that can sink to the seafloor and be stored for centuries or longer.

Doney (2023) Marine Carbon Dioxide Removal: Potential Ways to Harness the Ocean to Mitigate Climate Change

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Blue Carbon

Carbon burial in seagrass meadow sediment

Johannesen

Blue carbon will not solve climate change. The effect is too small; existing sediment carbon stock is a liability; and there is a timescale mismatch between ancient fossil fuel emissions and uptake by vegetation. Clearer communication would support informed decision-making.

The protection or expansion of blue carbon ecosystems can only make a very limited contribution to solving the problem of excess atmospheric CO2. In this Comment, we address three issues that relate to this point: (1) the magnitude of the effect, (2) the security of the existing sediment carbon stock, and (3) the mismatch in timescales. Despite these limitations, blue carbon ecosystems are important ecologically and can play a role in short-term carbon sequestration.

The global rate of blue carbon burial in seagrass meadow sediment has been greatly overestimated as a result of systematic methodological problems. Briefly, most global estimates neglect the effects of sediment mixing (wave mixing or bioturbation), which overestimates sedimentation rates; neglect remineralization of organic carbon in surface sediment, which overestimates carbon burial rates; include terrigenous organic carbon, much of which would have been buried even in the absence of the seagrass meadow; and extrapolate from a few sites with tropical species that have extensive, carbon-rich root mattes to the whole global extent of seagrass habitat

Also, many estimates of organic carbon accretion do not consider the effect of CaCO3 formation, which releases carbon to the atmosphere and negates a variable fraction of the drawdown associated with organic carbon burial or the release of CH4 or N2O from seagrass meadows and salt marshes.

Even the most optimistic estimates suggest that full restoration of mangrove, salt marsh and seagrass ecosystems would only provide an ongoing sink equivalent to 3% of current global anthropogenic emissions. Full restoration is unlikely, and the 3% estimate relies on carbon burial rates that are almost certainly too high.

Existing sediment carbon stock is a liability, not an asset

Blue carbon stock refers to the inventory of organic carbon stored over a defined depth (often 1 m) in the sediment of vegetated coastal ecosystems. Most blue carbon papers quantify sediment carbon stock, rather than ongoing burial rates.

The existing stock is buried in sediment but no longer draws down any more carbon dioxide from the atmosphere. In fact, existing sediment carbon stock represents a potential liability, i.e., an insecure reservoir of carbon that could be released into the atmosphere in the future. This is an important factor that has been largely overlooked in the public discussion of offsetting schemes.

When a seagrass meadow dies or a forest burns, some of the stored carbon is re-released into the atmosphere. Existing stocks are increasingly threatened as a result of climate change, both by sea-level rise and by episodic marine heatwaves. The magnitude of the re-release of carbon as a result of these processes is unknown, but integrated over a long enough time, it could easily become as large as or larger than ongoing burial. Accretion is gradual and incremental, while release is episodic and highly variable.

Timescale mismatch

Even if we exclude the possibility of avoided emissions offsets, a fundamental problem with the idea of blue carbon offsets for fossil fuel emissions is the orders of magnitude difference in timescales. The modern carbon cycle acts on timescales of days to about a century, or up to a few thousand years in the case of equilibration with the deep ocean Carbon exchanges readily among the atmosphere, surface ocean, vegetation and surface sediment: the expansion of a seagrass meadow moves some carbon from the atmosphere into vegetation and surface sediment; a forest fire releases carbon from the trees back into the atmosphere. These processes only represent exchange among the compartments of the active, modern carbon system, and not a true removal from the system.

By contrast, fossil fuels have been isolated from the active carbon cycle for hundreds of millions of years. Burning fossil fuels adds ancient carbon into the modern carbon cycle, increasing the total amount to be distributed among the atmosphere, vegetation, etc. The timescale for the removal of the excess carbon dioxide by natural processes is tens of thousands to hundreds of thousands of years for silicate rock weathering and hundreds of millions of years for the reformation of fossil fuels. Moving carbon from one short-term reservoir to another does not remove it from the actively cycling modern system.

Important role of blue carbon ecosystems

Blue carbon ecosystems do serve important functions. They provide critical habitat for juvenile fish and other marine species; they protect shorelines from erosion; they provide food security for coastal communities; and they protect existing stocks of organic carbon.

Johannesen (2023) Why blue carbon cannot truly offset fossil fuel emissions

14

ERW - Enhanced Rock Weathering

Ho

Enhanced rock weathering (#ERW) seems like a promising way to remove CO from the atmosphere. However, this paper says that to remove 1 billion tonne of CO per year requires land area larger than the entire United States.

Ho (2023) Mastodon

Linke Abstract

The ability of engineered enhanced rock weathering to impact atmospheric CO2 has been challenging to demonstrate due to the many processes occurring in soils and the short time span of current projects. Here we report the carbon balance in an Icelandic Histic/Gleyic Andosol that has received large quantities of basaltic dust over 3,300 years, providing opportunity to quantify the rates and long-term consequences of enhanced rock weathering. The added basaltic dust has dissolved continuously since its deposition. The alkalinity of the soil waters is more than 10-times higher than in equivalent basalt-dust-free soils. After accounting for oxidation and degassing when the soil waters are exposed to the atmosphere, the annual CO2 drawdown due to alkalinity generation is 0.17 tC ha-1 yr-1. This study validates the ability of fine grained mafic mineral addition to soils to attenuate increasing atmospheric CO2 by alkalinity export. Induced changes in soil organic carbon storage, however, likely dominate the net CO2 drawdown of enhanced weathering efforts.

Linke Conclusions

The results of this study confirm the ability of the addition of fine-grained basaltic rock to soils to enhance CO2 drawdown directly from the atmosphere due to alkalinity production. In total it is estimated that 17 ± 3.6 g C m− 2 yr− 1 is currently drawn down and added to rivers by alkalinity production from our South Iceland field site. The enhanced alkalinity production of our soils was produced by the addition of approximately 1.7–2.6 t m− 2 of basaltic dust to this soil over 3,300 years. Upscaling of this process to address even a small fraction of the mass of anthropogenic CO_2 emissions to the atmosphere, however, may be challenging for two reasons: 1) this enhanced weathering process is slow and would require more land than what is available for a sizeable drawdown of anthropogenic CO_2 through alkalinity production and 2) the here to date unquantified effect of adding basalt powder to soils on soil organic matter. So, although this study serves as a proof of concept of the potential of enhanced weathering efforts to contribute to attenuating atmospheric CO_2 concentrations, the degree to which this approach will prove successful at a larger scale remains unclear.

Linke (2023) Direct evidence of CO_2 drawdown through enhanced weathering in soils

15

Biochar

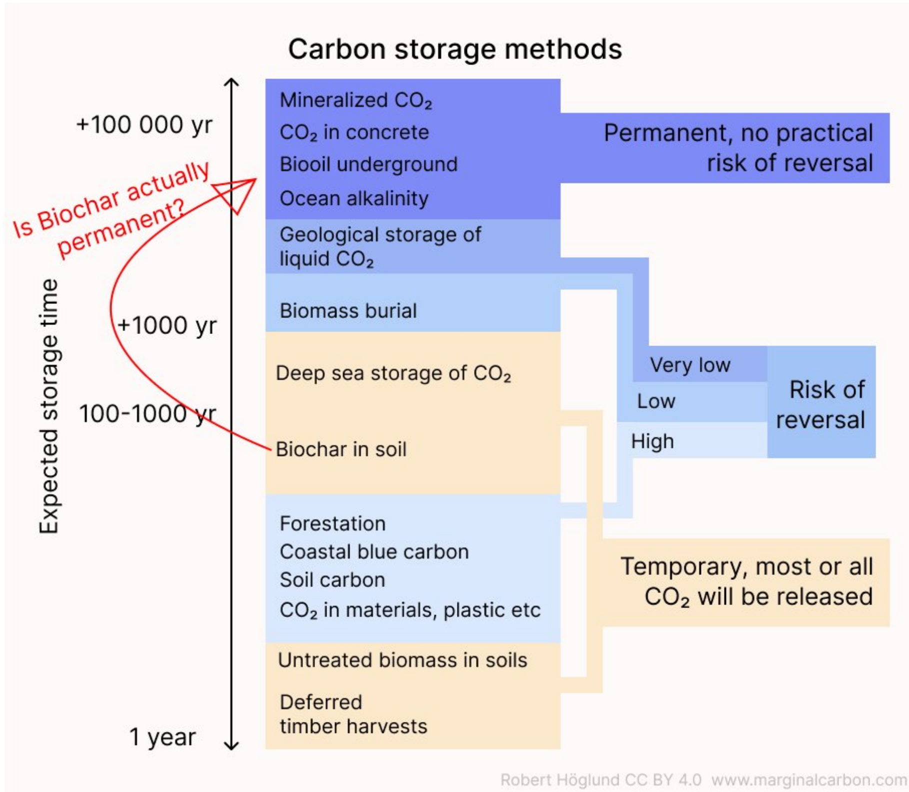
Höglund

Looks like I may need to redraw this graph. A new peer-reviewed paper points to biochar being permanent carbon storage with just a small part decomposing.

Previous meta-studies have estimated that around 20% of the carbon in biochar is lost after 100 years and half after 500 years. It is challenging to prove empirically since the decay you see in the first years may be just the volatile parts being lost, it does not necessarily say anything about the fate of the bulk of the char. The new paper uses a novel method to test the stability and proposes a new test to determine permanence, "Random reflectance" (Ro). It finds that most biochar is actually "inertinite", stable for millions of years.

The transformation of biomass to inertinite is one of the two main natural pathways exerted by Earth to permanently store organic carbon, mineralization being the other.

The paradigm shift has started, but I would be curious to hear what other biochar researchers have to say.



Höglund (2023) X post

Sanei Abstract

The natural removal of carbon dioxide and its permanent storage by the Earth system occurs through (i) inorganic carbon and (ii) organic carbon pathways. The former involves the "mineralization" of carbon and formation of carbonate minerals, whereas the latter employs the "maceralization" or natural carbonization of biomass into the "inertinite maceral". The production of biochar is a carbon dioxide removal (CDR) method that imitates the geological organic carbon pathway, using controlled pyrolysis to rapidly carbonize and transform biomass into inertinite maceral for permanent storage. Therefore, the main challenge in assessing biochar's permanence is to ensure complete transformation has been achieved.

Inertinite is the most stable maceral in the Earth's crust and is hence considered an ultimate benchmark of organic carbon permanence in the environment. Therefore, this study aims to measure the degree of biochar's carbonization with respect to the well-established compositional and microscopic characteristics of the inertinite. The random reflectance (Ro) of 2% is proposed as the "inertinite benchmark" (IBRo2%) and applied to quantify the permanent pool of carbon in a biochar using the Ro frequency distribution histogram. The result shows that 76% of the studied commercial biochar samples have their entire Ro distribution range well above IBRo2% and are considered pure inertinite biochar. The oxidation kinetic reaction model for a typical inertinite biochar indicates a time frame of approximately 100 million years for the degradation and loss of half of the carbon in the biochar. This estimate assumes exposure to a highly oxidizing environment with a constant surface temperature of 30°C, highlighting the inherent "permanent" nature of the material. In a less hostile environment, the expected permanence of inertinite is generally anticipated to be even longer.

In addition to the inertinite that constitutes the largest fraction of the typical commercial biochar, an incompletely carbonized biochar may contain up to three other organic pools in descending order of stability. The relative concentration of these pools in a biochar can be quantified by a combination of geochemical pyrolysis and random reflectance methods. Furthermore, the Ro can be used to calculate the carbonization temperature (CT oC) of a biochar, which is the maximum temperature to which biochar fragments have been exposed during pyrolysis. This indicator provides important information about the efficiency of the carbonization process and subsequently the biochar's stability, with respect to production temperature (PT oC), heating residence time, and thermal diffusivity.

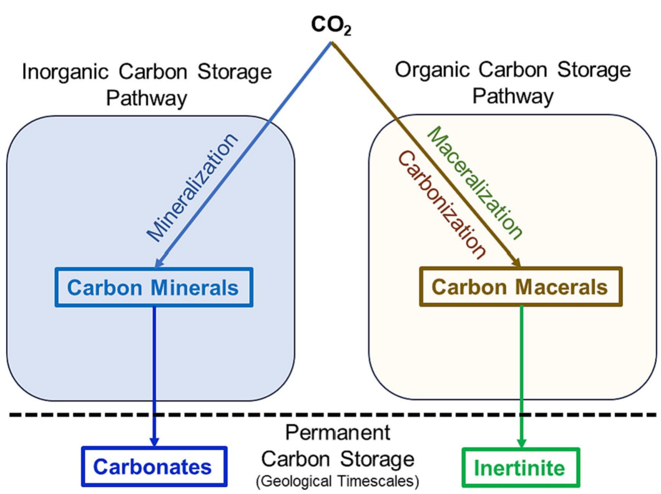


Figure: A simplified schematic representing permanent carbon storage through natural inorganic and organic carbon pathways. In the inorganic pathway, CO2 is mineralized into carbonate minerals, enabling the permanent storage of carbon. Simultaneously, the organic pathway involves the carbonization (maceralization) of biomass into inertinite maceral for permanent carbon storage.

The accelerated carbon mineralization via industrial processes is a widely accepted CDR method. This acceptance is largely rooted in the notion that mineral carbon is seen as a "permanent" storage of inorganic carbon. However, a notable discrepancy arises when considering CO2 removal through the organic carbon pathway. While inertinite maceral is generally believed to be the most stable form of organic carbon in the sedimentary systems, the same benchmark of permanence accepted for mineral carbon does not exist for organic carbon stored in the inertinite macerals. Biochar uses pyrolysis and subsequent rapid carbonization of biomass to enrich carbon in a stable form for storage in soil. Production of biochar imitates the natural organic carbon pathway by accelerating the biogeochemical processes responsible for transferring a fraction of organic carbon from the biosphere into the geosphere.

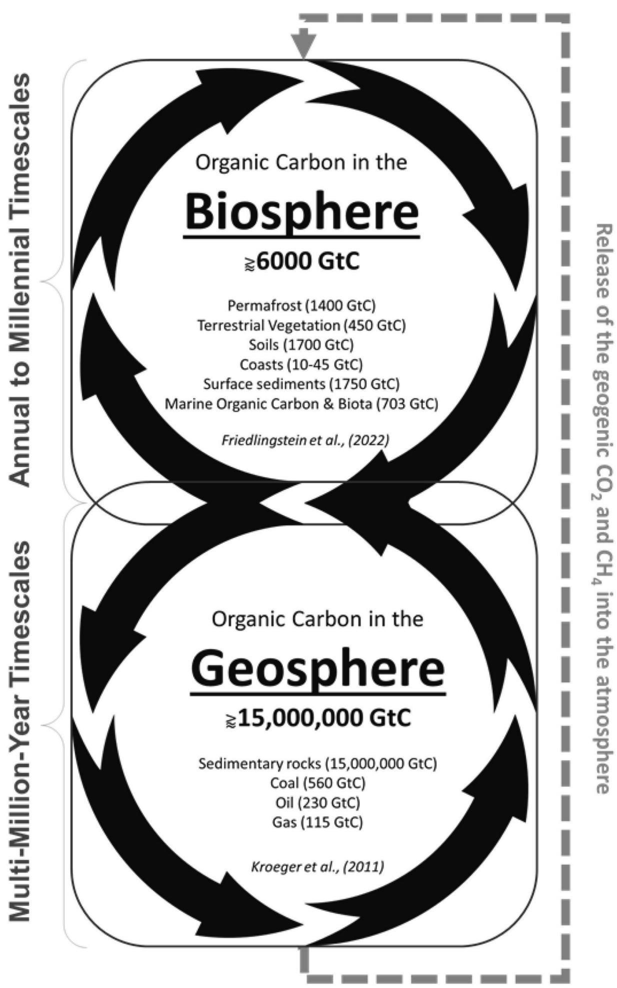


Figure: A schematic illustrates the organic carbon cycle within the biosphere and geosphere. A portion of preserved organic matter is transported into the geosphere/lithosphere through the uppermost diagenetic layer of the Earth's surface (2 km). Within the geosphere, this organic matter undergoes a multi-million-year cycle.

For more than a decade, the issue of the biochar's permanence has been explored within the realm of bioscience, using methods typically dedicated to studying organic carbon turnover in the biosphere. However, with the exception of the microscopic structure inherited from its biological precursor, there is nothing compositionally biological about biochar. The high pyrolysis temperature alters biological molecules into a highly refractory, carbon polymer that is on par with the most stable form of organic carbon maceral, referred to as "inertinite." As the name suggests, inertinite is commonly believed to be chemically inert and abundantly preserved in carbonaceous rocks of any age and depositional environment (from anoxic to highly oxic). Inertinite is the most stable form of organic maceral in the Earth's crust, and any further alteration of it may only occur beyond sedimentary conditions involving high temperature metamorphism.

Transformation of biomass into inertinite maceral through the process of carbonization or "maceralization" is one of the two main natural pathways exerted by Earth to permanently store organic carbon. "Carbon mineralization" is the other geological process, which involves the inorganic carbon pathway.

Inertinite macerals can be formed either through slow and gradual carbonization (organic carbon maturation), which results from the continuous bacterial and thermal alteration of organic matter during the sedimentary burial process and over geological timescales. Alternatively, rapid carbonization of biomass in oxygen-depleted natural wildfires could expedite the maceralization process. Production of biochar imitates the latter process, using controlled heating pyrolysis of biomass to rapidly carbonize and transform the organic matter into the inertinite maceral. The degree to which the carbonization process has achieved the complete transformation of biomass into the inertinite maceral is an important outcome that defines the biochar's permanence.

Sanei (2023) Assessing biochar's permanence: An inertinite benchmark

Graham

The process of turning wood, twigs or leaves into biochar, through a procedure called pyrolysis, could turn about half of that matter's original carbon content into a stable form that could stay in the ground for centuries. A study published in March in the Journal of Environmental Quality also found that using biochar, which helps keep nutrients like nitrogen in the ground, could cut planet-warming nitrous oxide emissions from agriculture by almost one-fifth.

Fig: The biochar retort, an airtight tank

As soon as you start converting forests or fields into rows of crops with the aim of producing biochar, you get into a lot more complicated questions. At that point, if you factor in the greenhouse gas emissions caused by the changes in land use (say, logging), then biochar may worsen climate change, not solve it.

While there's significant demand for biochar on the carbon market, industry proponents are trying to generate more interest among farmers and other businesses, such as concrete companies that are adding the soot to asphalt to make their product less carbon-intensive or governments that could pour it into abandoned oil and gas wells.

Biochar doesn't exactly fit into the standard American farming curriculum. It's neither a fertilizer nor a pesticide, and it doesn't supercharge crop production.

Not all biochar is equal. How it's made and how it's applied to soil can affect how it works.

Graham (2023) Biochar is a proven form of carbon removal. Can it scale up?

Hammond Abstract

Life cycle assessment (LCA) of slow pyrolysis biochar systems (PBS) in the UK for small, medium and large scale process chains and ten feedstocks was performed, assessing carbon abatement and electricity production. Pyrolysis biochar systems appear to offer greater carbon abatement than other bioenergy systems. Carbon abatement of 0.7–1.3 t CO2 equivalent per oven dry tonne of feedstock processed was found. In terms of delivered energy, medium to large scale PBS abates 1.4–1.9 t CO2e/MWh, which compares to average carbon emissions of 0.05–0.30 t CO2e/MWh for other bioenergy systems. The largest contribution to PBS carbon abatement is from the feedstock carbon stabilised in biochar (40–50%), followed by the less certain indirect effects of biochar in the soil (25–40%)—mainly due to increase in soil organic carbon levels. Change in soil organic carbon levels was found to be a key sensitivity. Electricity production off-setting emissions from fossil fuels accounted for 10–25% of carbon abatement. The LCA suggests that provided 43% of the carbon in the biochar remains stable, PBS will out-perform direct combustion of biomass at 33% efficiency in terms of carbon abatement, even if there is no beneficial effect upon soil organic carbon levels from biochar application.

Biochar systems offer greater carbon abatement than combustion or gasification. Carbon abatement of 0.7−1.4t CO2e/dry tonne of feedstock processed was found. Change in soil organic carbon stocks induced by biochar is the key sensitivity. Biochar systems produce less electricity then combustion or gasification.

Hammond (2011) Prospective life cycle carbon abatement for pyrolysis biochar systems in the UK

16

OAE -Ocean Alkalinity Enhancement

16.1 Tranform Faults

Reusch

Ocean alkalinity enhancement (OAE), in which the addition of ions like Mg2+ and Ca2+ (sourced from materials such as olivine or lime) to the ocean drives more dissolution of atmospheric CO2 to form bicarbonate (HCO3–), holds considerable promise, because the ocean's capacity for storing bicarbonate is ample on the relevant time frame.

Indeed, OAE approaches—often involving materials dispersed at the ocean surface—are being studied, though they, too, face questions about their large-scale feasibility.

Are there other marine settings where OAE could be pursued on a broad scale and with durable results?

Transform Faults Offer a Transformative Approach

Earth's mantle, constituting more than 80% of the planet's volume, is a vast reservoir of ultramafic (low-silica) rock. In concept, a small fraction of this rock—minimally about 600 cubic kilometers if completely converted to carbonate—could neutralize the entire slug of Industrial Age fossil carbon in the atmosphere.

Oceanic transform faults and their fracture zone extensions present tectonic settings where such reactive mantle rocks, which are typically buried under kilometers of crust, are exposed at Earth's surface. The discovery of transform faults—which connect the divergent plate boundaries located at mid-ocean spreading centers—was key to unleashing the plate tectonic revolution in the 1960s. And today, the co-occurrence of the right rocks and high-relief bathymetry presents an optimal combination of chemical and gravitational disequilibria, suggesting a potential for large-scale CDR found nowhere else on Earth (Figure 1).

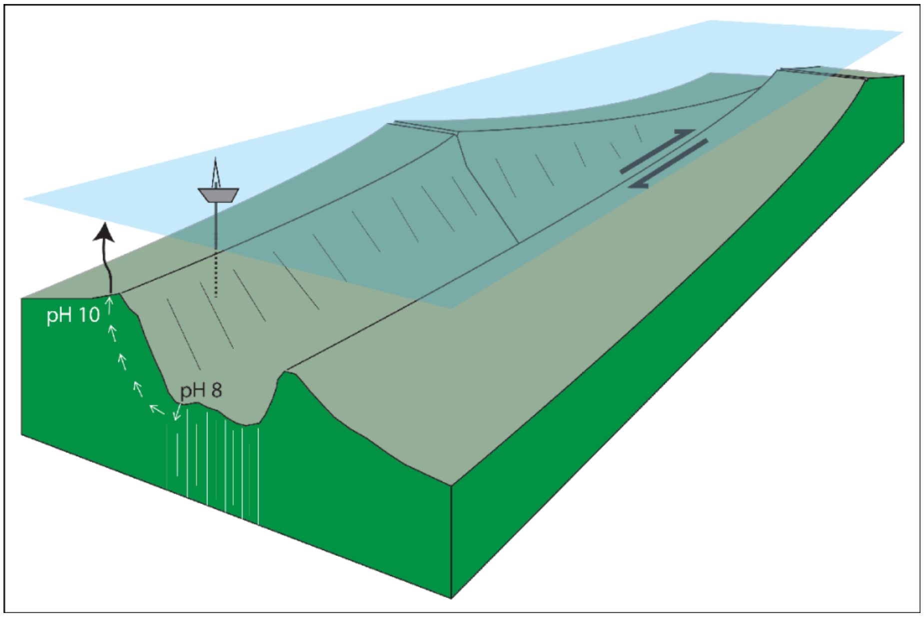


Figure: Oceanic transform faults and their fracture zone extensions (vertical white lines) may be settings where a natural carbon dioxide removal (CDR) process could be enhanced. In these settings, seawater (pH ~ 8) infiltrates fractured rock below the seafloor, where it can react with rock (e.g., peridotite), releasing thermal and mechanical energy and creating alkaline hydrothermal fluids (pH ~ 10) that buoyantly rise (small white arrows) and precipitate mineral carbonate when they mix with seawater back at the seafloor. The drilling ship shown on the ocean surface suggests how this process might be enhanced by creating additional fractures around the fault to drive more hydrothermal circulation. The resulting hydrothermal fluids might be piped (black vertical arrow) to the surface ocean mixed layer where they counter ocean acidification and remove carbon dioxide from the atmosphere. The approximate width, length, and height of this block diagram are 100, 400, and 10 kilometers, respectively, with 5:1 vertical exaggeration.

Especially at magma-poor slow spreading (<4 centimeters per year) plate boundaries, transform fault settings feature relatively fast reacting magnesium silicate minerals in abundance. The scale of transform fault valleys dwarfs that of terrestrial erosional features such as the Grand Canyon. Submarine valley walls are prone to mass wasting, which exposes fresh surfaces of reactive silicate minerals. Locally, the motion of almost-horizontal detachment faults results in portions of crust sliding off the underlying mantle, allowing further exposure of ultramafic rock on the seafloor.

Active fracturing, needed for water-rock reactions to yield alkaline solutions, is widespread. Slow velocities of seismic waves observed along oceanic transform faults imply that water penetrates to depths of more than 30 kilometers. Because of differential cooling in the seafloor rock in these settings, the fracture zone extensions of transform plate boundaries also continue to experience differential vertical movement and fresh fracturing. In addition, active faults exposing reactive mantle rock are locally present along ridge crests and along trench walls.

Drilling and hydrofracturing at sites of active mass wasting would create fresh reactive mineral surfaces and promote serpentinization, further cracking, and the production of greater volumes of alkaline, high-pH hydrothermal fluids. Then the fluids could be either pumped or directed to rise buoyantly through insulated pipelines to raise the alkalinity of the surface ocean mixed layer. By comparison with the existing fossil fuel infrastructure that crisscrosses the continents and seafloor, piping these fluids to the surface should be eminently doable. As for surface infrastructure, mothballed fleets of aircraft carriers—presumably powered by nonfossil sources of energy such as nuclear or wind—might serve as drilling platforms. Earth's transform fault scarps cover on the order of 100,000 square kilometers, an area likely more than sufficient for this approach to CDR.

Even if the fundamental technology and scale of exposed mantle material are available, however, there are practical scientific questions to address. For example, additional research would be needed to understand the relative importance of negative and positive feedbacks in low-temperature hydrothermal settings. Negative feedbacks might include "clogging," where the precipitation of secondary minerals inhibits permeability and the production of alkaline fluids. Positive feedbacks that keep these systems going, meanwhile, are evidenced by both the long lives of vents and the pervasiveness of fractured and altered rock.

There are also potential kinetic issues to contend with—although the chemistry favors increased consumption of CO2 in the ocean, the pace of the reactions may be too slow to matter on human timelines. Several options have been explored to accelerate rates of CO2-consuming reactions. The rate of olivine carbonation increases a millionfold above typical rates at the optimal reaction temperature of 185°C (365°F) and high partial pressures of CO2. Electrochemical strategies to accelerate the process have also been explored.

Methane

Methane, a potent greenhouse gas, is a ubiquitous product of serpentinization. What role do carbon-free minerals play in the formation of carbon-rich methane?

In serpentinization reactions, mantle olivine, a solid solution of typically 90% forsterite (Mg2SiO4) and 10% fayalite (Fe2SiO4), releases reduced iron (Fe2+), which is the culprit. Water oxidizes the reduced iron, forming molecular hydrogen (H2) in the process (i.e., 3Fe2SiO4 + 2H2O → 2Fe3O4 + 3SiO2 + 2H2).

This hydrogen then converts any oxidized carbon (e.g., CO2) present to methane (i.e., $4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$). It clearly would be undesirable to create or enlarge methane sources and have the gas end up in the atmosphere.

Both hydrogen and methane gases are energy sources—the former a clean energy source. Harvesting the gases could help to meet continuing demand for conventional energy and growing demand for clean energy while also helping to finance drilling and CDR infrastructure. In an alternate, economically focused framing, the main goal for expanding hydrothermal vent systems as described could even be to produce and market income-generating sources of hydrogen gas, with CDR as a beneficial by-product.

Whether an artificial infrastructure would focus the gases produced without excessive leakage is an open question.

Proximity to sites of high heat flow is to be avoided.

Drilling above fault scarps could also conceivably trigger mass wasting events and tsunamis.

Activities associated with the proposed CDR approach could also disrupt seafloor and ocean surface habitats.

Is this a potentially planet-saving idea worth exploring, or an intriguing but distracting one?

Reusch (2023) A Transformative Carbon Sink in the Ocean?

17

DAC -Direct Air Capture

> If direct air removal costs $500 per tonne, removing just US emissions would cost ~$3 trillion annually (that's ~4x US military spending). It would also require twice the total power generation capacity of the US today (and it has to be carbon-free). Ho toot

House

Separating carbon dioxide from air, while technically straightforward, is outrageously expensive.

House (2023) Direct air capture: An expensive, dangerous distraction from real climate solutions

Room

DACCS - a costly distraction

DACCS systems generally use enormous fans to push large volumes of air over either a liquid solvent or solid sorbent that absorbs CO2. Then a large amount of energy is needed to release the CO2 and regenerate the sorbents. The overall efficiency of this process is very low (5% to 10%) and the price very high because CO2 in the air is so diluted—it's 300 times more diffuse than the CO2 in a coal plant's flue gas, and the entire Houston Astrodome contains only about 1 ton of CO2.

Per ton of CO2 captured and stored, current DACCS costs range from several hundreds of dollars to $1000 or more. A 2018 "techno-economic assessment" of DAC concluded, "CO2 separation from air is unable to economically compete with CCS."

At more than 50 times the cost per metric ton of most natural climate solutions, long-term solutions [like DACCS] today are both limited in availability and practically cost prohibitive. These prices for carbon removal assume DACCS is powered entirely by carbon-free power such as solar and wind. Powering DACCS system by natural gas, increases costs for the negative emissions by 250%.

DAC is an expensive and inefficient way to use vast amounts of renewables (or nuclear power). That carbon-free power could have been used to directly replace the CO2 emissions from fossil fuel plants and cars cheaply and efficiently.

Only when the region's electricity system is nearly completely decarbonized, do the opportunity costs of dedicating a low- carbon electricity source to DAC disappear.

DACC is unfortunately an energetically and financially costly distraction in effective mitigation of climate changes at a meaningful scale.

The affordability, scalability, and wisdom of running DACCS on carbon–free power are likely to remain problematic for decades. Yet, tree planting also has limited scalability, and scaling up BECCS increases CO2 in the air for several decades.

Since CDR will very likely be a bit player for decades, "net zero" is a dangerous myth.

The idea we can overshoot a temperature target by mid-century and then turn global emissions massively negative to quickly cool back down is magical thinking.

(Reference contains usefull introduction to DACCS in the appendix):

Romm (2023) Why direct air carbon capture and storage (DACCS) is not scalable and 'net zero' is a dangerous myth (pdf)

Gallucci

The startup Heirloom says it's capturing CO2 from the sky and locking away the planet-warming gas, making it the first and only commercial U.S. plant to do so. On Thursday, the startup Heirloom unveiled its "direct air capture" facility in Tracy, California, which the company says has so far clocked nearly 1,000 hours of operations. Heirloom's technology uses limestone to absorb CO2 from the atmosphere. Through a novel process, the captured carbon is then injected into concrete, where it ostensibly stays trapped forever.

To be sure, Heirloom's plant is hardly capable of reversing the damage caused by decades of rampant fossil fuel consumption. The open-air warehouse, located some 70 miles east of San Francisco, can absorb a maximum of 1,000 metric tons of CO2 per year — less than 0.1 percent of the annual emissions from a single gas-fired power plant.

In 2017, the Swiss company Climeworks opened the world's first DAC facility near Zurich, which used large fans to suck air into containers and filter out CO2 molecules. Although that facility stopped operating last year, Climeworks now runs a 4,000-metric-ton plant in Iceland.

Heirloom's own process begins with an industrial kiln, which the company says is powered by renewable electricity from a local provider. Inside the kiln, limestone is heated to 1,650 degrees Fahrenheit, which breaks down the mineral into its constituent parts of calcium oxide and CO2. The same reaction occurs in cement-making, which is why cement is one of the world's top-emitting industries.

But instead of releasing CO2 like cement kilns do, Heirloom's kiln pumps the gas into a storage tank. The remaining calcium oxide is then spread onto hundreds of flat silver trays that are stacked vertically on 40-foot-tall racks, resembling a bakery of comically large proportions. The racks are exposed to open air for several days, during which time the white powder soaks up CO2 from the air like a sponge. Once saturated, the material heads back into the kiln, and the process starts again.

According to Heirloom, the captured CO2 gas could eventually be permanently stored "safely underground." For now, however, the company is working with the startup CarbonCure to turn the CO2 into a dry-ice-like material and mix it with concrete, where the CO2 mineralizes and gets trapped.

By some estimates, DAC currently costs around $600 to $1,000 per metric ton of CO2.

Direct air capture allows polluting industries to live on, when we should be focusing on a just transition to renewables.

Gallucci (2023) America's first commercial direct air capture plant just got going

18

GMO - enhanced photosynthesis

Corbyn

Carbon-guzzling trees and crops, genetically altered to boost photosynthesis and store carbon in the roots, could absorb millions of tonnes of CO_2 from the atmosphere

There are projects under way around the world to genetically engineer plants – namely crops – for traits such as bigger yields, disease resistance or drought or heat tolerance. But efforts to engineer them to do better at drawing CO_2 out of the atmosphere to fight the climate crisis directly are newer.

Living Carbon, founded in 2019 and which has received $36m in venture capital funding to date, is in the vanguard of establishing the technology in trees. Meanwhile, a handful of others, including two world-leading California-based scientific institutions, are tackling how it might be done in agricultural crops. Both the Salk Institute for Biological Studies in San Diego and the Innovative Genomics Institute (IGI) in Berkeley, a joint venture between the University of California, Berkeley and UC, San Francisco, have received large amounts of philanthropic funding.

The possible impact of this approach on global CO_2 emissions is difficult to quantify – it depends on how significant the gains could be, and how widely it's deployed. But its proponents are bullish that if scaled up it could make a significant contribution and buy the world some time.

It is by increasing the efficiency of photosynthesis – the process by which plants use light, water and CO_2 to make sugars that fuel plant growth (with oxygen as the byproduct) – that Living Carbon's trees are able to capture more CO_2 than they naturally would.

In a scientific paper published this April, the company reports that in a four-month-long greenhouse trial its modified poplars increased in biomass by 35-53% over its controls, equivalent to removing 17-27% more CO2 from the air.

It has been found, for example, that trees now growing in warmer conditions because of climate change grow faster because they suck up more CO2 anyway – though the trade-off is that they might die sooner.

Corbyn (2023) Could superpowered plants be the heroes of the climate crisis?

19

CCS - Carbon Capture and Storage

Most existing CCS projects in the world are enhanced oil recovery projects. That means that the captured carbon is used to produce more oil, not to reduce emissions.

The push for offshore CCS reflects the same attitude that has left the oceans in crisis today: treating them as a limitless resource to exploit and a bottomless receptacle for humanity's waste.

Offshore CCS represents the next frontier of ocean abuse by the fossil fuel industry.

Whether on land or under the sea, CCS is not a solution to the climate crisis. Experience shows it is costly and ineffective, and only prolongs dependence on fossil fuels.

Carbon Storage in Theory Once CO is captured, operators can inject it underground or under the seabed into a variety of different geologic formations, including saline aquifers, oil and gas reservoirs, coal seams, basalt formations, and organic shale formations.3 While storage in each of these formations is theoretically possible, there are geologic variables at each injection site that make it difficult to predict the behavior of the CO underground.4 In principle, each of these formations can hold the CO underground at a temperature and pressure that keeps the CO in a supercritical state, meaning that it has properties of both a liquid and a gas. Depending on the site's geology, the CO may dissolve into some of the brine underground or trigger a chemical reaction that slowly turns the carbon into a solid mineral, over thousands of years, but most injected CO

> is physically held underground by a seal known as a caprock.5 Descriptions of how CO storage may work must be interpreted in light of the limited experience with CO sequestration to date, the site-specific nature of geologic variations and leakage pathways, and the difficulty of tracking these developments over geological rather than human timescales.

Tooze on IEA Report

One scenario that the fossil fuel industry should not comfort itself with, according to the IEA (pdf), is the idea that gigantic carbon capture will permit a continuation or even expansion of the current industry.

> If oil and natural gas consumption were to evolve as projected under today's policy settings, this would require an inconceivable 32 billion tonnes of carbon captured for utilisation or storage by 2050, including 23 billion tonnes via direct air capture to limit the temperature rise to 1.5 °C. The necessary carbon capture technologies would require 26 000 terawatt hours of electricity generation to operate in 2050, which is more than global electricity demand in 2022. And it would require over USD 3.5 trillion in annual investments all the way from today through to mid-century, which is an amount equal to the entire industry's annual average revenue in recent years.

Given the industry's heavy reliance on carbon capture fantasies, this is a strong and important statement from the IEA.

Tooze (2023) Carbon Notes 7 - The IEA's message to the oil and gas industry: wake up!

CIEL

Deep Trouble

Facing growing scrutiny over their contributions to climate change, polluting industries are increasingly looking for ways to cover up their continued emissions rather than phase out the fossil fuels driving them. One way companies claim the world can continue producing and using oil, gas, and coal without harming the climate is through carbon capture and storage (CCS), which purports to enable polluters to trap their carbon dioxide (CO_2) emissions and bury them underground or under the seabed.

Despite the fanfare around CCS, it is a costly and risky endeavor and nearly all the world's past CCS projects have experienced unexpected problems or failed outright. The technology's poor track record hasn't stopped the fossil fuel industry from championing new projects, and over the last few years, companies and governments have put forward a rash of new proposals that aim to store industrial emissions offshore under the seabed.

A new wave of proposed projects aims to pool CO_2 waste from various fossil fuel and industrial activities for injection in offshore storage "hubs" in oceans around the world. This untested technique, which involves a step change in the scale and complexity of offshore CCS, poses uncalculated risks. Some of the envisioned hubs are associated with the buildout of new fossil fuel projects, and most would store waste from industries that must be scaled down or phased out if the world is to avoid catastrophic climate change.

Deep Trouble: The Risks of Offshore Carbon Capture and Storage explains the threat presented by a massive buildout of offshore CCS infrastructure and uncovers the government financing and fossil fuel interests enabling and advancing this new wave of projects. The report concludes that governments must halt the expansion of offshore CCS by ending subsidies and support for these projects, while interpreting existing laws and strengthening emerging regulations to protect the oceans from absorbing even more of humanity's waste and safeguard communities, the environment, and the global climate.

**Ciel memo*

Until now, global experience with offshore CCS has been based on just two projects in Norway, both of which encountered unpredicted problems despite their relatively simple designs and small scales. Far from a proof of concept, those projects prove the complexity of offshore CCS and raise serious con- cerns about proposals to ramp it up in size and scope.

Injecting CO under the seabed presents uncalcu- lated risks and untested monitoring challenges. Whether onshore or offshore, injecting CO under the Earth's surface has the potential to contaminate groundwater, cause earthquakes, and displace deposits of brine, which can be toxic. These risks have never been confronted at scale, and the magnitude of offshore injection contemplated by proponents would create unprecedented challenges in managing reservoir pressure and monitoring CO plumes in the depths of the ocean.

Proposed CO storage hubs are concentrated in areas most prone to leaks. The single biggest risk of CO leakage comes from the interaction of injected CO with legacy oil and gas wells.

Offshore CCS projects are costly and largely dependent on public subsidies. CCS is inherently expensive, and the costs for its deployment are only heightened offshore. These high costs are driving industry demands for public subsidies, which effec- tively pay polluters to bury some of their pollution rather than require them to stop generating it in the first place.

Regardless of how the captured carbon is used, any CCS project requires significant energy inputs and a web of different facilities to function, and all of this infra- structure poses risks to the public. CO processing facilities, for example, release large amounts of air pollutants like sulfur dioxide, while carbon capture equipment is known to greatly increase the amount of ammonia that a facility spews into the air. Running carbon capture equipment is also enormously energy-intensive, increasing the overall emissions of the facility where the capture equipment is installed.14 This is known as an "energy penalty."

At high concentrations, CO is a toxic gas and an asphyxiant capable of causing “rapid ‘circulatory insufficiency,’ coma and death.” (When a CO pipeline ruptured in Mississippi in 2020, dozens of people nearby were knocked unconscious and at least forty-five wound up in the hospital).

Tthe total projected capture amount of 450 million metric tons (tonnes) remains relatively insignificant from a climate change perspective, amounting to approximately 1.5 percent of current annual global CO emissions from energy and industry.

The very idea that offshore CO storage is feasible at all is based almost entirely on two small projects, both in Norway. These storage ventures both encountered problems in their early phases and prove that CO storage is a challenging and unpre- dictable task.26 Moreover, uncertainties remain regarding the permanence of storage, processes for long-term monitoring, and liability for leaks. Many of these risks have yet to be fully assessed, let alone comprehensively regulated.

Sleipner and Snøhvit

he world’s first offshore CCS project, called Sleipner, began operating in 1996. The Norwegian petroleum company Statoil (now Equinor) started capturing CO from its Sleipner gas field and inject- ing it into saline reservoirs beneath the North Sea in order to avoid paying the 1991 Norwegian CO tax.32 In 2008, Statoil launched a second CCS project that began capturing CO from its offshore operations at the Snøhvit gas field and reinjecting it beneath the seabed.

In both projects, geologists failed to accurately predict how the injected CO would behave under- ground. At Sleipner, the CO migrated upward from its intended storage point into a different layer of the subsurface. The Snøhvit project turned out to have significantly less storage capacity than expected, forc- ing Equinor to sink an unplanned USD225 million or so into identifying the problem and developing a new storage site. A 2023 report on Sleipner and Snøhvit from the Institute for Energy Economics and Financial Analysis (IEEFA) points to the projects’ problems as evidence that storing CO underground is “not an exact science,” and that CCS, even after “extensive repeated study, using the most modern methods, is not foolproof.”

Despite the significant challenges with these two relatively simple projects, industry leaders still often refer to Sleipner and Snøhvit as success stories that substantiate the safety and feasibility of much larger, more complex offshore CCS projects, such as the hubs being proposed worldwide. The projects have emboldened Equinor and the Norwegian govern- ment to promote Norway as a primary destination for CO waste from other countries.

Until now, these two projects have received little scrutiny in Norwegian political debate or in the broader environmental movement — perhaps due in part to the dearth of independent research into CCS free of funding or participation by the oil and gas industry, including at Norwegian higher education institutions.

Both the Norwegian projects are relatively small in scale: They each have a maximum injection rate of less than 1 million tonnes per year. This amounts to less than one thirtieth of Norway's annual emissions, and pales in comparison to the much larger ambitions of major proposed projects.

CCS Hubs

The pervasive concept of offshore "CCS hubs" introduces additional complexities beyond what stand-alone facilities like Sleipner and Snøhvit were designed for. Both Sleipner and Snøhvit involve CO captured from a single source, while many new CCS proposals envision storing CO from multiple sources in one location. Because different indus- trial processes produce CO streams with different chemical makeups, hub operators would need to ensure that the substances they accept from different industries would not damage their infrastructure or elevate risks. Impurities like water, hydrogen sulfide, sulfur oxides, or carbon monoxide can all be present in industrial CO streams at varying levels.40 These impurities can cause pipeline corrosion41 and compound the dangers workers would face from a blowout: Even with pure CO , a blowout could be deadly due to the risk of asphyxiation, but impurities could make a rupture toxic as well.

Denmark

Denmark's embrace of CCS is at odds with its commitment to phase out fossil fuels. As a found- ing member of the Beyond Oil and Gas Alliance (BOGA) launched in 2021 at the 26th Conference of the Parties to the United Nations Framework Con- vention on Climate Change (UNFCCC COP26),55 Denmark promised to sunset oil and gas production domestically by 2050. And yet, the offshore CCS projects Denmark is promoting only prolong reliance on oil and gas.

Longship

In 2020, the Norwegian government announced plans to launch a large-scale CCS demonstration project in an effort to create a new market for CO disposal as a service across the European continent. The project, known as Longship, would be an open- source network of CCS infrastructure that includes carbon capture at industrial facilities throughout the continent, paired with transport and storage in a sub-seabed site located off the western coast of Norway. The Norwegian government will fund two- thirds of the project, an estimated USD1.57 billion (NOK 16.8 billion), while the remaining costs will be shared among the project's partners. The transport and storage component of the project, is known as Northern Lights.

Northen Lights

In Norway, developments are underway for a new offshore CCS project — led by Equinor in partnership with Shell and Total — called Northern Lights. The Norwegian government is providing 80 percent of the funding for the first phase.48

The project would seek to inject 1.5 million tonnes per year of CO in its first phase and up to 5 million in its second. This second phase would increase the amount of CO injected under the seabed by a large margin, but even so, it remains a drop in the proverbial bucket: The carbon injected would amount to less than one tenth of 1 percent of Europe's annual CO emissions from fossil fuels in 2021.

Northern Lights project involves transporting CO captured from European industrial facilities by ship to an onshore receiving terminal and then moving it back offshore via pipeline for injection into a storage reservoir beneath the North Sea. The subsea storage site is located about 2,600 meters (1.6 miles) beneath the seabed. Phase 1 of the project aims to capture and store 1.5 million tonnes of CO per year and be operational by 2024.

The Longship project was initially planned to start with carbon capture at two Norwegian facilities, the Heidelberg Materials cement plant in Brevik and the Hafslund Oslo Celsio waste-to-energy plant. Con- struction is underway at Heidelberg Materials, but the Hasflund Oslo Celsio plant suspended the installation of carbon capture equipment in April 2023 after the project exceeded its budget.

Longship is seeking additional emitters within and outside of Norway to sign onto the project, exem- plifying how the "carbon management" economy depends on steady pollution streams. In late August 2022, the project announced an agreement with the Norwegian fertilizer firm Yara to transport and store CO captured from Yara's Sluiskil ammonia plant in the Netherlands.

Although Northern Lights is pitched as a major proj- ect, its potential contribution to climate mitigation is quite limited. The project aims to scale up beyond the starting goal of storing 1.5 million tonnes of CO per year, adding 3.5 million tonnes of capacity to reach 5 million tonnes depending on market demand.

This represents a potential five-fold increase in the offshore injection rate compared to Norway's flagship Sleipner project, and with it, increased complexities. But the scale of emissions must be kept in perspective: Norway's emissions alone amounted to about 49 million tonnes carbon dioxide equivalent (CO e) in 2021. The CO volumes that this project aims to bury — drawn from the entire continent — are minor in comparison.

RISKS

> The risks of offshore CO injection must be considered in the context of the myriad pressures facing global oceans and seas, including those from increasing temperatures, acidification, nitrogen and other chemical pollution, and the proliferation of microplastics.

While carbon capture equipment may reduce the CO emitted from a facility, it perpetuates, and can even increase, the release of other air pollutants that harm public health and the environment, undermining human rights.

The CCS process itself presents hazards to the climate and environment. Whether onshore or offshore, injecting CO under the Earth's surface has the potential to contaminate groundwater, cause earth- quakes, and displace deposits of toxic brine.

Brines can be detrimental to surrounding sea life because they can have salt concentrations far in excess of seawater and can contain contaminants such as heavy metals.

Preventing or mitigating hazards associated with CCS is even more technically challenging and expensive at great depths under the sea, where the dynamics of CO may be harder to ascertain than on land and the resulting problems harder to resolve.

It isn't only the offshore storage of CO that presents possible hazards. Each stage of the CCS process — capture, transport, injection, and storage — has the potential to harm communities and the environ- ment, jeopardizing the right to a clean, healthy, and sustainable environment and other human rights.

Operation of carbon capture equipment could increase emis- sions of harmful fine particulate matter (PM2.5) and nitrogen oxide, and significantly increase toxic ammonia emissions.

Existing oil and gas pipelines, designed to withstand much less pressure, cannot readily be repurposed for moving large amounts of CO .

A large vessel capable of storing CO does not yet exist, much less a fleet of them.

Unlike gas or oil pipelines, the risk from a CO pipeline rupture is not combustion, but **asphyxiation**. CO is heavily pressurized and denser than air, so if a pipeline bursts, large volumes can be released extremely quickly and stay close to the ground, threatening people in a wide radius from the release.

The US has the largest pipeline network in the world and only has about 8,000 kilometers (km) (about 5,000 miles) of active CO pipelines, compared with 425,605 km (about 265,000 miles) of oil and gas pipelines.

Although experience operating CO pipelines is lim- ited, extensive experience with oil and gas pipelines makes one thing clear: **Pipelines leak**. Over an eight-year period in the US, there were more than 2,000 recorded incidents with gas pipelines alone. These incidents resulted in more than 100 deaths and nearly 600 injuries.

Presence of water, contaminants, or impurities such as hydrogen sulfide in the CO stream increases the risks of pipe corrosion.

Shipping CO increases emissions in one of the most difficult-to-decarbonize trans- port sectors. Generating fossil fuel emissions to transport fossil fuel emissions is counterproductive at best. Refrigerating the CO cargo — which must be kept under high pressure and low temperature to be transported in liquid form — and powering the ship requires burning more fossil fuels. Research by oil and gas industry analyst Rystad, considering potential CO_2 shipping routes, found that some vessels traveling long distances could produce emissions equivalent to as much as 5 percent of the CO_2 being transported.

CO_2 leaks would affect the marine environment as well. Its interactions with the sea would be complex: hydrates and ice might form, and temperature differences would induce strong currents. Some of the gas would dissolve in the sea, but some would be released to the atmosphere.

The injection of high-pressure CO_2 under the seabed is a complicated process that creates significant risks and uncertainties beyond just leakage. The aquifers into which CO_2 could be injected are not simply empty pockets underground, but porous rock formations that can be filled with brine, water, sand, or other materials. CCS operators propose injecting CO_2 into the "pore space" that these other substances occupy. Injecting the CO_2 into this space displaces whatever was there before, elevating the pressure underground and often pressurizing areas well beyond the boundaries of the injection site. Too much pressure can cause the **caprock**, the impervious rock layer that seals the brine and CO_2 underground, to crack, causing a leak. Operators must also limit pressure build up in order to avoid triggering earth- quakes, a known risk with any subsurface injection.

Brine can leak from pipelines and needs to be properly managed and disposed of to avoid contaminating the environment. As acknowledged in an EU-funded report involving Statoil (now Equinor), the high salinity of brine can be toxic to benthic (deep sea) organisms like coral and sea anemones.

If brine is allowed to percolate to the surface of the seabed, such brines could cause a ten-fold increase in local salinity in surface sediments and seabed depressions, thus representing a potentially severe source of osmotic shock to benthic organisms.

New studies demonstrate the risks of assuming that the ocean has a vast storage capacity. Researchers warn that the dynamics within each individual geologic formation are unpredictable, and that macro estimates of geologic storage capacity are likely flawed.

Building out industrial-scale CCS may not be as feasible as current regional inventories suggest and pressure management techniques may not function as planned.

Legacy deposits of oil in offshore wells can react with injected CO_2 to form bitumen, a viscous hydrocarbon substance, creating blockages and reducing the ability to inject more CO_2.

If CCS is widely deployed onshore and offshore, even a 0.1 percent leakage rate could cause up to 25 gigatonnes of additional CO_2 emissions in the 21st century, posing a major risk to the climate.

Despite the fact that legacy oil and gas wells pose the single greatest risk of CO leakage at offshore storage sites, the areas being heavily targeted for offshore CCS development are precisely those zones where old wells abound: sites of long-standing oil and gas drilling.

There is little reason to believe that injecting CO into areas where countless existing leaks from oil and gas wells go undetected or unreported would guarantee "permanent" storage.

In the event of a storage well failure or other extreme release of CO offshore, the problem may be very difficult, if not impossible, to correct.

CO might cause wells to fail due to its incompatibility with certain commonly used materials.

If there is a leaking CO well or a blowout, the mitiga- tion measures used for oil and gas well accidents, like a physical barrier, won't work to contain CO . The only option may be to stop injection altogether.

Significant uncertainties about the long-term performance of a CO storage site should be resolved prior to injection of large volumes of CO ; if uncertainties cannot be resolved, injection should be stopped.

If injection is halted, the CO that would have been captured to supply the injection site will end up simply vented into the atmosphere, assuming the underlying emitting activity is not also paused. This would undermine any climate rationale for operating a carbon capture system in the first place.

CIEL (2023) Deep Trouble -The Risks of Offshore Carbon Capture and Storage (pdf)

19.1 CCS Costs

Beslik

Oxford University conducted a massive study of the phenomena known as rights law, the cost-reduction curves for technologies, and we've seen in our lives some stunning examples: the mobile phones, the flat screen TVs, not to mention computer chips.

And so they studied all of them, and some go down in cost very rapidly, some a bit slowly. They have a very small category labelled non-improving technologies. That's the category that carbon capture and sequestration is in. For 50 years, there has been zero reduction in cost for carbon capture and sequestration. ZERO.

Beslik (2023) Oil-Cave Jabs and the Dramatic Dance of Petrostates at COP28

19.2 EOR - Enhaced Oil Recovery

CIEL

The vast majority of the CO captured at existing carbon capture and storage (CCS) projects around the world is used in oil fields, where it is injected into depleted wells to force more oil to the surface, a process known as enhanced oil recovery (EOR)

CIEL (2023) Deep Trouble -The Risks of Offshore Carbon Capture and Storage (pdf)

20

Deep-sea mining

Chung

As the world's hunger for metals and minerals to go green increasingly clashes with the realities of the mining process, the deep sea has become the latest focal point. Ultimately, manufacturers aim to create a circular "closed-loop" system, where old electronics are recycled and their metals are used to build new products.

But reaching that goal is expected to take decades. Debate about whether sensitive ecosystems on land should be dug up have empowered deep-sea mining advocates. Some companies competing with The Metals Co believe that the robotic vacuum is the problem, and are offering potential solutions.

The startup Impossible Metals has developed a robotic device with a large claw that collects nodules as the claw glides along the seafloor. Using artificial intelligence, the robot's claw is able to distinguish between nodules and aquatic life, the company says.

"From day one, we are focused on preserving the ecosystem," said Jason Gillham, the CEO of Impossible Metals. However, while the Impossible Metals robot is battery-powered, its energy comes from a diesel generator on a ship at the ocean's surface, fueling charges that the company's methods are not fully green.

A Japanese company plans to start mining next year in territorial waters controlled by Tokyo. Chinese officials have acknowledged they lag behind other nations in the deep-sea race, but are vowing to vigorously compete in this "new frontier for international competition." China is already exploring a massive part of the Pacific seabed west of Hawaii - an area that dwarfs the CCZ. Norway, already a prolific offshore oil producer, is on track to be the first country to allow deep-sea mining if its parliament approves, as expected, plans to mine hydrothermal vents.

For now, the ISA's members are hotly debating the best standards for deep-sea mining.

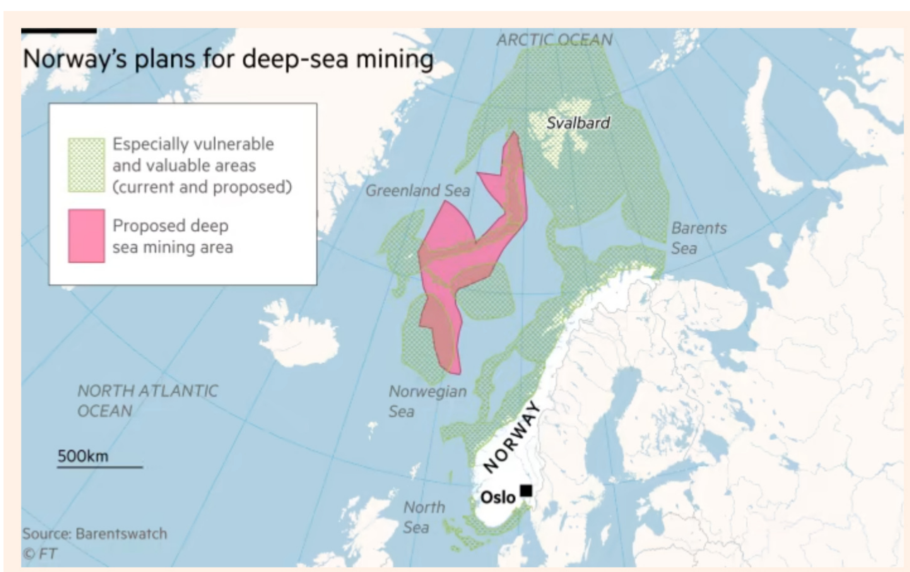
"Nothing we do will have zero impact," said Joe Carr, a mining engineer with the metals consultancy Axora. "We're going to need mining for the green energy transition."

Chung (2023) The promise and risks of deep-sea mining (scroll-graphics)

Tooze

Norway has secured a parliamentary majority for its plans to open up for deep-sea mining despite opposition from environmentalists and the fishing industry, who warn that the move risks further damage to fragile oceans. The country's minority centre-left government on Tuesday said it had won the support of the two main opposition centre-right parties for deep-sea mining exploration but that there would be tough environmental criteria to proceed with any extraction. "The renewable green industries run on minerals. This is an important contribution internationally," said Bård Ludvig Thorheim, an MP from the main opposition Conservatives. But the decision by Norway, western Europe's largest petroleum producer, drew fierce criticism from environmentalists as the Nordic country aims to become the first in the world to conduct deep-sea mining on a commercial scale.

Oslo's plans could also generate geopolitical tensions. The area it proposes to open up to exploration, in the Barents Sea and Greenland Sea, is close to Svalbard, the Norwegian archipelago in the Arctic. Norway believes it has exclusive mining rights off the Arctic islands, a position disputed by Russia, the EU and UK.



Tooze (2023) Not so green Norway

21

Geoengineering

Harvey

Climate Overshoot Commision Report

The Climate Overshoot Commission, a group of senior former diplomats, policy experts and scientists including Laurence Tubiana, the former French diplomat who was one of the main architects of the Paris agreement, focused on solar radiation management because that is one of the most controversial and dangerous ideas.

While regrowing trees is usually regarded as safe, putting mirrors in space to reflect sunlight or seeding clouds to reflect more rays into space could have huge impacts that would be hard to control, and would be impossible to confine within country borders. As well as the risks inherent to changing the climate in one place, there could be a "termination shock" – the concern that if emissions continued to pour into the atmosphere while geo engineering was used, stopping use of the technology would cause severe disruption to the climate as the underlying heating effect took hold again.

Harvey (2023) Experts call for global moratorium on efforts to geoengineer climate

21.1 Ocean Geoengineering

Mehta

- Carbon dioxide makes seawater more acidic while warmer seas bleach corals and absorb less CO2
- Nascent technologies aim to remove CO2 by tapping into the ocean's natural carbon cycles

- Ocean alkalinity enhancement decreases acidity encouraging absorption of more CO2
- Estimates suggest the technology could reach 2 gigatons of removals across the world's coastlines
- Other systems use membranes to filter CO2 from seawater and convert it for capture and storage

Carbon dioxide makes seawater more acidic, so it's harder for sea creatures to grow shells, while the heat bleaches corals and destroys breeding grounds for fish and marine mammals. Warmer waters also absorb less CO2.

Finding ways to increase the carbon sink at the depths of the ocean, where it can be stored for millennia, and to extract carbon dioxide from surface water offer opportunities to remove CO2 at scale.

Summary

- Carbon dioxide makes seawater more acidic while warmer seas bleach corals and absorb less CO2
- Nascent technologies aim to remove CO2 by tapping into the ocean's natural carbon cycles
- Ocean alkalinity enhancement decreases acidity encouraging absorption of more CO2 Estimates suggest the technology could reach 2 gigatons of removals across the world's coastlines
- Other systems use membranes to filter CO2 from seawater and convert it for capture and storage

Much of our planet is covered by oceans, which protect us from the worst ravages of global heating. Water and air are constantly exchanging carbon dioxide, and the seas around us have absorbed about a third of the CO2 we've pumped into the air, as well as the bulk of the warming it has caused. This has come at a huge cost to marine ecosystems. Carbon dioxide makes seawater more acidic, so it's harder for sea creatures to grow shells, while the heat bleaches corals and destroys breeding grounds for fish and marine mammals. Warmer waters also absorb less CO2. Over a year. 02:00 02:28

Now a clutch of startups are trying to open up new avenues to remove even more carbon dioxide from our atmosphere by tapping into the ocean's natural carbon cycles.

Proponents say finding ways to increase the carbon sink at the depths of the ocean, where it can be stored for millennia, and to extract carbon dioxide from surface water offer opportunities to remove CO2 at the scale required to meet the goals of the Paris Agreement. While the chemistry and modelling may stack up, these are nascent technologies. How can we be sure they'll work in practice and won't ultimately cause even more damage to the delicate ecosystems on which we rely?

Some startups want to speed up the natural process by which biomass from land reaches the depths of the ocean. Israel-based Rewind plans to transport forest and agriculture residues to the bottom of the Black Sea. This is an ideal environment, the company says, because it lacks oxygen, so the residues will decompose only very slowly.

U.S. startup Running Tide is designing "carbon buoys", combinations of biomass and alkaline minerals which could help reduce the acidity of ocean surface waters or provide a growth medium for macroalgae. Later these would be sunk to take carbon to the bottom of the ocean.

Another pathway is to speed up the natural weathering of rock that washes carbonate and bicarbonate minerals into the sea through adding alkaline minerals. So called ocean alkalinity enhancement decreases acidity, so encouraging the absorption of more CO2 from the atmosphere.

David Keller, a scientist at the GEOMAR Helmholtz Centre for Ocean Research in Germany, is coordinating a pan-European project to assess the feasibility of using the ocean to stabilise the climate. Experiments where an alkaline mineral is added to closed tanks floating out at sea suggest it's safe to do field trials of ocean alkalinity enhancement. There are upper limits because too much alkalinity can cause the release of CO2.

By volume, the ocean holds 150 times more CO2 than the atmosphere, requiring less water to be processed for the same impact. But water is heavier so takes more energy to move. Co-locating Captura's systems with desalination plants or harnessing ocean currents could cut energy needs. Energy consumption will be about 20-25% of DAC systems today.

Technology developed at UCLA is being exploited by spin-out, Equatic, to both produce clean hydrogen and capture CO2 from air and seawater. In its process, electrolysis of seawater produces hydrogen and creates an alkaline and acid stream of water. In the alkaline stream, the dissolved carbon dioxide forms solid calcium carbonate which can be stored, used to make cement or put back into the sea, where it's already prevalent. Bubbling air through this (now CO2 depleted) seawater captures more CO2, which gets locked up for thousands of years as a bicarbonate. On the other side of the equation, the addition of olivine (one of the most common minerals on the planet) neutralises the acidic seawater. In turn it too should take up more CO2 from the atmosphere, when returned to the sea.

Ebb Carbon's solution would take the water flowing out of a desalination plant or cooling water from a power plant and put it through a series of membranes to remove acidity, in the form of hydrochloric acid. The less acidic water that goes back into the sea will draw down atmospheric CO2, to be converted to bicarbonate ions and held in that form for thousands of years. There's enough existing desalination and power-plant infrastructure to reach the two gigaton scale soon.

For now, the challenge is accurately measuring and verifying how much CO2 is being locked away, and that's where Ebb's emphasis is. "There's a lot of rigour, a lot of science behind the detailed measurements and modelling that enable us to say, with a high degree of certainty, how much CO2 is pulled out of the air," says Tarbell. That monitoring, reporting and verification is going to be critical to provide faith in the removals companies hope to claim. Nor is it cheap, suggests GEOMAR's Keller. There are no standard approaches to do this.

As the entrepreneurs press on with modelling and experiments, they argue there's no choice but to recruit the ocean's natural systems if we're to limit further warming. Our carbon emissions are already destroying the marine biodiversity upon which we depend, so we have to try everything to prevent things getting far worse.

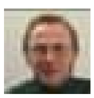
Mehta (2023) Should we be geo-engineering the oceans?

Part I

Appendices

Appendix A

About



Dyre Haugen and *Dyrehaugen* are Webians for *Jon Martin* - self-owned Globian, Webian, Norwegian and Canarian with a background from industrial research policy, urban planning and economic development consulting on global, regional and urban scales. I am deeply concerned about the (insane) way humanity (i.e. capitalism) interfere with nature. In an effort to gain insights in how and why this happens stuff is collected from around the web and put together in a linked set of web-sites. The sites are operated as personal notebooks. However, these days things can be easily published to the benefit of others concerned with the same issues. But be aware - this is not polished for presentation or peer-reviewed for exactness. I offer you just to have a look at my 'work-desk' as it appears in the moment. Any comment or suggestion can be mailed to dyrehaugen@pm.me Currently migrating from twitter (@dyrehaugen) to Mastodon (@dyrehaugen@mastodon.online) Thanks for visiting!

Appendix B

History

In Norwegian Allerede på 1950-tallet oppdaget en gruppe amerikanske forskere tegn på at menneskelig aktivitet kunne gjøre jorda varmere.

Prinsippene bak global oppvarming hadde da vært kjent siden slutten av 1800-tallet.

Det skulle likevel ta lang tid før temaet fikk stor oppmerksomhet her i landet.

I 1959 dukket for første gang ordet «drivhuseffekt» opp i en norsk avis. Men vi skal langt inn på 1980-tallet før den norske offentligheten fikk et forhold til det som senere blir omtalt som klimaendringer eller global oppvarming.

Klimaforskerne varslet ikke (Lars Sandved Dalen i Forskning.no)

Replikk til Dalen

Appendix C

Links

Current Dyrehaugen Sites:

- Capitalism (github) (geek) (loc)
- Climate System (github) (geek) (loc)
- Climate Models (github) (geek) (loc)
- Climate Impacts (github) (geek) (loc)
- Climate Actions (github) (geek) (loc)
- Economics (github) (geek) (loc)
- Economics of Countries (github) (geek) (loc)
- Finance (github) (geek) (loc)
- Energy (github) (geek) (loc)
- Environment (github) (geek) (loc)
- History (github) (geek) (loc)
- Marxian Economics (github) (geek) (loc)
- Statistics (github) (geek) (loc)
- Synthesis (github) (geek) (loc)
- Urbanization (github) (geek) (loc)
- Varia (other themes)(github) (geek) (loc)
- Wisdom (github) (geek) (loc)

Blogs:

- Opinions - Blog in English (github) (geek) (loc)

- Ytringer - Blog in Norwegian (github) (geek) (loc)

Discontinued:

- Climate Change (Up to Sept. 2023) (github) (geek) (loc)
- Collection (Jekyll) (up to 2018) (github) (geek) (loc)
- Collection (Hugo) (2019-2020) (github) (geek) (loc)

Not listed:

- (q:) dhe dhn jrw56
- (z:) rcsa rpad rstart

Appendix D

NEWS

D.1 230908 Antarctica Polar Amplification

Antarctica is likely warming at almost twice the rate of the rest of the world and faster than climate change models are predicting, with potentially far-reaching implications for global sea level rise.

Scientists analysed 78 Antarctic ice cores to recreate temperatures going back 1,000 years and found the warming across the continent was outside what could be expected from natural swings.

In West Antarctica, a region considered particularly vulnerable to warming with an ice sheet that could push up global sea levels by several metres if it collapsed, the study found warming at twice the rate suggested by climate models.

Climate scientists have long expected that polar regions would warm faster than the rest of the planet – a phenomenon known as polar amplification – and this has been seen in the Arctic.

Antarctica was warming at a rate of between 0.22C and 0.32C per decade, compared to 0.18C per decade predicted by climate models.

Part of the warming in Antarctica is likely being masked by a change in a pattern of winds – also thought to be linked to global heating and the loss of ozone over the continent – that has tended to reduce temperatures.

Guardian (2023) Antarctica warming much faster than models predicted in 'deeply concerning' sign for sea levels

D.2 230116 No US Green Monetary Policy - but EU?

Jay Powell has said the Federal Reserve will not become a “climate policymaker”, as he mounted a full-throated defence of the US central bank’s independence from political influence.

In a speech delivered on Tuesday, the Fed chair said the central bank must steer clear of issues outside its congressionally mandated purview and instead maintain a narrow focus on keeping consumer prices stable, fostering a healthy labour market and ensuring the safety of the country’s banking system.

“It is essential that we stick to our statutory goals and authorities, and that we resist the temptation to broaden our scope to address other important social issues of the day,” he said at a conference hosted by Sweden’s central bank. “Without explicit congressional legislation, it would be inappropriate for us to use our monetary policy or supervisory tools to promote a greener economy or to achieve other climate-based goals.” He added: “We are not, and will not be, a ‘climate policymaker’.”

At the same event, Isabel Schnabel, a member of the six-person executive board of the European Central Bank, advocated greater action to address climate change.

The German economist pledged to “ensure that all of the ECB’s policies are aligned with the objectives of the Paris Agreement to limit global warming to well below 2C”. The ECB’s position is clear. It worries that high interest rates to control inflation will undermine the green transition by raising the cost of investing in wind, solar, hydrogen and other clean energies necessary for moving to a net zero carbon world.

But ECB and Fed are aligned on two important issues:

First, that the primary role of green intervention lies not with independent central banks but with governments. Powell said that “in a well-functioning democracy, important public policy decisions should be made, in almost all cases, by the elected branches of government”. Schnabel concurred, saying, “governments must remain in the lead in accelerating the green transition”.

Second, they agree central banks have a role when supervising the banking system in ensuring commercial banks understand and manage financial risks from global warming. These include weather-related risks to infrastructure that banks have financed or fossil fuel assets that might become near-worthless in future.

ESG on a Sunday

D.3 211104 Global CO2 emissions have been flat for a decade, new data reveals

Global carbon dioxide (CO2) emissions from fossil fuels and cement have rebounded by 4.9% this year, new estimates suggest, following a Covid-related dip of 5.4% in 2020.

The Global Carbon Project (GCP) projects that fossil emissions in 2021 will reach 36.4bn tonnes of CO2 (GtCO2), only 0.8% below their pre-pandemic high of 36.7GtCO2 in 2019.

The researchers say they "were expecting some sort of rebound in 2021" as the global economy bounced back from Covid-19, but that it was "bigger than expected".

While fossil emissions are expected to return to near-record levels, the study also reassesses historical emissions from land-use change, revealing that global CO2 output overall may have been effectively flat over the past decade.

The 2021 GCP almost halves the estimate of net emissions from land-use change over the past two years – and by an average of 25% over the past decade.

These changes come from an update to underlying land-use datasets that lower estimates of cropland expansion, particularly in tropical regions. Emissions from land-use change in the new GCP dataset have been decreasing by around 4% per year over the past decade, compared to an increase of 1.8% per year in the prior version.

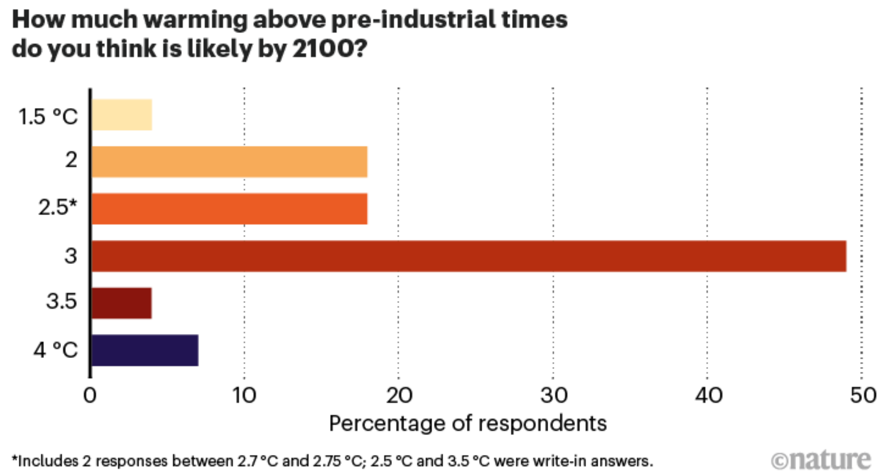
However, the GCP authors caution that uncertainties in land-use change emissions remain large and "this trend remains to be confirmed".

CarbonBrief

D.4 211104 Top climate scientists are sceptical that nations will rein in global warming

Nature conducted an anonymous survey of the 233 living IPCC authors last month and received responses from 92 scientists — about 40% of the group. Their answers suggest strong scepticism that governments will markedly slow the pace of global warming, despite political promises made by international leaders as part of the 2015 Paris climate agreement.

Six in ten of the respondents said that they expect the world to warm by at least 3 °C by the end of the century, compared with what conditions were like before the Industrial Revolution. That is far beyond the Paris agreement's goal to limit warming to 1.5–2 °C.



Most of the survey's respondents — 88% — said they think global warming constitutes a 'crisis', and nearly as many said they expect to see catastrophic impacts of climate change in their lifetimes.

Nature

D.5 210921 Microsoft CO2-removal

In January this year, Microsoft made a major announcement: it had paid for the removal of 1.3 million tonnes of carbon dioxide from the atmosphere. Among its purchases were projects to expand forests in Peru, Nicaragua and the United States, as well as initiatives to regenerate soil across US farms. Microsoft will pay the Swiss firm Climeworks to operate a machine in Iceland that pulls CO2 from the air and injects it into the ground, where it mineralizes and turns to stone. The amount of CO2 to be removed is equivalent to about 11% of the annual emissions from Microsoft's value chain; of this, the company will count less than half as being certified to officially compensate for its emissions. It is the largest corporate procurement of carbon removal so far.

Microsoft did this as part of its 2020 commitment to slash its greenhouse-gas emissions to 'net zero' — as one of more than 120 nations and 1,500 companies to set such goals1. By 2030, the company will reduce its emissions by half or more, and will have 100% of its electricity consumption matched by zero-carbon energy purchases. It will electrify its vehicle fleet, stop using diesel for backup energy and reduce emissions across its value chain. Emissions that are harder to abate, including historical emissions, will be compensated for by withdrawing carbon from the atmosphere. The firm is levying an internal carbon tax across all types of greenhouse-gas emission. It has set up a US$1-billion fund to invest in carbon reduction and removal technologies, and partnerships to provide social and environmental benefits. The aim is that, by 2030, the company will be carbon negative. By 2050, it will have removed all of its emissions since it was founded in 1975.

Here we summarize the lessons learnt from Microsoft's carbon-removal efforts, along with those from another early corporate procurement — the $9-million purchases of carbon removal in 2020 and 2021 by the US–Irish financial-infrastructure company Stripe. Although these are just two companies' efforts, they are the first significant open solicitations focused exclusively on carbon removal. We write as a team composed of Microsoft staff working on the company's carbon-negative programme and research scientists who analyse carbon reduction and removal strategies.

We highlight three 'bugs' in the current system: inconsistent definitions of net zero, poor measurement and accounting of carbon, and an immature market in CO2 removal and offsets. These challenges need to be overcome if the world is to reach net zero by mid-century.

Nature

D.6 210909 ORCA turned on - Iceland

The world's largest plant designed to suck carbon dioxide out of the air and turn it into rock has started running, the companies behind the project said on Wednesday.

The plant, named Orca after the Icelandic word "orka" meaning "energy", consists of four units, each made up of two metal boxes that look like shipping containers.

Constructed by Switzerland's Climeworks and Iceland's Carbfix, when operating at capacity the plant will draw 4,000 tonnes of carbon dioxide out of the air every year, according to the companies. The climate crisis requires a new culture and politics, not just new tech Peter Sutoris Read more

According to the US Environmental Protection Agency, that equates to the emissions from about 870 cars. The plant cost between US$10 and 15m to build, Bloomberg reported.

To collect the carbon dioxide, the plant uses fans to draw air into a collector, which has a filter material inside.

Once the filter material is filled with CO2, the collector is closed and the temperature is raised to release the CO2 from the material, after which the highly concentrated gas can be collected.

The CO2 is then mixed with the water before being injected at a depth of 1,000 metres into the nearby basalt rock where it is mineralised.

Guardian

D.7 210715 Arctic Sea Ice at Record Low

ARCTIC SEA ICE AT RECORD LOW for this time of year. This is an enormous source of amplifying feedback. Losing the remaining Arctic sea ice and its reflection of solar energy back to space would be equivalent to another one trillion tons of CO2.

Peter Carter (twitter)

D.8 210526 Dutch Court against Shell

This is a real ruling: it includes Scope 3 emissions.

Rechtspraak

De rechtbank Den Haag beveelt Royal Dutch Shell (RDS) om via het concernbeleid van de Shell-groep de CO2-uitstoot eind 2030 terug te brengen tot netto 45% ten opzichte van het niveau van 2019.

Rechtsspraak (Dutch) English Translation

D.9 210509 NDCs need 80% increase to 2°C

On current trends, the probability of staying below 2 °C of warming is only 5%

Liu (2021) Nature (pdf)

D.10 210508 Young Legal Action

The young people taking their countries to court over climate inaction

Children and young adults around the world are demanding action from governments on global heating and the ecological crisis,

Guardian

D.11 210424 Earth's Axis tilted by Melting Glaciers

Since the 1990s, the loss of hundreds of billions of tonnes of ice a year into the oceans resulting from the climate crisis has caused the poles to move in new directions.

The direction of polar drift shifted from southward to eastward in 1995 and that the average speed of drift from 1995 to 2020 was 17 times faster than from 1981 to 1995.

Since 1980, the position of the poles has moved about 4 metres in distance.

The accelerated decline [in water stored on land] resulting from glacial ice melting is the main driver of the rapid polar drift after the 1990s.

Guardian

D.12 210410 CO2 and Methane surged in 2020

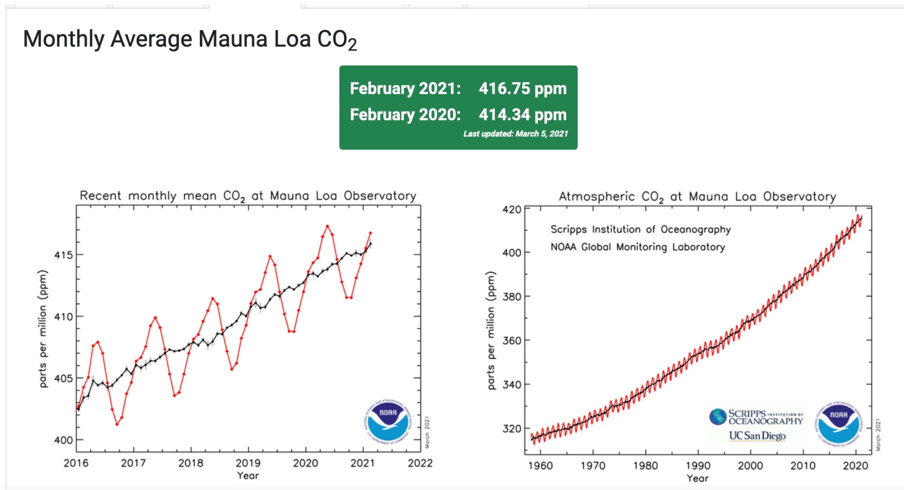
Levels of the two most important anthropogenic greenhouse gases, carbon dioxide and methane, continued their unrelenting rise in 2020 despite the economic slowdown caused by the coronavirus pandemic response.

CO2

The global surface average for carbon dioxide (CO2), calculated from measurements collected at NOAA's remote sampling locations, was 412.5 parts per million (ppm) in 2020, rising by 2.6 ppm during the year. The global rate of increase was the fifth-highest in NOAA's 63-year record, following 1987, 1998, 2015 and 2016. The annual mean at NOAA's Mauna Loa Observatory in Hawaii was 414.4 ppm during 2020.

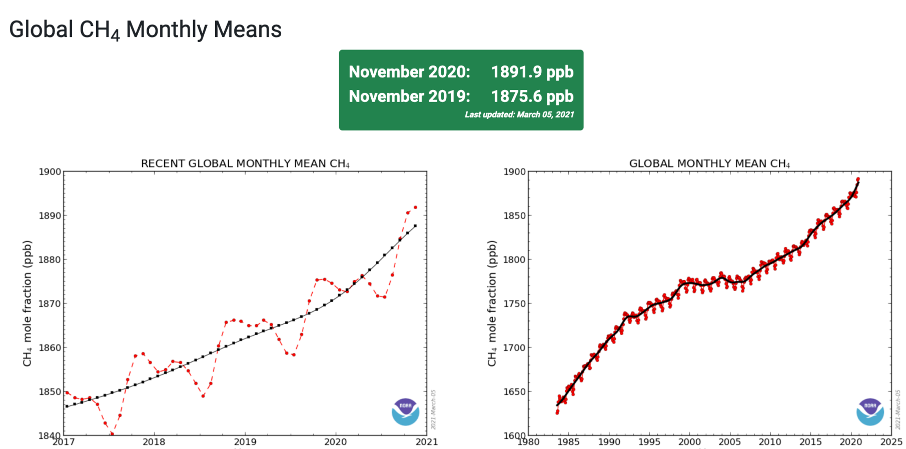
The economic recession was estimated to have reduced carbon emissions by about 7 percent during 2020. Without the economic slowdown, the 2020 increase would have been the highest on record, according to Pieter Tans, senior scientist at NOAA's Global Monitoring Laboratory. Since 2000, the global CO2 average has grown by 43.5 ppm, an increase of 12 percent.

The atmospheric burden of CO2 is now comparable to where it was during the Mid-Pliocene Warm Period around 3.6 million years ago, when concentrations of carbon dioxide ranged from about 380 to 450 parts per million. During that time sea level was about 78 feet higher than today, the average temperature was 7 degrees Fahrenheit higher than in pre-industrial times, and studies indicate large forests occupied areas of the Arctic that are now tundra.



Methane

Analysis of samples from 2020 also showed a significant jump in the atmospheric burden of methane, which is far less abundant but 28 times more potent than CO2 at trapping heat over a 100-year time frame. NOAA's preliminary analysis showed the annual increase in atmospheric methane for 2020 was 14.7 parts per billion (ppb), which is the largest annual increase recorded since systematic measurements began in 1983. The global average burden of methane for December 2020, the last month for which data has been analyzed, was 1892.3 ppb. That would represent an increase of about 119 ppb, or 6 percent, since 2000.



NOAA

D.13 210404 Gas Sustainability

**Scientifically Sustainable*

The European Commission is attempting to finish its sustainable finance taxonomy, a landmark regulation that from next year will define what can be labelled as a sustainable investment in the EU.

A leaked proposal for the rules, shared with EU states last week, would label as sustainable some gas plants that generate power and also provide heating or cooling. That came after the Commission's original proposal – which denied natural gas-fuelled power plants a green label, following the recommendation of the bloc's expert advisers – faced resistance from some EU countries.

Nine members of the expert group advising the European Union on its sustainable finance rules have threatened to step down if Brussels pushes ahead with plans that they say would discredit its efforts to fight climate change.

EU countries disagree on what role natural gas should play in meeting climate goals. Gas emits roughly half the CO2 of coal when burned in power plants, but gas infrastructure is associated with leaks of methane, a potent greenhouse gas.

"The concept of what is scientifically sustainable, that's really not for politicians to decide," said Andreas Hoepner, a professor at University College Dublin who signed the letter.

Reuters

D.14 210220 US SCC Update in Progress

In its 2013 revision of the SCC, the Obama IWG arrived at a central value of around US$50 per tonne of CO2 emitted in 2020 (all values expressed in today's dollars). It also established a range for the SCC ($15–75) and presented an estimate at the 95th percentile ($150). The time is ripe for this update,

That IWG did a careful job, but devastating storms and wildfires are now more common, and costs are mounting. Advances in attribution science mean that researchers can now link many more extreme weather events directly to climate change, and new econometric techniques help to quantify the dollar impacts. The monetary losses exceed the predictions of early models. The same goes for sea-level rise and many other types of damage.

Plenty of scientific and economic judgements need to be made. These include how to deal with endemic uncertainties, including sudden and irreversible 'tipping points', such as ice-sheet collapses. Ethical questions must be considered, including the consequences for vulnerable communities and future generations.

Revising the SCC will take extensive research. A 2017 study by the US National Academies of Sciences, Engineering, and Medicine proposed building a new climate-economy model based on modules — separate components that handle climate change, socio-economic projections, damages, valuation and discounting

Other nations use widely different SCC values or overall approaches2. Germany's 2020 guidance presented two values: €195 (US$235) and €680 ($820). Some countries instead establish a goal for emissions reductions (such as the United Kingdom's 68% reduction by 2030 compared to 1990 levels) and then focus on minimizing the costs of achieving it, estimated at $20–100 per tonne of CO2. This is called a target-consistent approach.

Wagner (Nature)

D.15 210215 Focus on Steel, Meat and Cement

Bill Gates has written about Climate Change.

His assessment is that there is not the time, money or political will to reconfigure the energy sector in 10 years, and encouraging an impossible goal dooms the world to short-term measures that prove insufficient.

Crucially, people need to radically change how they produce the worst climate offenders: steel, meat and cement. Making steel and cement accounts for roughly 10% of all global emissions, and beef alone 4%.

Bill Gates

D.16 210127 10 New Insights in Climate Science 2020

Someof which are:

Earth's temperature response to doubling the levels of carbon dioxide in the atmosphere is now better understood. While previous IPCC assessments have used an estimated range of 1.5–4.5°C, recent research now suggests a narrower range of 2.3–4.5°C.

Emissions of greenhouse gases from permafrost will be larger than earlier projections because of abrupt thaw processes, which are not yet included in global climate models.

Global plant biomass uptake of carbon due to CO 2 fertilization may be limited in the future by nitrogen and phosphorus.

Rights-based litigation is emerging as a tool to address climate change.

Moving forward, the latest research calls for innovative, imaginative, and transformative approaches to building sustainable and resilient human societies. For instance, by strengthening global cooperative frameworks and building new governance arrangements that can include bottom-up community initiatives. In the short term, we have a one-off opportunity to get on the right path by directing post-pandemic recovery spending to green investments. If the focus is instead on economic growth, with sustainability as an afterthought, it would jeopardize our ability to deliver on the Paris Agreement. Alarmingly, governments do not yet seem to be seizing the opportunity to shift towards low-carbon, healthier, and more resilient societies.

futureearth (pdf)

D.17 210130 Adaptation Summit

Climate change adaptation seems to be a fairly new concept to many leaders. It were sometimes mix-ups with mitigation during the high-level talks. Mitigation and adaptation are both important and sometimes they overlap, so mix-ups are understandable. Climate adaptation involves many communities and disciplines (e.g. weather forecasting, climate services, regional climate modelling, "distillation", disaster risk reduction).

Financing is clearly needed for climate change adaptation. To ensure progress and avoid lofty visions without results on the ground, there may also be a need for tangible results and to show examples and demonstrations. One specific type discussed at the summit was "Early warning systems" which play an important role.

But early warning systems, the way I understand them, don't provide information about climate risks on longer timescales. Weather and climate – short and long timescales – are of course connected but nevertheless different

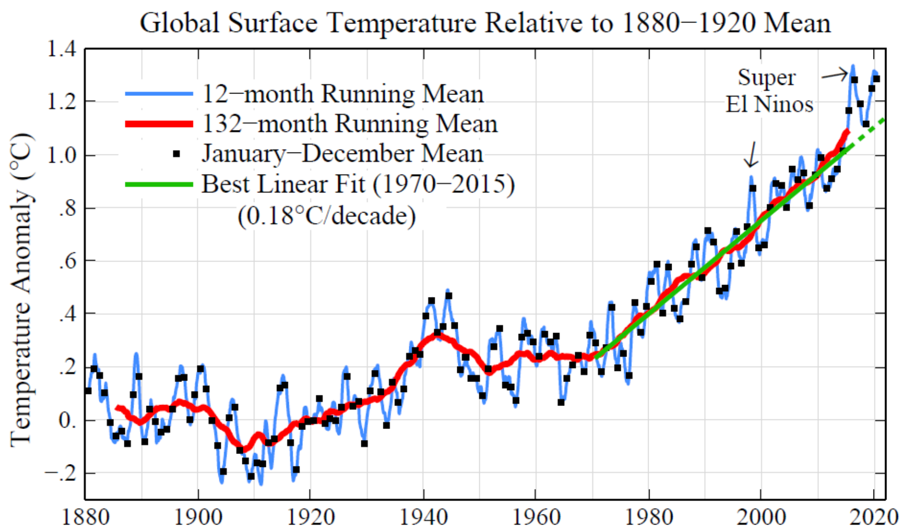
Rasmus (2021) Adaptation Summit

D.18 210118 Warming all anthropogenic

Parties to the Paris Agreement agreed to holding global average temperature increases "well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels". Monitoring the contributions of human-induced climate forcings to warming so far is key to understanding progress towards these goals. Here we use climate model simulations from the Detection and Attribution Model Intercomparison Project, as well as regularized optimal fingerprinting, to show that *anthropogenic forcings caused 0.9 to 1.3 °C of warming in global mean near-surface air temperature in 2010–2019 relative to 1850–1900, compared with an observed warming of 1.1 °C.* Greenhouse gases and aerosols contributed changes of 1.2 to 1.9 °C and −0.7 to −0.1 °C, respectively, and *natural forcings contributed negligibly.* These results demonstrate the substantial human influence on climate so far and the urgency of action needed to meet the Paris Agreement goals.

Nature (paywall)

D.19 21014 Globale Temperature 1880-2020



The rate of global warming has accelerated in the past several years. The 2020 global temperature was +1.3°C (~2.3°F) warmer than in the 1880-1920 base period; global temperature in that base period is a reasonable estimate of 'pre-industrial' temperature. The six warmest years in the GISS record all occur in the past six years, and the 10 warmest years are all in the 21st century. Growth rates of the greenhouse gases driving global warming are increasing, not declining.

[GISSTEMP 2020 Update] (https://mailchi.mp/caa/global-temperature-in-2020?e=96d59a909f)

D.20 210104 Not so long lag?

> Until recently, Mann explained in The Guardian, scientists believed the climate system—a catch-all term for the interaction among the Earth's atmosphere, oceans, and other parts of the biosphere—carried a long lag effect. This lag effect was mainly a function of carbon dioxide remaining in the atmosphere and trapping heat for many decades after being emitted. So, even if humanity halted all CO2 emissions overnight, average global temperatures would continue to rise for 25 to 30 years, while also driving more intense heat waves, droughts, and other climate impacts. Halting emissions

> will take at least twenty years, under the best of circumstances, and so humanity was likely locked in to at least 50 more years of rising temperatures and impacts.
>
> Research over the past ten years, however, has revised this vision of the climate system. Scientists used to "treat carbon dioxide in the atmosphere as if it was a simple control knob that you turn up" and temperatures climb accordingly, "but in the real world we now know that's not what happens," Mann said. Instead, if humans "stop emitting carbon right now … the oceans start to take up carbon more rapidly." The actual lag effect between halting CO2 emissions and halting temperature rise, then, is not 25 to 30 years but, per Mann, "more like three to five years." (October 2020)

Guardian article

Covering Climate Now article

D.21 210102 Climate Finance Shadow Report 2020

Oxfam has released this report with subtitle *Asessing progress towards the $100 billion commitment* Progress is NOT in line with need or pledges.

> Climate change could undo decades of progress in development and dramatically increase global inequalities. There is an urgent need for climate finance to help countries cope and adapt. Over a decade ago, developed countries committed to mobilize $100bn per year by 2020 to support developing countries to adapt and reduce their emissions. The goal is a critical part of the Paris Agreement. As 2020 draws to a close, Oxfam's Climate Finance Shadow Report 2020 offers an assessment of progress towards the $100bn goal.
>
> Based on 2017–18 reported numbers, developed countries are likely to claim they are on track to meet the $100bn goal. And on their own terms, they may be. But how the goal is met is as important as whether it is met. The dubious veracity of reported numbers, the extent to which climate finance is increasing developing country indebtedness, and the enduring gap in support for adaptation, LDCs and SIDS, are grave concerns. Meeting the $100bn goal on these terms would be cause for concern, not celebration.

Oxfam Report (pdf)

Appendix E

Sitelog

Latest Additions