NEGEM

Quantifying and Deploying Responsible Negative Emissions in Climate Resilient Pathways

Principles for carbon negative accounting

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Executive Summary and policy relevant messages

We need technologies and processes to remove carbon dioxide from the atmosphere. However, removals accounting and targets must remain separate from those for GHG emissions; and only real removals should be taken into account.

Emission reduction and carbon dioxide removal accounting and targets need to be kept strictly separate to ensure removals can play the roles science says they need to: 'compensate' for the very last emissions to be abated and slash atmospheric GHG concentrations.

Separate accounting frameworks mitigate the risk of mitigation deterrence, i.e. removals slowing down decarbonisation efforts, and the potential for false equivalency. A tonne emitted does not equal a tonne removed, and this commonly held false equivalency undermines society's capacity to maintain global heating to 1.5°C.

Not only do removals only undo up to 90% of the impact of an emission on the climate breakdown, but some impacts of the climate emergency itself (such as rising sea levels) cannot be dealt with through removals in relevant timelines.

In addition, only real removals should be counted: a removal process must actually deliver net-negative emissions. Carbon must be sourced from the atmosphere, and be intended to be stored for at least several centuries and ideally much longer. In addition, all emissions and removals throughout the full value chain of the process must be comprehensively estimated and included in the emission balance - and removals should end up larger than associated emissions.

Getting the accounting of carbon dioxide removals right is crucial, but pales in comparison to the need to reduce emissions drastically - both in scope and speed. Removals can supplement emissions reductions, but cannot replace them. Carbon accounting has to reflect that simple truth. The atmosphere cannot be cheated.

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Introduction

Carbon dioxide removals (CDR), also known as negative emissions or carbon removals, refers to sucking this greenhouse gas from the atmosphere and storing it permanently - either on land, underground or in the oceans. This could be based on natural processes, such as forests, grasslands and wetlands, that act as "carbon sinks", or a variety of technology solutions.

Interest in carbon removals has been steadily growing in recent years.

The Intergovernmental Panel on Climate Change's (IPCC) Special Report on 1.5°C[1] makes it clear that large quantities of carbon removals will very likely be necessary this century. Even the pathways to 1.5°C with limited or no overshoot (i.e. the planet does not pass the 1.5°C threshold before forcing temperatures back down by lowering concentrations of GHGs in the atmosphere) project that 100-1,000 gigatonnes of CO2 would need to be removed from the atmosphere over the 21st century. Koljonen et al. (2021) found median estimates for CDR across nearly 350 climate change mitigation scenarios of 12 GtCO2/year in 2050 and 30 GtCO2/year in 2100 respectively.[2]

The science is clear that we will most likely need to remove enormous quantities of carbon from the atmosphere this century, and many countries and companies are making pledges or claims, or setting targets that implicitly or explicitly rely on CDR. Black et al. (2021) found that countries, regions, cities and companies with net-zero targets represent at least 61% of global emissions, 68% of global GDP and 56% of the global population.[3] One of those regions with a net-zero target is the European Union. The EU Climate Law states that GHG removals and emissions need to be balanced across the bloc at the latest by 2050[4].

However, there is a lack of clear and consistent accounting rules for CDR and technologies or practices that could result in carbon removals[5]. Accurate carbon accounting is a necessity for the creation and operation of a coherent CDR policy framework and to ensure real removals take place[6]. This is especially the case in the EU, where a number of legislative proposals (both under the 'Fit for 55' package and the Circular Economy Action Plan) are directly related to CDR:

- The LULUCF Regulation[7] and its proposed revision covers emissions and removals in the land use, land use change and forestry (LULUCF) sector. The proposal for revising this legislation seeks to use removals (mostly from European forests) to offset continued emissions from the agricultural sector by setting a net zero target for the AFOLU sector (agriculture, forestry and land use)[8]

[1] IPCC, 2018

[2] Koljonen et al, 2021

[3] And while those are very high percentages, Black et al. also found that only 20% of these targets meet a minimum set of robustness criteria set out by the UN's Race to Zero Campaign.

[4] EU, 2021a

[5] Fuss et al, 2016

[6] Zero Emissions Platform, 2021

[7] EU, 2018

[8] EU, 2021b

- The European Commission is due to publish a Communication on ‘Restoring Sustainable Carbon Cycles’ by the end of 2021. It will present a long-term vision for ‘sustainable carbon cycles’ including carbon removals (for example through so-called carbon farming)[9]

- Finally, European Commission President Ursula von der Leyen announced a legislative proposal on carbon removal certification during her 2021 State of the Union address[10]. This proposal would set up a regulatory framework for certifying carbon removals, based on robust and transparent carbon accounting. The goal would be to monitor and verify the authenticity of carbon removals to enable scaling up removals in the EU

Robust accounting could help incentivise CDR deployment and scaling[11], and if accounting for the climate impacts of removals is questioned it will undermine confidence in removals[12]. Cox et al. (2020) already noted that removals were perceived as a means to slow climate action rather than addressing the root causes of the climate breakdown.

The goal of any climate-related accounting framework must be to describe and account for what the atmosphere experiences. This is no different when discussing carbon removal accounting. Brander et al. (2021) named this the ‘reality principle’: report emissions and removals when and where they actually occur. They highlighted five key accounting issues for carbon removals. This paper builds upon that work, but simplifies it to two overarching principles: first, only count real removals. Second, separate emissions reduction and carbon removals accounting.

If these two principles are implemented together, they help avoid many pitfalls related to CDR accounting, including relying on false removal solutions and letting removals slow down emission reduction efforts.

1 Removing ambiguity

The first necessary step for correct accounting is to ensure that only real removals are being labelled as such. It is therefore imperative that removals are well defined. Tanzer and Ramirez (2019) conducted extensive research into the use of the term ‘negative emissions’, and found inconsistent use in the literature. They concluded that “misinterpreting or miscounting negative emissions could have unintended, and possibly dangerous, consequences, such as policy incentives that reward increasing atmospheric greenhouse gas concentrations under the guise of negative emissions”.

This goes to the heart of the environmental integrity of any strategy or process which involves carbon removals: carbon removals should, of course, not exacerbate climate change directly by leading to increased emissions. The atmosphere cannot be cheated, so definitions used by scientists, policy makers and civil

[9] EU, 2021c

[10] EU, 2021e

[11] Peters & Geden, 2017

[12] Creutzig et al., 2019 and Nemet et al., 2018

society must respect the laws of physics and ensure the environmental integrity of removals if they are to play the role society attributes to them.

There are ample recent examples of confusion being created which potentially affects policymaking[13]. This confusion can be between removals and emission reductions, avoided emissions, carbon capture and storage (CCS) and carbon capture and utilisation (CCU). Morrow and Thompson (2020) use two questions to limit confusion on what is a removal: where does the carbon come from, and where does it end up?

We propose using the elegant and short checklist suggested by Tanzer and Ramirez (2019). For a process, technology or project to create removals, at the very least four principles need to be met:

1. Physical greenhouse gases are removed from the atmosphere
2. The removed gases are stored out of the atmosphere in a manner intended to be permanent
3. Upstream and downstream greenhouse gas emissions associated with the removal and storage process (such as biomass origin, energy use, what happens to any GHGs embedded in gasses or coproducts linked to process, etc.) are comprehensively estimated and included in the emission balance
4. The total quantity of atmospheric greenhouse gases removed and permanently stored is greater than the total quantity of greenhouse gases emitted to the atmosphere

These four principles should be seen as minimum requirements. If they are not satisfied, the process should be discounted from the removals debate, and kept out of policies or schemes that deploy removals. Humanity has limited time and resources to tackle the climate crisis, so it is important to ensure that false removal solutions are excluded beforehand, instead of identifying and seeking to rectify mistakes after they occur. Such false removal solutions include delayed emissions (for example, though short-term storage or CCU) and captured carbon being used to increase fossil fuel production, so-called enhanced oil or gas recovery (EOR/EGR).

1.1 Principle 1: Physical greenhouse gases are removed from the atmosphere

The first principle answers the question: where does the carbon come from? Any removal process must source its carbon from the atmosphere.[14]

Any process that does not remove atmospheric carbon, such as those that capture it from fossil-fuelled point sources (power plants, factories, etc) is disqualified as a potential carbon removal process. Such processes are at best emission reduction processes, but can never be ‘carbon negative’.

[13] Carbon Market Watch 2020, 2021a, 2021b and 2021c; Stoefs, 2021

[14] Note that this could include carbon filtered from sea water due to the interaction between the atmosphere and oceans - in 2005 the IPCC concluded that the oceans have absorbed 500 GtCO2 from the atmosphere over the last 200 year - or approximately 40% of a total of 1300 GtCO2 anthropogenic emissions (IPCC, 2005). More recent estimates indicate that oceanic absorption rates could even be significantly higher (Watson et al. 2020). Atmospheric carbon can thus be indirectly captured from oceans, as lowering carbon concentrations in sea water will lead to lower atmospheric concentrations as well.

Figure 1 shows a simplified scheme for atmospheric removal which will be expanded upon in the discussions on each subsequent principle.

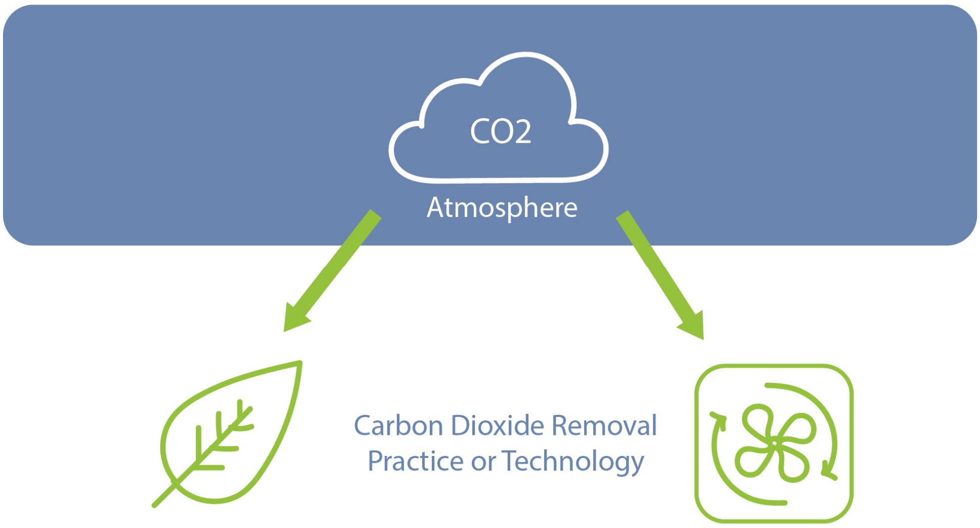

Figure 1. Capture of atmospheric carbon though Direct Air Capture or nature based solutions (principle 1 is respected)

1.2 Principle 2: The removed gases are stored out of the atmosphere in a manner intended to be permanent

Once the carbon has been removed from the atmosphere, the next important question is: where does it end up? If the captured carbon is not permanently stored, it does not contribute to long-term temperature stabilisation[15], and could undermine 'net-zero' targets[16]. Captured carbon ending up back in the atmosphere undoes the result of the process to remove it from the atmosphere in the first place (principle 1), and may even result in higher atmospheric GHG gasses than if the sequestration never happened. This can occur, for example, if the removal was used to offset continued emissions[17].

This raises the question of what exactly permanent means.

Guaranteeing permanent storage on geological time frames is impossible - we do not know what the earth or human society will be like in 100 years, let alone 100,000. If we demand that a removal is stored for thousands to millions of years, we are in essence making it impossible to give the label 'carbon removal' to any technology or process. Therefore, a more workable solution is necessary.

[15] Scott et al., 2015
[16] Reiner et al., 2021
[17] Carbon Market Watch, 2021d; Thamo and Pannell, 2015

A practical way forward is to set the timescale for 'permanence' as keeping the carbon out the atmosphere until humanity has had the time to rein in the climate breakdown and deal with the associated impacts. Another way of stating this idea is that carbon stored now is not released while it can still contribute to the climate crisis or while future generations are still getting a handle on the climate. Putting an exact number of years on this is impossible, but it means we need to keep a timeframe of at least centuries in mind. Ramirez et al. (2020) suggest that permanent storage means at the very least five centuries (and preferably longer). This time horizon also reflects the 300 to 1000 year timescale carbon dioxide actually stays in the atmosphere once emitted[18]. For the remainder of this paper a timeframe of at least 2-3 centuries will be considered 'permanent storage'.

While temporary removals can, theoretically, be replaced by other temporary removals *ad infinitum*[19] to create a 'dynamic permanence', this shifts responsibility to future generations, who may not be willing or able to continue the chain. A cycle of temporary storage cannot be deemed equivalent to permanent storage, even if it might play a role in emissions reduction[20].

It is important to note that this principle states that storage needs be intended to be permanent, as even the most stable sequestration can be undone in the future. This means that the entity storing the carbon should plan, to the maximum extent possible under current knowledge, minimum 200-300 years storage. As mentioned, guaranteeing permanence is impossible, but at the very least the plan of the entity storing the carbon and the capacity of the selected storage method should be able to safeguard sufficiently long-term storage.

It can be argued that nature-based solutions should not be considered removals due to their vulnerability to reversals. They cannot be deemed as having the same potential for multi-century storage as some geological storage processes. However, nature-based solutions should not be discounted for two reasons. First, mechanisms to monitor and safeguard natural carbon stocks can be put in place. This is not a trivial issue, as the difficulties of robust monitoring of stocks and flows of CO2 in natural sinks are significant[21]. And second, far more importantly, nature-based solutions can have significant benefits beyond climate mitigation (including soil health and resilience, agricultural efficiency, water quality, climate adaptation and biodiversity). It can be argued that these 'co-benefits' are more important to realise, and that carbon storage should actually be considered the co-benefit instead of the primary goal.

However, the climate benefits of some nature-based solutions are likely to be too challenging to assess, monitor and maintain, strongly undermining their practical use as potential removal practices. Land management practices can, for example, increase flows of carbon into soils (carbon sequestration). This carbon is withdrawn from the atmosphere but the management practices have to be actively maintained to retain the stored carbon. Given there is a substantial risk that abandoning these practices could re-emit the stored carbon[22], monitoring is critical. However, the mechanism to monitor and verify the storage is likely to be prohibitively expensive and complex.

18 Nasa, 2019

19 Brander et al., 2021

20 (for example products that store carbon for a short time crowding out fossil fuel use)

21 See for example Carbonplan (2021) on the difficulties of crediting soil carbon sequestration

22 Thamo and Pannell, 2015; Dynarski et al., 2020

Furthermore, storage methods that can only lead to short term storage should in any case be disqualified from receiving the label 'carbon removal'. This includes any product containing captured carbon that will be released when the product, such as fuels, wood-based products or plastics, is used or when it is dumped or incinerated.

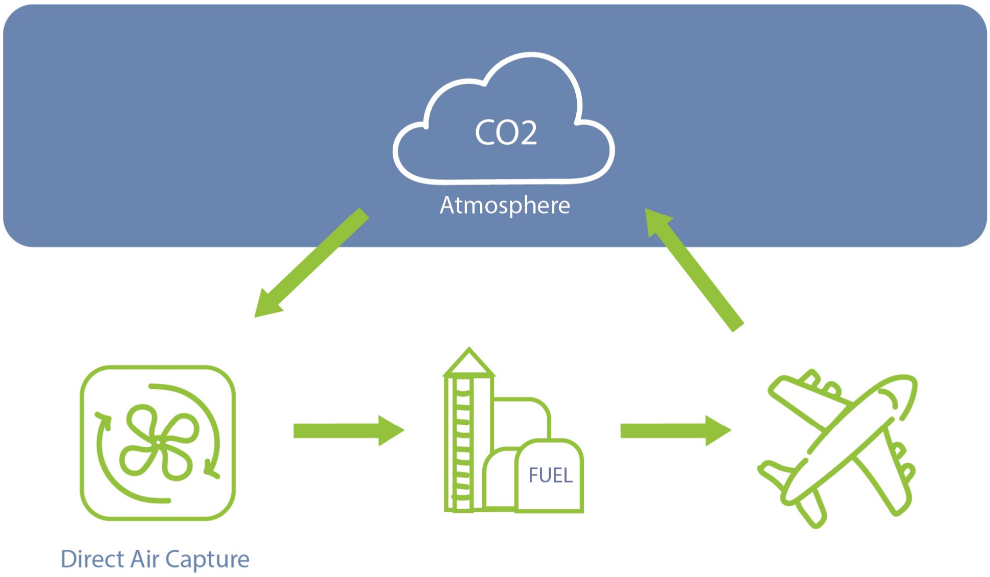

Figure 2. Atmospheric carbon is used for short term storage (respecting principle 1, but not 2)

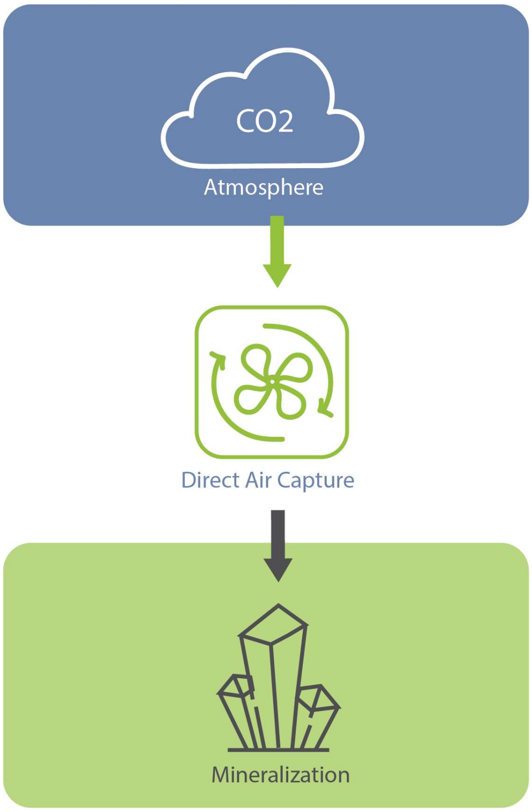

Figure 3. Atmospheric carbon is used for long term storage through mineralization (respecting principles 1 and 2)

Liability for potential non-permanence

Even if a storage solution is intended to be permanent, leaks or reversals remain a possibility, and the issue of liability remains a challenging problem to address, especially as a removal process can span continents and generations.

In some cases, biomass for a European Bio-Energy and Carbon Capture and Storage (BECCS) facility might come from outside Europe (for example, North America or Africa). The regrowth of that biomass over time is crucial for that biomass to be considered climate neutral[23]. Moreover, the CO2 from that BECCS plant might be transported across borders to a storage site. This means that guarantees of permanent storage have to be accepted and verifiable across borders as well. Liability becomes a major factor (for leakage of storage and regrowth of the biomass). This is particularly challenging when you consider that it may be decades to centuries later that this BECCS facility proves not to be carbon negative after all[24].

[23] Note that real world examples of this proof that the 'carbon neutral' label on biomass is abused to justify deforestation (CNN, 2021)
[24] Peters and Geden, 2017

If the leak happens in the distant future, it becomes very challenging to hold anyone accountable. For example, soil carbon sequestration at a family-owned farm might be undone years to generations later. If the farmer who started the management practices that led to carbon sequestration received financial rewards for this, are we going to demand repayment from his as-yet-unborn great-grandchild? And who is going to compensate the atmosphere for the extra burst of heating gases? Note that leakage concerns are not a reason to not undertake CDR practices (especially if there are significant co-benefits), but does mean that liability concerns need to be addressed, and that accounting the removal news to take possible reversals into account.

Liability is related to risks, both known and unknown. Removal processes carry plenty of both. Known risks can be incorporated in accounting, if it is known that geological storage has a 0,01% risk of failure, a minimum of 0,01% of the removals should be discounted. This could be operationalised using so-called 'buffer pools' where anyone undertaking the storage has to block a certain amount of funds to be used to undo any damage through leaks or repair storage sites in the (distant) future. However, this pool would need independent oversight[25], and might yet fail.

Offset certifiers typically require 20% of credits to be set aside as a buffer in case "reversals" occur (fires, insects, disease). While they will usually cancel all credits remaining in this buffer pool at the end of the project, they don't require permanence afterwards. After the project period reversals can occur without any liability, and if they surpass the equivalent of 20% of the cancelled buffer credits, then the safeguard fails. Note that while this can mitigate the risks of overcounting removals when reversals have occurred, it does not mitigate risks of indirect emissions: by protecting a tract of land, exploitative industry might be pushed to other areas - resulting in a potential zero-sum game with no benefits in terms of carbon removal and storage.

In our view, reversal risks can be extremely challenging to predict or quantify as they can happen over centuries. This is especially the case as the climate breakdown might lower the resilience of natural carbon stocks by, for instance, increasing the risks of forest fires, pests, droughts and floods. This highlights the need for rigorous and detailed monitoring of storage sites. Monitoring geologic storage sites might be less challenging, but it still needs to be done.

Long-term liability might be too great a problem to tackle through a fully private solution, according to de Figueiredo et al. (2007). This implies that governments will have to take on (part of) the responsibility for potential future reversals or leaks, though full government responsibility might make entities undertaking the storage act more recklessly. However, governments should have full responsibility with regards to accounting leaks and reversals in national GHG inventories at the least.

[25] Ingelson et al., 2010

1.3 Principle 3: Upstream and downstream greenhouse gas emissions associated with the removal and storage process are comprehensively estimated and included in the emission balance

Carbon that is extracted from the atmosphere and stored in a manner intended to be permanent is still not automatically a carbon removal. The removal and/or storage process might entail or cause significant GHG emissions - for example, when it is embedded in the energy, materials or land used or produced. Therefore, rigorous life cycle assessments (LCA) need to be undertaken of the full removal process - including any up- or downstream steps[26]. This encompasses scope 1, scope 2 and scope 3 emissions[27], and all GHGs that are emitted must be accounted for[28] . The outcome of such a life cycle assessment should prove without a doubt that the removal technology, process or practice has indeed led to an overall decrease in atmospheric GHG concentrations. If the outcome is a range, the most conservative estimate should be used[29].

LCAs could quantify how an action affects total system-wide emissions[30]. Such LCAs could be conducted at the technology level (also to identify potential sources of emissions related to a CDR technology or process, or climate forces such as changes in albedo), but ideally are done at the project-level[31]. Note that the results of these LCAs can differ across projects using the same technology - and should be done on a case-by-case basis[32]. And as the transition develops, the outcomes could also change over time, such as through access to additional renewable energy. The key concern will always remain on capturing the total impacts of a given CDR process or project though a comprehensive LCA.

The 'reality principle' should be followed here as well: report emissions and removals where and when they really happen[33]. The choice of boundaries for the LCA is of critical importance, as Figure 4 shows. The system itself remains the same, but the boundaries of the accounting vary greatly. By choosing what to account for and what not, very different pictures emerge on whether this system actually delivers carbon removals[34].

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26 Royal Society, 2018

27 Scope 1 emissions are direct emissions from owned or controlled sources. Scope 2 emissions are indirect emissions from the generation of purchased energy. Scope 3 emissions are all indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions. (Greenhouse Gas Protocol, 2021). For a clear graphic representation of these scopes, please visit this website.

28 For example in CO2 equivalences (Zero Emissions Platform, 2021)

29 Zero Emissions Platform, 2021

30 Brander et al., 2021

31 Torvanger, 2018

32 Zero Emissions Platform, 2021

33 Brander et al., 2021

34 Tanzer and Ramirez, 2019

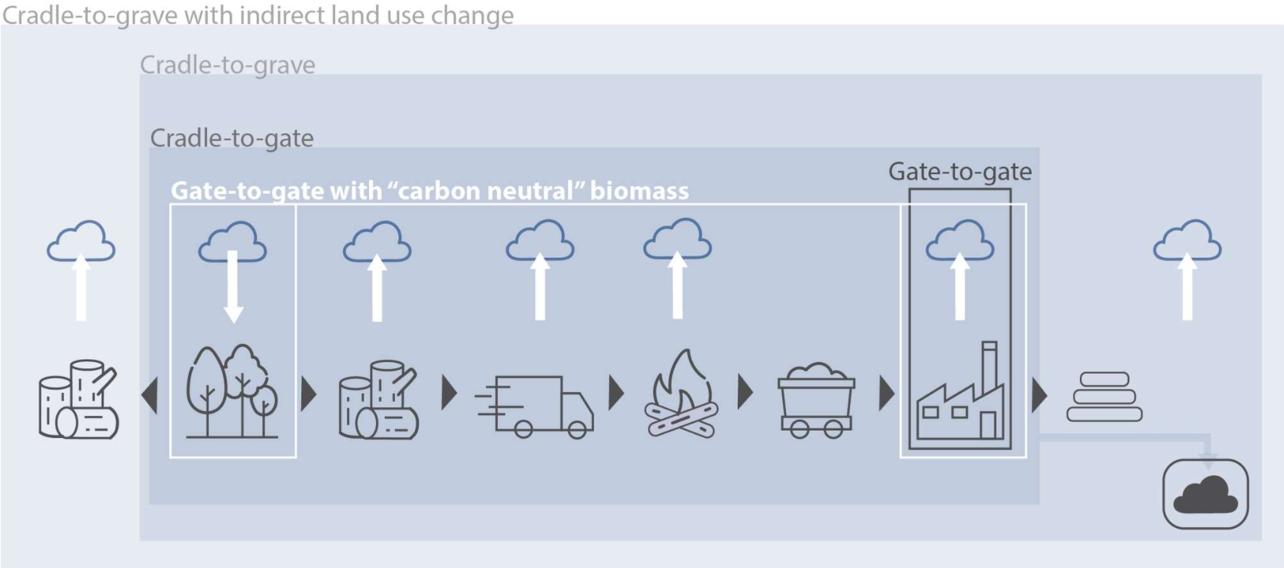

Figure 4. Different ways to perform the carbon removal accounting for a BECCS facility (Source: based on Tanzer and Ramirez (2019))

Note that Figure 4 ignores several additional elements. First, what the land used to grow biomass could have been used for or was used for before becoming part of this BECCS system. Would it have been left wild, or is it currently used for another economic or environmental purpose? The reference land use (i.e. what it would have been used for in absence of the BECCS system) also needs to be considered within the LCA to fully understand the impacts of the removal activity[35]. Second, the emission reduction potential of the BECCS plant: is it displacing more emission intensive energy generation? This should not count towards the removals by this installation, but might showcase that the CDR project has additional co-benefits beyond removing and storing carbon.

Even a DAC facility could have very different carbon removal impacts depending on the specific case: including how and where inputs (such as energy and materials) are sourced and how the captured carbon is used. For example, additional renewable energy would need to be generated in order not to increase overall GHG emissions from the power sector (renewable power purchase agreements could increase fossil-fuelled generation elsewhere through waterbed effects). The current energy mix of the location the DAC facility is located in plays a large role here. Patrizio et al. (2021) show that the efficiency of a DACCS system in the EU depends heavily on how it is powered and where it is built. In EU countries with power grids dominated by coal power a DACCS facility actually results in net-emissions: more GHGs are emitted into the atmosphere by the DACCS' need for energy than the facility draws back down.

Note that this is not an easy principle to operationalize in the real world. As stated earlier, removal processes can span continents and generations. Biomass for bioenergy is commonly imported into Europe from across the globe, and storage sites (including the Northern Lights project in Norway) would accept CO2 from other

[35] Koponen et al., 2018

European countries for storage. Decades later a project might turn out to not be carbon negative, after all, due to such factors as deforestation or leakage.

In that sense, removal projects may create a ‘carbon debt’, especially BECCS plants. Building the BECCS facility, harvesting, transporting, and burning the biomass[36] and capturing, compressing, transporting and injecting the CO2 all have associated CO2 emissions. These create a ‘carbon debt’ that is repaid over time as the biomass regrows. However, it can take multiple decades for this debt to be fully repaid (Brander et al., 2021) - and this is time we do not have[37]. Note that all removal projects, including DACCS facilities, can incur a carbon debt[38].

Some nature-based solutions might even never be able to pay their carbon debt back. The cumulative emissions from maintaining a non-permanent sink (e.g. replanting and harvesting trees) could at some point be larger than the carbon actually captured in that natural sink (Brander et al. 2021). For a stylised example see Figure 5.

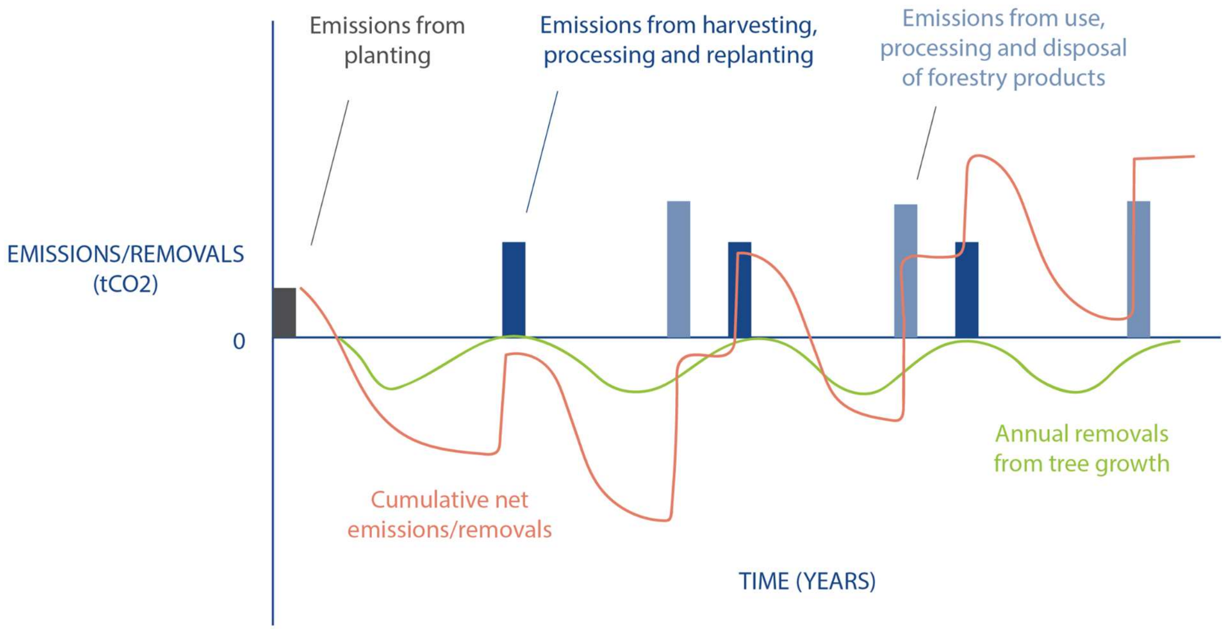

Figure 5. Example of cumulative emissions from maintaining a non-permanent sink outgrowing the sink itself

This example highlights that for nature-based solutions, accounting should happen at the moment of storage - rather than banking all removals on day one of the process.

36 Including GHGs that are not captured on site - no CCS technology can capture 100% of emissions. Historically, 90% capture rate was deemed feasible, though 95% might be possible (though expensive) now. Note that most operational CCS facilities capture far less than 90% (ESWET, 2020)

37 IPCC, 2021

38 Terlouw et al., 2021

1.4 Principle 4: The total quantity of atmospheric greenhouse gases removed and permanently stored is greater than the total quantity emitted

This principle is an accounting principle, and brings the first three principles together to answer the key question: did the removal process actually lower atmospheric greenhouse gas concentrations? It sums up:

1. all the GHG emissions *removed* from the atmosphere (principle 1) and stored (principle 2) over the process, and
2. all the emissions *generated* over the process (using a comprehensive LCA - principle 3)

It then subtracts the removals from the emissions. If the result is negative the action has resulted in removals. If the sum is positive the process has resulted in more emissions than removals and so is not an actual removal process. Note that on both the removals and emissions side all associated up- and downstream carbon flows need to be comprehensively accounted for.

Good and bad removals

A process might fulfil all four principles, result in definitive carbon removals but still not be a good and sustainable process. Every removal project isn't automatically a great project - it must also not do any significant harm.

Removal projects could have considerable social, economic and environmental impacts that make them undesirable[39]. For example, a monoculture plantation to grow biomass for a BECCS facility might have significant impacts:

- Environmental: It could undermine resilience and climate adaptation compared with the original land use. It could have repercussions on water availability and quality, soil quality and/or biodiversity; including through spreading pests or invasive species. It could even increase emissions outside the boundaries of the activities through waterbed effects on biomass availability. On climate change, it might change surface albedo and strengthen the greenhouse effect
- Socio-economic: The land could be grabbed *ad infinitum* from local or indigenous communities who rely on it for economic or social activities, without their consent and without compensation. Such land grabs have negative repercussions on human rights. Funds invested in the plantation cannot be used for other purposes with more direct and positive sustainable development impacts. The process could have rebound effects increasing consumption.

Potential adverse impacts of removal projects need to be taken into account, and social, political, economic and environmental safeguards are necessary to ensure the overall benefit to society and

[39] Smeets et al., 2014; Smith et al., 2016 and Tanzer and Ramirez, 2019

vulnerable stakeholders is positive. Tanzer and Ramirez (2019) add that it is important to even leave space for 'unknown unknowns' - impacts which we don't even realise could happen - and to incorporate increasing understanding of impacts as real world deployment happens and impacts become visible and measurable.

Inversely, a project might have limited removal potential (for example because of high risk of reversals), but still be a worthwhile project due to significant co-benefits. Especially nature-based solutions can have environmental (biodiversity, climate adaptation, water quality, soil health, etc), social (health, human rights, equity, etc) and economic (employment, income generation and diversification, etc.) co-benefits - in some cases outweighing their removal value.

Potential harm caused by, and co-benefits from, CDR processes and projects highlight that projects should be assessed on a case-by-case basis - and not only on their carbon removal merit. However, significant co-benefits do not mean that CDR accounting should not be done in a rigorous manner.

Defining what is a real removal, and what is not, is a vital first step to good CDR accounting. However, it is not sufficient. Accounting also plays an important role in ensuring removals actually help to reach the climate goals society has set itself. The best way to achieve this is by separating removals accounting from emission reduction accounting.

2 Net zero is not zero

Accounting of removals should fully support the role society assigns carbon removals in the coming decades and century/centuries. Carbon removals can play multiple roles[40]:

- Mitigating climate change by lowering peak atmospheric concentrations of GHGs, thereby limiting the devastating impacts of the climate breakdown
- 'Compensating' for residual emissions left over from hard-to-abate sectors while decarbonisation efforts continue, with sufficient carbon removals ensuring society reaches net-zero emissions
- Reaching net-negative emissions where removals draw down the remaining "legacy carbon" by sucking in more carbon than is emitted, thereby actively lowering atmospheric GHG concentrations. Without fulfilling this role (over time) removals will not keep us within 1.5°C global heating.

[40] Morrow and Thompson, 2020

All three roles would be better served by having separate accounting systems and policy frameworks for removals and emissions reductions[41]. All three roles need the development and upscaling of removal technologies over time.

Critical in this perspective is that removals are regarded and implemented as supplements to, rather than substitutes for, deep emission reductions[42] because driving down emission across all economic sectors is necessary[43], and should be the current political, social and environmental priority[44]. 'Keeping 1.5°C alive' means accelerating decarbonisation efforts and results. Substituting emission reductions with removals could undermine efforts to reach the critical threshold for maintaining Earth as a safe home for all life we know exists in the universe[45]. This is particularly the case when you consider that current annual emissions from fossil fuels are approximately tenfold what could be removed by land sinks[46].

Separate accounting can lower negative impacts on emission reductions compared to not keeping removals and emissions separate in climate mitigation strategies, including technological[47] and high-carbon lock-in. A separated CDR policy framework even helps provide predictability to project developers, ensures high environmental and sustainability standards[48], and benefits climate planning at multiple levels[49].

Separate accounting systems ensure that removals are not used as a smokescreen to avoid reductions or act as a deterrent to taking robust action to lower emissions.

'Mitigation deterrence' occurs when removals (or the perception that they will become available in the future) undermine current and future efforts to reduce emissions. It is often referred to as a 'moral hazard'[50]. The option of 'compensating' with removals in the near or distant future could push industrial sectors (many of which claim to be 'hard-to-abate' sectors) to delay action hoping to be considered part of the residual emissions which are assumed to be balanced out by removals.

Mitigation deterrence has already had an impact on climate policy, according to McLaren et al. (2019), including the use of removals to facilitate the continued exploitation and consumption of fossil fuels. Some fossil fuel giants have even been using removals to greenwash their atmosphere heating products and label them 'carbon neutral'[51]. A social licence to operate for CDR is not a given and large-scale deployment of removals without corresponding emission reduction efforts could be unacceptable to many people[52].

41 McLaren et al., 2019
42 Morrow and Thompson, 2020
43 IPCC, 2018
44 Carbon Market Watch, 2021a
45 McLaren et al., 2019
46 Steffen et al., 2016
47 McLaren et al., 2019
48 Reiner et al., 2021
49 McLaren et al. 2019
50 Carton et al., 2021
51 Carbon Market Watch, 2021d
52 Cox et al., 2020

We identify two main potential and interrelated drivers of the mitigation deterrence effect: a false equivalency between emissions reductions and carbon removal, and an overreliance on future CDR technologies that currently do not exist and may never exist, at least not at the required scale or cost.

2.1 Tonnes of false equivalency

A frequent mantra in climate policy is that 'a tonne is a tonne'. However, this is demonstrably false when comparing a tonne of carbon removed and a tonne emitted. The IPCC (2021) concludes that a tonne removed may have 10% less impact on atmospheric CO2 concentrations than a tonne emitted, due to interactions with land and ocean carbon stocks.

In addition, GHG pollution could have long-lasting impacts on life on Earth that removals would not be able to 'clean up' or 'compensate' for. Removals will not undo every impact of the climate breakdown. IPCC (2021) states with high confidence that 'If global net negative CO2 emissions were to be achieved and be sustained, the global CO2-induced surface temperature increase would be gradually reversed but other climate changes would continue in their current direction for decades to millennia'. They add that, for example, it could take centuries to millennia for global mean sea levels to stop increasing - even under large net negative emissions. The main tool to limit the magnitude of these impacts is to reduce emissions.

This strongly implies that even at a meta-level removals and emissions are not equivalent, but if we dig a bit deeper, several other false equivalencies appear. For example, removals through natural processes (e.g. tree planting) are inherently vulnerable and could be easily reversed (through forest fires, pests, droughts, human clearing, etc.)[53]. Note that many of these risks would also be exacerbated by the climate breakdown itself, with reversal of natural removals potentially forming an additional climatic tipping point.

Carton et al. (2021) provide an excellent overview of false equivalences between removals and emission reduction. They highlight three key areas in which emissions and reductions are not equivalent. These are mainly related to natural removals, but should also be considered pertinent for technological removals. They are carbon, geographical and temporal equivalences.

Carbon equivalence is the main false equivalence, and refers to considering each tonne of carbon equivalent and interchangeable. However, this obscures major differences, especially between 'fossil' and 'biogenic' carbon. These two types of carbon are often included under the same climate targets, though differ incomparably with regard to timescale involved. This difference in timescales is seen as a fundamental barrier to equivalence[54].

Fossil carbon is part of the long or slow carbon cycle, in which storage of carbon is for all practical purposes permanent (for example coal started developing approximately 300 million years ago in the Carboniferous period)[55].

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[53] McLaren et al., 2019

[54] Carton et al., 2021

[55] National Geographic, 2021

Biogenic carbon, in contrast, is part of the short-term carbon cycle - operating over the span of a few years to centuries. It recycles (mainly through plants and phytoplankton) carbon between the ocean, atmosphere and land[56] and is also known as the 'active carbon cycle'.

Burning of fossil fuels shifts carbon from the slow carbon cycle into the fast carbon cycle, increasing the aggregate sum of carbon in the fast cycle. This is the primary driver of the climate breakdown. Many removal practices, however, do not fully reverse this as they do not shift carbon from the fast back into the slow carbon cycle.

Mackey et al. (2013) suggest that removing carbon and storing it on land essentially compensates for past emissions, not present or future ones. It mainly undoes legacy human-induced land use changes, such as centuries of extensive deforestation. We are primarily removing biogenic carbon from the atmosphere that was added to the atmosphere by humans over the past millennia. Offsetting the burning of fossil fuels through nature-based sinks is, therefore, deeply flawed.

There is not only no equivalence between fossil and biogenic carbon, but also between various 'types' of biogenic carbon. There is a spectrum of natural removals, according to their quality, longevity, and stability[57]. For example, biodiversity can have a strong impact on ecosystem integrity and carbon sequestration[58], and diverse and intact ecosystems are more resilient than fast-growing (monoculture) tree plantations[59]. Keith et al. (2021) highlights that this false equivalence between types of biogenic carbon stocks has led to planting trees with high carbon uptake rates, instead of protecting natural forests that are more stable as carbon sinks.[60] They add that, as yet, carbon accounting does not differentiate between the quality of the natural carbon sinks.

Geographic equivalence implies that there is no difference between where a natural carbon stock is located and where it is claimed. There are several main biases underpinning this equivalence, including ignoring equity and climate justice concerns.

Key studies on the availability of land for natural removals seem to disregard local communities and how the land is currently used[61]. For example, pastoralists are commonly ignored. This implies that land to be used for natural removals is deemed more available in low-income countries rather than richer regions based solely on formal land ownership rather than land rights.

Another example of false geographic equivalence is the use of land resources in poorer countries to offset emissions in richer countries rather than for the benefit of the citizens of those underprivileged societies. For example, countries complying with international climate obligations or company claims related to net-zero (or 'climate neutral') products or services use afforestation or reforestation projects in low-income

56 Nasa, 2021

57 Carton et al., 2021

58 Labiere et al., 2016

59 Seddon et al., 2019

60 Note, however, that even some protected UNESCO Natural World Heritage forests have been sources of emissions, rather than net-sinks, the past 20 years (UNESCO, WRI and IUCN, 2021).

61 Bastin et al, 2019, and Pozo et al., 2020

countries[62] (NewClimate Institute, 2020) because they represent a cheap option for appearing to be green, effectively delaying decarbonisation efforts.

This makes mitigation deterrence also an issue of climate justice. First, poorer countries and regions see the benefits of low hanging climate fruits (i.e. cheap removal options) go to richer countries and corporations, in the process losing the possibility of relying on these themselves for reaching climate neutrality or net-negative emissions[63]. Second, emissions and emission intensive lifestyles in richer countries can continue by limiting the choices and livelihood opportunities in poorer countries[64]. Finally, continued emissions not only increase the need for future removals, but they also increase the severity of the impacts of the climate breakdown - which will disproportionately impact people in poorer and more vulnerable parts of the world[65].

Temporal equivalence implies that future action can compensate for present inaction. It suggests that continued emissions in the present (or near future) can be fully substituted by removals in the future. As mentioned, a removed tonne might only have up to 90% of the impact on the climate as a tonne emitted - plus removals in the future would not be able to undo long lasting impacts of the climate crisis caused now (such as rising sea levels)[66]. Lenton et al. (2019) highlight that there are major risks for climate tipping points even at global temperature rises of between 1 and 2°C, and that a global climate cascade is a possibility that cannot be ruled out. Future removals will not help avoid or undo such tipping points[67]. Note that the climate breakdown (even without dramatic tipping points) could undermine the stability of natural carbon sinks[68] which further underscores the false temporal equivalence.

The idea of temporal equivalence underpins many net-zero claims and targets. To those making the claims, it doesn't seem to matter when emission reductions happen, only that at a certain arbitrary point in the future removals balance them out. This lies at the core of mitigation deterrence and incentivises delaying costly or difficult changes[69] to behaviour, economic sectors and societies instead of pushing for fast and deep emission cuts now. This is particularly perplexing when you consider that each emission reduction is, by its nature, permanent and requires no continuous supply of removals to remain balanced in carbon budgets. In addition, many removals are by nature reversible (especially nature-based solutions), while emissions are permanent. This risk for future reversals of CDR further undermines the case for equating removals with emissions.

There is also a climate justice angle to temporal equivalence: current emissions cannot be substituted by future emission reductions in terms of impacts on the global carbon budget. Delaying emission reductions leads to a greater need for removals in the future, transferring the burden and risk to future generations who will pay the heavy price without enjoying any of the benefits. The people who will have to deal with a failure of a strategy relying on removals are different from those deciding to postpone emission reductions now[70]. Note that countries and companies that are responsible for current high atmospheric GHG concentrations

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62 NewClimate Institute, 2020

63 Rogelj et al., 2021

64 Gore et al., 2020

65 IPCC, 2014

66 IPCC, 2021

67 Shue, 2017

68 McLaren et al., 2019

69 Carton et al., 2021

70 Shue, 2017

should also bear responsibility for future removals[71] - offsetting continued fossil fuel use just compounds this historic injustice.

Continued emissions not only increase the need for future removals[72], but they also narrow the space for removals to be used to compensate for future residual emissions or to draw down legacy CO2 from the air.

2.2 Overconfidence in removals

Overconfidence in removals is hugely risky and is being pushed by those with an interest in status quo business models[73], including to use removals as a decoy to postpone the phasing out of fossil fuels[74]. McLaren et al. (2019) highlight that this is already happening, and that removals have to be complements - not substitutes - for emission reductions if the 1.5°C climate target is to remain feasible.

Some of the main pitfalls associated with the overreliance on removals are the risk of unknown consequences, limited potential for removals due to economic, technological ecological and social boundaries, and the lower-than-expected effectiveness of removals[75]. The latter two have already been discussed above and relate to potential tipping points, the irreversibility of some climate breakdown-induced impacts and that nature-based removals themselves could be at risk of reversals (potentially becoming sources of carbon rather than sinks) due to global heating. IPCC (2021) adds that CDR can have wide-ranging impacts - not only on the climate breakdown, but also on water availability and quality, food production and biodiversity.

As there is limited experience with deploying removals there are risks with unknown probabilities related to large-scale deployment. Society has an understanding of current opportunities and risks related to climate action, but the same cannot be said of future removals. Those reliance on future removals seems to count strongly on immature removals with unknown risks related to scaling[76]. The lack of certainty on whether a global strategy reliant on removals will prove successful - and avoid a massive overshoot in emissions and greater climate-induced devastation - also means that, based on the precautionary principle, emissions reductions need to be prioritised[77] and far outweigh removals in the short-term.

There is also a risk of scarcity of removals, due to the enormous need for land and energy resources. By allowing for the offsetting of emissions with current or future removals, we risk amplifying that scarcity. If we allocate our limited removals capacity to 'compensate' for emissions that could actually be reduced, we drive down the availability of future removals while increasing their cost[78]. Fuss et al. (2018) highlights the limitation to scientific understanding on the exact limitations and challenges related to various carbon

71 McLaren et al., 2019
72 Ibid.
73 Kremer, 2021
74 Perlman, 2020
75 Kartha and Dooley, 2016
76 Anderson and Peters, 2016
77 Larkin et al., 2018
78 McLaren et al., 2019

removal technologies and processes - and how these options differ with respect to scalability, permanence, cost, impacts on land use change, and biodiversity impacts.

Kartha and Dooley (2016) find that the scale of removals put forward by the IPCC (up to 1,000 Gt of CO2 by 2050)[79] cannot be met safely with confidence. The work by Fuss et al. (2018) agrees with this: an absorption capacity of a thousand gigatonnes appears unrealistic to them in light of biophysical and economic limitations.

Larger and faster emission reductions are more feasible and desirable. In such a scenario, the majority of removals necessary under a 1.5°C aligned pathway could even be provided by ecosystem restoration and rewilding. This would also limit reliance on removals with higher risks of technical infeasibility or large ecological and social impacts (such as BECCS)[80]. The IPCC (2018) supports some of those conclusions by stating that removals are "subject to multiple feasibility and sustainability constraints" and that deep and fast emission reductions could help limit removal needs to the scale of several hundred Gts of CO2.

3 Conclusions

It is abundantly clear from the above that emissions reductions and removals should be kept separate, in terms of both targets and accounting. The key reason is that emissions reductions must enjoy clear primacy and, to do so, we must avoid mitigation deterrence effects. In the climate crisis, a tonne emitted 'weighs' more than a tonne removed. This means that overreliance on removals not only risks a deeper climate breakdown, it also shifts risks and burden to the underprivileged of the world and to future generations - both of whom cannot be held responsible for the current climate crisis.

The risks and uncertainties related to the large-scale deployment of removals makes a strong case for making emission reductions the clear political priority, also to limit global dependence on removals[81]. Separation creates a space for development and deployment of removals (including through targeted support) without undermining emission reduction efforts[82].

Failing to distinguish removals from reductions by allowing for offsetting between both risks undermining political and public acceptance for removals, and could negatively impact the international credibility of the EU[83].

But merely separating removals and emission reductions is not sufficient to ensure good accounting: any CDR accounting has to reflect what the atmosphere actually experiences[84]. This means defining removals in a robust manner to ensure only real removals are counted. We suggest that any policy instrument that would

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79 IPCC, 2018

80 Kartha and Dooley, 2016

81 Fuss et al., 2018; Royal Society, 2018

82 McLaren et al., 2019

83 Geden and Schenuit, 2020

84 Brander et al., 2021

promote CDR technologies and practices puts, at the very least, the four principles from Tanzer and Ramirez (2019) at its heart:

1. Physical greenhouse gases are removed from the atmosphere.

2. The removed gases are stored out of the atmosphere in a manner intended to be permanent.

3. Upstream and downstream greenhouse gas emissions associated with the removal and storage process, are comprehensively estimated, and included in the emission balance.

4. The total quantity of atmospheric greenhouse gases removed and permanently stored is greater than the total quantity of greenhouse gases emitted to the atmosphere.

This pierces to the heart of the environmental integrity of any strategy or process which involves carbon removals: carbon removals must not exacerbate climate change directly by leading to increased emissions. In addition, non-CDR co-benefits and risks/damage needs to be assessed as well. Nature-based removals (such as rewilding) can provide other ecosystem services (water, food, biodiversity, etc) which make them very much worthwhile, without even looking at their removal potential. There is a risk that focusing exclusively on CDR leads to prioritising some types of carbon removals over others that may have significantly more benefits to society. DACCS does not have equivalent societal co-benefits to rewilding.

Removals must not undermine climate efforts or harm current or future generations (for example by fuelling land grabs), but help keep ‘1.5°C alive’. This means no offsetting continued emissions, or misusing- or abusing the ‘removal’ label. A tonne is not a tonne - and the proposed straightforward equivalency between each tonne emitted and each tonne removed is false. Definitions and scenarios used by scientists, policymakers and civil society must respect the laws of physics and ensure the environmental integrity of removals if they are to play the role society attributes to them

The atmosphere cannot be cheated.

In preparing this report, the following deliverable/s have been taken into consideration:

D#	Deliverable title	Lead Beneficiary	Type	Dissemination level	Due date (in MM)
7.2	Extended MONET-EU	ICL	R	Public	17
8.1	Stocktaking of scenarios with negative emission technologies and practises. Documentation of the vision making process and initial NEGEM vision	VTT	R	Public	8

NEGEM

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