CNCE Report

Working Paper Series

Nov. 2022
Issue #1

Carbon Removal Accounting Methodologies:

How to rethink the system for negative carbon emissions

ASU
Center for Negative Carbon Emissions
Arizona State University

CNCE Working Paper Series

CNCE 2022-001

CARBON REMOVAL ACCOUNTING METHODOLOGIES:

HOW TO RETHINK THE SYSTEM FOR NEGATIVE CARBON EMISSIONS

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November 2022

CNCE working papers are circulated for discussion and comment purposes. They have not gone through the peer-review process.

How to cite:

Arcusa S., Lackner K., Page R., Sriramprasad V., Hagood, E. (2022). Carbon removal accounting methodologies: how to rethink the system for negative carbon emissions. CNCE Working Paper No. 0001 November 2022. Arizona State University KEEP Repository, https://hdl.handle.net/2286/R.2.N.170043.

Abstract

We analyze current approaches to carbon accounting for removed carbon sold on carbon markets, focusing on carbon crediting under the framing of a remaining carbon budget, the issue of durability, and approaches to accounting methodologies. We explore the topic of mixing carbon with other problems in developing carbon accounting methodologies and highlight the open policy questions. We conclude with a suggested framework for accounting for carbon removal accounting that simplifies climate action and enables a world with negative carbon emissions.

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1 Carbon crediting in a finite budget

Increasing carbon dioxide (CO_2) concentration in the atmosphere due to burning fossil fuels and calcinating carbonates to produce cement is causing climate change (IPCC, 2022a). Other greenhouse gases like methane and nitrous oxide play a role, but their characteristics differ in terms of their lifetime in the atmosphere (Lackner, 2020; Pierrehumbert, 2014; Solomon et al., 2009). Once in the atmosphere, 20-35% of the emitted CO_2 will remain there for hundreds of thousands of years (Archer et al., 2009). Despite higher potency, this longevity is not the case for other greenhouse gases. Earth will likely recover from the massive increase in CO_2 concentration since the start of the industrial revolution. Still, for humans and most species, the climate changes will appear to be a permanent state shift (Tierney et al., 2020). The carbon problem is not a century-scale problem but rather one that operates on a multi-millennia scale more reminiscent of the longevity of nuclear waste.

As a result of this multi-millennia characteristic of CO_2, CO_2 emissions accumulate in the atmosphere and tightly linked reservoirs like the surface ocean. This accumulation occurs because the Earth's processes cannot remove the CO_2 gas fast enough to match the rate caused by humans (Solomon et al., 2009). The accumulation of CO_2 (and other greenhouse gases) increases the global temperature. Simply reducing emissions is not enough, as the remaining emissions continue to contribute to increasing the total atmospheric CO_2 concentration. Instead, current emissions (and some past emissions) must be eliminated or canceled out, a situation that calls for zero emissions. Additionally, any future emissions, once emitted, must be removed. The elimination and removal of emitted carbon is the basis of the Intergovernmental Panel on Climate Change (IPCC) concept of the remaining carbon budget (IPCC, 2022a). This concept collides with carbon credits based on trading emissions reductions and carbon storage that is measured in decades or centuries rather than tens of thousands of years.

Meeting the Paris Agreement commitment to 1.5 °C means staying within a finite carbon allowance that is quickly diminishing as emissions continue (IPCC, 2022a). Therefore, achieving the Paris Agreement commitment using carbon markets and offsetting practices means that carbon credits must represent a complete and virtually permanent removal. Credits for emission reduction used for offsetting emissions continue to diminish the budget because emissions are still produced. Moreover, because the world has delayed climate action for three decades (Stoddard et al., 2021), staying within a 1.5 °C budget will require negative emissions (IPCC, 2018; Morton et al., 2021). Negative emissions are only possible through carbon removal as CO_2 concentrations are irreversible on human timescales (Solomon et al., 2009).

Alignment with the Paris Agreement commitment means emission reduction credits cannot continue to be used as offsets. Through their use, the remaining carbon budget will continue to shrink, bringing the world closer to breaching the Paris commitments and going well beyond. Furthermore, emission reductions should not be certified as being the same as emission removal; the mantra of a ton is a ton is flawed. Reducing one emission cannot be used to cancel out another emission. Both emissions will have to be eliminated. In a zero-emission world, nobody should have a right to emit freely (Lackner and Jospe, 2017), and certainly not a right that can be transferred to another emitter. Removing an equivalent amount of carbon is the only way to neutralize an emission. Carbon removal is the price to pay for not eliminating emissions. Put differently, with the 1.5 °C carbon budget in mind; carbon removal should be the standard for carbon credits. If removal (or negative emissions) is the standard, then reduction (or decreasing positive emissions) should not be given the same value by the carbon market. The argument that removing a ton is equivalent to avoiding a ton in a world of voluntary action is not entirely correct.

There is nothing wrong with rewarding action, just like it may be worthwhile to reward emissions reduction during the transition to a net zero economy. However, issuing carbon credits is the wrong approach. For example, capturing CO_2 from the environment and using it for synthetic fuels helps approach a net-zero economy, even though the carbon ends up in the atmosphere as CO_2 again. However, this process does not generate a carbon credit. Instead, it avoids the need for one.

2 The issue of durable storage

Once one accepts that offsetting can only use carbon removal, one must also understand the distinction between certifying carbon sequestration and other forms of carbon offsets for two reasons: durability (i.e., permanence) and accounting.

Carbon removal includes capture and sequestration. Durable sequestration is the essential element that matters for climate change mitigation. CO_2 captured from the environment and released (even 100 years later) has little benefit for climate mitigation since CO_2, once re-emitted, will resume causing damage for hundreds of thousands of years (Archer et al., 2009; Kirschbaum, 2006). Temporarily sequestered CO_2 has a benefit for the generations of humans and other species that live during the sequestration period because it minimizes the overshoot (i.e., the exceedance of the limits set in the commitments of the Paris Agreement) (Dornburg and Marland, 2008; Girardin et al., 2021). This argument is valid if one takes the optimistic view that global atmospheric concentrations will peak and come down within the span of temporary sequestration, which implies active measures to remove carbon from the environment. Unless active carbon removal is maintained, releasing carbon from temporary storage will create a cycle of degradation of the climate and the human environment. Temporary storage without the obligation of re-sequestering losses from storage represents a willful neglect of the interest of future generations to lower the cost of a habitable climate for our generation.

CO_2 captured from the environment and sequestered durably mitigates climate change and allows the world to transition to net negative emissions. This condition will be necessary to uphold the Paris Agreement commitments. However, this all depends on the definition of durability. An arbitrary selection of a timeframe, or applications of discounting, ignores the well-being of future generations. Intergenerational equity should be as much a consideration for carbon accounting as calls for sustainable development and safeguards on gender equality, labor, the environment, indigenous rights, biodiversity, human rights, and land ownership. The Paris Agreement is clear; parties must consider intergenerational equity in tackling the climate crisis (United Nations, 2015). Furthermore, a continuing cycle of 50-100 years of carbon released from storage will impede the world from reaching a stable net-zero target and net negative emissions – it is an issue of ongoing maintenance and incompatibility with net-zero goals.

The definition of durability must be commensurate with the damage we are trying to prevent (Arcusa and Lackner, 2022). Preventing damages from temperature requires storage on timescales of multiple centuries to millennia to match the absorption of CO_2 into the biosphere and its transfer into the oceans (Archer and Brovkin, 2008). However, climate change is not only about temperature (IPCC, 2022b). The scientific community has reported on the significant damages that will be caused by ocean acidification (Branch et al., 2013; Doney et al., 2020; Guinotte and Fabry, 2008; Hoegh-Guldberg et al., 2017; Narita et al., 2012). Preventing those will require storage over tens to hundreds of thousands of years to match the timescales of calcium carbonate reaction and the silicate rock cycle (Archer et al., 1998; Archer and Brovkin, 2008).

The urgency of the climate crisis is such that nations must deploy carbon removal at scale within the coming decades (Fuss et al., 2018; IPCC, 2018). However, this goal comes with two obstacles. Activities that could provide long-term sequestration are expensive and will take time to deploy at the necessary scale. Activities available today are relatively cheap and could provide large-scale removal with the right incentives, but they cannot offer long-term sequestration in many instances. Therefore, all forms of carbon removal must be considered despite the shorter expected storage durations from some.

How this impermanence is treated is one of the core aspects of carbon accounting. One suggestion has been to differentiate carbon removal credits based on the variations in the expected storage durations. However, suppose removed carbon is to be used in a net-zero economy. In that case, it needs a ton of removal to be equivalent to a ton of emissions, and it needs to be equal across all types of carbon removal.

Various mechanisms have been proposed to create equivalence across carbon removal of different expected storage durations, for example, by selecting a commitment period, discounting short-term storage, renewing expiring credits, or transferring responsibility through time (Brander et al., 2021; Kim et al., 2008; Marland et al., 2001; Wenger et al., 2022; Whitmore and Aragones, 2022). Apart from the perpetual renewal of expiring credits and transferring responsibility, none of the other mechanisms result in a true equivalence if the timescales are not commensurate with the climate damages. Commitment periods used in standards vary between 10 and 100 years, ending the responsibility of the buyer and the storage operator after a set time, effectively deciding that a partial cleanup of carbon waste is acceptable. Discounting short-term storage on timescales of tens of thousands of years very quickly demonstrates the futility of temporary storage to tackle the carbon problem. The perpetual renewal of expiring credits was unsuccessful in the Clean Development Mechanism because buyers wanted to avoid repurchasing (Neeff and Ascui, 2009). While responsibility transfer is a promising mechanism, it is only being used for geological storage (Dixon et al., 2015). This short analysis demonstrates the durability issue of carbon removal needs to be solved adequately in carbon accounting. Because certain sequestration activities cannot provide durable storage yet must be used to scale carbon removal quickly, and because the integrity of the total sequestration effort dictates the success of carbon removal as a climate mitigation strategy, there must be a bridge between temporary sequestration activities and durable ones.

In addition to variable expected storage durations, most carbon removal is susceptible to premature carbon release. Requiring compensation for reversals, whether intentional or accidental, is consistent with carbon removal for climate mitigation. A commonly used mechanism is to reserve a certain percentage of issued credits in buffer pools to compensate for reversals during a commitment period (Gillenwater and Seres, 2011). Unfortunately, this practice fails to ensure durable sequestration. The method protects the integrity of the sequestration during the commitment period, which, as discussed, falls short of the durations necessary for climate mitigation. Moreover, if inappropriately diversified, buffers are examples of correlated risks; one forest fire could destroy the reserve. This risk means buffer pools need actuarial analyses to adequately set aside sufficient credits of adequate types to guarantee the integrity of sequestration even during the commitment period (Badgley et al., 2022a). The buffer pool must also be continuously replenished as credits are used for compensation. Continuous replenishment causes an issue of sourcing: if the credits are only set aside for the buffer as projects are developed, the buffer pool can only be replenished by a pyramid scheme. Such a system would never transition to a net-zero stage, and projects would need to continually be set up under the threat of emissions being released from storage elsewhere. How standards and certification handle the durability issue will have significant implications for the global climate goals and the well-being of future generations.

3 Accounting methodologies

A rational and prudent accounting system allows for a universal understanding that will lead to acceptance. Certification must focus on the accounting for sequestration, not capture, to gain wide acceptance. The capture of CO_2 is comparatively easy, and although one may want to check the source of the CO_2 (atmospheric vs. fossil), it will require much less involvement than sequestration. Sequestration is the activity that must be continuously maintained, monitored, and verified to build trust.

CO_2 is a colorless and odorless gas, and carbon removal moves this gas into a reservoir which is often unseen because it is underground or underwater. As a result, verification is critical to trust the system at the point of sequestration and the point of claim. Verification at the point of sequestration can cast aside doubt if it compares a measurement made by a reservoir manager against an independently measured value produced by a third party. Verification at the point of claim can cast aside doubt if it compares a measurement made by a third party against the number of credits awarded. It is essential to create a fully verifiable system. It means measurements are necessary, not models, probabilities, declarations, or scenarios. This approach will be challenging and costly for certain sequestration activities, but the research community can find measurement-based, reproducible solutions in most instances.

Allowing methodologies that rely on counterfactual scenarios and Life Cycle Analysis to account for removed carbon as the norm does not set up a verifiable system. Counterfactual scenarios are representations of an alternative world where something does not happen (e.g., there is no change in practice and business as usual continues), and one is allowed to take credit for deviating from this potential alternative reality. Because the counterfactual does not happen, it cannot be verified (Lohmann, 2005), although one can show it to be plausible using external information. While methodology development can take conservative approaches, baselines are easily manipulated (Badgley et al., 2022b; Liu and Cui, 2017). This baseline scenario is then compared to a form of Life Cycle Analysis (LCA) that estimates net removals within the boundaries of an activity.

LCAs are very useful for understanding where emissions come from in a process or comparing the efficiency across different processes of the same type of system. Despite their vast and increasing application in carbon accounting (Guinée et al., 2011), LCAs are not helpful for carbon removal accounting purposes. Three decades of research have amassed a large body of literature on the issues with LCA, some of which are particularly pertinent to carbon removal, and many remain unresolved.

The type of LCA will depend on the system being assessed (Brander et al., 2021), which is problematic when carbon removal accounting spans activities as incomparable as forest growth and direct air capture and injection in geologic formations. Furthermore, they require knowledge of elements that are known only approximately or rely on generic datasets (Plevin et al., 2013). Drawing boundaries for LCAs is a subjective yet essential part of the process (Reap et al., 2008a). The subjectivity makes LCAs easy to manipulate and inaccurate for accounting. LCAs also rely on large amounts of data that are frequently unknown or modeled, making the attribution of emissions a challenge (Reap et al., 2008b). LCAs must also make a value-judgment decision on the question of durability (Brandão et al., 2013), which has significant consequences, as discussed in section 2. Moreover, because LCAs for carbon accounting encapsulate other greenhouse gases (e.g., methane, nitrous oxide), it requires the reliance on Global Warming Potential, another unverifiable and modeled approach that makes a value-judgment on time horizons (Balcombe et al., 2018). Even with calls to switch from attributional to consequential accounting (Brander et al., 2021) (that purports to measure the change in emissions due to some action), some of these problems persist. For example, consequential accounting cannot produce definitive quantitative estimates of actual outcomes (Plevin et al., 2013), a clear issue if carbon accounting is verifiable. The complexity, expense, and time necessary to perform an LCA make it a poor candidate as the tool to account for carbon removal.

Accounting methodologies that rely on counterfactuals and LCA often request that estimates be made conservatively (Gustavsson et al., 2000). Conservative estimates should always be the right approach when accounting for crediting purposes. Yet, what determines conservativeness can be challenging to assess when many factors are impossible to validate. By relying on counterfactuals and LCA, the market trades credits of removed carbon that it cannot verify. This approach to carbon accounting does not create a trustworthy industry.

4 Mixing carbon with other problems

The climate change problem is a development issue. However, it has become a development issue because the world has failed to act on the root cause of climate change. The world has allowed energy generation to release emissions, either by failing to develop other energy sources or by failing to hold fossil fuel sources accountable for environmental clean-up. The world may have been naïve about the carbon problem three decades ago; it cannot make that claim today. Focusing on carbon will simplify climate action. Creating a more equitable world by focusing on sustainable development goals in carbon accounting standards is admirable but misplaced. To accept the conclusions of the IPCC reports is to accept the severity of the climate impacts. A world that does not seriously start managing carbon very quickly will be a world where safeguards and a focus on sustainable development goals will no longer hold much weight. Carbon accounting must tackle carbon to mitigate the climate crisis, not co-benefits or sustainable development goals. Those additional critical efforts must occur in tandem, but not at the detriment of getting right the carbon accounting that will support the system the world needs to reach net zero.

Some customers may wish to pay a premium for carbon credits if they come with certain co-benefits and enhance sustainable development. Flagging out those differentiating features may therefore be a worthy endeavor. Still, it does not substitute for a well-designed accounting system that ensures carbon emissions have been durably removed. Carbon accounting requires credible, stringent rules to produce credits that represent what they say they are. Credits represent a guarantee that carbon has been durably removed from the environment and that the process by which this is accomplished satisfies all applicable safety, environmental and ethical standards as they would in any other industry. Embellishing shoddy and cheap carbon credits with attractive side benefits leaves the purchaser open to a charge of greenwashing. Bundling quality carbon credits with other products that do not easily find purchasers is unlikely to advance the rapid introduction of carbon credits. Indeed, the current high cost of trustworthy carbon credits would suggest that selling such a bundle at a premium is hard.

5 Policy decisions

At the core, many carbon accounting issues are policy questions that have yet to be sufficiently debated in the public sphere. The questions are:

- Is the accounting for and verification of carbon removal a valuable part of achieving net-zero emission goals?
- Is it acceptable to give credit to something that was not proven with measurement?
- Is it acceptable to discount the wellbeing of future generations?
- Is it acceptable to hold the carbon producer only partially accountable?
- Is it acceptable to pay others to do something that they should do anyhow?
- Do we want a definitive solution to climate change, or let climate change remain an ongoing crisis?

These are serious questions about preferences that will have long-term consequences. Methodologies of carbon accounting will embed the decisions to these questions. It must be clear to all who will benefit, who will pay, and who will decide. The world depends on carbon removal to succeed as a climate mitigation solution, and success starts with a solid framework that evolves from addressing the root of the problem.

6 A framework for carbon removal accounting

For the certification of carbon removal, there are two critical issues. First, a certificate of sequestration deals with carbon removed and either stored permanently or in the case of short-term storage, including the reservoir manager's liability for any carbon lost from storage (Arcusa and Lackner, 2022). This view, of course, means that monitoring and verification become critical. Permanent in this context means "as long as the climate impact of carbon would last" (Arcusa and Lackner, 2022). At a minimum, this is a few thousand years. One ought to accept that carbon in the ocean is also a problem, then the time scale is measured in tens of thousands of years. The required storage times far exceed human ability to create institutional safeguards against losses from storage. Therefore, it becomes necessary to have a scientific consensus that the probability of loss from a storage system over such time scales is small enough to eliminate most of the risk of harm associated with the amount of carbon stored.

That awareness creates several categories of storage options. Short-term methods like products and biomass would require an ongoing chain of obligated remediation (i.e., storage of carbon released from storage). Midterm methods such as biochar are far too long for institutional means of guaranteeing re-sequestration when needed but still too short to prevent handing the climate problem to future generations. And certain methods can be scientifically verified as thousands of years, such as mineralization. To issue a certificate of sequestration to a method, it must show a long-term obligation either through convincing evidence of permanence or the reservoir manager has a firm obligation to re-sequester once the carbon escaped.

Second, the best way to deal with the carbon problem is to demand a certificate of sequestration the moment the carbon comes out of the ground (Lackner et al., 2000; Allen et al., 2009). Carbon should not percolate its way through the supply chains, which makes it virtually impossible to account for it, and instead, people should be held accountable at the point of extraction (Lackner and Wilson, 2008). If the carbon is cleared the moment it comes out of the ground, LCA is unnecessary to figure out who is responsible for what. All carbon captured from the air, the surface ocean, and anthropogenic point sources would qualify for generating new certificates of sequestration. A power plant could generate 90% of the certifications it will need to purchase tomorrow's fuel by capturing CO_2 from the plant. The rest, the fuel producer, will have to buy from other people.

Instead of an LCA, direct measurements are necessary. Each carbon reservoir would need specific equipment and sampling plans. Still, all accounting methodologies would need to meet a set of requirements: methods must exist to delineate the boundaries of the reservoir, quantify the addition of carbon to the reservoir, quantify the changing carbon content of the reservoir at reasonable intervals in the future, and quantify the error bars and uncertainties of the associated measurements. The benefit of measurements is that they can be verified by a third party, providing proof that can stand up to scrutiny. Auditors, paid by a public agency that collects fees from auditees, could check their measurements of the reservoir content against the reservoir manager's claims providing assurances for the reservoir manager's insurance, investors, and clients.

There would be a transition in this model as the carbon removal industry ramps up. However, the liability to match all extracted carbon with removal should begin as soon as possible, ideally today. With such a policy change in place, fossil fuel extractors would purchase certificates of sequestration and futures that commit right now to the removal of the extracted carbon at a prescribed future date. If one can prove removal capability, one should be allowed to sell futures (in lieu of certificates) that come due in a staggered phased-in timeframe. This would make it possible for society to start demanding carbon neutrality now and build carbon removal capacity with a proven future market.

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