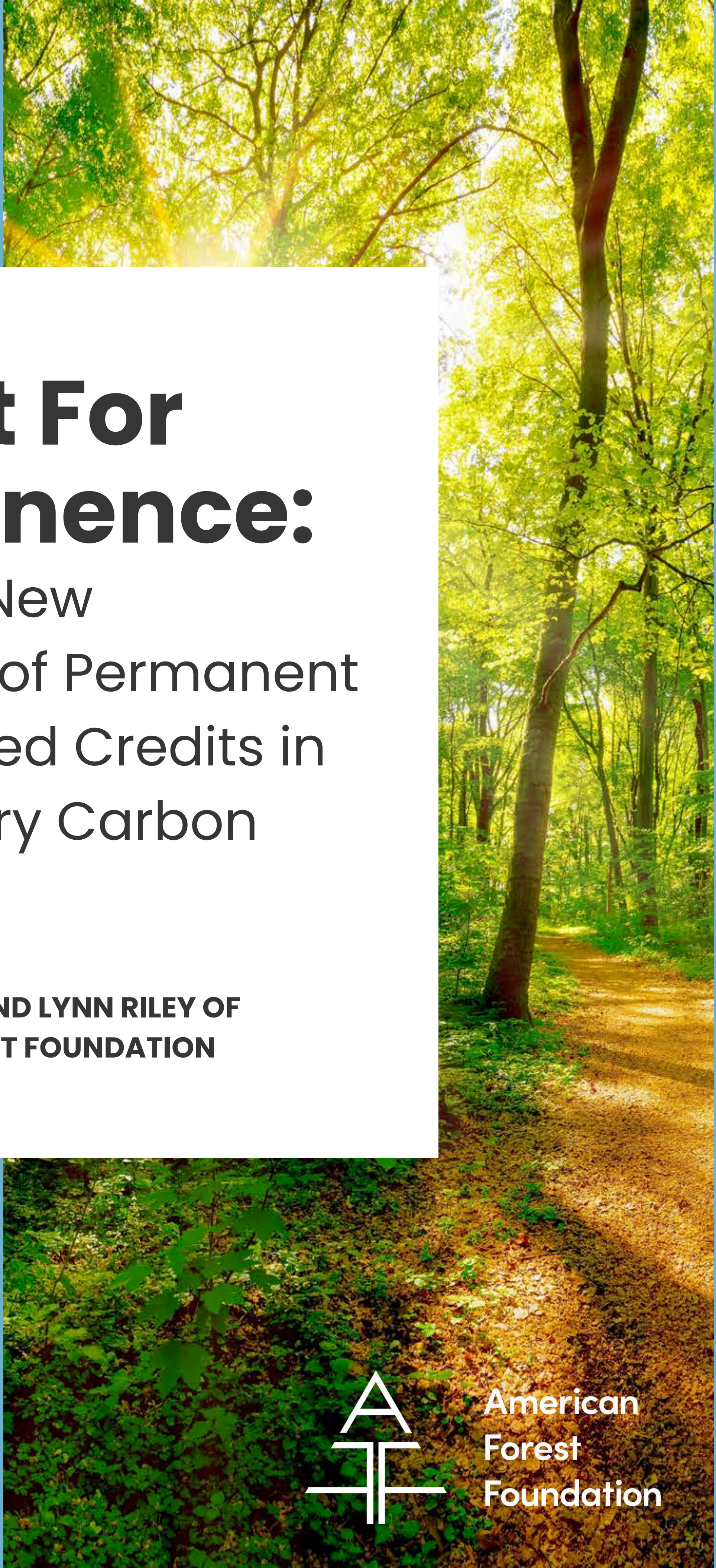
A Trust For Permanence:

Enabling a New Generation of Permanent Nature-Based Credits in the Voluntary Carbon Market

BY NATHAN TRUITT AND LYNN RILEY OF THE AMERICAN FOREST FOUNDATION



American Forest Foundation

Abstract

Natural Climate Solutions (NCS) protect, restore, and manage ecosystems to create climate and other benefits, presenting a significant opportunity for meeting global climate mitigation goals. Where NCS are used to address unabated emissions – for example, when buyers in the voluntary carbon market (VCM) purchase and retire a carbon credit to "offset" their unabated emissions —the persistence of the emissions benefits those credits represent (e.g., their "permanence") becomes critical to their value for buyers and atmospheric integrity. We propose design criteria for ensuring permanence of NCS outcomes based on our experience as an NCS implementer, a participant in standards development, and a seller of NCS outcomes. With a focus on forest-based NCS, we reviewed current methods for NCS permanence and found that none meet our design criteria. By looking at other socioecological institutions that have lasted millennia, we propose a novel method for ensuring NCS permanence that meets the design criteria: the Permanence Trust.

Unlike existing models that attempt to predict how much climate mitigation to set aside today to make up for non-permanence centuries in the future, the Permanence Trust instead relies on models that suggest how many financial resources should be set aside today to grow and be actively used to manage non-permanence risk through monitoring of carbon stocks, prevention of carbon stock degradation, and compensation for observed reversals through the retirement of permanence liabilities via geologic storage. This approach will allow people and forests to adapt as needed over the coming centuries while maintaining the resources necessary to sustain credited climate benefits, create clear and sustainable liability for NCS permanence, and, for the first time, align the price of an NCS outcome with a clear and meaningful assurance of permanence. We note challenges to this approach and seek interested partners in its further development, piloting, and feedback.

Introduction

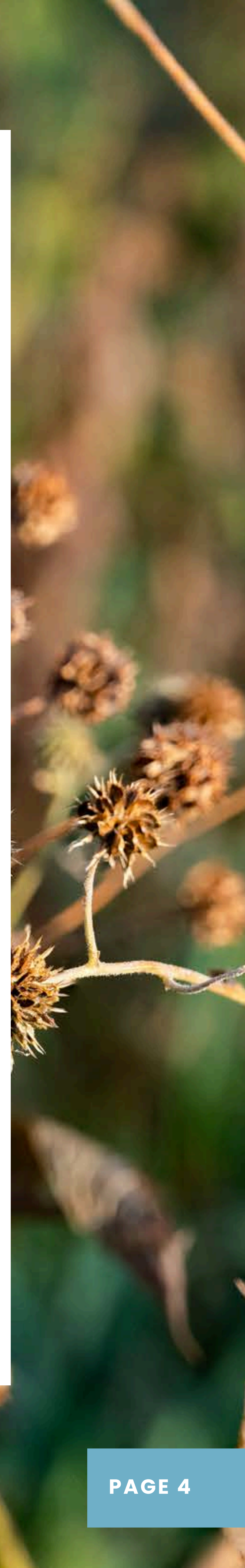
Natural Climate Solutions (NCS) that protect and restore ecosystems to create climate and other benefits are essential and accessible pathways for a chance to remain under 1.5 or 2°C of warming above pre-industrial temperatures, as set out in the Paris Agreement. Credible NCS ensure the durability of their claims (Ellis et al, 2024), that is, whether and for how long the climate benefit persists. As carbon markets have emerged as a critical funding pathway for NCS, and carbon credits sold within such markets may be used to offset greenhouse gas (GHG) emissions that last for millennia in the atmosphere, the required length of acceptable durability essentially becomes "permanence."

Assured permanence is one of several key assumptions—including additionality, leakage, equitable benefit sharing, and others—underpinning the role of the voluntary carbon market (VCM) in addressing climate change: that carbon credits represent a CO2 emission reduction and/or CO2 removal that is equivalent to the emission for which the credit serves as compensation (Zickfield et al., 2023). The market has come under sustained public criticism due to some credits that lack this equivalence (e.g., West et al., 2023), either because they miscalculatetheir climate impact or because the GHG emission reductions and/or CO2 removals they represent do not last long enough to compensate for an emission, which can persist in the atmosphere for hundreds if not thousands of years (Zickfield et al., 2023). Mechanisms to ensure some level of permanence are found within carbon crediting standards, but an increasing body of evidence points to the fact that most credits issued in the VCM lack adequate assurance of permanence (Anderegg et al., 2024). This is especially the case with NCS credits, which face, in the words of the Integrity Council on the Voluntary Carbon Market's (IC-VCM) Core Carbon Principles (CCPs), a "material risk of reversal." Various disturbances – wildfire, development, pests and disease, drought, and others – could reverse the carbon stocks that inform the measured climate impact of an

Introduction

NCS credit long before the fossil fuel emission for which the credit served as compensation has left the atmosphere.

These concerns regarding the risk of reversal for nature-based storage have led to an explosion of interest in technological innovations that remove CO2 or other greenhouse gases from the atmosphere and store them in geologic reservoirs. These projects are subject to a much lower risk of reversal. However, there are at least four challenges to relying solely on them in the context of climate change: first, they are costly, and while it is reasonable to expect the costs of such innovations to drop as they reach commercial scale, the cost “floor” for such technologies will likely remain extremely high relative to that of NCS (NewsRx Science 2024). Second, the growth of such technologies is not occurring at a pace sufficient to meet the need for immediate removal of atmospheric carbon dioxide at an unprecedented scale (Zhang et al., 2024). Even the proponents of such technologies do not propose scenarios in which technological removals can generate more than a gigaton of removals on an annual basis by 2030, while pathways to achieving the Paris Agreement require 3.5 – 5.4 Gt of annual CO2 removals by 2030 (Smith et al, 2024). Third, de-prioritization and delays in NCS could further decline natural ecosystems’ ability to sequester and store CO2 as a sink into the future (Rogelj et al., 2013; Ke et al., 2024). Fourth, and perhaps most importantly, these innovations do not provide the other benefits of nature-based interventions, such as avoiding emissions by protecting existing biogenic stocks. Preventing emissions from the degradation or destruction of biogenic carbon stocks is a much more effective mechanism for limiting warming than the removal of such emissions once they have already occurred (Solomon et al., 2009), in addition to numerous other socioeconomic and ecological benefits that are critical to local communities and landowners who live in and steward these ecosystems. NCS can promote soil quality, water quality, biodiversity, clean air, ecosystem resilience, adaptation, climate-smart products, and sustainable and diversified incomes for local communities, among other benefits.

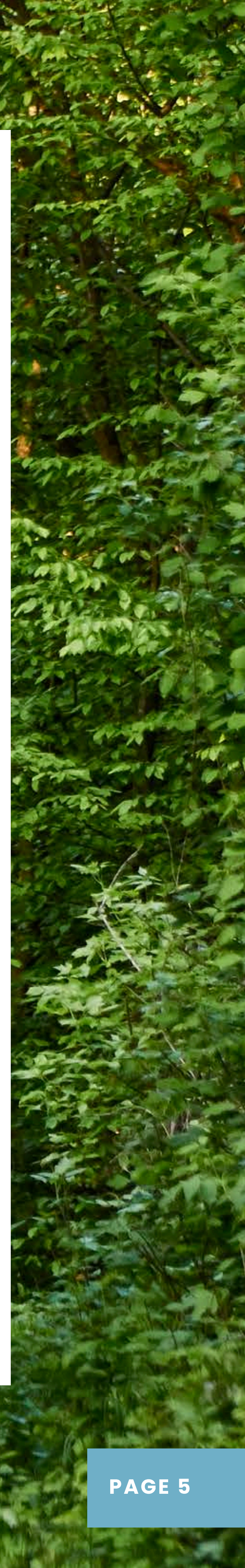


Introduction

In short, despite their advantage regarding the question of permanence, and acknowledging the clear role such innovations will play, it is not possible to rely solely on technological removals to provide climate mitigation at the pace and scale required. As the Intergovernmental Panel on Climate Change (IPCC) demonstrates, we need an “all-of-the-above” strategy that includes nature-based interventions to avoid biogenic emissions, nature-based removals, and technological removals to have any chance at limiting warming to 1.5 or 2ºC over pre-industrial levels.

Because NCS projects are critical, because carbon markets – both compliance and voluntary – provide the most immediate and feasible mechanism for funding NCS interventions, and because those markets require a robust assurance of permanence, permanence for NCS must be addressed as part of our collective efforts to mitigate climate change.

We aim to offer a new path for addressing the permanence of the climate impact generated by NCS. It is based on the American Forest Foundation (AFF) 's work to imagine a novel permanence solution for NCS projects. That work has been informed by AFF’s collaboration with the IC-VCM on permanence through a summit on the topic hosted by Cambridge University and the subsequent Continuous Improvement Work Program (CIWP) on permanence. It has also been informed by our on-the-ground work with the more than 900 individuals and families who have enrolled in the Family Forest Carbon Program (FFCP), a carbon project designed by AFF, and by our 80-plus-year history working with multigenerational ownerships of private forestland throughout the United States. Finally, it has been informed by hundreds of conversations on permanence with climate scientists, financial investors, government agencies, project developers, auditors, verifiers, non-governmental organizations, etc. While many of these conversations have been with international stakeholders, we note that our proposed design was built in the context of U.S.-based improved forest management (IFM) and afforestation, reforestation, and revegetation (ARR) carbon projects, and we



Introduction

would benefit from future work with more stakeholders to ensure our concept's applicability to broader contexts.

This paper is divided into five sections: in section one, we examine the issue of permanence as it applies to NCS projects, assessing the extent to which such projects are truly subject to the "risk of reversal" and suggesting that non-permanence is not a foregone conclusion but rather a risk that needs to be managed. In section two, we briefly summarize the existing approaches to managing non-permanence risk among actors in the VCM and the strengths and shortcomings of those approaches. Section three clarifies the goal for any permanence solution and briefly discusses why that goal is important. In section four, we introduce the concept of the Permanence Trust, summarize the potential benefits of such an approach, and provide an illustrative example of how the concept might work. In section five, we name the challenges to this approach and outline the next steps to developing this concept. In our conclusion we invite a broad range of partners to join us in deciding what will come next.

Forests have been a part of the earth for approximately 385 million years (Barras 2019) . To the extent that there is a limitation to how long a forest – or any other natural system – can store CO_2, it is a failure of our imagination to think about how to manage and support such systems. This paper aims to reimagine our approach and in so doing unlock the power of NCS projects as a cost-effective and **permanent** climate solution.

Part One: Risk of Reversal

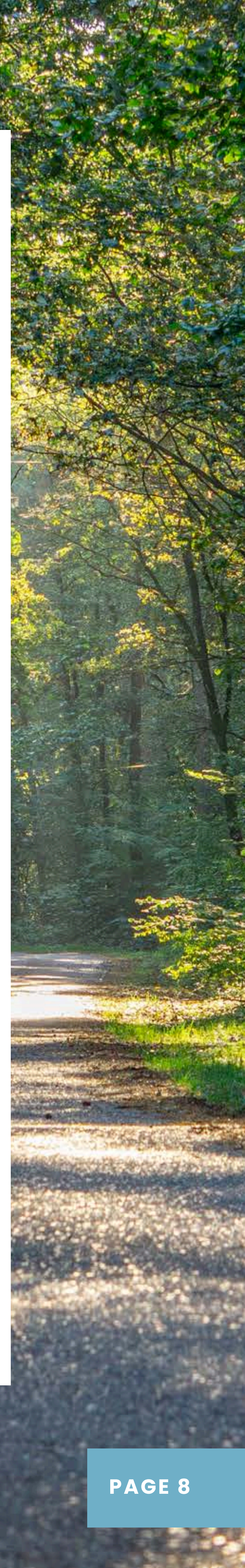
Forests and other natural systems are subject to disturbances that can cause the release of CO_2 or other GHGs stored in those systems into the atmosphere. Concern over the risk of reversal faced by NCS projects is based on the realization that it is difficult to assure that a natural system storing carbon as part of a carbon project won't be subject to disturbance after the project is completed and won't subsequently release CO_2 back into the atmosphere. This assurance becomes especially challenging when evaluating timescales comparable to the duration that CO_2 from fossil fuel combustion remains in the atmosphere. Many forests have typical rotations or successional cycles lasting decades to centuries (Bauhus et al., 2009), while emissions can remain in the atmosphere and cause warming for millennia. Here, we define permanence as the durability of credited CO_2e benefits for at least 1,000 years. In other words, true permanence for NCS is the maintenance of credited climate benefits for at least 1,000 years (Brunner et al., 2024) from when the benefit occurred. A loss of permanence occurs when a eversal occurs, which we define as any instance in which the amount of CO_2e stored in a project's reservoir (defined by the project boundary) falls below the reservoir's pre-project amount plus the amount credited to that project at any time within 1,000 years from the time the credited benefit occurred. A reversal occurs even if regrowth makes up for it later.

Put simply, we cannot reasonably expect that a particular natural system will not be subject to reversal over the next 1,000 years. However, just because a natural system *might* be subject to reversal does not mean it *will* be. In addition, not all disturbances result in a complete reversal of credited climate benefits, and many of those that do will also experience regeneration or other management interventions that mitigate the extent of the reversal. Discussions that omit these observations overstate the non-permanence risk to natural systems.

We propose that the risk of non-permanence posed to natural systems by disturbance is overstated. While every year, forests or other natural carbon sinks burn in wildfires, are cut down to facilitate land use change, suffer pest and disease outbreaks, or are damaged by hurricanes or other severe weather events, the much greater portion of natural systems, by orders of magnitude, remains undisturbed and continue to sequester and store carbon. Globally, forests store 600 Gt of C and can store an additional 217 Gt using NCS (Mo et al., 2023), including 4 Gt CO2e of regrowth annually (Allen et al., 2024). By comparison, in 2023, emissions from wildfires were "only" 2.17 Gt CO2 (CAMS 2024) – not enough to counterbalance annual forest sequestration and far less than the total storage capacity of forests.

Therefore, the concern over the permanence of carbon storage in natural systems must be framed as a concern over the *risk* of reversals rather than *certainty*. Furthermore, that risk is not equally spread across geographies. Wildfire, one of the most frequently cited examples of non-permanence risk, is a persistent risk in some geographic regions (such as the Western United States) and a less severe risk in others—a risk that will change over time.

Furthermore, some misconceptions about reversal risk stem from misunderstandings of how reversals are defined within a carbon accounting framework. Since carbon markets account for climate benefits at a project level, reversals must also be accounted for at that level. Just as carbon credits are issued based on the net carbon gains within a project area—not just the best or highest-performing areas—reversals occur only when net losses are within that area, not when analyzing particular sections in isolation. Put simply, "there can be transience at the scale of individuals, and permanence at the scale of a collection of individuals" (Harmon 2001). As forest-based NCS projects enable long-term changes to, or protections against, landscape-level disturbance regimes (for example, enabling more sustainable harvest norms), carbon stores within the forest can be reliably increased even amid stand-level flux (Harmon 2001). This is important because many NCS projects cover a significantly large area, which itself provides a degree of inherent risk mitigation due to size alone. Assuming that any disturbance within a portion of the overall project area automatically constitutes a reversal mistakes the part for the whole.



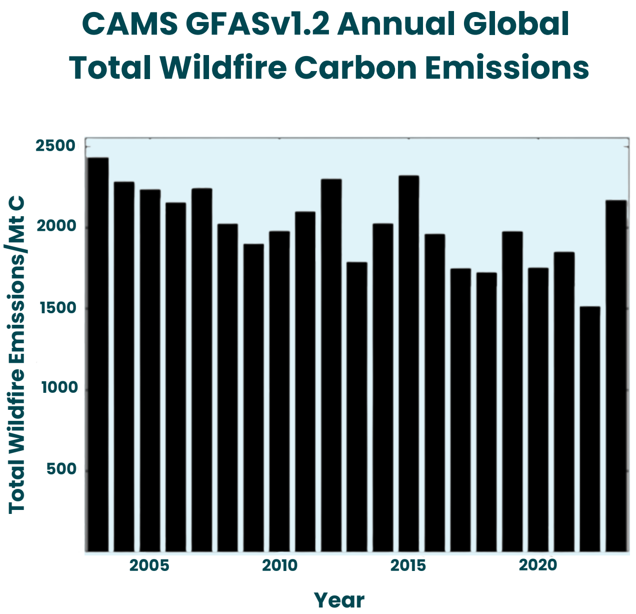
Part One: Risk of Reversal

That said, some disturbances could cause reversals even at the project level, even in projects large or geographically distributed enough to mitigate against disturbance-related risk. Consider mega-fires in the Western U.S.— it is possible for a fire of such a scale and intensity to burn an entire project area or at least enough of an area to trigger a reversal under project-level accounting (Anderegg et al., 2024). Some studies already warn that large wildfire emissions in U.S. project areas could exceed the capacity of current permanence mechanisms, leading to potential insolvency (Badgley et al., 2022). Furthermore, many disturbance regimes are expected to intensify under the impacts of climate change. Wildfires, drought, pest and disease outbreaks, severe wind storms and weather events are all projected to increase dramatically, even under a 1.5-degree scenario (Seidl et al., 2017). In addition, increased demands for food and fiber to support a rapidly growing global population could accelerate the degradation of natural systems (Bousfield et al., 2024).

Although disturbances are expected to increase, and the drivers of human disturbances like deforestation may also increase, there are reasons to believe that increases in the risk of these disturbances will not necessarily result in significant carbon losses (of course, human, infrastructural, and economic losses of the sort in Los Angeles in early 2025 might indeed increase as the interaction between natural and human systems becomes increasingly fraught). For instance, technological advancements have already improved our ability to manage forest disturbances and will continue to improve. In recent years, we have seen significant improvements in our knowledge of wildfire behavior, the ability to target and conduct hazardous fuel treatments, early warning systems, as well as advancements in prescribed fire and its potential to create resilient forest landscapes, fire-adapted species, and rapid response strategies to limit carbon damage from megafires. Many of these advancements merge Western applied science with Indigenous knowledge and practices (Eisenburg et al., 2024). Although these advancements have yet to fully counteract the increasing

risk posed by climate change and past forest management decisions (Eisenburg et al., 2024), they are already helping to reduce the carbon impact of wildfires. In a world in which the incentives to reduce emissions continue to increase, it is reasonable to expect that these innovations will improve over time and that, therefore, the carbon loss from wildfire or other disturbances will be less than anticipated given our current level of understanding and technology, just as human longevity has continued to increase, on average, despite the dramatic increase in the rates of cancer. As support for this admittedly optimistic view, here is a chart depicting global annual emissions from wildfire from 2003 to 2023.

Figure 1. Source: CAMS 2024



Similarly, human-driven disturbances could also decline over time. As companies face growing pressure to decarbonize their value chains, and as guidance for reporting on biogenic emissions and removals within a corporate emissions inventory become more rigorous, it is reasonable to expect that government and private sector actors are likely to take greater action to mitigate the impact of natural degradation within their footprint. For example, policy changes in the Amazon regarding beef and soy production, alongside increased international scrutiny of business operations in the region, have already reduced deforestation rates (Levy et al., 2023), a trend we can expect to continue.

If this section seems overly optimistic, consider recent critiques of NCS carbon projects. Over the past few years, many scientific and journalistic organizations have published critiques of specific NCS projects. Many of these critiques have analyzed the counterfactual baselines used by those projects and found that they **overstated** the projected losses that would have occurred absent the project or activity, resulting in over-crediting. In other words, they found that *actual carbon stock loss on the landscape was* f*ar less prevalent than those project proponents had predicted.* Now, apply that finding to this question. If it is indeed the case that actual, observed carbon stock loss occurs at a slower rate than that assumed by exercises that start from a set of assumptions about stock loss and project those assumptions into the future, does it not follow that carbon stock loss is likely a rarer event than we might otherwise assume? And is there any reason to believe that the same dynamic will not persist into the future? Put another way; it is somewhat challenging to find the kind of large-scale, systemic stock loss that would constitute the gradual reversal that many critics of the non-permanence of NCS take as a given. At the very least, this should make us wary of accepting at face-value predictions that such large stock loss events will be unavoidable in the future.

The purpose of this section is not to argue that NCS projects will never experience reversals. Reversals and disturbances will occur, especially over extended timescales subject to as much unpredictability as 1,000 years. We do not claim that we should not worry about reversals. Instead, the *way* we think about reversal matters.

We propose the following principles:

1. Reversals at the project level *may* occur but are not *inevitable*-they should be managed as a *risk*, not a certainty.
2. The risk of reversal varies by project, geographic location, size, and design.
3. Most NCS projects can manage reversal risk effectively.
    a. Common analytical mistakes include:
        i. Conflating carbon loss in a subset of a project's area with a project-level reversal.
        ii. Assuming all climate-driven increases in disturbance risk will directly translate to actual carbon loss.

By framing non-permanence as a risk to be managed rather than an unavoidable flaw, we can focus on evaluating current risk mitigation methods and improving them where necessary.

Part Two: Current Approaches to Managing Non-Permanence Risk in NCS Projects

Currently, carbon markets treat non-permanence as a risk, as the section above suggests. However, their risk management mechanisms do not guarantee permanence to market, regulatory, public, financial, and academic stakeholders . This has caused some market participants to advocate for abandoning a risk mitigation framework in favor of other accounting approaches. In this section, we first share the functional criteria we propose in a market mechanism for managing non-permanence risk; then, we summarize the current market mechanisms for NCS projects and assess their strengths and weaknesses against the necessary functions. Finally, we briefly turn to different accounting approaches proposed to eliminate the need for evaluating and managing non-permanence risk and argue that both are steps in the wrong direction.

We suggest the following core features for any mechanism to manage non-permanence risk for NCS:

Core Features to Manage Non-Permanence Risk

A. **Clear, equitable, and feasible liability for reversals**, so we know who is responsible for permanence and that they will be able to meet that responsibility.

B. **A mechanism for recourse when reversals are identified**, so we know how they will be addressed when they occur.

C. **A clear length of time is needed to define permanence** so that we know how long the liability for reversals lasts. For example, we use 1,000 years as a definition in this paper.

D. **Transparent acknowledgment and standardization of the time of assured permanence by a credit,** so we know how long an individual credit assures permanence.

Core Features to Manage Non-Permanence Risk

E. **Systems for monitoring reversals** so we know where and how many have occurred. Systems should be built in such a way that they anticipate and allow for technological improvements that facilitate better and more accurate monitoring over time.

F. **Incentives and systems not just to compensate for reversals, but also to proactively manage the risk** so that wherever possible, reversals are avoided.

G. **Mechanisms to incorporate feedback from ongoing observations into adaptive management** so that we learn what level of risk management is required. The limitations of what we know today should not limit our ability to ensure permanence to the timescale required.

H. **Scalability**, so that it does not prevent the pace and scale of NCS deployment required by the climate crisis, nor create greater complexity than already exists within the market and thus create barriers to participation.

Buffer Pools

Most carbon market standards use a buffer pool to address non-permanence risk for NCS projects. A project is assessed at each verification using a non-permanence risk tool or analysis and third-party auditors review assessments. Each standard maintains its own slightly differentiated version of such a tool, the purpose of which is to assign a risk score to each project and its issued credits based on the non-permanence risk present in the project. For example, where the project is located in a geography with relatively higher wildfire risk, the project receives a higher risk score. Non-environmental risks like financial risk and political risk are also assessed. This concept recognizes both non-permanence as a risk and the extent of that risk, which will depend on factors unique to each project. Buffer pools start to run into problems regarding what they do to address the differentiated risks identified in project risk assessments.

Part Two: Current Approaches to Managing Non-Permanence Risk in NCS Projects

Generally, the risk "score" generated by the non-permanence risk tool or analysis is used to justify withholding a certain number of carbon credits that the project would otherwise have monetized. These credits are held in a pooled buffer, along with credits from other projects, to provide what is essentially insurance against reversals. Rules differ between standards regarding how and when the buffer pool is used, and when and how a project developer is liable for replenishing it. In general, however, most standards have an architecture in which:

- During the crediting period—when projects are issuing credits—they are required to report any events of carbon stock loss that could impact previously issued credits and follow up to determine whether a reversal occurred and, if so, the extent of that reversal.
- If reversals occur that are "avoidable" (i.e., resulting from project implementation failure, such as when landowners break their contractual obligations), the project developer must replenish the full amount to the buffer pool during the crediting period.
- The buffer pool compensates for "unavoidable" reversals during this period, and the project is responsible for refilling the buffer with credits beyond what it had deposited to date. Unavoidable reversals would include natural and human disturbances beyond the project developer's reasonable control. If an unavoidable reversal exceeds the project's total buffer pool deposits, the project is responsible for making up the difference.
- Once the crediting period is complete, any remaining credits in the buffer pool are typically canceled under the assumption that these credits should cover future reversals up to a specified date in the future. For example, Verra's buffer pool is designed to cover reversals for 100 years from the date of the non-permanence risk assessment.

This system has three significant challenges. First, the assignment of liability for risk and the responsibility for monitoring and reporting reversals are unclear and sometimes even within standards, causing market confusion. The best example is the diversity of approaches to setting the "crediting period" and its relationship with the "project longevity period." Most standards place liability for reversals—in terms of requiring buffer pool replenishment in the the crediting period. However, because credits can be issued throughout the crediting period and because crediting periods vary in length between standards, it is possible to purchase a credit for which a developer has the liability to reimburse at least some reversals for **one** year (if, for example, you bought a credit issued under Verra's Verified Carbon Standard from a developer in year 39 of a 40-year crediting period). It is **also** possible to purchase a credit for which a developer has a liability to compensate for at least some reversals for **159** years (if, for example, you bought a credit issued under the Climate Action Reserve's standard from a developer in year 1 of a 100 year crediting period with a subsequent 60-year monitoring period). The market currently makes little distinction between these two credits in acknowledging their different levels of permanence assurance and their desirability or the price buyers are willing to pay. The project developer in the first case would likely have contributed more credits to the buffer pool than the second given their reduced project longevity, thus costing the project lost credit revenue; but this is not visible on registries to credit buyers looking for permanence assurance to match the permanence of their emissions. Notably, neither of these cases achieves the permanence length to match the 1,000-year bar we discussed earlier.

Second, no mechanism exists to monitor and verify reversals after the relevant project and monitoring periods. Therefore, there is no way to validate that the amount of credits in the buffer are sufficient to cover any reversals experienced. The remaining credits in the buffer are canceled, and it is assumed that the volume of canceled credits across the buffer pool, derived from the non-permanence risk tools described earlier, is sufficient. Given the decades to centuries that these buffer pools should cover and our increasing inability to predict risk as we move further back in time from the event we are predicting (Bonnedahl et al., 2022), today's buffer pools may not be able to accurately predict risk for the entire period they are expected to cover. While there could be some balancing out where some projects end up being more permanent than predicted and others less than anticipated, we do not have systems to know when these have occurred.

Third, and perhaps most importantly, even if we could solve the first problem by assigning clear liability for reversals to different actors over standardized and sufficiently long periods, and even if we could also solve the second problem by, for example, implementing a long-term

Part Two: Current Approaches to Managing Non-Permanence Risk in NCS Projects

monitoring system to identify reversals over time (as Verra is attempting to do (Verra 2022)); there is no mechanism to compensate for reversals that exceed the amount of canceled credits in the buffer pool. There is, in short, no “backstop” for claims against the buffer, and so if the monitoring system determines reversals have exceeded the amount covered by the buffer, the atmosphere suffers, and the claims underwritten by those credits—which, when used for offsetting, rely upon equivalence between the metric tonne emitted and the metric tonne sequestered and stored—are viewed as illegitimate. This is an unacceptable outcome for the atmosphere, for the companies buying the credits as part of robust net zero claims, for the stakeholders (such as SBTi) that are interested in regulating the integrity of those claims, and for people around the world who suffer from continued effects of unmitigated climate change.

Now, we need not conclude that the buffer pools *are* insufficiently stocked with credits to determine that the buffer pool system as a whole is inadequate. However, the mere possibility that they *might be* insufficiently stocked prevents us from making robust claims on behalf of nature-based
systems or providing the VCM with adequate risk mitigation mechanisms that mimic those present in traditional financial markets. Reasonable people can disagree on whether contributions to the buffer are too small or too large to cover expected reversals. As we discussed above, there is ample reason to think that the non-permanence risk to NCS projects is not as significant as is commonly understood, but that doesn’t necessarily mean the buffer pools as constituted are sufficient. Rather than argue one way or the other on this question, we should reflect on how this question demonstrates the inadequacy of the buffer pool concept. Because buffer pools work on the idea that for each credit that is reversed in the future, we have set aside an equivalent credit to replace it, for buffer pools to work, we have to believe that we have the ability to predict, with a reasonable degree of certainty, how many credits will be reversed and, therefore, how many credits will be needed to compensate for those reversals. We also must believe that the credits in the buffer used to compensate are sufficiently

equivalent to those reversed, and that they themselves will not be reversed. If this model of the future involves a low amount of reversals, the buffer pool could be sufficient; if, on the other hand, our view of the future includes a higher amount of reversals, the buffer pool will likely be inadequate. In either case, we are evaluating the sufficiency of the mechanism based on an *ex ante* (i.e., based on forecasted rather than actual results) estimate of the likelihood of reversals. There is no mechanism to adjust that *ex ante* estimate based on what *actually happens*, because, by the time the future has come into being, the decisions regarding the sufficiency of the buffer have long since been made. To be clear, any attempt to manage risk inescapably requires us to make predictions, but the particular method for compensation used by the buffer pool—in which one credit from the buffer is used to replace one credit from a project that has suffered a reversal—makes the buffer pool especially vulnerable to mistakes made in the process of predicting the future. We will return to this weakness and suggest a different approach in a later section. For now, it is enough to conclude that, due to the weaknesses outlined above, buffer pools are unlikely to provide the robust level of assurance regarding permanence needed for NCS credits to be viewed as high-integrity credits comparable to those produced hrough technological means.

Many observers and innovators, having arrived at a similar conclusion regarding the insufficiency of the market's buffer pools as a risk management tool, throw out the concept of managing reversal risk and instead propose different accounting approaches that, to varying degrees, eliminate permanence as a concept in carbon accounting. Below, we summarize the three most prevalent attempts in this direction and briefly assess their sufficiency to scale the NCS market.

Removing Permanence Requirements

The first approach is straightforward and involves removing the concept of permanence altogether from carbon accounting. In this view, if a century from now, we are interrogating long-term monitoring data to determine whether NCS credits have experienced reversals, we will have fundamentally succeeded in our quest to limit the worst impacts of climate change, so does it really matter? According to this view, the science regarding the need for immediate activation of NCS far outweighs concerns over reversal risk, making those latter concerns essentially negligible.

Although we are sympathetic to this view, we do not find this approach sufficient for scaling the market for NCS projects for two reasons. First, the science surrounding the value of temporary carbon storage clearly shows that there is a difference between temporary and permanent storage (Matthews et al., 2023), and that difference should not be dismissed lightly. For example, the integrated assessment modeling (IAM) the IPCC uses assumes that all CO2 removals are permanently stored. If residual emissions of 6 Gt CO2/year are addressed at global net zero through removals, and those removals are stored for only 100 years, the result would be an additional 1.1°C of warming by 2500, which is not aligned with the goals of the Paris Agreement (Brunner et al., 2024).

Second, key market participants—including but not limited to SBTi and other NGO stakeholders—have clearly and unequivocally rejected this view, meaning corporate buyers will likely hesitate to participate in the market if it proceeds without addressing permanence concerns.

Tonne-Year Accounting

The second approach is to eliminate non-permanence risk by accounting only for the observed duration of a carbon credit using tonne-year accounting. In this system, each year of carbon storage is treated as equivalent to a fraction of permanent storage, and the price of a credit reflects only that fraction of storage that has been observed and verified. While tonne-year accounting could support delayed or reduced peak warming (FAO 2024), there are many complex and controversial questions, including but not limited to: what the reference permanence level should be (most tonne-year systems use 100 years, not 1,000, as their reference point); whether any discount rate should be applied to account for the social benefits of delaying emissions; and whether such systems rely on the assumption that buyers will continue to participate year after year, and if so, for how long. Therefore, tonne-year credits are not equivalent to permanent mitigation. Market participants have also resisted participation in or recognition of tonne-year systems (e.g., Verra 2022), so they are unlikely to be adopted to the extent required.

Emissions Liability Management (ELM)

The third approach transfers the need to track and account for permanence from the credit producer to the buyer. Under this approach, called "Emissions Liability Management (ELM)," a buyer is required to "stack" temporary credits of various durations one after another so that, in the end, they add up to permanent storage (Roston et al., 2023). This system labels credits according to their various durabilities, and liability is strictly assigned to the buyer. There may or may not still be buffer pools, but their use is strictly limited to covering reversals during the project and/or monitoring periods. Interestingly, this idea has been developed on both the demand and supply sides in relative independence. Some supply-side actors favor retiring the term "permanence" in favor of the term "durability" and labeling credits based on their various durabilities. Demand-side observers, often academics, advocate that businesses adopt ELM systems. Although this solution neatly addresses the challenges of permanence and we will adopt key aspects of ELM in our proposed solution, it is insufficient to scale NCS because of the complexities it enforces on various market participants. Most obviously, businesses would need to develop individual systems and policies to manage their emissions liabilities, limiting market participation to corporations that can afford robust carbon management functions. Also, standards and project developers would need to create systems to assess, label, and differentiate carbon credits of various durabilties. This seems like the wrong direction for a market with a complex and fragmentary nature that already hampers its scalability. Indeed, financial and regulatory stakeholders have criticized this approach for its implementation difficulty.

Part Two: Current Approaches to Managing Non-Permanence Risk in NCS Projects

Table 1. Comparison of existing permanence mechanisms within the VCM and our assessment of their ability to fulfill the core functionalities necessary for permanence. These represent our view of the different mechanisms based on our experience thus far engaging with each. Green means the method does solve for the needed functionality; yellow means that some do and some do not; and red means that the method does not consider or solve in any way for that functionality.

Permanence Method	Clear Liability	Mechanism for Recourse	Definition and Length of Permanence	Clear Acknowledge-ment of credit- level permanence	Operational Long-Term Monitoring System	Incentive to Prevent Reversals	Scalability
Buffer Pool	!	!	!	!	✗	✓	✓
Removing Permanence Requirements	✓	✗	✗	✗	✗	✗	✓
Tonne Year Accoutning	✓	✗	✓	✓	✗	✗	✓
Emissions Liability Management	✓	!	✓	!	✗	!	✗

In conclusion, the current mechanisms for managing non-permanence risk associated with NCS credits provide insufficient assurance to enable the scaling of markets for those credits and fail to ensure that markets can scale meaningful climate mitigation. At the same time, approaches that seek to eliminate risk management entirely through novel accounting methods result in more complexity and confusion or have been rejected by a sufficiently large number of market actors, making reliance on them inadvisable.

We now turn to other potential mechanisms for managing the non-permanence risk associated with NCS credits. However, before we do, we need to discuss the level of assurance the marketplace requires for NCS to scale and create meaningful climate mitigation.

Part Three: What is "Good Enough" Permanence for NCS Projects?

Before we discuss our proposed innovation regarding the permanence of NCS credits, it is important to transparently communicate the design principles we used in brainstorming, refining, and modeling ideas. What is "good enough" for NCS credits from a permanence perspective?

There are two ways to approach this question. The first is scientific: robust scientific literature has estimated the radiative forcing associated with the storage of a metric tonne of CO2 across various timeframes. That research concludes that, under most emissions scenarios, temporary storage has a fraction of the impact of truly permanent storage (Matthews et al., 2023). Therefore, from a purely scientific perspective, permanent should mean "permanent," or perhaps, "equivalent to geologic storage."

The second way to approach this question is from the perspective of carbon credit buyers. To attract investment, NCS projects must produce credits that buyers in carbon markets value. We ought, therefore, to ask: what do buyers use credits for, and how, if at all, does permanence influence the utility of NCS credits for buyers? The proper use of carbon credits is a subject of debate (e.g., UN GCNU 2021), and some stakeholders reject the idea of carbon credits under any circumstances. On the other end of the spectrum, some believe that a "tonne is a tonne" (assuming proper accounting) and carbon credits should have equal weight to other kinds of climate mitigation, including internal decarbonization. Most stakeholders fall between these extremes, so for the remainder of this section, we will attempt to represent the current "consensus" view while acknowledging the controversial current state of discussion.

Corporate claims are evolving within a context where "net zero" is the overriding goal for global climate action (Christiansen et al., 2023). Within the context of net zero, each emission an entity cannot reduce or avoid must be balanced, or "neutralized," with an equivalent removal of CO2 from the atmosphere. For this use case, the permanence of those removals is

.

essential because the emission for which for which the removal is compensating originates from geologically stored carbon (i.e., fossil fuels). Thus the removal ought to have the same storage requirements. This aligns with the scientific perspective shared above.

Net zero as a scientific concept was developed at a *global* level and represents a scenario in which global anthropogenic removals balance global anthropogenic emissions. The Science Based Targets initiative (SBTi) has led the way in attempting to take the principles of global net zero and downscale them to the context of an individual corporation. There is some controversy regarding the extent to which this is an appropriate application of the net zero concept, not least because, unlike the planet as a whole, accounting boundaries for any entity overlap with the accounting boundaries of other entities pursuing the same net zero goal, creating confusion about the responsibility any one company bears for accounting for— and thus, eventually, "neutralizing"—an emission. However, most have accepted the net zero framework, as evidenced by the more than 1,000 companies that have committed net zero under SBTi's reaches net zero.

There is additional complexity regarding whether and how a company should address emissions on the *road* to net zero. Neither the current standard nor the *Beyond Value Chain Mitigation* guidance released by SBTi have a firm stance on whether carbon credits purchased by a company along the road to net zero need to meet any particular threshold for permanence. However, observed buyer behavior suggests that buyers strongly prefer to buy credits that meet the thresholds for credits they will eventually need to buy for neutralization purposes. In other words, for emissions on the road to net zero or un-abatable emissions at net zero, buyers would prefer that "permanence" means *permanent*.

Proponents of NCS have tended to approach the permanence of carbon credits not from these perspectives but from an understandable standpoint of pragmatism and feasibility. Through that lens, NCS carbon credits should not be required to achieve physical equivalency with fossil fuel emissions because doing so is impossible. No credible developer could design a project that ensured NCS carbon credits' permanence at this timescale. This pragmatic lens has led to the construction of buffer pools to provide "good enough" assurance.

Part Three: What is "Good Enough" Permanence for NCS Projects?

Table 2. Market stakeholder perspectives on the requirements of permanence.

Stakeholder	Perspective on Permanence Requirement for Carbon Credits
Scientists	Credits should be physically equivalent to the fossil fuel emission for which they compensate
Buyers: At or after net zero	Credits should be physically equivalent to the fossil fuel emission for which they compensate
Buyers: On the road to net zero	Although physical equivalency with emissions regarding permanence is not required (at least not yet), it is strongly preferred
NCS project implements	There should be no requirement; buffer pools and limited liability through a crediting period should be "good enough" because anything more than that is impossible

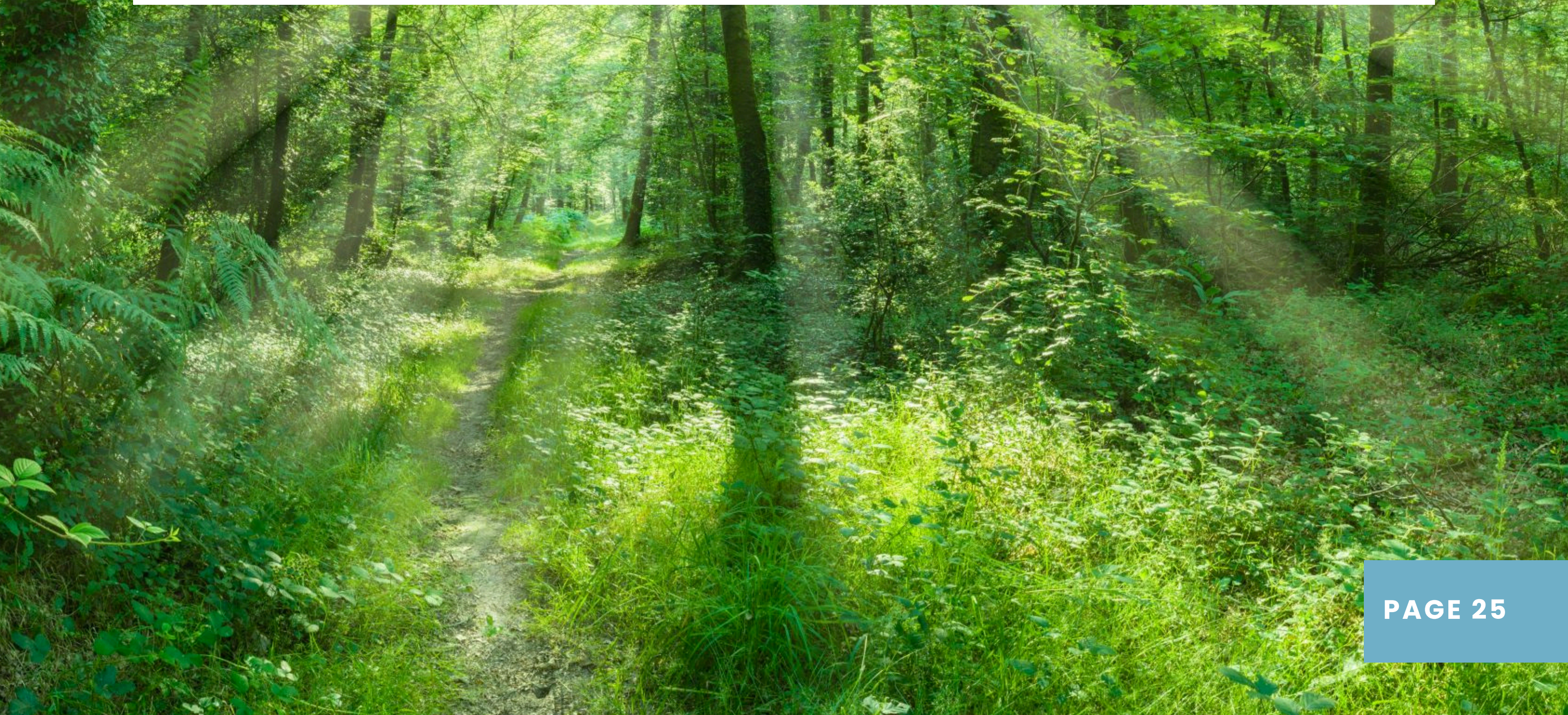
Table 2 summarizes the challenge. Whereas the scientific and buyer communities are clear in their requirement for permanent carbon credits, implementers of NCS carbon projects tend to believe achieving such an outcome is practically impossible.

This has led NCS proponents to advocate for proposals, like those that we summarize in Section Two, that seek to sidestep the issue of permanence, or to argue that, because of the multiple co-benefits of using NCS and the urgency of their immediate activation, we should agree to an admittedly lower threshold. IC-VCM, for example, received criticism regarding the first version of their Core Carbon Principles regarding permanence, in which they established 40 years as an initial minimum threshold for NCS credits (IC-VCM 2024). Notably, they were criticized from both sides, with some saying the threshold was too **low** given the scientific literature and market demands and others arguing it was too **high** and made implementing certain projects impossible. We would suggest that **both** criticisms are legitimate, reflecting the truths of differing perspectives.

Part Three: What is “Good Enough” Permanence for NCS Projects?

Those of us who advocate for the importance of NCS projects, and who view the VCM as one of the most essential tools to drive funding to critical efforts that both protect and restore natural systems must be clear-eyed in our realization that less-than-permanent carbon credits will **not meet** the needs of the expanding market. If we persist in insisting on a different and lower bar for NCS in regards to permanence, NCS will not be incorporated into the VCM at any meaningful scale, nor into evolving international and compliance schemes, like the Paris Crediting Mechanism (PCM) described by Article 6.4, which mandates features such as post-crediting period monitoring through demonstration of reversal remediation and/or that the remaining risk of reversal is negligible (UNFCCC 2024). As another example, consider the draft of the Carbon Dioxide Removal (CDR) Act in the U.S., which would offer tax credits for the production of carbon removals only if such removals “demonstrate a high likelihood of storing CO2 for at least 1,000 years” (Lebling et al., 2024). Put simply, if we want NCS to be a serious player in global climate mitigation, whether it is market- or policy-based, we have to accept that the permanence challenge is real.

At the same time, buyers and other stakeholders must also accept that NCS simply cannot provide the necessary assurance of permanence with the proposed mechanisms. Therefore, the imperative from a design perspective is to design a system in which NCS's inability to ensure permanence is reconciled with the market’s demand for it. In addition to this design criteria and the core features described in Section 2 above, other design principles that we have identified include:



Design Principles for Managing Non-Permanence Risk

- **Transparency**: any permanence solution must be subject to public scrutiny from various stakeholders, including the systems that identify reversal events and volumes.
- **Simplicity**: any permanence solution must not burden market actors with significant additional complexity.
- **Rigor**: any permanence solution must meet the most rigorous standards regarding carbon accounting and climate science.
- **Solvency**: any permanence solution must have appropriate recourse to alternative mechanisms if its chief hypotheses fail.
- **Feasibility**: any permanence solution must be feasible for market actors to implement. This includes the buyer's willingness to cover the costs of any enhanced permanence solution.
- **Efficiency**: The system should not introduce unnecessary costs, time delays, bureaucracy, etc., into the market.
- **Longevity**: the system should evolve and persist indefinitely within a changing technological and market ecosystem.

Clarity over what is required can unleash creativity and new perspectives. In the next section, we discuss the results of our internal design process. While we hope the specific solution we propose is widely accepted, just as important to us is the acceptance that these principles are the right ones. If further discussion and iteration with the community results in a wholly different solution, but one that meets these principles and functions, we will consider that an unqualified success.

Part Four: The Permanence Trust

In the summer of 2017, AFF began to explore the potential for a grouped carbon project for small landowners. For over 80 years, AFF's mission has been to achieve meaningful conservation impact by empowering America's family forest owners. Today, families and individuals own almost 40% of U.S. forests in relatively small parcels (the average size is ~30 hectares). They represent the single largest ownership group of U.S. forests, and collectively, the land they manage is roughly equal in size to the states of California and Texas combined.

We realized that climate change represented both the single greatest threat to our mission—because unmitigated climate change would degrade these forests and effectively disempower landowners—and the single greatest opportunity to fulfill it, as climate finance could be accessed to provide landowners with the technical and financial assistance they needed to implement more sustainable management practices while generating climate mitigation in the process.

Collaborating closely with The Nature Conservancy, TerraCarbon, and other partners, we designed and launched the Family Forest Carbon Program in 2020 to engage small landowners in carbon projects and access climate finance through the Voluntary Carbon Market. While fundamental for permanence, we learned early on that contract length was a significant obstacle to engaging these landowners. In general, these landowners are older and tend to feel that signing a contract that extends far beyond their own lifetime is unacceptable because it reduces the autonomy of their heirs. To make the project feasible, we had to reconcile landowners' desire for shorter contract lengths (maximum 20 years) with the requirements of the Verified Carbon Standard regarding project longevity (minimum 40 years) and the time of assessment of non-permanence risk (100+ years).

This immediately caused us to think about permanence in a fundamentally different way. At that time, project longevity—a component of permanence regarding the length of time a practice is committed to being implemented—in forest carbon projects was handled almost exclusively by syncing the length of landowner contracts with the requirements of standards and methodologies. However, to effectively engage small landowners, we were forced to think of novel mechanisms to ensure a high level of permanence without relying on commensurate contract lengths. We landed on two innovations:

Permanence Trust Innovations

1. "Sticky" Practice Design During the Contract

We used climate finance **not** to pay a landowner to do something they otherwise wouldn't, but rather to **transition** that landowner to a new mode of forest management that would be self-sustaining once the transition was made. The purpose of the finance was not to compensate a landowner for lost income from pursuing a path with lower financial returns; instead, it was to cover the cash flow gaps that arose when a landowner transitioned from reactive, short-term, unplanned management to long-term, planned, proactive and truly sustainable management.

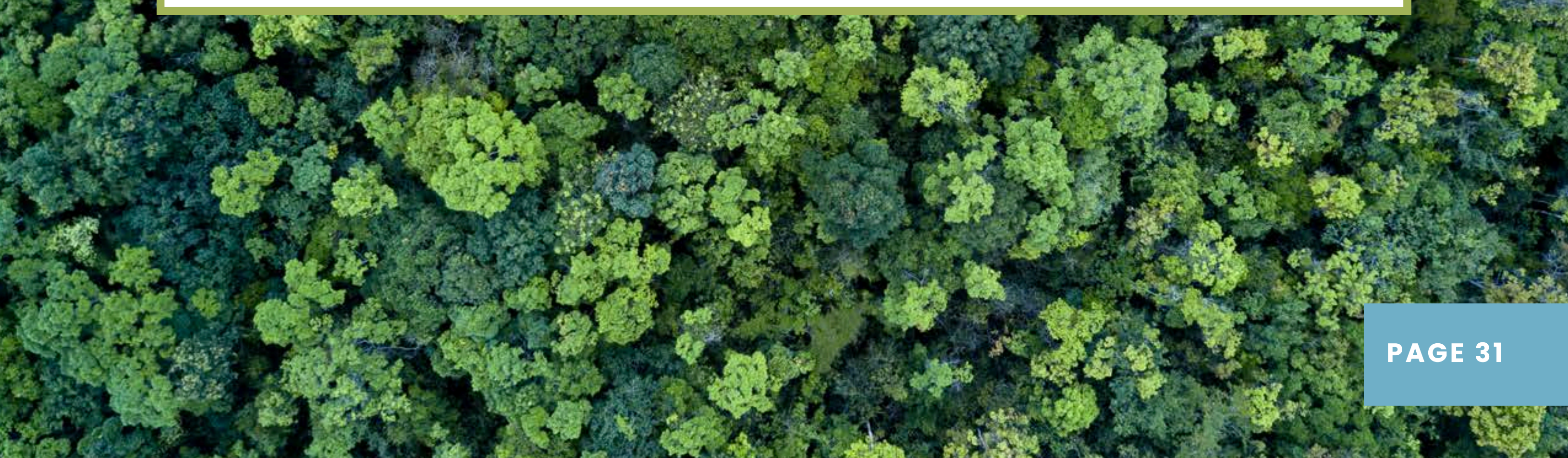
2. Encouraging Sustainable Management Post Contract

When planning for post-contract management activities, we immediately encountered a fundamental problem: we had no way of predicting what the future would look like and, therefore, what kind of support landowners would need to adapt and sustain their forests. This realization was liberating because it led us to understand that what we needed was not a specific plan but rather a pool of flexible resources to address whatever challenges and opportunities might arise in the future. The Family Forest Carbon Program's (FFCP) Permanence Fund came from this realization. FFCP puts 10% of the proceeds from selling its carbon credits into an endowment. Those funds are invested with a fund manager and grow with the market. They become available for FFCP to use as landowners' contracts expire. We arrived at the figure of 10% through modeling potential costs and a reasonable rate of return expected across that timeframe. We have set aside over $600,000 in the Permanence Fund, with many more contributions on the horizon.

permanence liability associated with that credit at some future date by maintaining the credited climate benefit on the landscape, replacing it with another temporary storage solution, and/or purchasing a removal credit with geologic storage.

To determine the size of the fee required, the Trust will create and maintain a model that includes the following core variables:

1. **The anticipated decay rate of the carbon storage associated with the issued credit:** This variable will be based on a non-permanence risk assessment. We can use non-permanence risk assessment tools developed by standards organizations, insurance agencies, and others as a starting point and refine them further.
2. **The anticipated cost of mitigating the risk of reversal through some mixture of the following:**
    a. **Monitoring** the persistence of the credited climate benefit on the landscape;
        i. Frequency of such monitoring (e.g., annual, as suggested by UNFCCC, 2024—"The calculation…shall be carried out for each year of the post-crediting monitoring period.")
    b. **Management** actions to preserve the storage of the existing climate benefit.
    c. **Replacement** of any credit experiencing a reversal event with another temporary credit.
    d. **Purchase** of appropriate insurance policies, when available, to address temporary gaps.
    e. **Eventual retirement** of the liability through the purchase of a removal credit with permanent geologic storage.
3. **The anticipated rate of return on funds invested in the Trust, net of administrative and other management fees.**



Part Four: The Permanence Trust

In exchange for this fee, the Trust will assume the liability for monitoring the persistence of credited climate benefits, engaging in management efforts to reduce the risk of reversal, and compensating for any observed reversals of climate benefits after the periods/monitoring periods required by the relevant standards have ended. This means that standards and developers retain liability for reversals during that period and may continue to use instruments like buffer pools to address this more limited liability. Through this mechanism, we can ensure that any NCS credit that is issued and participates in the Permanence Trust by voluntarily paying the assessment described above is indeed functionally equivalent to a credit representing geologic storage and, therefore, to a fossil fuel emission (at least insofar as it pertains to permanence).

The Permanence Trust takes the core idea behind **Emissions Liability Management** (see Section 2). It removes its chief challenge, the significant additional reporting and management burdens required of buyers, standards, and developers under that decentralized approach. Instead, The Permanence Trust assumes responsibility for Emissions Liability Management on behalf of all market actors willing to pay into the system – developers, standards, and buyers. Centralizing this function serves four critical objectives:

1. It simplifies the system for those actors.
2. Pooling the risks associated with the vast multiplicity of projects and credits is a potentially effective risk management tool.
3. It allows the Trust to achieve economies of scale regarding the functions necessary for Emissions Liability Management to work.
4. It creates an independent entity whose mission is to ensure permanence, thus negating conflicts of interest that arise when other market stakeholders take on this role. These roles include but are not limited to monitoring for reversals, trust management, implementation of risk mitigation activities to reduce the rate of observed reversals, strategic acquisition of and/or investment in geological removals, and risk assessment and management.

Part Four: The Permanence Trust

At its core, the Permanence Trust is an effective solution for any carbon market that wishes to issue credits to NCS projects. It forces those projects to internalize the cost of transitioning from short-term to long-term carbon storage. Currently, that cost is unknown, and as a result, different market actors treat it differently. One way to think about companies that pay $1,000 / tonne or more for technological removals is that they believe that cost to be extremely high. Companies paying lower prices for NCS removals likely believe the cost is extremely low. The truth is likely somewhere in the middle. By explicitly identifying and including that cost in the core price of a credit, we enable the market to "price in" permanence risks and more effectively allocate capital to projects with the greatest long-term impact on the climate.

A concept like the Permanence Trust has received support within the global climate mitigation and VCM ecosystem, including language in the latest UNFCCC Requirements for activities involving removals under the Article 6.4 mechanism, indicating that the "Supervisory Body will consider…Procedures for establishing, managing, and using a monetary permanence reserve enabling remediation of reversals through the direct or potentially centralized purchase and cancellation of A6.4ERs with negligible or no reversal risk" (UNFCCC 2024).

Below are three examples of how the Permanence Trust would work in practice:

1. A soil carbon project that incentivizes agricultural landowners to adopt different management practices to sequester additional carbon in agriculturally productive fields.
2. An improved forest management project that incentivizes landowners to change harvesting behavior over twenty years.
3. An afforestation project that seeks to create permanent new forest reserves.

How might the Permanence Trust price the risk of reversal differently for each project?

Part Four: The Permanence Trust

Please note these examples are illustrative and reflect no deep analysis of specific projects or project types. That kind of analysis will be a requirement for the operationalization of the Permanence Trust and is discussed in more detail in Section Five below. This section aims to demonstrate the core concepts of the Trust and how those concepts might impact projects differently.

Please also note that below, we introduce a new term, "credit liability period." The "credit liability period" is the time following the issuance of a credit during which the developer and standard maintain direct responsibility for reversals (which may be adequately managed through contracts with landowners, a pooled buffer, etc.). Put simply, this is the period during which a project developer agrees to be liable for maintaining the credited climate benefit represented by an issued carbon credit. If a reversal occurs during that period, the developer, **not** the Trust, is liable for compensation.

The table below summarizes the assumptions and results of a basic modeling exercise regarding The Permanence Trust. These assumptions should be further validated and revised in the next design phase of developing the Permanence Trust. The exercise assumes the issuance of 1,000 credits.

Table 3. Shared assumptions for initial conceptual modeling example of the Permanence Trust.

SHARED ASSUMPTIONS					
Rate of return on invested funds			6.0%		
Cost per tonne of geologically permanent storage			$150.00		
Project	Credit Liability Period (years)	Annual Decay Rate After Credit Longevity Period	Per Credit Assessment at Issuance	% of carbon benefit persisting after 100 years	Permanence Trust Balance: maximum Liabilities at Year 100
Agriculture Soil Project	10	2%	$22.26	16.6%	1.11
Improved Forest Management	40	1%	$2.43	55.3%	1.01
Afforested Nature Reserves	50	0.5%	$1.00	78.2%	1.00

In the above table:

- The **rate of return on invested funds is the expected annual** return on funds invested in the Permanence Trust.
- The **cost per tonne of geologically permanent storage** is the estimated cost of retiring one credit's worth of obligation by purchasing a geologic storage credit.
- The **credit liability period (years)** is the time from issuing a credit during which the developer and standard maintain direct responsibility for reversals.
- The **annual decay rate after credit longevity period** represents the percentage of carbon stored by the project that is released back into the atmosphere each year after the credit longevity period has ended. Note that this decay rate is applied to the carbon remaining from the project each year, not to the total amount of credits issued. For example, if 1,000 credits are issued and the decay rate is 2%, 20 tonnes are reemitted in the first year after the credit longevity period. In the subsequent year, only 19.6 tonnes are reemitted (1000-20 = 980 *.02 = 19.6).
- The **per credit assessment at issuance** is the amount the developer pays to the Permanence Trust per credit issued[MW3] [NT4] , based on a calculation of the cost of monitoring, managing, and eventually retiring the permanence obligation associated with the credit.
- The **% of carbon benefit persisting after 100 years** represents the percentage of carbon from the year of issuance that remains stored by the project 100 years after credit issuance under these decay rate assumptions.
- **The permanence trust balance:** maximum liabilities at year 100 is the ratio of the Permanence Trust's balance for the project to the liabilities represented by the carbon that has remained stored by the project.

Part Four: The Permanence Trust

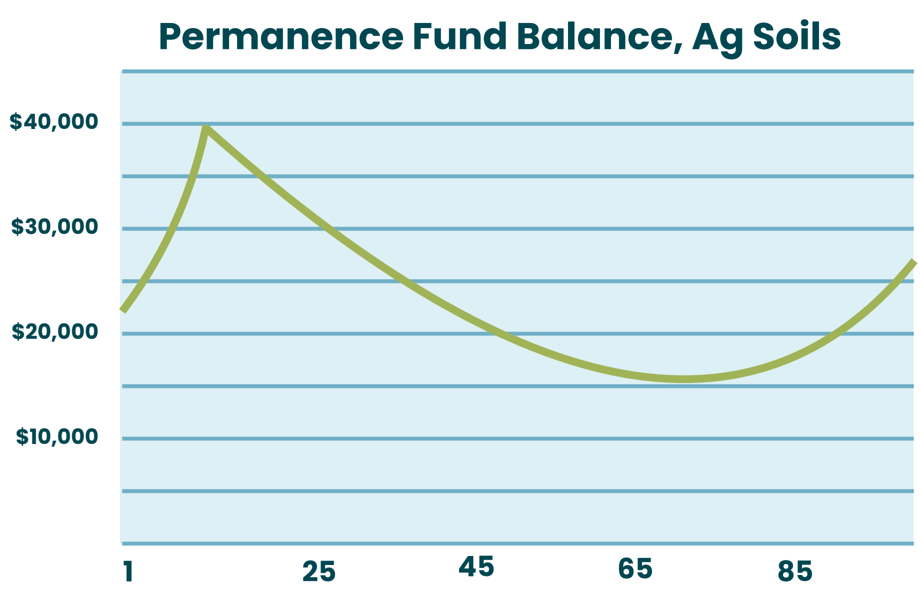
The **Agricultural Soil Project** is one in which farmers are paid to adopt agricultural practices that sequester more carbon in their soils. The project is a grouped project in which each landowner signs a ten-year contract and the developer and standard collaborate to ensure that any credit issued will be secured for a minimum of ten years.

After that ten-year credit liability period, it becomes challenging to guarantee that carbon sequestered by the project will remain because of the dynamic nature of agricultural markets and projected land ownership changes. However, the practices implemented through the project are also self-sustaining, allowing farmers to produce more consistent yields with less use of fertilizer and herbicides and with the potential for market premiums. For this reason, we suspect that carbon will decay fairly slowly from the project, at a rate of 2% per year.

Under these assumptions, to secure a guarantee of equivalence to geologic storage, a buyer must agree to pay a premium of approximately $22.26 per credit.

This would be sufficient for the Permanence Trust to pay for a credit representing additional geologic storage for each tonne reemitted at the time it was reemitted and to maintain a balance in the Trust at 100 years to fully cover remaining liabilities, even if they were all realized at once (Figure 2).

Figure 2. Illustrative Permanence Trust model for an example soils NCS project



Part Four: The Permanence Trust

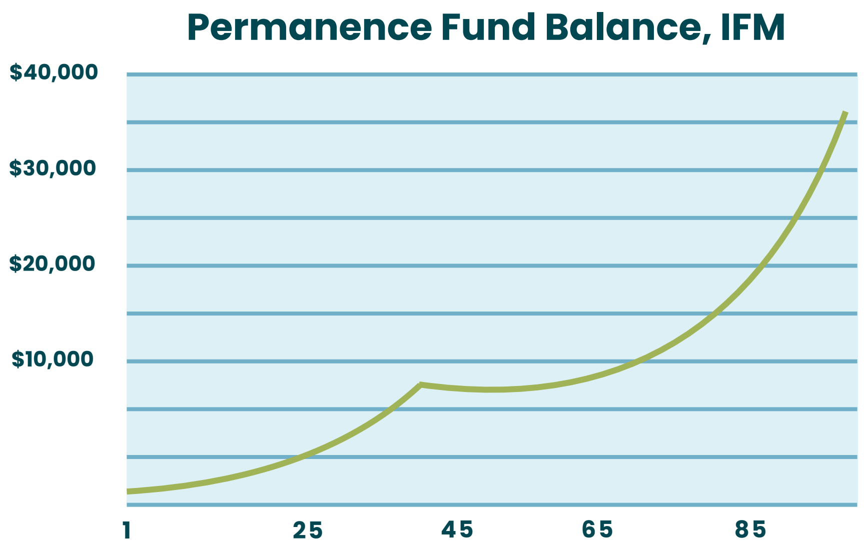
The **Improved Forest Management Project** is one in which family woodland owners are paid to adopt harvesting practices that increase the productivity of their forests over time. The project is a grouped project in which each landowner signs a twenty-year contract and in which the developer and standard collaborate, through the management of the size of the pool and through a pooled buffer, to ensure that any credit issued will be secured for a minimum of forty years.

After that 40-year credit liability period, the carbon stocks established on woodland properties will be sufficient to enable ongoing sustainable management that maintains carbon stocks while producing timber income for the landowner. Therefore, although widespread reversals are unlikely, the improved forests will be subject to ongoing physical risks and the potential for conversion to other land uses. Consequently, we suggest a more modest estimate of carbon decay equal to 1% per year.

Under these assumptions, to secure a guarantee of equivalence to geologic storage, a buyer must agree to pay a premium of approximately $2.43 per credit.

This would be sufficient for the Permanence Trust to pay for a credit representing additional geologic storage for each tonne reemitted at the time it was reemitted and to maintain a balance in the Trust at 100 years to fully cover remaining liabilities, even if they were all realized at once (Figure 3).

Figure 3. Illustrative Permanence Trust model for an example Improved Forest Management NCS project



Part Four: The Permanence Trust

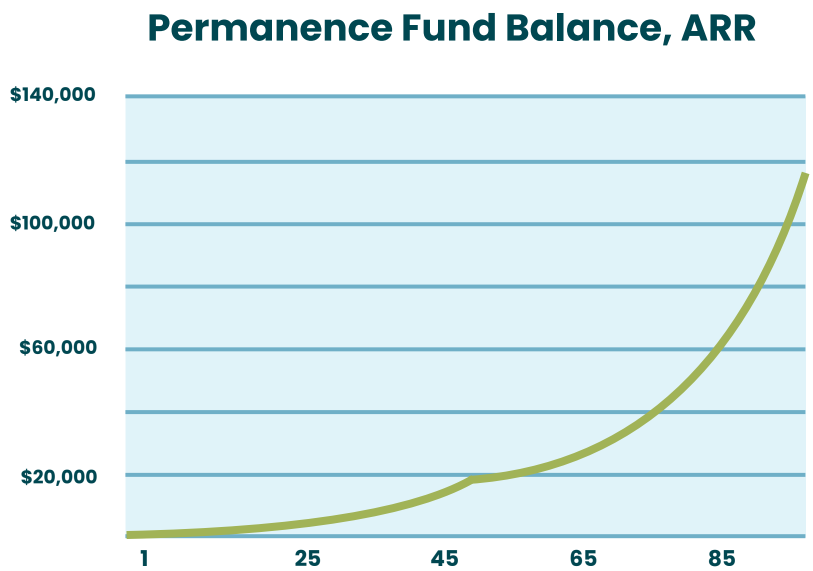
The **Afforestation Project** involves purchasing private land to restore native forests. Over time, the resulting forests are transferred to public ownership for use as nature reserves. The strong contractual agreements involved in the project give the developer and the standard confidence that any credits issued will be secured for a minimum of 50 years.

After that 50-year credit liability period, the carbon stocks established will be subject only to physical and external (e.g., political) reversal risk. Therefore, widespread reversals are unlikely, and carbon decay is estimated at 0.5% per year.

Under these assumptions, to secure a guarantee of equivalence to geologic storage, a buyer must agree to pay a premium of approximately $1.00/credit.

This would be sufficient for the Permanence Trust to pay for a credit representing additional geologic storage for each tonne reemitted at the time it was reemitted and to maintain a balance in the Trust at 100 years to fully cover remaining liabilities, even if they were all realized at once (Figure 4).

Figure 4. Illustrative Permanence Trust model is an example of the Reforestation NCS project



Although the above three examples are illustrative, they demonstrate how a Permanence Trust concept would work with and enable different project types.

Part Four: The Permanence Trust

The table below summarizes how different variables would impact the cost and viability of the Permanence Trust concept as applied to Natural Climate Solutions:

Variable	Impact on Viability and Cost of Permanence Trust
Credit liability period	The longer the period during which the developer and/or the standard is willing to assume liability for reversals, the lower the assessment for the Permanence Trust, simply because the longer the Trust has to grow the initial assessment through investment, the fewer resources it needs at the outset to cover eventual reversal risks.
Rate of return on invested funds	The higher the projected rate of return, the lower the assessment required by the Permanence Trust because the funds assembled in the Trust grow faster. Therefore, the time necessary for them to grow to cover liabilities is shortened. There is likely a minimum threshold for returns below which the Permanence Trust becomes a non-viable solution.
Carbon decay rate	The higher the carbon decay rate after the credit longevity period, the higher the initial assessment for the Permanence Trust, because the Trust must cover more reversals quickly. Projects with an extremely high carbon decay rate would demand such a high assessment that it may make the resulting cost per issued credit too high for buyers to contemplate. Because of the difficulty of accurately predicting carbon decay rates, there will likely need to be a floor for this value below which no project is assessed.
Cost per tonne of geologic storage	As the projected value for the geologic storage cost rises, so does the projected assessment for the Permanence Trust. The opposite is also true. If the costs of geologic storage are extremely high, the Permanence Trust is likely not a viable solution.

One of the benefits of the Permanence Trust is that, by forcing projects and their buyers to fully internalize the cost of permanence, it provides a powerful incentive for projects to develop more durable designs.

A project with a short credit liability period and high carbon decay rate will not be able to utilize the Permanence Trust because it cannot afford to internalize the actual cost of permanence; conversely, a project with a long credit liability period and a low carbon decay rate will be subject to a minimal Permanence Trust assessment and will easily internalize the true cost of permanence. This effect of the Permanence Trust is one of the strongest arguments in its favor because it will lead to higher-quality projects that are more sustainable and better at maintaining biogenic carbon stocks for longer periods.

Part Five: Challenges to the Permanence Trust and Next Steps for Development

Although we believe strongly that this approach to ensuring the equivalence of an NCS credit to geologic carbon storage has many benefits, there are some challenges we must consider.

The first challenge is how such a Trust would become established in the marketplace and how standards would need to evolve to accommodate it.

This raises several questions:

- Would contributions to the Permanence Trust be mandatory or voluntary?
- If voluntary, who would decide whether or not to participate? A project, a standard, or a buyer?
- How would standards manage the transition from the concept of project longevity to the concept of credit liability, which is a necessary prerequisite for the Permanence Trust to function?
- How will definitions of Permanence and Reversals solidify, and should/will they align with those proposed in this document?
- Regarding the Credit Liability Period, who would set it? Would there be minimums? Would all projects be required to meet a minimum or standard Credit Liability Period? If not, how would credits with differing liability periods be identifiable?
- How would the Trust's reversal liabilities and compensations be accounted for within NDCs, which may or may not have included land-based mitigation in their initial NDCs at the time of removal or reduction, but may have expanded their NDCs to include the land-based sector by the time reversals occur? This temporal imbalance would need to be addressed to ensure compatibility between markets and NDCs

These are all critical questions. However, we feel they could be addressed by the broader market if and when there is a consensus that such an institution is needed. We hope to take the first step to establishing such a consensus through piloting the Permanence Trust concept (see below).

The second challenge to the Permanence Trust is the legal structure of the Trust itself. Here, we encounter the following questions:

- Shouldn't private, for-profit entities execute this concept? After all, several companies are developing similar ideas, including but not limited to carbon insurance.
- Should there be one Permanence Trust or several providers competing to provide the services the Trust would provide?

In our view, the permanence of NCS has a significant bearing on the public good. As such, the responsibility for tracking and retiring permanence liabilities likely should be vested in a non-profit organization accountable to the broader public rather than shareholders or other capital providers. Vesting such a responsibility in a non-profit (or public) entity also avoids many potential conflicts of interest that could arise in the operation of such an organization. Finally, since so much of the Trust's effectiveness depends on distributing risk as widely as possible, there is reason to suspect that there are advantages to creating a single, market-wide Trust. Another argument favoring a single, independent entity is the specialized knowledge and expertise required for permanence management and assessment. It would likely be more efficient for a single entity to pursue this expertise rather than multiple entities building out the same technical capabilities for something that shouldn't necessarily be competitive. However, these questions should also be discussed after pilot implementation.

The third challenge is that the Permanence Trust might become insolvent.

This means the Trust's model for estimating key variables—such as the rate of return on investments, the future cost of carbon removal with storage, and the carbon decay rate of participating projects—might be incorrect. As a result, the Trust might be unable to cover the liabilities generated by removals.

At first glance, this is a severe challenge. However, for two reasons, we believe it is a less significant challenge to the Permanence Trust concept than it first appears.

First, the principles of risk management allow us to manage this risk by, for example, diversifying the projects (in terms of type, geographic location, and other variables) for which the Permanence Trust has assumed liability for long-term reversals. By doing so, we reduce the chances that a single mistake in assessment will lead to the overall insolvency of the Trust. Second, and much more importantly, the concept of insolvency does not quite apply to the Permanence Trust in the same way it would apply to other financial institutions. In a traditional financial institution, financial assets are weighed against financial liabilities, and when liabilities exceed assets, the institution can be considered insolvent.

However, we are weighing financial assets against physical liabilities for the Permanence Trust. Suppose in any given year, the Trust cannot address its “balance” of physical liabilities by purchasing carbon removal with geologic storage. In that case, it can simply wait until its financial reserves recover to retire the liability. Although that would seem to undermine the purpose of the Trust and its assurance of permanence, the impact would be negligible from the perspective of the radiative forcing caused by a CO2 emission. This can be seen by comparing the radiative forcing of a tonne of CO2, which is sequestered and stored for 100 years, to the radiative forcing of a tonne of CO2 that is sequestered and stored for 100 years, released back into the atmosphere for 10 years, and then sequestered and stored permanently. It is clear from this comparison that the impact of the Permanence Trust, even if it encountered periods of temporary “insolvency,” would be a material improvement over the status quo. The length of such temporary insolvencies and reasonable assurance that they would be sufficiently temporary remains something for research and consideration through the subsequent Permanence Trust design phases. In addition, the Trust could employ shorter-term solutions to address such gaps, such as using emerging carbon reversal insurance, already offered by several insurance providers at reasonable annual premiums.

There is a flip side to the challenge of insolvency. What if the Permanence Trust **overestimated** the carbon decay rates of projects for which it assumed liability for compensating for reversals? After all liabilities had been retired, it would then have a surplus of funds, which it could devote to purchasing excess carbon removal (thus enhancing global mitigation), addressing the biodiversity crisis, or other public goods.

The fourth challenge to the Permanence Trust is that there is not a clear, widely understood, and accepted definition of what constitutes a "reversal" and how to monitor it.

This topic, which we touched on above in Section Two, where we discussed the flaws of accounting for reversals at the level of individuals (trees) rather than groups (forests), is worthy of a separate paper (and indeed, writing one is on the agenda for the pilot phase). Here, it is sufficient to admit that this is a **major** challenge to the execution of the Permanence Trust concept. The Permanence Trust exists to retire permanence obligations for reversals through the purchase of carbon removal with geologic storage, a widely agreed-upon definition of a reversal that enables them to be monitored and reported with little to no ambiguity necessary for the Trust to function. We submitted proposed definitions for "permanence" and "reversal" earlier in this paper, which would need wider refinement and adoption.

The fifth challenge to the Permanence Trust is the issue of monitoring itself.

The Permanence Trust will only function if the carbon stocks underlying carbon projects can be accurately and cost-effectively monitored after the project ends. This ensures that reversals are identified and addressed and that feedback is provided on how the Trust can most effectively mitigate future reversals by identifying changing risks.

The scenarios analyzed above included no monitoring costs and, therefore, understated the monitoring costs the Permanence Trust would need to incur. Furthermore, although remote sensing and analysis trends suggest a future in which such a global system for monitoring carbon stocks could exist, we must acknowledge that we have no way of knowing if or when such a system will come into being.

To address these and other challenges, we aspire to pilot the Permanence Trust concept in 2025, seeking to validate key hypotheses, including:

- That standards and developers will be willing to and can manage the shift from the concept of "project longevity" to "credit liability," including revisiting or, for the first time, defining "permanence" and "reversal" as described above, and otherwise make the resulting changes to the standard to make such a concept operable.
- We can build a credible, evidence-based methodology for assessing the probable carbon decay rate for carbon credits beyond the Credit Longevity period, and, equally important, this methodology can change and adapt over time as science advances and monitoring datasets grow.
- We can accurately—and, like above- adaptively—forecast other key variables vital for the Trust's operation, including the projected return rate for funds invested in the Trust and the future cost of carbon removals with geological storage.
- We can identify a long-term monitoring system, or at least a theory for such a system, and incorporate the costs of such a system into the design of the Trust.
- Buyers will be willing to pay the increased price for NCS projects participating in the Permanence Trust.

To pilot the Permanence Trust concept, we are recruiting the following types of partners:

Table 4. Partners needed to pilot the Permanence Trust in 2025.

Partner Type	Role
Standards and regulators	Modify, on an experimental basis, the standard to allow for the testing of the Permanence Trust
Buyers	Purchase credits, which include the cost of the Permanence Trust assessment in their price
Developers	Submit a portion of credits for assessment and market those credits to buyers
Financial endowments/ managers	Provide advice and expertise on key variables for the Trust to consider
Providers of carbon removal with geologic storage or equivalent)	Engage in transparent discussions about the likely future prices and volumes of CDR and the mechanisms by which the Permanence Trust could most effectively secure it
Insurers and/or Academics	Assist with constructing a model to estimate Carbon Decay rates and pricing short-term instruments such as reversal insurance that could help the Trust cover gaps
Donors	Provide for the significant human, technical, and financial resources the pilot require

Part Five: Challenges to the Permanence Trust and Next Steps for Development

We are seeking a discrete number of partners in each of the above categories willing to devote their time and expertise to the pilot. We anticipate each of these groups' lasting impact on the effectiveness and scalability of NCS.

It is our ambition to execute the pilot in 2025 so that at COP 30, we can deliver:

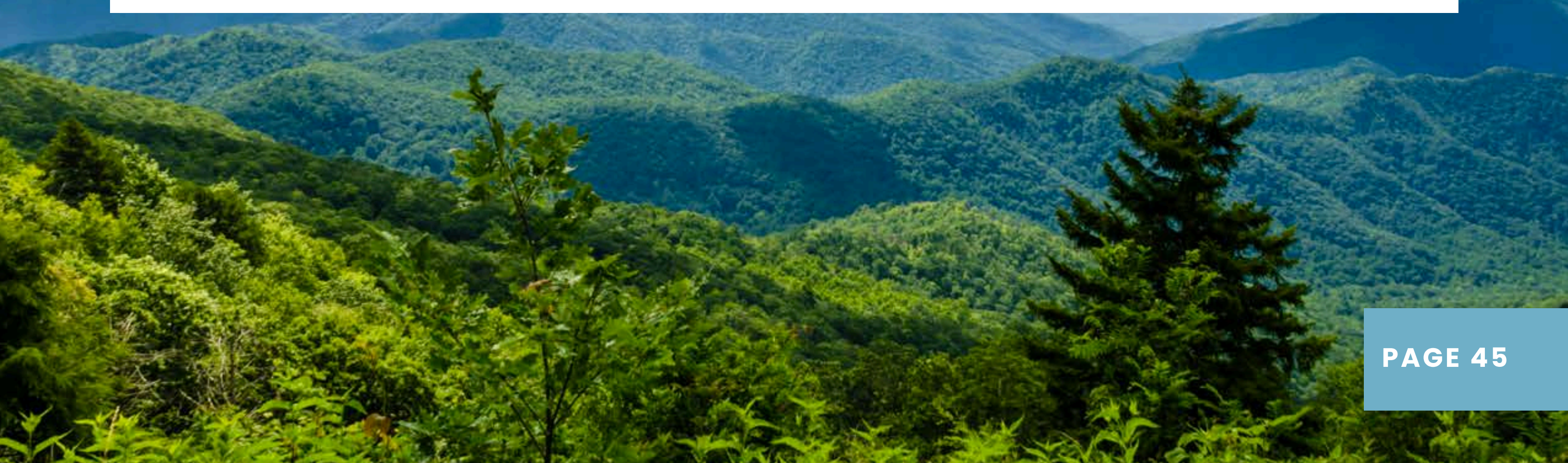
- A report on pilot outcomes
- A recommendation as to the next steps for the Permanence Trust, if any
- Concrete work plan to accomplish outcomes

Conclusion

An Invitation

The world needs NCS. And the world also needs the permanent storage of carbon dioxide and other greenhouse gases. Although some in the current carbon market view these two statements as mutually exclusive, we believe we have demonstrated they are ideas that, while in tension with one another, can be reconciled within the appropriate design.

We believe that together, we can create something that will unlock millennium-length permanence for NCS, enabling more effective NCS implementation, more funding for NCS, and reaching the scale of ecosystem protection, restoration, and management needed for our world. We invite you to join us on this journey and to assist in designing the Permanence Trust.



References

Anderegg, W. R. L., Trugman, A. T., Vargas, G., Wu, C., Yang, L. (2024). Current forest carbon offset buffer pools do not adequately insure against disturbance-driven carbon losses. BioRxiv. https://doi.org/10.1101/2024.03.28.587000

Badgley, G., Chay, F., Chegwidden, O. S., Hamman, J. J., Freeman, J., Cullenward, D. (2022). California's forest carbon offsets buffer pool is severely undercapitalized. Frontiers in Forests and Global Change. 5. https://doi.org/10.3389/ffgc.2022.930426

Barras, C. (2019). Scientists have discovered the world's oldest forest—and its radical impact on life. Science. https://www.science.org/content/article/scientists-have-discovered-world-s-oldest-forest-and-its-radical-impact-life

Bauhus, J., Puettmann, K., Messier, C. (2009). Silviculture for old-growth attributes. Forest Ecology and Management, 258(4), 525–537. https://doi.org/10.1016/j.foreco.2009.01.053

Bonnedahl, K. J., Heikkurinen, P., Paavola, J. (2022). Strongly sustainable development goals: Overcoming distances constraining responsible action. Environmental Science & Policy, 129, 150–158. https://doi.org/10.1016/j.envsci.2022.01.004

Bousfield, C. G., Morton, O., Edwards, D. P. (2024). Climate change will exacerbate land conflict between agriculture and timber production. Nature Climate Change. https://doi.org/10.1038/s41558-024-02113-z

Brunner, C., Hausfather, Z. & Knutti, R. Durability of carbon dioxide removal is critical for Paris climate goals. Commun Earth Environ 5, 645 (2024). https://doi.org/10.1038/s43247-024-01808-7

Buis, A. (2019). The Atmosphere: Getting a Handle on Carbon Dioxide. NASA. https://science.nasa.gov/earth/climate-change/greenhouse-gases/the-atmosphere-getting-a-handle-on-carbon-dioxide/

Christiansen, K. L., Hajdu, F., Planting Mollaoglu, E., Andrews, A., Carton, W., Fischer, K. (2023). "Our burgers eat carbon": Investigating the discourses of corporate net zero commitments. Environmental Science & Policy. 142, 79–88. https://doi.org/10.1016/j.envsci.2023.01.015

References

Copernicus Atmosphere Monitoring Service (CAMS). (2024). 2023: A year of intense global wildfire activity. https://atmosphere.copernicus.eu/2023-year-intense-global-wildfire-activity

Eisenberg, C., Prichard, S., Nelson, M. P., Hessburg, P. (2024). Braiding Indigenous and Western Knowledge for Climate-Adapted Forests: An Ecocultural State of Science Report. https://depts.washington.edu/flame/mature_forests/pdfs/BraidingSweetgrassReport.pdf

Ellis et al. (2024). The principles of Natural Climate Solutions. https://doi.org/10.1038/s41467-023-44425-2

Griscom et al. (2017) Natural Climate Solutions. https://doi.org/10.1073/pnas.1710465114

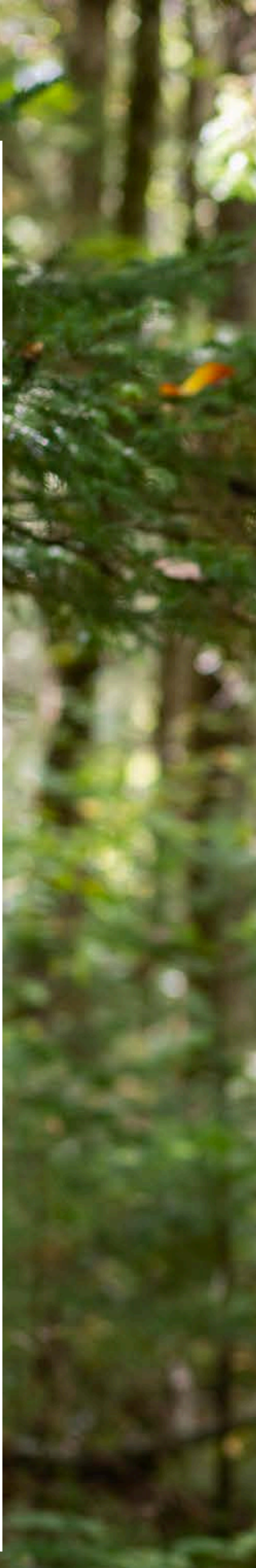
Harmon, M. E. (2001). Carbon Sequestration in Forests: Addressing the Scale Question. Journal of Forestry. 99(4), 24–29. https://doi.org/10.1093/jof/99.4.24

The Integrity Council for the Voluntary Carbon Market (IC-VCM). (2024). Core Carbon Principles, Assessment Framework and Assessment Procedure, Version 1.1. https://icvcm.org/wp-content/uploads/2024/02/CCP-Book-V1.1-FINAL-LowRes-15May24.pdf

Ke, P., Ciais, P., Sitch, S., Li, W., Bastos, A., Liu, Z., Xu, Y., Gui, X., Bian, J., Goll, D. S., Xi, Y., Li, W., O'Sullivan, M., de Souza, J. G., Friedlingstein, P., Chevallier, F. (2024). Low latency carbon budget analysis reveals a large decline of the land carbon sink in 2023. https://doi.org/10.48550/arxiv.2407.12447

Lebling, K., Rennicks, J., Haley, L.B. (2024). Carbon Dioxide Removal Investment Act. https://www.wri.org/update/carbon-dioxide-removal-investment-act

Levy, S. A., Cammelli, F., Munger, J., Gibbs, H. K., Garrett, R. D. (2023). Deforestation in the Brazilian Amazon could be halved by scaling up the implementation of zero-deforestation cattle commitments. Global Environmental Change. 80, 102671. https://doi.org/10.1016/j.gloenvcha.2023.102671



References

MacCarthy, J., Richter, J., Tyukavina, S., Weisse, M., Harris, N. (2024). The Latest Data Confirms: Forest Fires Are Getting Worse. World Resources Institute. https://www.wri.org/insights/global-trends-forest-fires

Matthews, H. D., Zickfeld, K., Koch, A., Luers, A. (2023). Accounting for the climate benefit of temporary carbon storage in nature. Nature Communications, 14(1), 5485–5485. https://doi.org/10.1038/s41467-023-41242-5

Mo, L., Liang, J., de Miguel, S., Nabuurs, G.-J., Araza, A., Herold, M., Mirzagholi, L., Phillips, O. L., Hordijk, I., Alberti, G., Alvarez-Loayza, P., Antón-Fernández, C., Araujo-Murakami, A., Arroyo, L., Baker, T. R., Bastin, J.-F., Bitariho, R., Bongers, F., Brancalion, P. H. S., … Zawiła-Niedźwiecki, T. (2023). Integrated global assessment of the natural forest carbon potential. Nature. 624(7990), 92–101. https://doi.org/10.1038/s41586-023-06723-z

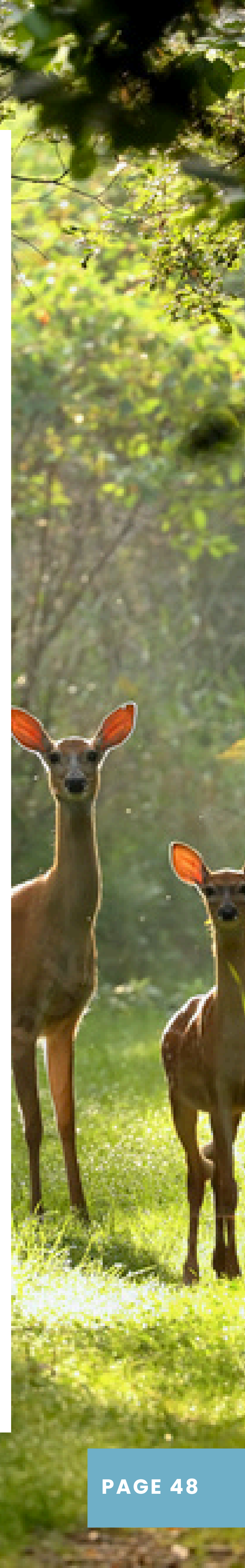
Cost of direct air carbon capture to remain higher than hoped. (2024). In NewsRx Science (pp. 111). NewsRX LLC.

Rogelj, J., McCollum, D.L., Reisinger, A., Meinshausen, M., Riahi, K. (2013). Probabilistic cost estimates for climate change mitigation. Nature. 493, 79–83. https://doi.org/10.1038/nature11787

Roston, M., Seiger, A., Heller, T. (2023). What's next after carbon accounting? Emissions liability management. Oxford Open Climate Change, 3(1). https://doi.org/10.1093/oxfclm/kgad006

Seidl, R., Thom, D., Kautz, M., Martin-Benito, D., Peltoniemi, M., Vacchiano, G., Wild, J., Ascoli, D., Petr, M., Honkaniemi, J., Lexer, M. J., Trotsiuk, V., Mairota, P., Svoboda, M., Fabrika, M., Nagel, T. A., Reyer, C. P. O. (2017). Forest disturbances under climate change. Nature Climate Change. 7(6), 395–402. https://doi.org/10.1038/NCLIMATE3303

Smith, S. M., Geden, O., Gidden, M. J., Lamb, W. F., Nemet, G. F., Minx, J. C., Buck, H., Burke, J., Cox, E., Edwards, M. R., Fuss, S., Johnstone, I., Müller-Hansen, F., Pongratz, J., Probst, B. S., Roe, S., Schenuit, F., Schulte, I., Vaughan, N. E. (2024). The State of Carbon Dioxide Removal 2024 - 2nd Edition. https://osf.io/f85qj/



References

Solomon, S., Plattner, G.-K., Knutti, R., Friedlingstein, P. (2009). Irreversible climate change due to carbon dioxide emissions. PNAS. 106(6), 1704–1709. https://doi.org/10.1073/pnas.0812721106

Solomon, S., D. Qin, M. Manning, R.B. Alley, T. Berntsen, N.L. Bindoff, Z. Chen, A. Chidthaisong, J.M. Gregory, G.C. Hegerl, M. Heimann, B. Hewitson, B.J. Hoskins, F. Joos, J. Jouzel, V. Kattsov, U. Lohmann, T. Matsuno, M. Molina, N. Nicholls, J. Overpeck, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, R. Somerville, T.F. Stocker, P. Whetton, R.A. Wood and D. Wratt. (2007). Technical Summary. In: Climate Change 2007: The Physical Science

Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-ts-1.pdf

UNFCCC. (2024). Requirements for activities involving removals under the Article 6.4 mechanism (Version 01.0). https://unfccc.int/sites/default/files/resource/A6.4-SBM014-A06.pdf

UN Global Compact Network UK (UN GCNU). (2021). BRIEFING: DEBATING CARBON OFFSETS: THE ROLE OF OFFSETTING IN THE TRANSITION TO NET ZERO. https://www.unglobalcompact.org.uk/wp-content/uploads/2021/12/Carbon-offsets-25-Nov.pdf

Verra. (2022). Development of Long-Term Monitoring System (LTMS) Begins. https://verra.org/development-of-long-term-monitoring-system-ltms-begins/

Verra. (2022). Verra Defers Updates to the VCS Program. https://verra.org/verra-defers-updates-to-the-vcs-program/

West, T. A. P., Wunder, S., Sills, E. O., Börner, J., Rifai, S. W., Neidermeier, A. N., Frey, G. P., Kontoleon, A. (2023). Action needed to make carbon offsets from forest conservation work for climate change mitigation. Science. 381(6660), 873–877. https://doi.org/10.1126/science.ade3535

References

Zickfeld, K., MacIsaac, A. J., Canadell, J. G., Fuss, S., Jackson, R. B., Jones, C. D., Lohila, A., Matthews, H. D., Peters, G. P., Rogelj, J., Zaehle, S. (2023). Net zero approaches must consider Earth system impacts to achieve climate goals. Nature Climate Change. 13(12), 1298–1305. https://doi.org/10.1038/s41558-023-01862-7

Zhang, Y., Jackson, C., Krevor, S. (2024). The feasibility of reaching gigatonne scale CO2 storage by mid-century. Nature Communications. 15(1), 6913–13. https://doi.org/10.1038/s41467-024-51226-8