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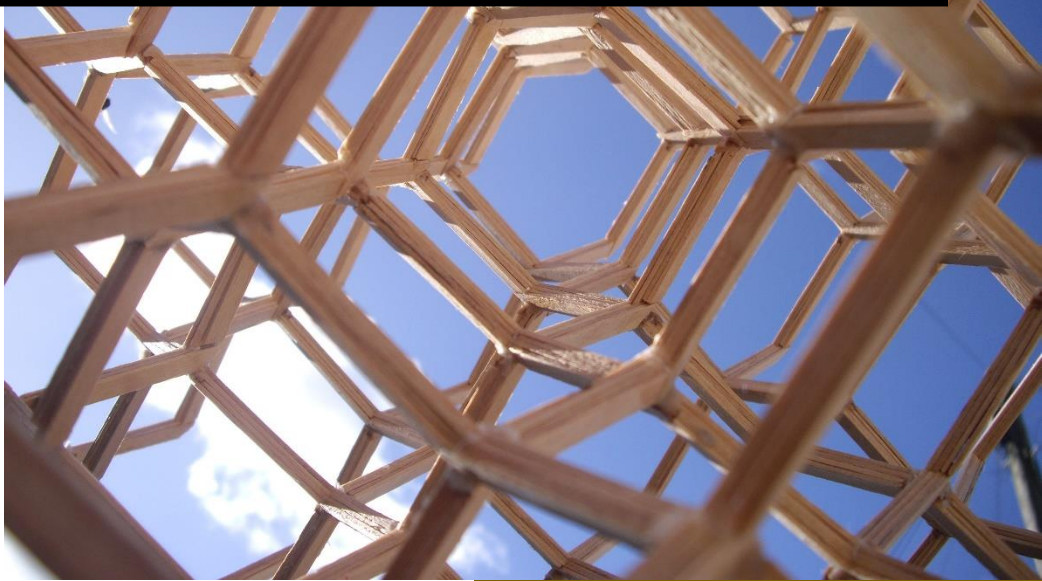
A conceptual framework for the certification of carbon sequestration



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A Conceptual Framework for the Certification of Carbon Sequestration

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Executive summary

Carbon sequestration will not be successful for climate mitigation unless it meets the required dimensions of scale, speed, performance, and safety for people and the environment today and in the future. As with any industry, standards and certification programs are a means to ensure that a product, process, or service meets expectations. Although informing buyers on what constitutes high quality sequestration certification is important, **the responsibility to define quality is at the stage of standard development**. Certificates of carbon sequestration should meet certain minimum requirements in their design and demand a minimum requirement from sequestration activities. Because carbon sequestration must be deployed immediately and at scale, a spectrum of activities will be needed, ranging from biotic and geologic, to oceanic. Thus, a common framework for the certification of carbon sequestration is necessary that is applicable for all activities.

This document details a **conceptual Framework for the Certification of Carbon Sequestration (FCCS)**. It is based on a system designed to support negative emissions. It provides the minimum requirements for the development of carbon sequestration standards and certificates of carbon sequestration. It allows the certification of standards so that they in turn produce certification of removed carbon that authenticates **durability** and **verifiability**. The framework (i) identifies an organizational structure for the certification system, (ii) clarifies the responsibility of participating entities, (iii) provides certificate designs and usages, (iv) details the requirements to develop measurement protocols, (v) provides mechanisms to support a long-term industry, and (vi) outlines a vision towards durable storage.

The FCCS exposes its underlying assumptions so they can be judged openly for the purpose of discussion and revision for the intent of improvement and eventually adoption. **The FCCS is conceptual at this stage, acknowledging gaps and requiring pilot tests.** The FCCS strives to create the simplest certification design.

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0.2	Mar-21	Revisions from early comments from CNCE members and Conservation International	SHA
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Terminology

Carbon Dioxide Removal (CDR) is defined by the IPCC (2021) as anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage but excludes natural CO_2 uptake not directly caused by human activities. For example, Direct Air Capture with mineralization or reforestation would be two CDR activities.

Certificate of carbon sequestration is defined within this framework as a document representing the certification of the verifiability and durability of carbon sequestered through the service of keeping a quantifiable unit of carbon away from the atmosphere. If stored carbon meets these requirements, it is considered *sequestered*. Certificates certifies sequestration.

Durability is the physical state of carbon storage as dictated by reservoir characteristics and risks.

Engineering-based CDR activity is understood to refer to activities that could not occur without engineering.

Hybrid CDR activity is understood to refer to activities that enhance natural processes through engineering or uses natural materials through engineering.

Mobile carbon pool consists of the atmosphere, surface ocean, and biomass (i.e., fast growing vegetation) due to their fast interconnections. For the opposite see *Stable carbon pool*.

Nature-based CDR activity is understood to refer to activities that restore ecosystems.

Negative emissions is defined by the IPCC (2021) as the removal of greenhouse gases (GHGs) from the atmosphere by deliberate human activities, i.e., in addition to the removal that would occur via natural carbon cycle processes. More negative than positive emissions would result in a net negative situation, reducing atmospheric concentration.

No harm in the context of CDR, is defined as not directly or indirectly harming people, infrastructure, or the environment, including ecosystems and the climate, by the activity and by the potential release of carbon from it in the future.

Offsetting is defined as the act of cancelling a unit of emissions with a unit of carbon sequestration. In this document, offsetting is not understood to mean cancelling a unit of emissions with an emission avoided or reduced. Nor is it understood to mean cancelling a unit of emissions with a removal that does not meet the criteria of verifiability and durability.

Permanent disposal is understood to mean sequestration that has been proven by scientific methods that carbon is contained in a form that can only escape on timescales of tens of thousands of years. Verified permanent disposal is sequestration. Permanent disposal passes a test where the probability weighted release during the required sequestration duration falls below the threshold of concern. Both the required sequestration duration and the threshold of concern are conventions that must also be defined. See *Required sequestration duration, Threshold of concern*, and *Sequestration.*

Point of responsibility transfer refers to the agreed point in time when the responsibility for the storage is transferred to a willing party at a fee. For the purpose of this conceptual paper the point is set to 50 years. Technical and jurisdictional experience may modify the selected period.

Precautionary principle is an approach to innovations with the potential for causing harm where scientific evidence may be lacking. The principle emphasizes caution, pausing, and reviewing before acting.

Removal is considered to mean the action of capture and storage performed by a CDR activity. Removal does not mean that it has met the criteria of verifiability nor durability for certification. Removal refers to the effect on carbon.

Required sequestration duration is defined as a period long enough so that the timing and magnitude of a release of carbon from a reservoir would not cause harm to any species. If impacts from temperature is the damage that is to be avoided, then sequestration on the scale of a thousand years is enough. If instead damage from ocean acidification is also to be avoided, then sequestration over ten thousand years will be required.

Reservoir is defined as a characterized natural or built pool where carbon can be collected. A reservoir has boundaries.

Reversal is defined as the release of carbon from a reservoir due to intentional and unintentional actions or events. Reversal and release are used interchangeably.

Sequestration is the process of keeping carbon away from the atmosphere durably and verifiably as determined by certification.

Stable carbon pool consists of reservoirs with slow connections to the carbon cycle including the deep ocean, fossil reservoirs, and slow growing biomass.

Storage is the state of carbon in a reservoir before it is certified. Once certified under the framework, storage is considered sequestration. Storage activity and CDR activity are used interchangeably even though the framework only certifies storage, and not capture and storage.

Successful CDR is CDR that meets the required dimensions of scale, speed, safety (to people, infrastructure, and the environment), performance, and equity (today and in the future).

Threshold of concern is defined as a 1% release of the total reservoir content over longer than 10,000 years, or conversely a risk of physical reversal of less than 0.01% per year. Scientific review of the selected amount (1%) is anticipated and may in the future adjust the percentage. For purposes of context and proportion this document relies on the 1% threshold.

Total sequestration refers to the global sequestration effort.

Verifiability means the possibility for an independent entity to confirm the amount that is claimed to be sequestered, through a hierarchy of actions including replication of measurements, auditing of process, measurements, and documents.

Introduction

For Carbon Dioxide Removal (CDR) to play a significant role in climate mitigation, the efforts must be scaled up to the multi-gigaton scale (IPCC, 2022). Any industry, and especially one of that scale, needs standards and certification programs to guarantee the safety, equity, and success of the activity. Standardized methods and certification programs can ensure a robust, efficient, and equitable CDR industry.

However, a snapshot of the current certification market ecosystem[1] revealed that this space is growing rapidly with many different standards and certificates from different organizations with varying criteria and rigor (Arcusa and Sprenkle-Hyppolite, 2022). On the one hand, the proliferation is a positive sign of development responding to urgent need. On the other, the proliferation of unregulated standards and certificates may jeopardize quality, success, and credibility, especially since assumptions underlying the standards are generally not made explicit and key questions regarding decision-making, usage, and definitions remain unanswered by the CDR certification community (Arcusa et al., 2022).

Buyers' guidances have been developed and can help the non-expert be informed regarding certification quality (Bey et al., 2022; Broekhoff et al., 2019; McDonald et al., 2022; Schneider et al., 2020; Zelikova et al., 2021). However, they do not solve the root problems. The buyer may lack guidance and is confused. Or the buyer may be greenwashing and looking for a cheap "attractive" certificate without wanting to pay for the real thing.

Furthermore, the many existing certification programs are not equivalent in terms of the measurement rigor and the treatment of sequestration duration. For the former, Carbon Plan reviewed 14 standards for soil carbon enhancement and found only three met their criteria of rigor including the inclusion of physical soil sampling, modeling tools, or a combination of approaches (Zelikova et al., 2021). For the latter, Arcusa et al. (in prep) reviewed the stipulated sequestration duration (i.e., "permanence") from 30 standard developing organizations and found definitions that varied from 1 year to over 100 years. This inability to cross-compare between standards splits the market.

The CDR industry needs guidelines to ensure a minimum level of quality is met. This can be delivered by a framework applicable to all CDR activities. This framework could be applied to new standards and through a reform process for existing standards, the

[1] https://embed.kumu.io/71b0790ef7c523fa5f40c9e83be16108

question of quality would be addressed, the burden of vetting carbon removal credits would be lifted from the buyer, and the public would be protected.

Substantial previous work exists on the development of standards for the certification of greenhouse gas emission reduction, avoidance, and removal. This body of work built on the Kyoto Protocol's Clean Development Mechanism (UNFCCC, 2006) and the IPCC's 2006 Guidelines for National Greenhouse Gas Inventories and its 2019 Refinement (IPCC, 2006; 2019). Moreover, decades of work have focused on designing various certification processes (Arcusa and Sprenkle-Hyppolite, 2022). This conceptual Framework for the Certification of Carbon Sequestration (FCCS) articulates the minimum requirements and responsibilities for the certification of carbon sequestration by building on and referring to this large body of existing work where appropriate.

This Framework for the Certification of Carbon Sequestration (FCCS) was developed following a survey of peer-reviewed and grey literature supplemented by extensive semi-structured interviews with practitioners and researchers on various aspects of carbon sequestration (**Annex 1**). This preliminary work was followed by a series of consultations with international standard developing organizations to bring additional depth and insights into the most challenging "open questions" for the framework, released publicly as a white paper (Arcusa et al., 2022). The current version (2.0) is offered as a starting point.

The FCCS draws lessons from the Oxford Principles for Net Zero Aligned Carbon Offsetting (Allen et al., 2020), the Science Based Targets initiative[2], Kyoto Protocol's Clean Development Mechanism (UNFCCC, 2006) the IPCC's 2006 Guidelines for National Greenhouse Gas Inventories and its 2019 Refinement (IPCC, 2006; 2019), and the Carbon Credit Guidance for Buyers of the Öko-Institut and Environmental Defense Fund (Schneider et al., 2020) to **provide guidance in the development of standards** and the restructuring of existing ones, so that the resulting certification programs guarantee successful sequestration from the onset, and present the buyer of carbon removal and the public with more transparency.

While this conceptual framework draws from existing literature, it also diverges in several fundamental ways. First, it is created to support a world that is aiming for negative emissions. Second, it does not try to change human behaviors, it is simply a certification system for carbon sequestration. Third, it draws observations from the first principles of climate science and therefore naturally reassesses many of the existing concepts and practices. Fourth, it aims to create equivalence between all

[2] Science Based Target initiative (SBTi) https://sciencebasedtargets.org/net-zero

forms of carbon sequestration in real terms. Fifth, it strives to bring simplicity. Lastly, it takes the long view of solving the climate change problem.

At the core, the framework guides the attribution of responsibilities necessary for the carbon sequestration activities. The framework focuses on “sequestration” as distinctive to “removal” or “storage”, as the certified criteria combining verifiability and durability.

The framework is applicable to standard developing activities specific to carbon sequestration as well as to the various decision-making levels of the certification process. Parts of the framework rely on policies that have not yet been implemented. Recognizing that whether these policies come to be or not is unknown, the framework offers temporary workarounds that enable the framework to operate regardless, albeit with added complexities.

The framework is presented at a conceptual stage, acknowledging that gaps remain. For example, it is unclear how sensitive the framework is to gaming by unscrupulous actors. It is yet unknown whether the rules have unintended consequences. Also unclear is how to finance the system to avoid conflicts of interest. Therefore, targeted research, pilot testing with storage operators, and public and academic scrutiny will be necessary for the framework to evolve. The framework is provided as a starting point for a new vision of the kind of structure necessary to operationalize carbon management in its simplest form.

Challenges

The following text aims to summarize the challenges related to CDR in general and carbon sequestration specifically that must be addressed within a framework for the certification of carbon sequestration (**Table 1**). These challenges are technical, relate to decision-making, and drive the motivation for and influence the design of the framework.

To limit global warming to below 1.5-2 ºC by 2100 as committed under the Paris Agreement, current CO_2 emissions will need to be phased out and historical CO_2 emissions will need to be removed (IPCC, 2018; 2022). As CO_2 remains in the atmosphere for tens to hundreds of thousands of years (Archer et al., 2009), the natural process of carbon removal will need to be enhanced through Carbon Dioxide Removal (CDR).

It may be necessary to remove and sequester an estimated 160-660 or 0-290 $GtCO_2$ from the atmosphere by the end of the century to keep within 1.5 and 2°C (IPCC, 2018; 2022), respectively, and perhaps more (Tokarska and Zickfeld, 2015), as the ocean and land sinks are likely to reverse and become carbon sources (Keller et al., 2018). Even more CDR would be required if humanity decides to return atmospheric concentrations to historical levels (Hansen et al., 2008). The scale (Scott et al., 2015a) and urgency (Lackner et al., 2012) of this goal implies that a diversified portfolio containing both nature- and engineering-based CDR systems will be necessary to meet those targets (Minx et al., 2018).

CDR faces many socioeconomic, political, and technical challenges related to deployment maturity, duration of storage, costs, co-benefits, resource availability, side effects and uncertainties, and social acceptance (Dowling and Venki, 2018; Fuss et al., 2018; Minx et al., 2018; Morrow et al., 2020; National Academies of Sciences Engineering and Medicine, 2019; Nemet et al., 2018). One of the greatest challenges is likely related to decision-making (National Academies of Sciences Engineering and Medicine, 2019), including creating the regulatory frameworks (Marshall et al., 2010; Moe and Røttereng, 2018; Morrow et al., 2020) that guarantee equitable, safe, and effective sequestration.

One aspect of CDR that will challenge socioeconomic and political norms is the requirement of maintenance through time. The physical limitations to the natural carbon cycle make it impossible to rely on natural processes to remove the excess carbon humans have added to the atmosphere, biosphere, ocean system (Solomon et al., 2009); the time scale for natural processes to rebalance the carbon in the environment is measured in tens of thousands of years (Archer et al., 2009). Climate change itself will last for millennia, even though a substantial fraction of the emitted carbon will acidify the ocean rather than increase the greenhouse gas load of the atmosphere. This suggests that sequestration on a decadal time scale is far too short to address the environmental insult of climate change. On the other hand, it is clearly better to sequester carbon for a few decades rather than not at all. Unfortunately, the required time scales for storage far exceed those of human institutions. This suggests that the ultimate guarantee of long-term sequestration must come from a scientific/technical assessment rather than millennial scale verification. It is possible to keep moving forward on a decadal time scale, as long as the responsibility for the next fifty to hundred years can be clearly spelled out.

Table 1. Challenges pertinent to the design of the certification of carbon sequestration.

Technical	**Relevant references**
Scale and urgency of the global CDR goal implies many types of CDR will be needed as none alone would be sufficient in capacity and deployment maturity.	(Minx et al., 2018; Torvanger, 2019)
Each reservoir has its own specific expected duration of storage and performance.	(Fuss et al., 2018; Minx et al., 2018; National Academies of Sciences Engineering and Medicine, 2019; Nemet et al., 2018)
The reservoirs that would provide the longest, most stable form of storage are not as mature in terms of deployment as those that are shorter lived with higher risk of reversal.	(Agron and Osborne, 2011; Anderegg et al., 2020; IPCC, 2005; National Academies of Sciences Engineering and Medicine, 2019; Nemet et al., 2018)
Each reservoir needs its own specific method to measure storage, additions and losses, and monitoring.	
Decision-making	
The impacts of large-scale CDR deployment would be both localized (e.g., environmental impacts in the vicinity of the project) and planetary (e.g., changing planetary albedo from increased forestation) through aggregation of all activities.	National Academies of Sciences, Engineering, and Medicine (2019), (Smith et al., 2016; Williamson and Bodle, 2016), Minx et al. (2018)
Because CDR is location specific, international cooperation would be needed to reach the goal at least cost while also raising the challenge of operators seeking the most relaxed set of certificates.	(Fajardy and Mac Dowell, 2020), (National Research Council, 2015)
Unequal contribution by nations to the accumulation of CO_2 in the atmosphere, suggest an unequal responsibility to clean-up.	(Fyson et al., 2020; Morrow et al., 2020)
CDR requires long-term management including monitoring and reporting.	(National Research Council, 2015)
CDR comes with the long-term responsibility to ensure the carbon remains stored.	Arcusa and Lackner (2022)
Each CDR activity carries different risks (e.g., accidental, or intentional, simultaneous, or sequential, partial, or complete reversals).	Fuss et al. (2018)
CDR is associated with different types of liability from the responsibility for released emissions from storage (e.g., in situ liability of harm to the environment, human health, and property and climate liability from leakage of carbon dioxide to the atmosphere)	(de Figueiredo et al., 2006),
Emission accounting rules must be consistent across reservoirs but also specific to each.	Fuss et al. (2018), Brander et al. (2021), Torvanger (2019)
The liability for lost carbon can be borne by different entities depending on the accounting rules.	(Marland et al., 2001)
Harmonized (liquid) or isolated (non-liquid) certification instruments will impact price.	

Principles

The following principles are intended to guide the development of the framework.

Uniformity:

- A certificate of carbon sequestration is to be agnostic to the type of storage reservoir to include the broadest range of activities that meet the criteria as possible.
- A certificate of carbon sequestration is to provide verifiable, evidence-based guarantee of durably keeping a volume of carbon out of the mobile carbon pool.

Equity:

- Environmental and Social Safeguards (ESS) are to be included in the development of CDR activities, including protection for the environment, present and future human generations as well as other species[3].
- A human-rights based approach ought to be followed in the development of any carbon sequestration activity. The Paris Agreement calls on its parties to take human rights into account when taking action to address climate change[4].

Transparency:

- Method development ought to follow an open process of expert peer-review, multi-stakeholder engagement, and public commenting, and be evidence based.
- Assumptions and reasons behind every decision ought to be made public in writing.
- The data and information used in the certification process ought to follow the FAIR principles[5] of findability, accessibility, interoperability, and reusability so they can be openly reviewed by independent actors.
- Standards ought to be made publicly available for independent scrutiny once completed.
- Standards ought to be periodically reviewed to incorporate new scientific evidence.

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[3] A universal ESS framework specifically for carbon sequestration does not currently exist. However, existing standards and publications have likely identified many aspects that could go into an universal ESS framework.

[4] UNFCCC, COP, Paris Agreement to the United Nations Framework Convention on Climate Change, 12 December 2015, Dec CP.21, 21st Session, UN Doc FCCC/CP/2015/L9, online: <unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf> [Paris Agreement]

[5] FAIR principles < https://www.go-fair.org/fair-principles/>

Assumptions

The following summary aims to expose the assumptions underlying the development of this framework to uphold the principle of transparency. These assumptions should be challenged. Detailed rational and implications for each assumption can be found in **Annex 2**.

- **Certificates of carbon sequestration certify the durability and verifiability of the service of keeping carbon out of the mobile carbon pool**. This framework focuses solely on the sequestration of carbon and no other greenhouse gas and does not cover any co-benefits that may result from the storage activity (**Annex 2.1**).

- **A certificate neutralizes a ton of fossil carbon.** The framework does not produce something equivalent to a traditional offset (**Annex 2.2). ** Traditional offsets have their own specific rules including demonstrating additionality in finance and regulation. After an initial measurement of the carbon content in a reservoir, the FCCS assumes the storage operator can take credit for natural uptakes, but this means they are liable for all losses (**Annex 2.3**).

- **The framework operates best if each ton of carbon extracted or imported be matched by a ton of carbon sequestered[6].** Once this situation has been achieved, carbon emitted by the CDR activity is already accounted for unless the CDR activity interferes with existing carbon reservoirs. A Life Cycle Analysis (LCA) is required at the stage of activity design but not for carbon accounting (**Annex 2.4**). In the absence of such a policy, CDR activities will have to disclose their emissions.

- **Certificates are best used or purchased upstream, on the supply side of carbon (i.e., point of fossil fuel extraction or import)** rather than downstream on the demand side (i.e., sectoral, supply chain, or individual emphasis) to increase efficiency and remove the need for a LCA for accounting purposes. A certification system could be devised to include activities and transactions that are safekeeping carbon along a supply chain (**Annex 2.4**).

- **The framework internalizes the failure of carbon sequestration to be permanent.** The framework assumes that only through permanent disposal can the responsibility of the carbon producer to remediate their carbon waste be fulfilled.

[6] This policy idea is popularized under the name Carbon Take Back Obligation (CTBO) (https://carbontakeback.org/) that requires matching each ton of carbon extracted or imported with a ton of carbon removed. A transition period and mechanism to handle the transition remains necessary to stop non-net negative activities and is discussed in Annex 2.4.

The framework defines permanent on timescales of 10,000 years or more. The framework proposes a mechanism to allow for storage today without compromising the future. The framework assumes that “storage” is temporary, whereas “sequestration” meets a scientifically defined permanence requirement (**Annex 2.5**).

- **The framework assumes the storage operator will be paid for taking on the liability of the carbon producer.** The carbon producer should not be required to pay repeatedly but they must pay for the entirety of the clean-up. Therefore, the storage operator is expected to take on the responsibility of providing sequestration. The operator will want to be paid appropriately for taking on the liability. The operator may want to be covered by insurance. Responsibility can be transferred between willing parties at a price paid upfront. This shift in responsibility forms the basis of a sustainable, long-term industry.

- **Certificates solely represent carbon removal from the environment and do not consider emission reduction or avoidance.** The framework separates removal from reduction and avoidance because the methodologies, contexts, impacts, and purposes of the three are not the same and therefore should not be made equivalent. Once a policy like the Carbon Take Back Obligation takes effect, avoidance and reduction will pay for themselves by not having to pay for removal (**Annex 2.6**).

- **Certificates propose true equivalence across storage activities by focusing on the common denominator of responsibility**. This framework proposes a true equivalence in terms of the duration of sequestration based on the inclusion of a mechanism of monitoring and remediation combined with a transfer of responsibility, and in some instances a permanence test (**Annex 2.5**). An alternative option using labeling is explored in **Annex 2.8** for completeness.

- **The framework focuses on carbon sequestration for the purpose of climate change mitigation.** The framework is not developed to conserve ecosystems, which is an incredibly important, but separate endeavor. The framework excludes activities that are built on the act of emptying existing carbon reservoirs. The framework emphasizes the creation of mechanisms that allow for the inclusion of nature-based sequestration for the purpose of climate change mitigation, including the restoration of ecosystems to their maximum potential.

A common unified framework

1.1 Summary

The FCCS proposes a structure and guidelines for the certification of standards for carbon sequestration. This naturally also includes guidelines for the certification of carbon, standard development, and certificate issuance. The FCCS is an umbrella above all standards that will guide standard development and approve standards.

Figure Figure *1* depicts a summary of responsibilities from six key actors, namely a certificate authority (CA), standards certification authority (SCA), standard developing organizations (SDO), storage operators (SO), a willing party, and external auditors. **Figure Figure *2*** shows one possible configuration of the organizational structure for operationalizing the framework.

The responsibilities of the various actors and the requirements of the standards remain the same for each type of storage activity. The requirements are kept to a minimum to be applicable for all activity types. However, the actual measurement protocols to fulfil the requirements will vary for all storage activities.

The guidelines for suitable natural and built reservoirs are designed to allow for sequestration to start today while protecting the integrity of the sequestration in the long-term. Under this framework, all certified storage activities are verifiable and durable. The disparate storage activities are unified through the “monitor and remediate” responsibility of the storage operator (SO). This responsibility is the basis for durability.

The framework allows for the “monitor and remediate” responsibility to end for the storage operator (SO) only under two conditions: a “transfer of responsibility” or passing the “permanent disposal test”. This structure ensures the resulting certificate represents long-term storage even if the activity is not long-term storage at the onset.

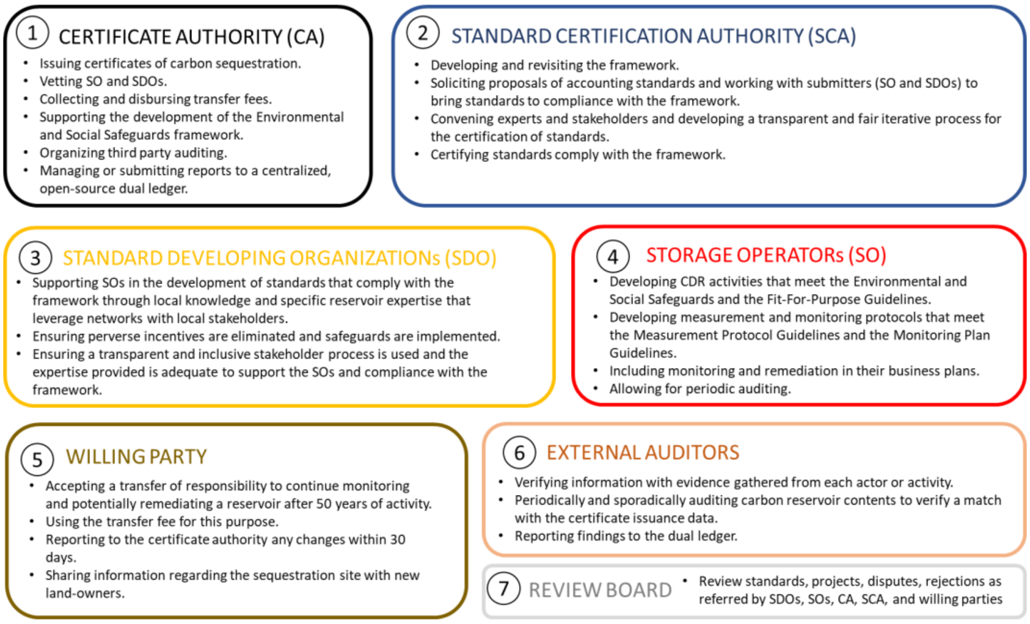

Figure 1. Actors and their main responsibilities in the Framework for the Certification of Carbon Sequestration.

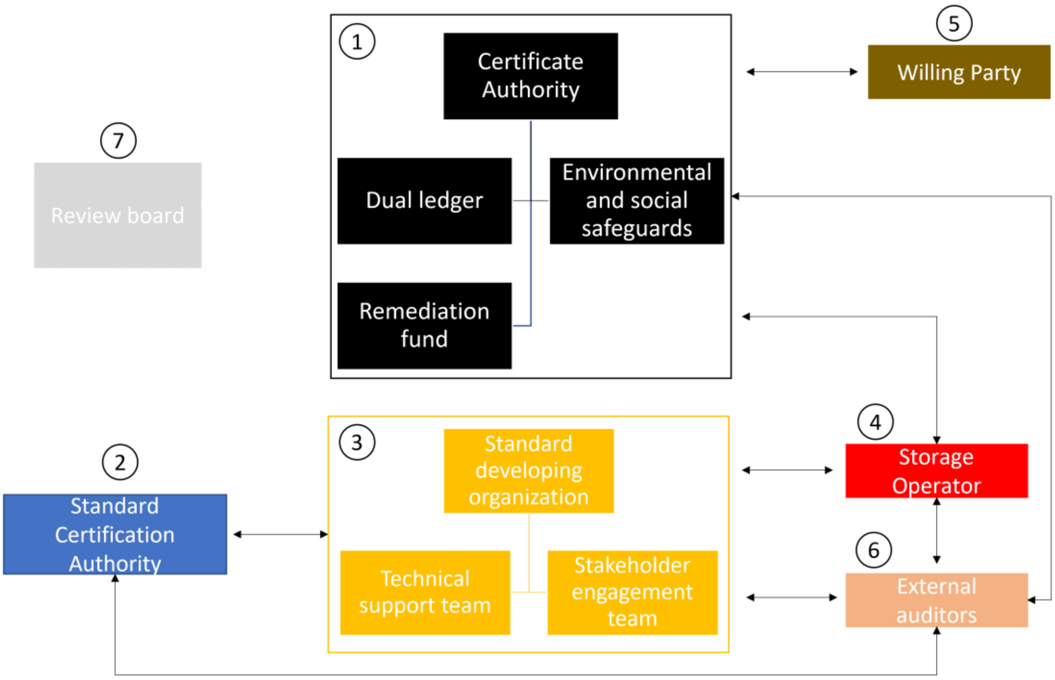

Figure 2. One possible configuration of the organizational structure to operationalize the Framework for the Certification of Carbon Sequestration.

1.2 Certificate design

A certificate is a document to certify an activity has fulfilled specific requirements or that a statement is true. **A certificate of carbon sequestration is a document that certifies the sequestration of carbon has occurred and met the specific requirements detailed in the framework.** A single certificate is available with three internal tracks depending on the responsibilities (**Figure Figure *3***). Differences and similarities between certification types are explored in **Table 2**.

Three types of responsibility tracks are identified to allow for (i) storage to start immediately with minimal risk exposure and without compromising the principles of the producer's responsibility and intergenerational equity, (ii) progressing most excess fossil-derived emissions (i.e., emissions from fossil fuels and limestone calcination) towards ***permanent disposal***[7], and (iii) carbon to be responsibly used (i.e., safekeeping) in products in supply chains.

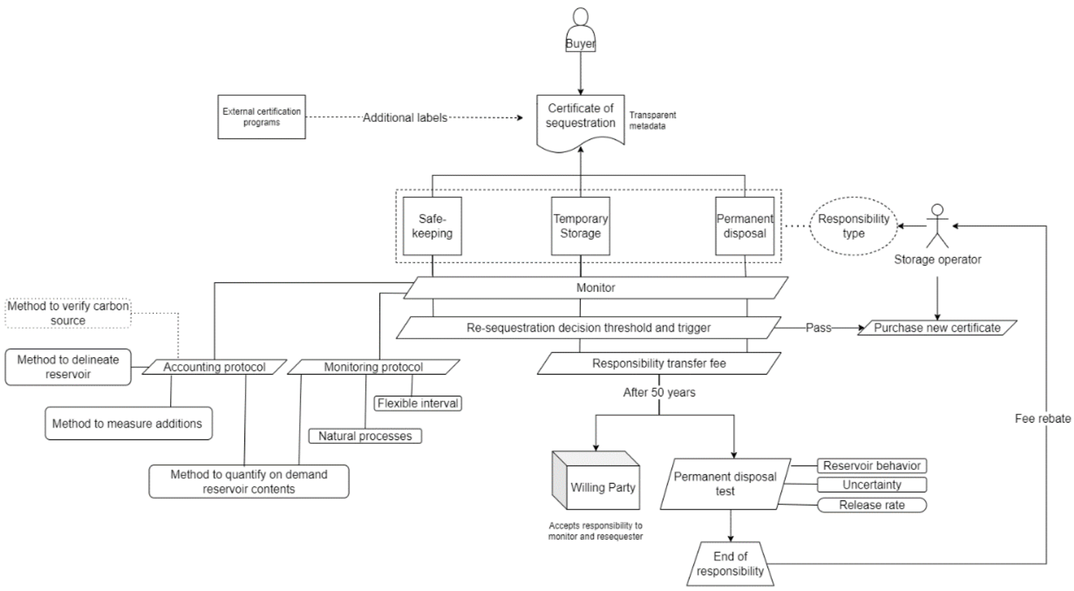

Figure 3. Schematic of the framework depicting the main tasks, actors, responsibility tracks.

1.2.1 Type I: Permanent disposal

- For activities and reservoirs that meet the requirements of the *Permanent Disposal Test*.

[7] The Oxford Principles for Net Zero Aligned Carbon Offsetting (Allen et al., 2020) suggest that all emissions must eventually end up in durable storage. The framework aligns with that observation. See **Annex 2.5** for more discussion on the assumptions.

- Carbon handled in this responsibility track will come to a point where the responsibility of monitoring can safely be fulfilled. Reduced monitoring will be based on the nature of the storage.

- Certificates produced from this responsibility track have market access. Monetary exchanges may occur.

1.2.2 Type II: Storage

- For activities that stores carbon in reservoirs that are transitory and from the onset are known they will not meet the requirements of the *Permanent Disposal Test*. It is expected that many activities will fall under this category.

- Certificates produced from this responsibility track have market access. Monetary exchanges may occur.

1.2.3 Type III: Safekeeping

- For activities that safekeep carbon in specific reservoirs within a supply chain. The purpose of this responsibility track is to safekeep rather than to store which allows for the responsible use of carbon.

- Certificates of safekeeping do not have market access. Monetary exchanges do not occur. Responsibilities are different than in certificate type I and II.

- This responsibility track will be detailed in a later addition to this framework.

Table 2. Differences and similarities between the certificate types.

	Permanent disposal	Storage	Safekeeping
Status	Deemed permanent	Transitory	Not for CDR
Monitoring responsibility	✓	✓	✓
Remediation responsibility	✓	✓	✓
Transfer of responsibility fee	✓	✓	
Permanent disposal test	✓		
Access to market	✓	✓	
Joint carbon and responsibility			✓

1.3 Actors and their responsibilities

1.3.1 Certificate Authority (CA)

A certificate authority (e.g., the Carbon Board of Lackner and Brennan (2009); the Global Merchant Bank of Mathews (2009), or other type of independent and accredited entity), oversees the certification process of the removed carbon and issues and tracks certificates. At a minimum, their responsibilities include:

- Relying on external auditors to verify the sequestration follows the appropriate standard.
- If external auditing finds a significant measurement discrepancy between reported amounts and verified amounts, the certificate authority will charge the storage operator for the difference.
- Assuring that verification and monitoring remains current for each standard operator.
- Collecting a fee for the transfer of responsibility to the willing party on every issued certificate of Type I and II. The fees are disbursed by the certificate authority to the willing parties to meet any remediation obligations after any carbon release is reported and verified. The funds will be used to balance the

sequestration of the storage operator. How the fund should be handled remains to be determined. *See Annex 2.5 and 2.6.*

- Coordinating and providing modes of communication between actors to eliminate unnecessary bureaucracy. To the maximum extent possible, documentation should be stored centrally and digitally.

- Supporting the development and periodic revisiting of an Environmental and Social Safeguards (ESS) framework in collaboration with appropriate stakeholders. The ESS provides the rules on activity operations and is to be provided transparently to storage operators wishing to have their removed carbon certified. See *Environmental and social safeguards*.

- Vetting storage operators:

    - Deciding whether the level of surety, performance, or contract bond or insurance held by the storage operator is sufficient to prevent the abandonment of stored carbon, due to bankruptcy for example.

    - Investigating whether the storage operator has engaged in disqualifying activities or violations listed in the EES and those in accordance with local ordinance and national laws and treaties.

    - Vetting of the storage operator probably incurs a charge. The application of charges and their nature will be governed by the jurisdiction responsible for accrediting storage. Jurisdiction may treat vetting like they do food and environmental inspections and not charge a separate charge.

- Building a network of standard developing organizations (SDO):

    - Identifying SDOs that could provide the local support, technical expertise, and network of local stakeholders to develop standards that comply with the framework.

    - Deciding if the SDOs have the capacity to provide rigorous advice and support to become part of the network of standard developing organizations for the framework.

    - Offering training material for SDO staff.

- Organizing periodic third-party audits of the operations including those of the standards certification authority, standard developing organizations, storage operators, and data collection.

- Managing a centralized dual ledger such as digital ledger technology that collects, stores, and openly displays data from each storage operator and the resulting certificates. Access to the ledger must be open to the public to allow for scrutiny (Ashley and Johnson, 2018; Mandaroux et al., 2021). The central ledger can be outsourced if an adequate alternative meets the FAIR[8] requirements.

- Retiring certificates from circulation once they have been spent and permanently attaching a notice of this retirement within the metadata of the certificate in the dual ledger.

- Managing the integrity of the total sequestration inventory so that at any given time the total amount of sequestration remains stable or is increasing. The inventory should not decrease. A decrease in the sequestration inventory would indicate carbon is prematurely released or accounting efforts were overestimated. The certificate authority must take remedial action to return the inventory to the total amount issued from the certificates.

- Periodically soliciting reports from independent research centers that assess the aggregated impacts of the total carbon sequestration operations. The certificate authority will collaborate with the centers to develop "lessons learned" reports following the model of the United States Nuclear Regulatory Commission, or similar taskforce.

- Referring issues to the Review Board.

1.3.2 Standards Certification Authority (SCA)

The standards certification authority's (SCA) mission is to certify standards developed by the standard developing organizations (SDOs) or directly by the storage operators (SOs). Neither the SDOs nor the SOs can certify their own standards. The SCA must be neutral, without real or perceived conflicts of interest.

The SCA should serve as 1) an accountant of storage providing the storage operators and the public a true record of activity, 2) as a judge checking and verifying that what is in the accounting record is truly stored and indicating the condition of that storage,

[8] ibid. 5

and 3) as a facilitator encouraging the growth and better means of storage, accumulating a list of what may be certified.

The SCA is separate from the certificate authority (CA) and the SDO. The SCA must comply with ISO: 17021: Conformity assessment — Requirements for bodies providing audit and certification of management systems[9]. At a minimum, their responsibilities include:

- Publishing the framework in an easily accessible format online[10] and keeping the documents up to date.

- Maintaining an open process for the framework to be challenged and receive feedback from researchers and the public.

- Reviewing challenges and feedbacks and calling for further research as necessary.

- Periodically reviewing and improving the framework after considering challenges, feedback, and research.

- Maintaining a process for standards to be proposed and allowing for a rolling submission deadline.

- Receiving submissions of proposed standards, reviewing submitted standards, and determining their accreditation:

    - In Phase I, the SCA will review submissions. The SCA will look for omittances and if necessary, provide basic guidance on changes that need to be made to meet the requirements of the framework in the context of the Fit-For-Purpose Guidelines, the Measurement and Monitoring Protocol Guidelines, and the Business Plan Guidelines. The submission can be reiterated until the SCA decides the submission can progress to Phase II.

    - In Phase II, the SCA will open a public review and consulting process for each submission, that includes:

        - Convening technical experts on the specific storage activity and reservoir that is being considered.

[9] ISO: 17021: Conformity assessment — Requirements for bodies providing audit and certification of management systems. Available at: https://www.iso.org/standard/61651.html
[10] Hard copies must be made available as necessary.

    - Convening the standard developing organizations and storage operators who designed the standard.

- Phase II provides recommendations in the context of the *Fit-For-Purpose* , the *Measurement Protocol* and the *Monitoring Plan Guidelines*

In addition to the measurement protocol, **each storage activity will need to have a monitoring plan specific to each reservoir and site**. The following must be considered:

- All reservoirs must have ongoing monitoring determined by one or multiple approved monitoring plan(s).

- The purpose of the monitoring is for conformance (assuring the reservoir behavior is understood), containment (ensuring the carbon is where it is expected to be), and contingency (to determine the quantity of carbon released that will need to be remediated).

- The monitoring plan must collect the appropriate data using appropriate tools at the appropriate sampling frequency and spacing to detect changes in the reservoir carbon content.

- Monitoring plans will vary according to reservoir characteristics. Monitoring for containment does not necessarily mean surface observations, or repeated observations at the same location, or sampling at regular intervals. In subsurface reservoirs, the appropriate monitoring may be in deep subsurface. In dynamic reservoirs, the appropriate monitoring may be repeated observations at irregular intervals to capture fluctuations. Monitoring may require targeting high-risk areas more frequently than other areas. Monitoring may (and probably will) include application of scientific proofs which will dictate monitoring that is not known or evident today.

- Monitoring for contingency (quantifying carbon release for the purpose of remediation) may require different data, tools, sampling frequency and spacing than monitoring for containment (ensuring carbon is where it is expected to be).

- The monitoring plan must be flexible to allow for scheduled and on-demand measurements that will vary for each reservoir depending on its characteristics.

- The monitoring plans may change with the process time of the storage activity. The process time refers to the period where there is a change in the physical characteristics of the carbon.

- Monitoring may change based on new advanced techniques and recommendations for improved practices from the standard developing organizations, storage operators, or standards certification authority.

- The monitoring can trigger a **remediation decision determined as a quantity exceeding the threshold of concern, outside of the bounds of agreed measurement uncertainty levels**. Note that all certificates are guaranteed. This means that the buyer is guaranteed the certificate will not expire or be voided. Internally, the storage operator and the certification authority will work to remediate the release and fulfill the guarantee.

- Once the remediation decision is triggered, the release is quantified and flagged in the ledger. The storage operator is responsible for remediation. *See Business Practice .*

- If monitoring never detects a change in the reservoir content until the point of transfer, given the measurement uncertainties, monitoring frequency can decrease thereafter, and eventually, the storage could be considered for the *Permanent Disposal Test* depending on the nature of the reservoir.

- All decisions must be justified.

The monitoring plan must meet the following requirements:

1. Monitoring frequency – a protocol must exist that identifies a flexible monitoring frequency, taking into consideration any natural fluctuations as dictated by the physical properties of the reservoir. Until the point of transfer, the maximum interval may not exceed 5 years. After the point of transfer is reached without triggering a remediation decision, depending on the characteristics of the process, the monitoring frequency may decrease up to a maximum of 50 years. These timeframes are established to create a framework to start the certification of carbon sequestration. Experience, jurisdictional preference, and scientific research may advocate modifying these timeframes. Future decreases or increases in frequency should be judged against this starting point as the prudent measurement.

2. Monitoring duration – monitoring, even at large intervals (50 years), must continue for as long the reservoir holds carbon. An expected, average storage duration can be used for planning the activity, but a margin of planning must be included for the possibility that the reservoir can exceed or fall short of expectations.

3. Monitoring equipment – the equipment must be adequate and provide accurate measurements within the agreed upon uncertainty level. Monitoring equipment should meet standard specifications that are published and available for review from third parties. Standardization of equipment will increase reliability, public acceptance, and reduce costs.

4. Monitoring sampling design – the sampling design must accurately report on the carbon content of the reservoir. This design can match the method used for measurement.

The design of the monitoring plan should consider the steps detailed in the Assessment of Low Probability Material Impacts:

1. Set quantitative and measurable success criteria
2. Model the occurrence of low probability material impacts (natural and man-made)
3. Model the response of monitoring systems to material impacts
4. Execute monitoring during project deployment
5. Reporting a finding that success criteria have been met

1.3.3 Durability and Permanent Disposal Guidelines

CO2 remains in the atmosphere indefinitely in the context of human timescales. However, unlike radioactive or other toxic wastes, it can be released into the environment and cleaned-up (i.e., neutralized) relatively easily (mostly) without immediate harm if the clean-up is also immediate. The harm develops when the clean-up occurs much later than the emission. For carbon sequestration to be considered a viable climate change mitigation solution, it requires a certification design that **considers the risk premium of a release of carbon and the principles of the producer's responsibility and intergenerational equity**. *See Annex 2.5 for more details on the assumptions.*

The framework understands **permanent disposal to mean a condition of a reservoir where the probability weighted release during the required sequestration duration falls below the threshold of concern.** This definition means:

- The stored carbon is only released in small enough quantities over a long enough period that it will no longer cause environmental damage because the quantities can be absorbed by the climate system.

- The release from one reservoir may not create damages, but damages will accrue if all reservoirs release carbon. Therefore, the release relative to the total will need to be considered.

- The **release must be spread over longer than ten thousand years**. **The threshold of concern may amount to 0.01% per year.** Scientific and jurisdictional debate over this percentage is inevitable. Considering the stakes if sequestration goes wrong, 0.01% is a justifiable starting point that ought to be maintained as the target unless there is overwhelming rationale to modify it. *See Annex 2.5 for more details on the assumptions.*

- In contrast, durability is the property of a reservoir to continue to store carbon through physical and contractual means. While durability does not have an end point, permanent disposal does. It uses physical properties and scientific process to assess the stability of the storage condition. The difference between permanent disposal and popular definitions of permanence is that it does not arbitrarily assign an end point.

Few reservoirs will meet this definition of permanent disposal, yet these still have a critical role to play; they are more likely to be deployable today and will diversify the portfolio of storage activities. However, all storage activities for the purpose of climate mitigation must be understood to be a serious undertaking for humanity. Regardless of how it is done, the gigantic volumes of carbon removal anticipated will be challenging to manage. Those volumes will be even more challenging if they require continuous maintenance. At the end of the day, reaching a state of permanent disposal is the only way to end the responsibility of having emitted CO2 in a fair manner. *See Annex 2.5 for more details on the assumptions.*

Therefore, the framework requires that all carbon certified as sequestered must meet the permanence guidelines: the **durability of all storage activities is ensured by the combination of monitoring and remediation.** The requirement of monitoring and remediation applies to all reservoirs. Because it is also a perpetual requirement, the framework offers a solution for the storage operator’s responsibility to end:

1. Some storage will pass a test of permanent disposal allowing for a less onerous continuum of monitoring activities.
2. Those that fail the test will require a transfer of responsibility of the reservoir.

All activities must include a fee for the transfer of responsibility. Those that pass the test may receive a rebate. Permanent storage, the reduction of monitoring, and the avoidance of future expense ought to be the long-term goals of sequestration. A strong and reliable certification program with universal adherence is a critical part of that path. The two mechanisms are described in detail.

1.3.3.1 *Responsibility transfer mechanism*

Some storage activities will be designed with longevity in mind and others will not. The framework offers infrastructure to support both with a mechanism that transfers to another party the storage operator's responsibility to monitor and remediate. Monitoring, remediation, and responsibility transfer meet the criteria for durability. The mechanism is summarized before the components are described:

A certificate is awarded for the increase of carbon in a reservoir. Each certificate incurs a fee. All reservoirs must be monitored by the storage operator. Any releases are remediated by the storage operator through the purchase of a new certificate, ensuring the integrity of the certificate. At the point of responsibility transfer, the responsibility for monitoring and remediation is transferred to a willing party.

The following conditions must be true for the transfer to be possible:

- The entity accepting the responsibility must do so willingly, i.e., knowingly and understanding the terms of the transfer.

- This willing party must be an entity that can be supported to continue their responsibilities on multi-generational timescales. The willing party can sub-contract the responsibility and structure recurring contracts.

To protect the willing party, the transfer cannot be free. Therefore, the responsibility to monitor and remediate can be transferred to the willing party at a fee on each certificate. The fee can be devised in many ways, but its **purpose is to pay for a new certificate of sequestration if needed once the willing party takes over after the point of transfer**.

The fee structure is ideally set to be equivalent to the price of the willing party purchasing a certificate after the point of transfer in today's value following an approved discount rate. The willing party receives the responsibility after the storage operator's years of operations meets the point of transfer.

Note: In a perfect world the transfer would be a transaction based on estimated value including a fee structure that would perpetuate the financing of the remediation of the storage. This preference for a fee for longevity may not be the only mechanism exercised for transfer. Understanding the systems in place a half century or century *into the future is not possible today and thus the arrangement may entail government or other agency involvement that would utilize tax revenue or some other form of financing. The critical feature is that transfer be to an entity that is capable and willing to continue the verification, and if necessary, remediation, of the storage.*

The remediation fund managed by the certificate authority will make the fees available for disbursement as needed.

All certificates will be imposed this fee. Activities that meet the *Permanent Disposal Test* could receive a refund *after the point of transfer* to incentivize the development of activities that meet the criteria of permanent disposal. For both societal and financial reasons, storage that meets the *Permanent Disposal Test* are likely to be favored going forward and incentives should be put in place to encourage such storage. Sequestration certificates purchased to meet the remediation requirement will not be imposed the fee, because the fee will already be paid. Further details in **Annex 2.6.**

The point of transfer is set to 50 years, assuming supporting structures are put in place. This may need to be revisited.

1.3.3.2 *Permanent Disposal Test*

Some storage activities will be built with longevity in mind. Based on science-based research and proof a consensus can be reached, a particular storage activity could be considered as effectively permanent. This assertion recognizes that no state is permanent within the Earth System, but states can be considered effectively permanent within the climate system.

To be considered to pass the *Permanent Disposal Test*, the following situations are anticipated:

(1) **The reservoir content can be observed.** The reservoir content must increase relative to the agreed and measured baseline. From the start of the activity until the point of transfer, no decrease in the content will have been observed. The monitoring frequency can decrease, but as releases may be rare but large, the monitoring must continue at a maximum interval of 50 years.

(2) **The reservoir content cannot be observed,** but a science-driven consensus has been reached that the reservoir characteristics and storage method means it cannot lose carbon over the required sequestration duration.

Monitoring will continue at the appropriate level with the aim to verify the consensus, and the science will be subjected to ongoing peer review.

A reservoir that passes the test and carbon storage is verified is considered permanently disposed.

Science-based methods will with time expand the range of storage methods acceptable to the Permanent Disposal Test.

- , and the *Business Practice* . Recommendations must be made from the lens of the precautionary principle.

- The SCA will determine the outcome of Phase II based on the recommendations. The outcomes can be:

    - Accepted, if all guidelines are met. The proposed standard will be certified.
    - Revise, if guidelines can be met but have not been. The proposed standard will go through a revision process that may include another review.
    - Rejected, if guidelines cannot be met at this time even with revisions.

- A rejection must be accompanied by an explanation which will trigger the SCA to determine that more basic research is necessary. The SCA will prepare a call for research targeting specific open questions.

- The SCA and storage operators can appeal a rejected outcome, providing new evidence and justifications. The case is then transferred to an established panel of judges who will review the appeals.

- The SCA is responsible for keeping an open database of all submitted standards including decisions from the review process.

- The SCA is responsible for organizing the review of all approved standards every 5 years (after initial practice adhering to a 5-year review, a modified timeframe may be developed). The SCA will convene a panel of experts including the SDOs who will assess whether science has evolved, comments from the public, the conclusions of the independent research on impacts, and the reports from the independent auditors. The SCA will determine if the standard can continue to be applied, needs revision, or needs to be terminated.

- A process free of conflicts of interest to charge for the certification of standards will need to be determined.

1.3.4 Standard Developing Organization (SDO)

The standard developing organization (SDO) is one of the entities that can develop and periodically improves accounting standards[11]. The SDO may provide the local knowledge, specific technical expertise, and stakeholder engagement networks that will support the development of framework complying standards.

Multiple SDOs may exist and many existing may decide to adopt and align their existing standards to this framework. The SDOs can work with the storage operators to develop, test, and improve standards. SDOs can be storage operators.

For each specific storage activity, at a minimum the standard developing organizations are responsible for:

- Supporting storage operators in the development of standards that fit their needs and comply with the framework by providing local knowledge, specific reservoir technical expertise, and developing stakeholder engagement networks.

- Assessing whether the proposed storage activity can be implemented safely, successfully, and equitably following the Environmental and Social Safeguards and the *Fit-For-Purpose* . It may be that certain systems are deemed too high risk in their social or environmental impacts to be acceptable or it may be that modifications can be proposed as safeguards.

- Upon meeting those criteria, developing activity-specific methods that follow the requirements described in the *Measurement Protocol* and the *Monitoring Plan Guidelines*

In addition to the measurement protocol, **each storage activity will need to have a monitoring plan specific to each reservoir and site**. The following must be considered:

- All reservoirs must have ongoing monitoring determined by one or multiple approved monitoring plan(s).

- The purpose of the monitoring is for conformance (assuring the reservoir behavior is understood), containment (ensuring the carbon is where it is expected to be),

[11] In theory, anyone could develop a proposed standard.

and contingency (to determine the quantity of carbon released that will need to be remediated).

- The monitoring plan must collect the appropriate data using appropriate tools at the appropriate sampling frequency and spacing to detect changes in the reservoir carbon content.

- Monitoring plans will vary according to reservoir characteristics. Monitoring for containment does not necessarily mean surface observations, or repeated observations at the same location, or sampling at regular intervals. In subsurface reservoirs, the appropriate monitoring may be in deep subsurface. In dynamic reservoirs, the appropriate monitoring may be repeated observations at irregular intervals to capture fluctuations. Monitoring may require targeting high-risk areas more frequently than other areas. Monitoring may (and probably will) include application of scientific proofs which will dictate monitoring that is not known or evident today.

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- Once the remediation decision is triggered, the release is quantified and flagged in the ledger. The storage operator is responsible for remediation. *See Business Practice .*

- If monitoring never detects a change in the reservoir content until the point of transfer, given the measurement uncertainties, monitoring frequency can decrease thereafter, and eventually, the storage could be considered for the *Permanent Disposal Test* depending on the nature of the reservoir.

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The monitoring plan must meet the following requirements:

5. Monitoring frequency – a protocol must exist that identifies a flexible monitoring frequency, taking into consideration any natural fluctuations as dictated by the physical properties of the reservoir. Until the point of transfer, the maximum interval may not exceed 5 years. After the point of transfer is reached without triggering a remediation decision, depending on the characteristics of the process, the monitoring frequency may decrease up to a maximum of 50 years. These timeframes are established to create a framework to start the certification of carbon sequestration. Experience, jurisdictional preference, and scientific research may advocate modifying these timeframes. Future decreases or increases in frequency should be judged against this starting point as the prudent measurement.

6. Monitoring duration – monitoring, even at large intervals (50 years), must continue for as long the reservoir holds carbon. An expected, average storage duration can be used for planning the activity, but a margin of planning must be included for the possibility that the reservoir can exceed or fall short of expectations.

7. Monitoring equipment – the equipment must be adequate and provide accurate measurements within the agreed upon uncertainty level. Monitoring equipment should meet standard specifications that are published and available for review from third parties. Standardization of equipment will increase reliability, public acceptance, and reduce costs.

8. Monitoring sampling design – the sampling design must accurately report on the carbon content of the reservoir. This design can match the method used for measurement.

The design of the monitoring plan should consider the steps detailed in the Assessment of Low Probability Material Impacts:

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1.3.5 Durability and Permanent Disposal Guidelines

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The following conditions must be true for the transfer to be possible:

- The entity accepting the responsibility must do so willingly, i.e., knowingly and understanding the terms of the transfer.

- This willing party must be an entity that can be supported to continue their responsibilities on multi-generational timescales. The willing party can sub-contract the responsibility and structure recurring contracts.

To protect the willing party, the transfer cannot be free. Therefore, the responsibility to monitor and remediate can be transferred to the willing party at a fee on each certificate. The fee can be devised in many ways, but its **purpose is to pay for a new certificate of sequestration if needed once the willing party takes over after the point of transfer**.

The fee structure is ideally set to be equivalent to the price of the willing party purchasing a certificate after the point of transfer in today's value following an approved discount rate. The willing party receives the responsibility after the storage operator's years of operations meets the point of transfer.

Note: In a perfect world the transfer would be a transaction based on estimated value including a fee structure that would perpetuate the financing of the remediation of the storage. This preference for a fee for longevity may not be the only mechanism exercised for transfer. Understanding the systems in place a half century or century into the future is not possible today and thus the arrangement may entail government or other agency involvement that would utilize tax revenue or some other form of financing. The critical feature is that transfer be to an entity that is capable and willing to continue the verification, and if necessary, remediation, of the storage.

The remediation fund managed by the certificate authority will make the fees available for disbursement as needed.

All certificates will be imposed this fee. Activities that meet the *Permanent Disposal Test* could receive a refund *after the point of transfer* to incentivize the development of activities that meet the criteria of permanent disposal. For both societal and financial reasons, storage that meets the *Permanent Disposal Test* are likely to be favored going forward and incentives should be put in place to encourage such storage. Sequestration certificates purchased to meet the remediation requirement will not be imposed the fee, because the fee will already be paid. Further details in **Annex 2.6.**

The point of transfer is set to 50 years, assuming supporting structures are put in place. This may need to be revisited.

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Some storage activities will be built with longevity in mind. Based on science-based research and proof a consensus can be reached, a particular storage activity could be considered as effectively permanent. This assertion recognizes that no state is permanent within the Earth System, but states can be considered effectively permanent within the climate system.

To be considered to pass the *Permanent Disposal Test*, the following situations are anticipated:

(3) **The reservoir content can be observed.** The reservoir content must increase relative to the agreed and measured baseline. From the start of the activity until the point of transfer, no decrease in the content will have been observed. The monitoring frequency can decrease, but as releases may be rare but large, the monitoring must continue at a maximum interval of 50 years.

(4) **The reservoir content cannot be observed,** but a science-driven consensus has been reached that the reservoir characteristics and storage method means it cannot lose carbon over the required sequestration duration. Monitoring will continue at the appropriate level with the aim to verify the consensus, and the science will be subjected to ongoing peer review.

A reservoir that passes the test and carbon storage is verified is considered permanently disposed.

Science-based methods will with time expand the range of storage methods acceptable to the Permanent Disposal Test.

- .

- Identifying perverse incentives (disqualifying activities)[12] by assessing that incentives align with the desired outcome (Brander et al., 2021) and provide requirement to mitigate against perverse incentives. See *Certificate Authority (CA)* for more details.

- Periodically participating in the reassessment of protocols as new evidence is available, as the scientific evidence evolves, or if a storage activity is found to breach evolving environmental and social safeguards. The standard developing organization will share new scientific evidence, best practices, and breaches in safeguards with the standards certification authority.

- The standard developing organizations may charge a charge to support the storage operator in the development process. Charge structures will evolve and may be co-opted by jurisdiction. For example, a government agency may determine that tax-based support of standards developing organizations is a public good and pay for the work of the standards developing organization.

1.3.6 Storage Operator (SO)

The storage operator (SO) is the entity being issued certificates by the certificate authority (CA) for providing the service of sequestration for each ton of carbon. A storage operator can also be a standard developing organization without conflict because only the standard certification authority can certify the standards meet the requirements of the FCCS.

In addition to abiding by the environmental and social safeguards detailed in the ESS, at a minimum, the storage operator's responsibilities include:

- Demonstrating and implementing within their business plan and operations the following:

    1. **Measuring** – The measurement of carbon following a standard developed and approved by the standards certification authority specifically for the reservoir used by the storage operator.

    2. **Reporting** – The reporting of measurements to the certificate authority to receive a certificate.

[12] For the example of bioenergy carbon capture and storage (BECCS), a perverse incentive might be for a storage operator to switch from growing food crops to energy crops.

3. **Monitoring** – The monitoring of the reservoir following a monitoring plan approved by the standards certification authority for the reservoir used by the storage operator, the cost of which is included in the business plan.

4. **External verification** – Allowing and paying for a reasonable number of verifications by an external auditor who must follow an approved verification plan.

5. **Remediation** – Paying for certificates of sequestration to cover the release of carbon from their reservoir[13].

6. **Pay the responsibility transfer fee** – For every certificate issued, the storage operator must pay a responsibility transfer fee to the willing party collected by the certificate authority. A certificate that is produced to remediate released carbon does not need to pay the transfer fee. Gaining a certificate obligates the storage operator. That obligation is in place until the obligation is successfully transferred to another party. More details under *Willing Party*.

- The storage operator can take credit for carbon uptake that could occur without their intervention. However, taking credit also incurs an obligation and means the storage operator is liable for losses that may occur. The storage operator should measure the carbon content of the reservoir prior to beginning the storage activity (i.e., the baseline) to determine the threshold for this obligation.

- The storage operator will need to provide surety for the remediation of any release of carbon for any reason at any time in the duration that the storage operator plans to operate, by including these costs in their business plans. If the carbon content drops below the baseline, the storage operator is responsible for the remediation and make-up of the loss (this may change with further research).

- If the storage operator decides to close their business prior to the point of transfer (see Responsibility *transfer mechanism*) the storage operator can transfer their responsibility to a willing party, or the storage operator can buy themselves out of the entirety of their obligation by purchasing certificates for each sequestered ton of carbon held in their reservoir. More details under *willing party*.

[13] Remediation may be performed by the storage operator's own activity. However, as the storage operator remediates, all resulting certificates are immediately retired until the remediation is completed.

- The storage operator may approach the standard developing organization to propose new storage activity and co-develop a *Measurement Protocol* and *Monitoring Plan Guidelines*

In addition to the measurement protocol, **each storage activity will need to have a monitoring plan specific to each reservoir and site**. The following must be considered:

- All reservoirs must have ongoing monitoring determined by one or multiple approved monitoring plan(s).

- The purpose of the monitoring is for conformance (assuring the reservoir behavior is understood), containment (ensuring the carbon is where it is expected to be), and contingency (to determine the quantity of carbon released that will need to be remediated).

- The monitoring plan must collect the appropriate data using appropriate tools at the appropriate sampling frequency and spacing to detect changes in the reservoir carbon content.

- Monitoring plans will vary according to reservoir characteristics. Monitoring for containment does not necessarily mean surface observations, or repeated observations at the same location, or sampling at regular intervals. In subsurface reservoirs, the appropriate monitoring may be in deep subsurface. In dynamic reservoirs, the appropriate monitoring may be repeated observations at irregular intervals to capture fluctuations. Monitoring may require targeting high-risk areas more frequently than other areas. Monitoring may (and probably will) include application of scientific proofs which will dictate monitoring that is not known or evident today.

- Monitoring for contingency (quantifying carbon release for the purpose of remediation) may require different data, tools, sampling frequency and spacing than monitoring for containment (ensuring carbon is where it is expected to be).

- The monitoring plan must be flexible to allow for scheduled and on-demand measurements that will vary for each reservoir depending on its characteristics.

- The monitoring plans may change with the process time of the storage activity. The process time refers to the period where there is a change in the physical characteristics of the carbon.

- Monitoring may change based on new advanced techniques and recommendations for improved practices from the standard developing organizations, storage operators, or standards certification authority.

- The monitoring can trigger a **remediation decision determined as a quantity exceeding the threshold of concern, outside of the bounds of agreed measurement uncertainty levels**. Note that all certificates are guaranteed. This means that the buyer is guaranteed the certificate will not expire or be voided. Internally, the storage operator and the certification authority will work to remediate the release and fulfill the guarantee.

- Once the remediation decision is triggered, the release is quantified and flagged in the ledger. The storage operator is responsible for remediation. *See Business Practice .*

- If monitoring never detects a change in the reservoir content until the point of transfer, given the measurement uncertainties, monitoring frequency can decrease thereafter, and eventually, the storage could be considered for the *Permanent Disposal Test* depending on the nature of the reservoir.

- All decisions must be justified.

The monitoring plan must meet the following requirements:

9. Monitoring frequency – a protocol must exist that identifies a flexible monitoring frequency, taking into consideration any natural fluctuations as dictated by the physical properties of the reservoir. Until the point of transfer, the maximum interval may not exceed 5 years. After the point of transfer is reached without triggering a remediation decision, depending on the characteristics of the process, the monitoring frequency may decrease up to a maximum of 50 years. These timeframes are established to create a framework to start the certification of carbon sequestration. Experience, jurisdictional preference, and scientific research may advocate modifying these timeframes. Future decreases or increases in frequency should be judged against this starting point as the prudent measurement.

10. Monitoring duration – monitoring, even at large intervals (50 years), must continue for as long the reservoir holds carbon. An expected, average storage duration can be used for planning the activity, but a margin of planning must be included for the possibility that the reservoir can exceed or fall short of expectations.

11. Monitoring equipment – the equipment must be adequate and provide accurate measurements within the agreed upon uncertainty level. Monitoring equipment should meet standard specifications that are published and available for review from third parties. Standardization of equipment will increase reliability, public acceptance, and reduce costs.

12. Monitoring sampling design – the sampling design must accurately report on the carbon content of the reservoir. This design can match the method used for measurement.

The design of the monitoring plan should consider the steps detailed in the Assessment of Low Probability Material Impacts:

11. Set quantitative and measurable success criteria
12. Model the occurrence of low probability material impacts (natural and man-made)
13. Model the response of monitoring systems to material impacts
14. Execute monitoring during project deployment
15. Reporting a finding that success criteria have been met

1.3.7 Durability and Permanent Disposal Guidelines

CO2 remains in the atmosphere indefinitely in the context of human timescales. However, unlike radioactive or other toxic wastes, it can be released into the environment and cleaned-up (i.e., neutralized) relatively easily (mostly) without immediate harm if the clean-up is also immediate. The harm develops when the clean-up occurs much later than the emission. For carbon sequestration to be considered a viable climate change mitigation solution, it requires a certification design that **considers the risk premium of a release of carbon and the principles of the producer's responsibility and intergenerational equity**. *See Annex 2.5 for more details on the assumptions.*

The framework understands **permanent disposal to mean a condition of a reservoir where the probability weighted release during the required sequestration duration falls below the threshold of concern.** This definition means:

- The stored carbon is only released in small enough quantities over a long enough period that it will no longer cause environmental damage because the quantities can be absorbed by the climate system.

- The release from one reservoir may not create damages, but damages will accrue if all reservoirs release carbon. Therefore, the release relative to the total will need to be considered.

- The **release must be spread over longer than ten thousand years**. **The threshold of concern may amount to 0.01% per year.** Scientific and jurisdictional debate over this percentage is inevitable. Considering the stakes if sequestration goes wrong, 0.01% is a justifiable starting point that ought to be maintained as the target unless there is overwhelming rationale to modify it. *See Annex 2.5 for more details on the assumptions.*

- In contrast, durability is the property of a reservoir to continue to store carbon through physical and contractual means. While durability does not have an end point, permanent disposal does. It uses physical properties and scientific process to assess the stability of the storage condition. The difference between permanent disposal and popular definitions of permanence is that it does not arbitrarily assign an end point.

Few reservoirs will meet this definition of permanent disposal, yet these still have a critical role to play; they are more likely to be deployable today and will diversify the portfolio of storage activities. However, all storage activities for the purpose of climate mitigation must be understood to be a serious undertaking for humanity. Regardless of how it is done, the gigantic volumes of carbon removal anticipated will be challenging to manage. Those volumes will be even more challenging if they require continuous maintenance. At the end of the day, reaching a state of permanent disposal is the only way to end the responsibility of having emitted CO2 in a fair manner. *See Annex 2.5 for more details on the assumptions.*

Therefore, the framework requires that all carbon certified as sequestered must meet the permanence guidelines: the **durability of all storage activities is ensured by the combination of monitoring and remediation.** The requirement of monitoring and remediation applies to all reservoirs. Because it is also a perpetual requirement, the framework offers a solution for the storage operator’s responsibility to end:

5. Some storage will pass a test of permanent disposal allowing for a less onerous continuum of monitoring activities.
6. Those that fail the test will require a transfer of responsibility of the reservoir.

All activities must include a fee for the transfer of responsibility. Those that pass the test may receive a rebate. Permanent storage, the reduction of monitoring, and the avoidance of future expense ought to be the long-term goals of sequestration. A strong and reliable certification program with universal adherence is a critical part of that path. The two mechanisms are described in detail.

1.3.7.1 *Responsibility transfer mechanism*

Some storage activities will be designed with longevity in mind and others will not. The framework offers infrastructure to support both with a mechanism that transfers to another party the storage operator's responsibility to monitor and remediate. Monitoring, remediation, and responsibility transfer meet the criteria for durability. The mechanism is summarized before the components are described:

A certificate is awarded for the increase of carbon in a reservoir. Each certificate incurs a fee. All reservoirs must be monitored by the storage operator. Any releases are remediated by the storage operator through the purchase of a new certificate, ensuring the integrity of the certificate. At the point of responsibility transfer, the responsibility for monitoring and remediation is transferred to a willing party.

The following conditions must be true for the transfer to be possible:

- The entity accepting the responsibility must do so willingly, i.e., knowingly and understanding the terms of the transfer.

- This willing party must be an entity that can be supported to continue their responsibilities on multi-generational timescales. The willing party can sub-contract the responsibility and structure recurring contracts.

To protect the willing party, the transfer cannot be free. Therefore, the responsibility to monitor and remediate can be transferred to the willing party at a fee on each certificate. The fee can be devised in many ways, but its **purpose is to pay for a new certificate of sequestration if needed once the willing party takes over after the point of transfer**.

The fee structure is ideally set to be equivalent to the price of the willing party purchasing a certificate after the point of transfer in today's value following an approved discount rate. The willing party receives the responsibility after the storage operator's years of operations meets the point of transfer.

Note: In a perfect world the transfer would be a transaction based on estimated value including a fee structure that would perpetuate the financing of the remediation of the storage. This preference for a fee for longevity may not be the only mechanism exercised for transfer. Understanding the systems in place a half century or century *into the future is not possible today and thus the arrangement may entail government or other agency involvement that would utilize tax revenue or some other form of financing. The critical feature is that transfer be to an entity that is capable and willing to continue the verification, and if necessary, remediation, of the storage.*

The remediation fund managed by the certificate authority will make the fees available for disbursement as needed.

All certificates will be imposed this fee. Activities that meet the *Permanent Disposal Test* could receive a refund *after the point of transfer* to incentivize the development of activities that meet the criteria of permanent disposal. For both societal and financial reasons, storage that meets the *Permanent Disposal Test* are likely to be favored going forward and incentives should be put in place to encourage such storage. Sequestration certificates purchased to meet the remediation requirement will not be imposed the fee, because the fee will already be paid. Further details in **Annex 2.6.**

The point of transfer is set to 50 years, assuming supporting structures are put in place. This may need to be revisited.

1.3.7.2 *Permanent Disposal Test*

Some storage activities will be built with longevity in mind. Based on science-based research and proof a consensus can be reached, a particular storage activity could be considered as effectively permanent. This assertion recognizes that no state is permanent within the Earth System, but states can be considered effectively permanent within the climate system.

To be considered to pass the *Permanent Disposal Test*, the following situations are anticipated:

(5) **The reservoir content can be observed.** The reservoir content must increase relative to the agreed and measured baseline. From the start of the activity until the point of transfer, no decrease in the content will have been observed. The monitoring frequency can decrease, but as releases may be rare but large, the monitoring must continue at a maximum interval of 50 years.

(6) **The reservoir content cannot be observed,** but a science-driven consensus has been reached that the reservoir characteristics and storage method means it cannot lose carbon over the required sequestration duration.

Monitoring will continue at the appropriate level with the aim to verify the consensus, and the science will be subjected to ongoing peer review.

A reservoir that passes the test and carbon storage is verified is considered permanently disposed.

Science-based methods will with time expand the range of storage methods acceptable to the Permanent Disposal Test.

- or attempt the development on their own.

- The storage operator must be provided with the environmental and social safeguards document, must follow all applicable laws, and include public engagement in their planning phase.

- The storage operator must accept that their operations will be publicly scrutinized through the open ledger reporting on the issuance of certificates and their auditing.

- The storage operator may be refunded the transfer fees for storage that has passed the permanent disposal test.

- The storage operator could transfer their responsibility to another storage operator if the new operator satisfied all the conditions as dictated in the FCCS and the certificate authority.

- It may be in the interest of storage operators to be bonded and insured. Whether this will be a requirement set by the Certificate Authority remains to be determined.

1.3.8 Willing Party

The willing party, or their designated and pre-agreed competent authority, willingly accepts the transfer of responsibility at a fee for activities that have sequestered carbon until the agreed point of transfer. The fee represents the potential purchase of a new certificate of storage after the point of transfer. If the storage operator and the willing party are both government entities, the jurisdiction may be obligated to finance the remediation *in lieu* of the fee. See Responsibility for more details.

The willing party differs from the storage operator in that they cannot free themselves of the liability of sequestration and they can access the remediation fund in the event of a release. At a minimum, the willing party's responsibilities include:

- Deciding to either continue to monitor the reservoir as detailed in the monitoring plan or purchase using the fees collected enough certificates to close the activity.

- Ensuring that information regarding the presence of the reservoir is passed on to future landowners by attaching requirements to the deeds of the land. Requirements may include the obligation to disclose the land is used for carbon sequestration. The new landowner can interfere with the reservoir only if they are willing to purchase the reservoir to the value of the certificates that would cover the carbon it contains.

- Reporting to the certificate authority the monitoring observations and authorizing auditing. The certificate authority will work with the willing party by disbursing the necessary fees to the purchase of a new certificate of sequestration to cover the remediation within 30 days. The willing party will use the fee collected at the issuance of the certificate kept in the remediation fund operated by the certificate authority for the purchase.

- Working with the certificate authority and the storage operators.

1.3.9 External auditors

The role of the external auditors is to verify information. Auditors are necessary at all stages in the certification program including:

- Periodically and randomly auditing the reservoirs contents to verify it matches the contents reported from the certificate issuance.

- Auditing the storage operators for compliance with the environment and social safeguards.

- Auditing the storage operators for compliance with their monitoring plans.

- Auditing the standard developing organizations for compliance with transparency and inclusion of stakeholders.

- Auditing the certificate authority for their certificate issuance and reporting to the ledger.

- Auditing the standards certification authority to verify their process matches the rules.
- Auditing the standards certification authority and standard developing organizations to verify their financial and administrative process.
- Reporting their findings transparently and openly to the ledger for public scrutiny.

1.3.10 Review Board

The review board exists to examine situations that may arise in the certification process that require an external, independent, process to decide whether to improve, correct, or change. Cases can be referred to the review board by all actors in the certification process, including appeals, challenges, complaints, and other issues. The review board may be tasked with making value-based recommendations. The review board shall be composed of independent members free of conflicts of interests. The selection process of these members is to be determined.

1.4 Standard development guidelines

The standard certification authority shall assess proposed standards based at a minimum on the fitness of the proposed activities, the measurement protocol, the monitoring plan, and the considerations of durability.

1.4.1 Fit-For-Purpose Guidelines

Carbon sequestration activities considered for certification ought to be fit-for-purpose. The main purpose of carbon sequestration is to improve the climate by storing excess carbon, and the impact it will have on the environment and communities is a tradeoff that will need to be managed through Environmental and Social Safeguards (ESS). The fit-for-purpose guidelines exist to help the standard certification authority assess the fitness of proposed carbon sequestration activities.

Unless scientific evidence can demonstrate otherwise, reservoirs and activities will be considered as fit-for purpose if:

- The reservoir can keep carbon away from the atmosphere and the amount of carbon added to the reservoir can be measured. The *Measurement Protocol* can be used to identify if the proposed activity requires further scientific research to demonstrate this is the case.

- The activity can remove more carbon than it emits.

  Ensuring that a planned activity approaches carbon negativity can be assessed through a Life Cycle Analysis (LCA). **Activities must remove more carbon than they produce**[14] to be economically viable. A Techno-Economic Assessment may quickly determine if this is the case.

  The storage operator ought to design their activities such that if the Carbon Take Back Obligation (CBTO)[15] or similar policy was to take effect, their activities would have the anticipated impact on emissions. The CBTO, or similar policy, would require that all fossil carbon use must be matched by a certificate of sequestration. All carbon released from carbon reservoirs would also need to be matched by a new certificate. An activity that produces more emissions than it removes would become economically unviable. Until the CBTO or similar policy takes effect, **each storage activity certified under the FCCS must publicly disclose how much carbon it emits compared to how much it has sequestered.**

- The reservoir does not fill spontaneously.

  Spontaneous filling may occur when reservoirs are connected, or the boundaries of a reservoir cannot be clearly identified. Storage activities using reservoirs that do not have clear boundaries are generally unsuitable, although activities will be considered if they can be justified on a scientific basis. Reservoirs that overlap between storage operators are generally unsuitable, but solutions for accurate accounting can be proposed, including through a system of carbon shares. The *Measurement Protocol* can be used to identify if the proposed activity requires further scientific research to demonstrate this is not the case.

- The reservoir does not have such large fluctuations in their carbon content that they cannot be measured within agreed certainty.

  A fluctuating reservoir can be fit-for-purpose but only if measurements can be made rigorously and convincingly. This implies demonstrating a deep understanding of the specific system, including where the uncertainties are and how large these are.

- The activity will not compromise existing reservoirs.

[14] In the context of this framework, the assumption is that every ton of carbon produced would incur the requirement of sequestering a ton. Designs that are not net negative would be economically unviable.

[15] Ibid 6.

Compromising existing reservoirs may mean the following situations amongst others, as decided by the standards certification authority. A planned activity must not breach the integrity of an existing reservoir such that carbon would be released. A planned activity must not intend to replace an existing reservoir with a new one unless it can be shown that significantly more carbon would be stored without delay.

The activity either does not degrade the environment (atmosphere, hydrosphere, biodiversity, and soil health) or considers safeguards to minimize environmental damage. Environmental damage according to local, existing regulation may include, but is not limited to, loss of species habitat, pollution, excessive noise, nutrient depletion, or water diversion, and unsustainable sourcing of inputs. Activities that remove carbon but produce other greenhouse gases will not be considered fit-for-purpose. Activities that cannot identify potential impacts on the environment ought to be considered from a precautionary lens. Further scientific research and pilot testing may be necessary.

- The activity removes carbon from the mobile carbon pool.

1.4.2 Measurement Protocol Guidelines

Each storage activity will need its own measurement protocol as equipment and methods will vary for each reservoir and each site. However, every measurement protocol will need to follow a minimum of technical requirements as follows:

1. Carbon source – the source of the carbon must be verifiable[16].

2. Reservoir delineation – a method must exist to identify the physical limits of the reservoir.

3. Additions – a method must exist to determine how much carbon is added to the reservoir[17] and there should be clarity as to the timeframe of the measurement.

4. On demand measurements – a method must exist to determine on demand, but not necessarily instantaneously, how much carbon is in the reservoir at a given time. This method can be applied to assess the baseline before the storage activity begins. Measurement may be based on scientific proof for reservoirs that could potentially pass the *Permanent Disposal Test.*

[16] This is only necessary if the Carbon Take Back Obligation, or similar policy, has not taken effect.
[17] Note: the addition may take time to be observed as a change in the carbon content of the reservoir.

5. Uncertainty assessment - a method must exist to quantify the uncertainty of each measurement of reservoir content or addition.

1.4.3 Monitoring Plan Guidelines

In addition to the measurement protocol, **each storage activity will need to have a monitoring plan specific to each reservoir and site**. The following must be considered:

- All reservoirs must have ongoing monitoring determined by one or multiple approved monitoring plan(s).

- The purpose of the monitoring is for conformance (assuring the reservoir behavior is understood), containment (ensuring the carbon is where it is expected to be), and contingency (to determine the quantity of carbon released that will need to be remediated).

- The monitoring plan must collect the appropriate data using appropriate tools at the appropriate sampling frequency and spacing to detect changes in the reservoir carbon content.

- Monitoring plans will vary according to reservoir characteristics. Monitoring for containment does not necessarily mean surface observations, or repeated observations at the same location, or sampling at regular intervals. In subsurface reservoirs, the appropriate monitoring may be in deep subsurface. In dynamic reservoirs, the appropriate monitoring may be repeated observations at irregular intervals to capture fluctuations. Monitoring may require targeting high-risk areas more frequently than other areas. Monitoring may (and probably will) include application of scientific proofs which will dictate monitoring that is not known or evident today.

- Monitoring for contingency (quantifying carbon release for the purpose of remediation) may require different data, tools, sampling frequency and spacing than monitoring for containment (ensuring carbon is where it is expected to be).

- The monitoring plan must be flexible to allow for scheduled and on-demand measurements that will vary for each reservoir depending on its characteristics.

- The monitoring plans may change with the process time of the storage activity. The process time refers to the period where there is a change in the physical characteristics of the carbon[18].

- Monitoring may change based on new advanced techniques and recommendations for improved practices from the standard developing organizations, storage operators, or standards certification authority.

- The monitoring can trigger a **remediation decision determined as a quantity exceeding the threshold of concern, outside of the bounds of agreed measurement uncertainty levels**. Note that all certificates are guaranteed. This means that the buyer is guaranteed the certificate will not expire or be voided. Internally, the storage operator and the certification authority will work to remediate the release and fulfill the guarantee.

- Once the remediation decision is triggered, the release is quantified and flagged in the ledger. The storage operator is responsible for remediation. *See Business Practice .*

- If monitoring never detects a change in the reservoir content until the point of transfer, given the measurement uncertainties, monitoring frequency can decrease thereafter, and eventually, the storage could be considered for the *Permanent Disposal Test* depending on the nature of the reservoir.

- All decisions must be justified.

The monitoring plan must meet the following requirements:

13. Monitoring frequency – a protocol must exist that identifies a flexible monitoring frequency, taking into consideration any natural fluctuations as dictated by the physical properties of the reservoir. Until the point of transfer, the maximum interval may not exceed 5 years. After the point of transfer is reached without triggering a remediation decision, depending on the characteristics of the process, the monitoring frequency may decrease up to a maximum of 50 years. These timeframes are established to create a framework to start the certification of carbon sequestration. Experience, jurisdictional preference, and scientific research may advocate modifying these timeframes. Future decreases or

[18] An example of a process time may be the period between when carbon is injection in a geological formation and when the carbon becomes mineralized. One monitoring plan would be designed for carbon stored as a supercritical gas, which would then transition to a monitoring plan for carbon stored as a mineral. Another example may be carbon stored in a forest first mostly in trees, then eventually mostly in soil matter.

increases in frequency should be judged against this starting point as the prudent measurement.

14. Monitoring duration – monitoring, even at large intervals (50 years), must continue for as long the reservoir holds carbon. An expected, average storage duration[19] can be used for planning the activity, but a margin of planning must be included for the possibility that the reservoir can exceed or fall short of expectations.

15. Monitoring equipment – the equipment must be adequate and provide accurate measurements within the agreed upon uncertainty level. Monitoring equipment should meet standard specifications that are published and available for review from third parties. Standardization of equipment will increase reliability, public acceptance, and reduce costs.

16. Monitoring sampling design – the sampling design must accurately report on the carbon content of the reservoir. This design can match the method used for measurement.

The design of the monitoring plan should consider the steps detailed in the Assessment of Low Probability Material Impacts[20]:

16. Set quantitative and measurable success criteria
17. Model the occurrence of low probability material impacts (natural and man-made)
18. Model the response of monitoring systems to material impacts
19. Execute monitoring during project deployment
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1.4.4 Durability and Permanent Disposal Guidelines

CO_2 remains in the atmosphere indefinitely in the context of human timescales. However, unlike radioactive or other toxic wastes, it can be released into the environment and cleaned-up (i.e., neutralized) relatively easily (mostly) without immediate harm if the clean-up is also immediate. The harm develops when the clean-up occurs much later than the emission. For carbon sequestration to be considered a viable climate change mitigation solution, it requires a certification design that **considers the risk premium of a release of carbon and the principles of the**

[19] Each reservoir type has an expected, average storage duration which may be exceeded or fall short at a particular site.

[20] Hovorka, S. (2017). Assessment of low probability material impacts. 13th International Conference on Greenhouse Gas Control Technologies, GHGT-13, 14-18 November 2016, Lausanne, Switzerland. Energy Procedia 114, 5311 – 5315.

producer's responsibility and intergenerational equity. *See Annex 2.5 for more details on the assumptions.*

The framework understands **permanent disposal to mean a condition of a reservoir where the probability weighted release during the required sequestration duration falls below the threshold of concern.** This definition means:

- The stored carbon is only released in small enough quantities over a long enough period that it will no longer cause environmental damage because the quantities can be absorbed by the climate system.

- The release from one reservoir may not create damages, but damages will accrue if all reservoirs release carbon. Therefore, the release relative to the total will need to be considered.

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Few reservoirs will meet this definition of permanent disposal, yet these still have a critical role to play; they are more likely to be deployable today and will diversify the portfolio of storage activities. However, all storage activities for the purpose of climate mitigation must be understood to be a serious undertaking for humanity. Regardless of how it is done, the gigantic volumes of carbon removal anticipated will be challenging to manage. Those volumes will be even more challenging if they require continuous maintenance. At the end of the day, reaching a state of permanent disposal is the only way to end the responsibility of having emitted CO_2 in a fair manner. *See Annex 2.5 for more details on the assumptions.*

Therefore, the framework requires that all carbon certified as sequestered must meet the permanence guidelines: the **durability of all storage activities is ensured by the**

combination of monitoring and remediation. The requirement of monitoring and remediation applies to all reservoirs. Because it is also a perpetual requirement, the framework offers a solution for the storage operator's responsibility to end:

7. Some storage will pass a test of permanent disposal allowing for a less onerous continuum of monitoring activities.
8. Those that fail the test will require a transfer of responsibility of the reservoir.

All activities must include a fee for the transfer of responsibility. Those that pass the test may receive a rebate. Permanent storage, the reduction of monitoring, and the avoidance of future expense ought to be the long-term goals of sequestration. A strong and reliable certification program with universal adherence is a critical part of that path. The two mechanisms are described in detail.

1.4.4.1 *Responsibility transfer mechanism*

Some storage activities will be designed with longevity in mind and others will not. The framework offers infrastructure to support both with a mechanism that transfers to another party the storage operator's responsibility to monitor and remediate. Monitoring, remediation, and responsibility transfer meet the criteria for durability. The mechanism is summarized before the components are described:

A certificate is awarded for the increase of carbon in a reservoir. Each certificate incurs a fee. All reservoirs must be monitored by the storage operator. Any releases are remediated by the storage operator through the purchase of a new certificate, ensuring the integrity of the certificate. At the point of responsibility transfer, the responsibility for monitoring and remediation is transferred to a willing party.

The following conditions must be true for the transfer to be possible:

- The entity accepting the responsibility must do so willingly, i.e., knowingly and understanding the terms of the transfer.

- This willing party must be an entity that can be supported to continue their responsibilities on multi-generational timescales. The willing party can sub-contract the responsibility and structure recurring contracts.

To protect the willing party, the transfer cannot be free. Therefore, the responsibility to monitor and remediate can be transferred to the willing party at a fee on each certificate. The fee can be devised in many ways, but its **purpose is to pay for a new**

certificate of sequestration if needed once the willing party takes over after the point of transfer.

The fee structure is ideally set to be equivalent to the price of the willing party purchasing a certificate after the point of transfer in today's value following an approved discount rate. The willing party receives the responsibility after the storage operator's years of operations meets the point of transfer.

Note: In a perfect world the transfer would be a transaction based on estimated value including a fee structure that would perpetuate the financing of the remediation of the storage. This preference for a fee for longevity may not be the only mechanism exercised for transfer. Understanding the systems in place a half century or century into the future is not possible today and thus the arrangement may entail government or other agency involvement that would utilize tax revenue or some other form of financing. The critical feature is that transfer be to an entity that is capable and willing to continue the verification, and if necessary, remediation, of the storage.

The remediation fund managed by the certificate authority will make the fees available for disbursement as needed.

All certificates will be imposed this fee. Activities that meet the *Permanent Disposal Test* could receive a refund *after the point of transfer* to incentivize the development of activities that meet the criteria of permanent disposal. For both societal and financial reasons, storage that meets the *Permanent Disposal Test* are likely to be favored going forward and incentives should be put in place to encourage such storage. Sequestration certificates purchased to meet the remediation requirement will not be imposed the fee, because the fee will already be paid. Further details in **Annex 2.6**.

The point of transfer is set to 50 years, assuming supporting structures are put in place. This may need to be revisited.

1.4.4.2 *Permanent Disposal Test*

Some storage activities will be built with longevity in mind. Based on science-based research and proof a consensus can be reached, a particular storage activity could be considered as effectively permanent. This assertion recognizes that no state is permanent within the Earth System, but states can be considered effectively permanent within the climate system.

To be considered to pass the *Permanent Disposal Test*, the following situations are anticipated:

(7) **The reservoir content can be observed.** The reservoir content must increase relative to the agreed and measured baseline. From the start of the activity until the point of transfer, no decrease in the content will have been observed. The monitoring frequency can decrease, but as releases may be rare but large, the monitoring must continue at a maximum interval of 50 years.

(8) **The reservoir content cannot be observed,** but a science-driven consensus has been reached that the reservoir characteristics and storage method means it cannot lose carbon over the required sequestration duration. Monitoring will continue at the appropriate level[21] with the aim to verify the consensus, and the science will be subjected to ongoing peer review.

A reservoir that passes the test and carbon storage is verified is considered permanently disposed.

Science-based methods will with time expand the range of storage methods acceptable to the Permanent Disposal Test.

1.5 Business Practice

To enable the operationalization of the certification system, certain business practices are required. The storage operator is responsible for the following:

- Demonstrating in the business plan of the storage activity:
    - The inclusion of the cost monitoring long enough to reach the point of transfer.
    - The inclusion of planning for the purchase of remediation if monitoring finds carbon to have been released for any reason until the point of transfer.
    - If the storage operator wishes to end their business before the point of transfer, the storage operator must either buy themselves out of the program, or a new entity must be contracted to assume the obligation

[21] This may not be at the level of the storage site, but more generally.

and put in place a new acceptable plan for storage. Moreover, this means that all carbon in the reservoir must be covered by remediation through the purchase of new certificates.

- Demonstrating to the certificate authority the understanding of being responsible to remediate any lost carbon from the reservoir for any reason at any time until the point of transfer. This requirement can be fulfilled by simply purchasing a certificate of sequestration.

- Providing evidence for the vetting process by the certificate authority of:

    - Documents demonstrating that the Environmental and Social Safeguards have been met.

    - Documents demonstrating the acquisition of a surety, performance, or contract bond or insurance as required by the certificate authority. It is in the interest of storage operators to be bonded and insured. The Certificate Authority may decide to make this a requirement.

1.6 Environmental and social safeguards (ESS)

The FCCS requires that the Certificate Authority adopts Environmental and Social Safeguards (ESS) guidelines to guide the vetting of Storage Operators. Storage operators that do not abide to the guidelines may not have their removed carbon certified by the Certificate Authority.

The ESS is different from the FCCS fit-for-purpose guidelines. The fit-for-purpose guidelines are there to help assess the proposed standards. These guidelines do not have a say on projects. Meanwhile, the ESS is there to decide if storage operator operations are acceptable and thus may apply on a case-by-case basis.

Although the FCCS leaves the development of the ESS open at this stage. Guidance may be sought from the UNDP Social and Environmental Standards[22], the

[22] Available at: https://info.undp.org/sites/bpps/SES_Toolkit/SES%20Document%20Library/Uploaded%20October%202016/UNDP%20Social%20and%20Environmental%20Standards_2019%20UPDATE.pdf

Accountability Framework[23] and the International Union for the Conservation of Nature[24].

The ESS may include a list of disqualifying activities[25]. Disqualifying activities may include acts such as environmental destruction (e.g., deforestation) prior to establishment of sequestration methods (e.g., reforestation); unsustainable sourcing of biomass or minerals (e.g., for Biomass Carbon Removal and Storage (BiCRS)); using inappropriate minerals for carbonation (e.g., heavy metals); displacement of local communities to establish sequestration activities (e.g., afforestation); depletion of nutrients, diversion of water, loss of habitats; unmitigated pollution, increase in local traffic.

The ESS must include a requirement for public engagement. Guidance may be sought from Arnstein's Ladder of Citizen Participation[26]. The activity must have followed prior, engaged, and due process with communities in which it will be located[27].

The stringency of the safeguards will need to be revised to meet societal tolerance.

1.7 Process information

1.7.1 Proposing new standards

Under the framework, anyone can design and develop new standards. Any activities can be proposed but only those that comply with the framework's *Fit-For-Purpose Activities* can be considered for certification. Any entity can provide comments on the guidelines which may be changed with sufficient evidence.

1.7.2 Developing new measurement protocols

New measurement protocols can be developed by storage operators or standard developing organizations, or anyone else. The standards certification authority can also solicit submissions for promising reservoir types.

[23] Available at: https://accountability-framework.org/wp-content/uploads/2020/09/OG_Monitoring_Verification-2020-5.pdf
[24] Available at: https://portals.iucn.org/library/sites/library/files/documents/2020-020-En.pdf
[25] In the absence of a Certificate Authority, an Environmental and Social Safeguards (EES) framework could be developed independently.
[26] Available at: https://www.citizenshandbook.org/arnsteinsladder.html
[27] A procedure specific to carbon sequestration and agnostic of activity type is yet to be widely accepted although many efforts are underway, and templates exist from other industries. See Burns (2016) for an example.

1.7.3 *Tracking carbon sequestration certificates*

All issued certificates must be tracked. A dual ledger will track issued certificates on one side and the chain of ownership on the other. An issued certificate cannot be removed from the tracking system, and they cannot be voided. Instead, the ledger keeps track of a tally of certificates for each storage operator. The tally changes with each monitoring. A tally that diminished will need to the replenished to the pre-release level by the storage operator purchasing new certificates to match the decrease. Thus, the tracking of carbon released from storage will be done at the level of storage operator, rather than at the level of the certificates to minimize complexity. However, each certificate will keep track of the project original metadata, the contents of which will be listed in *Annex 3* in future versions of the framework. Whether the certificate can be traced to a carbon release could be scientifically interesting but unnecessary for the system to operate. These conditions would likely require a central, open source, publicly accessible, international dual ledger that uses automation as much as possible to reduce paperwork.

1.7.4 *Steps to certification*[28]

1. Demonstrate the CDR activity meets the *Fit-For-Purpose Guidelines*

2. Develop a measurement protocol that meets the *Measurement Protocol*

3. Develop a monitoring plan that meets the *Monitoring Plan*

4. Demonstrate inclusion of monitoring and remediation in business plan as per the *Business Practice*

5. If necessary, measure and report reservoir carbon content prior to commencement of activities

6. Provide metadata to the dual ledger as per *Annex 3*

7. Measure added carbon to the reservoir

8. External auditor verifies reservoir content

9. Certificate of sequestration is issued

10. Monitor reservoir content through time, verify on schedule, and remediate as needed

11. Under the right conditions, pass the *Permanent Disposal Test.*

[28] The most efficient order remains to be tested.

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Annex 1

The framework reflects insights gained from interviews with experts on aspects related to carbon sequestration but may not in any way represent the interviewees' or reviewers' points of view. This version of the framework attempts to incorporate comments from external reviewers but may not represent the reviewers' points of view. The list of interviewees and external reviewers is provided here for transparency.

1.1 Interviewees

- Jorg Aarnes, Der Nordic Veritas
- Daniel Bodansky, Arizona State University
- Derik Broekhoff, Stockholm Environmental Institute
- William Burns, American University
- Norman Cocanour, insurance industry executive (AEGIS Insurance)
- Maggie Comstock, Conservation International
- Zachary Cooper, Arizona State University
- Katharyn Duffy, Northern Arizona University
- Katherine Forbes, International Red Cross, Chair Finance and Risk
- Michael Gillenwater, GHG Management Institute
- Allie Golstein, Conservation International
- Lorie Guetre, Carbon Engineering
- Thomas Hartley, insurance industry
- Christoph Jospe, Nori
- Daniel Karner, Electric Applications Inc.
- Kyrissa Kasprzyk, Conservation International
- Niall Mac Dowell, Imperial College UK
- Gary Marchant, Arizona State University
- Matt Ramlow, World Resources Institute
- Arnind Roopsind, Conservation International

1.2 Internal reviewers for version 0.2

- Habib Azarabadi, Arizona State University
- Kirk Thompson, Arizona State University

1.3 External reviewers for version 1.0

- Matthew Green, Arizona State University
- Bronson Griscom, Conservation International
- Norman Cocanour, insurance industry
- Maggie Comstock, Conservation International
- Thomas Hartley, insurance industry
- Daniel Karner, Electrical Applications
- Kyrissa Kasprzyk, Conservation International
- Matt Ramlow, World Resources Institute
- Philip Gough-Stone, Arizona State University
- Starry Sprenkle-Hyppolite, Conservation International
- William Brandt, Arizona State University

Annex 2

2.1 Co-benefits

Some existing certification schemes include co-benefits in addition to carbon (**Table 3**) (Broekhoff et al., 2019; Goldstein, 2016; McDonald et al., 2021). Co-benefits may include the well-researched impacts on ecosystems, economic activity, health, air pollution, and resource efficiency, as well as the less-researched impacts on conflict and disaster resilience, poverty alleviation (or exacerbation), energy security, technological spillovers and innovation, and food security (Deng et al., 2017). Important reasons exist for identifying co-benefits, as they can be a buyer's top concern in choosing one certificate over another, as seen in the market for carbon offsets (Hamrick and Goldstein, 2016).

Including co-benefits may be done through qualitative or quantitative means. **Table 3** demonstrates that specific standards add labels for co-benefits for informational purposes only. However, whether the project delivers those co-benefits could be questioned. Other standards not listed in the table (e.g., American Carbon Registry, MoorFutures) refer to co-benefits as minimizing harm or risks of negative externalities.

Despite the buyers' appeal, the FCCS takes the view that certifying co-benefits ought to have a dedicated process to uphold the integrity of the certified characteristics, just as certifying sequestration requires one. Moreover, certifying co-benefits within the same framework as sequestration would increase the certification cost and the complexity of the process. Nevertheless, additional and optional external certifications can provide evidence of co-benefits for additional costs to the storage operator, to be borne by consumers interested in those co-benefits. The FCCS can take co-benefits into account by identifying on the certificate the storage operation, and mention any otherwise certified co-benefits, without directly engaging into the latter certification.

Table 3. Evaluation of co-benefits inclusion in a sample of existing standards for carbon sequestration. Information derived from Table 1 in McDonald et al. (2021).

Standard developing organization	Co-benefit type
Label Bas Carbone	Environmental integrity must be demonstrated during the methodology approval process. Co-benefits are scored on a “co-benefit matrix” but all projects receive the same certification regardless of co-benefits. The co-benefits are labelled for the interest of the buyers. The program also allows for the use of an auditing tool to calculate certain co-benefits, and others can be added if they are monitored and verified.
New Zealand ETS	Information on the potential co-benefits is used to promote carbon removal activities.
Clean Development Mechanism (CDM)	Sustainable development criteria, including co-benefits, are mandatory to cover and justify the projects.
Joint Implementation (JI)	Technology transfer occurring during the JI is highlighted as a co-benefit of the program.
California’s Compliance Offset Program	Protocols are prioritized on criteria that include co-benefits.
VCS Jurisdictional and Nested REDD+ (JNR)	The program allows the use of other, optional but external programs that certify co-benefits like the Climate, Community & Biodiversity Standards or FSC.
Verra	Provides information on the potential co-benefits that the protocols could bring.
Woodland Carbon Code	The program refers to external research that has analysed its impact in terms of co-benefits.
Puro.Earth	The suppliers using Puro.Earth provides information on the potential co-benefits that they could bring.
California Low Carbon Fuel Standard	Provides information on the potential co-benefits that the protocols could bring.

2.2 Definition of a certificate

The FCCS defines a certificate as a document representing the guarantee of the service's performance and durability of keeping carbon away from the atmosphere. Certificates may be purchased to represent the amount of carbon removed from the environment.

The FCCS takes the position that a certificate of carbon sequestration may be considered a different type of instrument than a traditional carbon offset for various reasons. Originally, offsets were instruments to lower the economic burden of emission caps on heavy industries. Instead of direct emission cuts, industries under cap-and-trade could purchase offsets outside the cap. These offsets needed to be additional to the reductions under the cap to be made equivalent. Under the Kyoto Protocol, offsetting through carbon removal was also permitted from afforestation and reforestation projects developed under the Clean Development Mechanism. Eventually, offsets were also made available to the voluntary market for individuals and companies to reduce their emissions cheaply. In this context, offsets usually represented emission reductions, removed, or avoided elsewhere under the simplified observation that a ton is a ton.

Under the FCCS a certificate can be used to neutralize a ton of fossil carbon if done so at the point of extraction or import. Neutralizing at the onset avoids the issue that Zickfeld et al. (2021) raises about the asymmetry between the climate response to an emission and the response to a removal due to the land and oceans. Asymmetry comes into force over time and for large quantities of removal. Here the FCCS requires neutralization as close to the time of emission as possible. The situation may be different for the neutralization of very old historical emissions. Still, more research would be necessary to determine this and how it impacts the concept of "net-zero".

Furthermore, a certificate can be used for other purposes, including regulating Earth's temperature without attributing responsibility. For example, consider the case where decades into the future, humanity has reached negative global emissions whereby the atmospheric concentration of CO2 is declining. A certificate in that negative emission world will no longer cancel current emissions but a historical emission that may not be attributable. Nation states may be tasked with shared but differentiated burdens to pay for certificates, which could be tied to various metrics.

2.3 Additionality

For offsetting purposes, the additionality criterion, defined as whether a recognized policy intervention is causing a proposed activity, is critical (Gillenwater, 2012). This is because the activity could be used to claim an allowance for an emission regulated under a cap-and-trade system. If activities outside the cap are not additional, the climate benefits are reduced or even negated. This cap-and-trade understanding of additionality applies to instruments that represent carbon removal used for traditional offsetting. As the FCCS takes the position that certificates are not traditional offsets, this understanding of additionality does not apply. Instead, the FCCS requires balancing carbon upstream at the source of carbon extraction or import. In this sense, all carbon is under the cap.

Another understanding of additionality is avoiding financing activities that would have happened anyhow. This understanding pertains to emission avoidance and reduction but also to nature-based solutions where the output of the activities has a component that either cannot be measured directly or is naturally occurring, respectively. Examples for each are described further.

For emission avoidance, the output of the proposed activity cannot be measured. It can only be estimated as the difference between an alternative scenario and a Life Cycle Analysis. This method is used because something that is avoided cannot be observed in its occurrence. Emission avoidance rests on the premise of "not doing something," which means that financing activity not to occur that was never going to happen anyhow would be a waste of resources. If the activity is used for offsetting purposes, it would reduce the climate benefit or negate it altogether because an emission (that which is being offset) would still have been produced.

Moreover, certain carbon sequestration activities are enhancements of naturally occurring processes. These include enhanced weathering, reforestation, and enhanced downwelling, for example. These shifting baselines are impossible to directly measure once anthropogenic carbon removal activities have begun. In traditional offsets, this situation would require a counterfactual scenario to estimate the difference. Counterfactual baselines are unverifiable and unmeasurable, which goes against the principles of the FCCS.

To simplify and uphold the principle of verifiability and evidence, **the FCCS takes the position that the storage operator ought to take responsibility for all uptakes from the reservoir, regardless of cause.** This means that the concept of additionality if understood as not paying for sequestration that would have happened anyhow, is not required. It also means that anyone can be paid for the service of sequestering carbon, not only those who change behavior.

For clarity and completeness, the FCCS supports the following definitions:

A **baseline** is the measured amount of carbon already in a reservoir.

Additionality is the property of an activity being additional to the baseline.

A proposed activity is **additional** if it results in the measured accumulation of carbon to a reservoir which is distinct from the baseline.

The FCCS does indicate that a measurement of the reservoir content should be made before the commencement of the storage activities (i.e., the baseline). Storage operators can opt to do so, especially for reservoirs that may already contain carbon and have a higher risk of release. In this case, the storage operator also takes responsibility for a reservoir content that drops below the baseline and may only take credit for storage that is proven to be above the baseline.

2.4 Application of certificates

Certificates could be used for carbon accounting at various points in the economy. The current system is to account for emissions on the demand side, downstream. The emphasis is on sectoral, supply chain, or individual accounting. In this system, traditionally each entity performs an inventory of emissions using the scope 1-3 categories for attribution (e.g., The Greenhouse Gas Protocol[29]). The entities would then be responsible for the emissions they considered in their inventories. However, in this system attributions can be omitted or double counted. Scope 3 emissions, which can represent up to 90% of a company's emissions[30] are incredibly challenging to account for properly. For these reasons, consequential accounting is quickly rising as a more robust alternative where the entire supply chain is considered (Brander et al., 2021; Ekvall, 2019).

The issue is that even with consequential accounting, problems continue to arise: the boundaries of the inventory are subjective and the methodologies at each level of the supply chain introduce uncertainties. An entity at the end of the downstream receives the responsibility, but the responsibility may not be of the correct amount. Additionally, this entity may not have the power to do anything about the responsibility. The entity may be a small business or a business that has no alternatives. It is not surprising that after 30 years of climate agreements this accounting system has not yielded significant results (Stoddard et al., 2021).

[29] The Greenhouse Gas Protocol initiative produces standards for various scales. Available at: https://ghgprotocol.org/
[30] According to Carbon Trust research. Available at https://www.carbontrust.com/news-and-events/insights/make-business-sense-of-scope-3

Accounting downstream places a formidable unfair burden on all sectors of society, except on those which produced carbon in the first place and have the power to act.

The alternative approach is to account on the supply side, upstream. In this system, the emphasis is on the point of extraction of fossil carbon. The entities that extract fossil carbon would be responsible for the accounting because that is the last place that accounting is accurate (Lackner and Wilson, 2008). In this situation, the accounting would require mandatory matching of all carbon with sequestration (Lackner, et a., 2000; Allen et al., 2009), an idea known as the Carbon Take Back Obligation[31]. Over a defined transition period, the matching percentage could increase (Jenkins et al., 2022). The result of this system would be a situation where Life Cycle Assessments and emission inventories are no longer needed for accounting because all products, energy, or services that use the carbon downstream will be carbon neutral. This does not mean they would be obsolete as they could still be used for product design, analysis, and to help target action to reduce emissions.

Another major benefit relevant to certification would be that all carbon used by carbon removal activities will already be covered. Thus, a Life Cycle Analysis would only be necessary in the design phase of the activity and not for the accounting, greatly reducing the burden and complexity of the certification program. The certification program would be able to focus on making direct measurements, which are simpler than using counterfactuals or inventories. A carbon removal activity that requires more carbon than it stores would be economically unviable under this system (Lackner et al., in prep). The Life Cycle Analysis at the design stage would uncover such situations.

The FCCS does not need the whole world to be under a CTBO-like policy, just extractors and importers and storage operators who wish to use the FCCS. An entity could work to connect needs from extractors and importers with certificates from storage operators. Similar efforts, albeit targeting the mid-supply chain, are underway by Frontier and South Pole. Or jurisdictions could decide to apply the CTBO to their region by identifying all carbon generators and importers of raw fossil carbon (oil, coal, and gas) and their refined products. Additionally, some regions or nation states may already be in a CTBO-like situation or very close. For example, nations that only rely on renewable energy.

In the situation that such a downstream Carbon Take Back Obligation does not take effect, the FCCS can operate with some additional rules. The FCCS requires the disclosure of activity emissions. This information must be made public.

[31] Ibid 6.

2.5 Treatment of the potential failure of storage to be permanent

Different reservoirs have different expected storage durations because of their physical characteristics (Arcusa et al., *in prep*). Some reservoirs inherently keep carbon stored for longer periods than others. For example, a building material made of wood may contain carbon for the lifespan of the building or 50-300 years (Mequignon et al., 2013) whereas an old growth forest could remain for millennia (Wirth et al., 2009) and mineralized carbonates for hundreds of thousands of years (Lackner et al., 1995).

This difference in expected storage duration matters because once in the atmosphere, CO_2 will continue to impact temperature for tens to hundreds of thousands of years (Archer et al., 2009). Scott et al. (2015) argued that storage shorter than on this scale is inefficient and poses an intergenerational problem. The intergenerational equity principle refers to preserving the environment for the benefit of future generations (Venn, 2018). In addition to intergenerational equity, the failure of storage to be durable also presents a particular problem for the polluter pays principle (Arcusa and Lackner, 2022), and for risk exposure.

The polluter pays principle is also known as the producer's responsibility (Jenkins et al., 2022) and is a globally accepted principle. As Arcusa and Lackner (2022) explain, in a world where gigatons of carbon are stored for only 100 years, future generations could find themselves with increasing concentrations of CO_2 once again. They then would need to manage the situation through more CDR or adapt to rising temperatures. There is no guarantee that future generations will have access to our knowledge nor to the same level of technology. Thus, the failure of storage to be permanent pushes the climate change problem onto future generations, violating the intergenerational equity principle. Lastly the failure to adequately consider impermanence in the certification programs exposes buyers, sellers, and the public to avoidable risk. The United States' Securities and Exchange Commission (SEC) proposed rules for companies to disclose climate risks in their business. If impermanence in carbon sequestration certification continues to be externalized, the risk exposure ought to be also disclosed.

Many carbon removal activities are planning to use reservoirs that could potentially store carbon for hundreds of years. Without a mechanism to ensure that either the integrity of the storage continues, or the stored carbon transfers into durable storage, this situation will pose a problem that will violate the two principles and increase risk exposure. The time between payment for carbon removal by the producer and when the carbon could be released will be long enough to disconnect the liability link between them. In 100 years, and even in 50 years, it will be impossible to require the producer to pay again for carbon that was released from storage. If the producer does not pay again, then the burden falls on the future generations, violating the intergenerational equity principle.

This is not to say that storage activities that do not meet the definition of durability do not have value, nor that they shouldn't be pursued. Such storage, including various forms of biotic reservoirs and products, has a fundamental role to play to enable removal activities to start imminently because the know-how is mature. There will be such types of storage activities regardless of how much carbon will be stored in reservoirs that meet the definition of durability. Moreover, insofar as biotic reservoirs refer to activities that restore ecosystems, a world without natural ecosystems is an impoverished, inhabitable world. Restoring ecosystems is the ultimate goal. Ecosystems should be restored to their maximum potential with the understanding that expanding ecosystems beyond their natural capacities may have negative impacts and be unmaintainable. In any case, no storage can be allowed to be used that sacrifices future generations to climate change. Climate change must be taken care of today.

Ensuring that storage is permanent is an externality, one that is openly recognized (Miltenberger et al., 2021) and generally not addressed because neither the buyer nor the seller has incentive to. The options to internalize impermanence include (i) having effectively permanent storage on timescales of the climate system or (ii) perpetual remediation of released carbon. Mechanisms currently in use include crediting with fixed liabilities, buffers, long contracts, buyer repurchase, labeling, discounting, bundling, legal contract, and perpetual liability through assurance and responsibility transfer (Arcusa and Lackner, 2022; Whitmore and Aragones, 2022; and McDonald et al., 2021). All mechanisms except for legal contracts and perpetual liability do not internalize the potential that storage will not be permanent.

- Fixed liabilities implies that responsibilities from the storage operator end after a certain duration. This would be an acceptable mechanism if the duration was tens of thousands of years. For the obvious reason that the storage operator will not be around for that long, and the unfortunate observation that most fixed liabilities are set to 100 years or less (Arcusa et al., in prep), this mechanism does not internalize the potential that storage will not be permanent.
- Long contracts have the same implication, except that the termination may happen far enough into the future that the responsibility window (i.e., the time during which the producer can be held responsible) would end as discussed above.
- Buffers hold back a certain percentage of credits in a mutual pool, but the pool may or may not extend beyond the duration of the removal activity nor the duration of the contractual agreement.

- Buyer repurchases, whereby the removal credit is only valid for a certain duration and the buyer must repurchase once expired, has been tried by the Clean Development Mechanism. Subsequent research found that buyers did not want to buy again (Neeff and Ascui, 2009). Buyers cannot be made to repurchase and if they were this demand would eventually also terminate.
- Labeling is akin to fixed liabilities or long contracts, except that the externality is made explicit but not internalized.
- Discounting through ton-year accounting or otherwise is used to calculate the climate benefit based on storage duration (Wenger et al., 2022). However, this is akin to renting a climate benefit; the impact is only temporary, yet the producer's responsibility remains. If the ton-year calculation horizon was set to 10,000 years, the value of short-term storage would disappear.
- Bundling combines short-term storage with long-term storage, used one after the other through time, or stacks many short-term storages in the near term to theoretically have the same climate benefit as a pre-determine duration. The former may work if the long-term storage materializes in the future and the long-term storage also internalizes potential impermanence. However, by itself it will not. The latter is akin to discounting.
- Legal contracts can require remediation and can be perpetual. One example of remediation requires the balancing of released carbon by voiding emission permits, as used in the Joint Implementation, and the New Zealand ETS. However, this sort of balancing may not have an impact on the atmospheric carbon stock since an emission would still have been produced. One example of perpetual action is the land easements by a nation state or a company whereby land is set aside from land-use in perpetuity. If done by developed nations or corporation to developing nations, this will become problematic in international trade and has been described as a form of carbon colonialism (Bachram, 2004). Arguably, it may also be problematic within the same state if due process is not followed.
- Finally, perpetual liability through assurance and responsibility transfer is used only for geological storage (e.g., European Council Carbon Capture and Storage Directive) and refers to the combined use of (i) scientific evidence that a reservoir is behaving as expected to store carbon over thousands of years, (ii) various financial instruments to cover the cost of damages from a release such as bonds and mutual funds, and (iii) a transfer of responsibility from the storage operator to a nation state. This form of mechanism would start to internalize impermanence if in addition to covering non-climate related damages, the financial instruments were to cover the cost of remediation.

The main issues with most of these mechanisms is (i) the positioning of the responsibility, (ii) the duration of liability, and (iii) the responsibility itself. Most mechanisms place the responsibility onto the buyer who will not be made to purchase again. If the responsibility is placed on the storage operator it does so for a duration inconsistent with (i.e., shorter than) the understanding of the climate system. Moreover, the responsibility is not commensurate with the problem created by the carbon release: voiding emission permits or holding credits back in buffer pools does not remediate the release.

Thus, the framework draws from programs and Arcusa and Lackner (2022) who propose that all certification for any reservoir should include a mechanism to internalize the potential failure of sequestration to be permanent. They propose that the storage operator shoulder the responsibility by including the cost of monitoring and re-sequestration into their business model. The storage operator is thus responsible for any release of carbon. A fee is then included on the certificate price which covers the cost of monitoring and re-sequestration by the willing party which will take over the responsibility after the agreed point of transfer.

One aspect that remains unclear in the FCCS is how to treat the "no man's land", i.e., the expected storage durations too long to be managed through contracts but too short to neutralize an emission. An example of such an activity is biochar. The concern is that consecutive contracts can probably be written and upheld for 100-150 years, but not for 500 years. The FCCS uses a combination of contractual and scientific management (**Figure 4**). Contractual management is used to manage the shorter duration storage through the transfer of responsibility. Scientific management is used for very long timescales through the permanent disposal test. The activities with expected storage durations falling in between currently have no specific management solution. This will be dealt with in later versions.

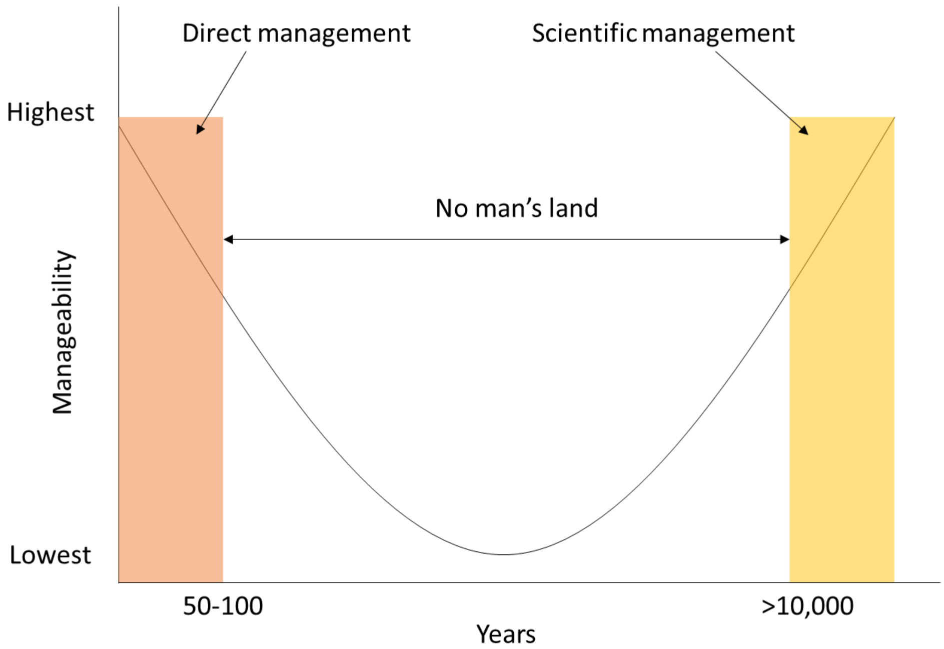

Figure 4. Manageability (y-axis) and management styles (boxes) for a spectrum of expected storage durations (x-axis). Direct management and scientific management are separated by "no man's land" activities that cannot be managed by either. How to deal with such activities is a gap of the FCCS.

2.6 Responsibility transfer

To meet the durability condition, requires that either a temporary storage activity is replaced in perpetuity, or that the storage be deemed effectively permanent. Anything in between discounts the wellbeing of future generations and absolves the carbon producer of their responsibility. Continuing an activity in perpetuity is difficult, so the FCCS offers the possibility to transfer the responsibility from the storage operator to another party.

It is perfectly acceptable for the storage operator to transfer their responsibility to another storage operator if all the conditions are met by the new operator, as determined by the FCCS and the certificate authority. To meet the durability condition, the storage will need to continue, which new operators may not want to take over. In this case, the responsibility can be transferred to a willing party who will be the final responsible party. The willing party can subcontract, but they are responsible for remediating lost carbon.

To protect the willing party and the public, the transfer should not be free. Therefore, the responsibility to monitor and remediate can be transferred to the willing party at a fee on each certificate. The purpose of the fee is to pay for a new certificate of sequestration to cover potential releases of carbon once the new owner, i.e., the willing party, takes over the storage activity at the transfer point.

All certificates would need to be imposed this fee. Except for (1) activities that meet the Permanent Disposal Test could receive a refund after the point of transfer, and (2) certificates of sequestration purchased to meet the remediation requirement would not be imposed an additional fee because the fee would already be paid for.

The fee structure could be structured as follows:

1. Be set to be equivalent to the price of the willing party purchasing a certificate in 50 years' time in today's value following an approved discount rate. The willing party receives the responsibility after the storage operator's 50 years of operations.

2. Be tied to a futures market if one exists.

3. Be based on the permeance factor of the storage creating a sliding scale for the fee. Storage that passes the *Permanent Disposal Test* might illicit a small fee and the other extreme storage that in its first 50 years have been unstable would illicit a large fee, as the willing party would be required to do more.

4. Some other mechanism.

The fee mechanism may need adjustment based on the experiences after transfers have been completed. For example, the initial owner of the storage and the new owner of the storage may need to post a surety that the storage is in the condition they purport it to be at transfer. The surety would safeguard the willing party from being drawn into a great deal of unexpected work when the storage does not perform as intended or expected.

Participation and stringency are tradeoffs in this system. Too stringent and no one participates. Too lenient and the goals are not met. This framework for certification makes certain assumptions and assigns timeframes and other specific variables. This is necessary to develop the framework, as without specificity ambiguity would take over and allow profiteering. The numbers selected may be the appropriate timeframes or they may not. Experience may advise that some or many be changed as certification proceeds. The standards certification authority and other agencies will work out how to make these changes. What is important now, at the start, is to have a framework that can be comprehended.

2.7 Treatment of emission removal, reduction, and avoidance

In recent times, creating equivalence between instruments representing different types of emission mitigation has been deemed undesirable due to its impact on various forms of equity (Carton et al., 2021). One debate relevant to this framework surrounds the equivalence or not of emission removal, reduction, and avoidance. In many ways, this debate relates to whether a certificate of carbon sequestration should be considered equal to a traditional carbon offset. Furthermore, this debate may extend to whether other greenhouse gases like methane ought to be treated equally, also.

First, we detail here without judgements the arguments favoring and opposing equivalence between the three types of mitigation impact. Then, we provide a rational for the FCCS and discuss the implications.

Opposing equal treatment

(1) Emission reductions should be front loaded in time and carbon removal certificates should be used cautiously, especially if they are to be used for offsetting practices (Fankhauser et al., 2022; McLaren, 2020; McLaren et al., 2019). Keeping reductions separate from removals would ensure transparency.

(2) Plans of reduction and removal ought to be kept separate (McLaren et al., 2019). This would support separate treatments.

(3) Under a best-case scenario, offsetting an emission using reduction or avoidance would result in a unit of emissions added to the atmosphere, whereas removal would cancel that emission (although this system will fail to work if all emissions are subject to cancellation at once. It is therefore unsustainable and should not be introduced for early stages) (**Figure 5**).

(4) Reduction or avoidance can only be calculated against a counterfactual, removal can be measured directly. Counterfactuals by their nature are unverifiable, direct measurements can be verified.

(5) Storage is necessary for removal but not necessarily for avoidance and usually not for reduction which implies a potential for reversal that needs to be treated specifically.

(6) A carbon neutral world is a world where carbon is either not used or each unit of carbon used is also disposed of. This is the implication of the paradigm of climate change as a waste management issue (Lackner and Jospe, 2017). This vision compares well with the IPCC’s vision of a total carbon allowance (i.e.,

budget) (Strauch et al., 2020). An emission cap implies the same two options: to either not produce emissions or to remove emissions.

(7) Although necessary today, emission reduction and avoidance will not take care of historical emissions, which will be needed to return the atmospheric concentration to a lower, “safer” level.

(8) Asymmetry in the climate system indicates the impact on the climate by a removal is smaller than the impact of avoiding emissions in the first place if neutralization is not instantaneous (Zickfeld et al., 2021).

(9) The certification of emission avoidance and reduction is challenging because of the need to estimate something that has not occurred. Something that has not occurred cannot be verified. This challenge adds a level of complexity, and thus uncertainty to method development. Treating emission removal as equal in certification would increase uncertainty for all.

(10) CO_2 is a special gas in terms of its contribution to climate change as it resides in the atmosphere and oceans over very long timescales (Archer et al., 2009, 1998; Kheshgi, 2004; Kheshgi et al., 2005). Other carbon-based gases such as methane have a stronger impact on climate in the short term (Balcombe et al., 2018) but is quickly recycled by natural processes (Turner et al., 2019) and the remainder will oxidize into CO_2 within a decade (Saunois et al., 2020). Certification of sequestration would thus need to treat carbon differently to methane.

(11) The equation of CO_2 to other greenhouse gases rests on the use of Global Warming Potential which is based on a counterfactual and uses a subjective time horizon.

Favoring equal treatment

(1) Because the world is in a transition it is possible to use offsets of emission reduction or avoidance to cancel emissions although this goes against the total budget concept.

(2) The “ton is a ton” argument provides economic flexibility.

(3) Although plans of reduction and removal ought to be kept separate (McLaren et al., 2019), labels could be used on the certificates to indicate if they represent removal or reduction.

(4) Despite their shortcomings, global warming potentials used to compare CO_2 to other gases are by now well established in practice. Equal treatment could follow a similar approach.

Weighing the arguments favoring or opposing inclusion, the FCCS takes the viewpoint that a certificate of carbon sequestration should solely represent and quantify emission removal and should not include partial quantification or representation of emission reduction or avoidance. The reason being that in a world where there is an emission cap, as indicated by the IPCC, the failure to avoid producing an emission is the requirement to pay for its removal. The cost of removal will motivate avoidance.

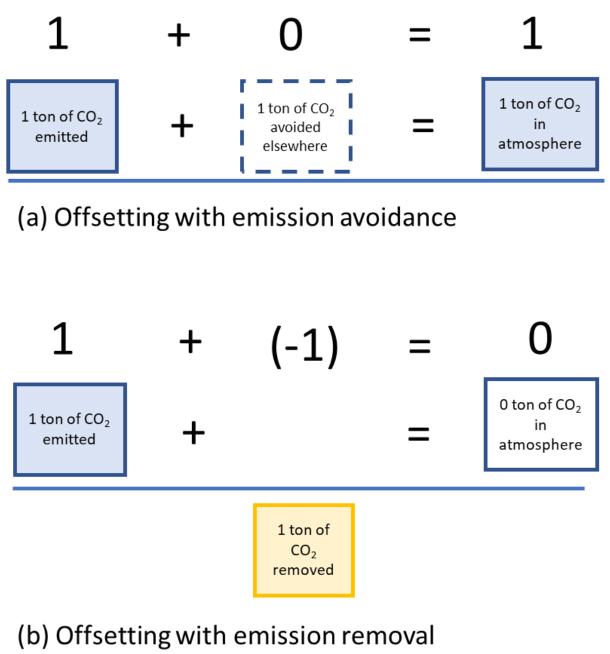

Figure 5. Climate impact of offsetting with (a) avoidance or (b) removal in a best-case scenario.

2.8 Differentiation of storage systems

In recent times, creating equivalence between different types of emission mitigation certificates has been deemed undesirable due to its impact on various forms of equity (Carton et al., 2021). In addition to the debate surrounding the equivalence or not of emission removal, reduction, and avoidance (**Annex 2.6**), another debate focuses whether emission removals from the land and forestry sector are equivalent to emission reductions from the energy sector because the former is subject to a risk of reversal (Dornburg and Marland, 2008; Fearnside, 2008; Fearnside et al., 2000; Kirschbaum, 2006; Marland et al., 2001; Marland and Marland, 2009).

In the context of the certification of carbon removal, this debate takes the form of whether a certificate of sequestration from one reservoir can be equal to another. For example, should a certificate of carbon sequestration from a building element be equal to one produced from mineralized carbonate? The expected duration of storage for either reservoir is vastly different as discussed in **Annex 2.5**. **This section only discusses the treatment of different reservoirs in the situation where there is a mechanism to treat for the potential failure of storage to be permanent.** This section does not analyze a situation where there is no mechanism.

To develop the rational for the framework, first, we detail here without judgements the arguments favoring and opposing equivalence between sequestration systems. Then, we identify a rational for the framework and discuss its implications.

Favoring equal treatment

(1) A certificate of sequestration ought to represent the same outcome regardless of the reservoir. Treating reservoirs unequally would imply that the certificates do not represent the guarantee of the performance and permanence of the service of keeping carbon away from the atmosphere.
(2) Reservoirs ought to be treated on an equal basis to remove competitive advantages that are not based on integrity.

Opposing equal treatment

(1) Reservoirs are too different in terms of their physical characteristics and risks to be treated equally.
(2) A "like-for-like" approach would bypass the argument. Emissions from fossil reservoirs would be matched by storage in geological reservoirs. Emissions from destruction of biotic ecosystems (e.g., fires, wetland drying) would be matched by storage in biotic reservoirs.

The FCCS takes the position that a common denominator between reservoir types can be found, and that denominator is responsibility. Each reservoir can have its own tailored equipment, methods, safeguards, and monitoring plans to make operations safe and measurements verifiable. However, all certificates, whether under the FCCS or others, must have the same outcome: they must represent the goal they have been assigned. The FCCS defines a certificate as the guarantee of the performance and permanence of the service of keeping carbon away from the atmosphere. Unequal treatment across reservoirs would breach that definition and goal. This is particularly relevant if certificates are to be used to match carbon extraction for the purpose of climate mitigation. The FCCS proposes to create this true time equivalence using the combined mechanism of monitoring, re-sequestration, responsibility transfer, and testing for permanent disposal.

An alternative to creating this true time equivalence is to create a separate certificate for each individual sequestration system or group of sequestration system (e.g., mineralization, soil, etc.), to label them either based on their physical duration of storage or their source carbon pool, and to only use them for emissions that were produced from that carbon pool (the "like-for-like" option) (Whitmore and Aragones, 2022). Although simpler in theory, each type of certification for each category of sequestration duration would then have its own set of rules. Moreover, trading between categories would have to be outlawed and any claims by purchasers would have to be verified. This is possibly doable.

One opposing argument is that it entirely excludes certain types of sequestration like long-lived products and ocean-based activities. A second opposition is that it limits the speed at which carbon removal activities can be deployed to neutralize fossil emissions. The policy pushes CDR to later in the century which may be a negative or positive consequence depending on the viewpoint. One supporting argument is that it imposes a physical limit on the potential for nature-based activities which is in line with its natural capacity. Another favorable argument is that it simplifies the issue of impermanent sequestration activities by not trying to make them eligible for neutralization claims. It would also be a cautious approach to not wasting storage capacity on current emissions.

The FCCS takes the viewpoint that creating different types of certificates of sequestration based on groups of durations and matching like-for-like simplifies the certification process and could be legitimate with verification. However, the FCCS also see the benefit of keeping all CDR options open in a regulated manner. For this purpose, the FCCS goes to great length to create equivalence between all options.

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Annex 3

Template to be added