Reversal risk and buffer pool contribution analysis

Discussion paper

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The analysis, findings and recommendations presented in this paper are those of the authors and do not necessarily reflect the views or official position of the German Federal Government.

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Abbreviations

ACR	American Carbon Registry
AFOLU	Agriculture, Forestry and Other Land Uses
A6.4ER	Article 6.4 Emission Reduction
BECCS	Bioenergy with Carbon Capture and Storage
CAR	Climate Action Reserve
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CO_2	Carbon Dioxide
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
GCS	Geological Carbon Storage
GHG	Greenhouse Gas
GS4GG	Gold Standard for the Global Goals
ICVCM	Integrity Council for the Voluntary Carbon Market
MEP	Methodological Expert Panel
OAE	Ocean Alkalinity Enhancement
PACM	Paris Agreement Crediting Mechanism
RAE	River Alkalinity Enhancement
RRBPA	Reversal Risk Buffer Pool Account
SBM	Supervisory Body of the Article 6.4 mechanism
VCM	Voluntary Carbon Market
VCS	Verified Carbon Standard

1. Introduction

Article 6.4 of the Paris Agreement establishes an internationally governed carbon crediting programme, known as the Paris Agreement Crediting Mechanism (PACM). Carbon crediting programmes, including the PACM, aim to mobilise finance for the reduction of greenhouse gas (GHG) emissions and for achieving removals of carbon dioxide (CO_2) from the atmosphere. They issue tradable carbon credits for emission reductions and removals that meet the programme's requirements. These requirements aim to ensure that each carbon credit represents at least one additional and permanent metric tonne of CO_2 equivalent (tCO_2e) of emission reduction or removal that is robustly quantified and independently verified. The detailed requirements for these criteria differ across carbon crediting programmes and evolve over time. The PACM carbon credits, referred to as Article 6.4 Emission Reductions (A6.4ERs), must meet the PACM requirements, including the requirement to minimize the risk of non-permanence and address reversals in full where those occur.

"**Non-permanence**" refers to the risk that carbon stored in a "**reservoir**" – such as trees and other vegetation, soils or geological formations – through a mitigation activity may be released back into the atmosphere. Such a release is referred to as "**reversal**" and may occur long after the implementation of the mitigation activity. The **risk** of reversals during a pre-defined period depends on various factors that differ between activity types and geographical locations of activities of the same type. The risk depends on the robustness of reservoirs to natural and anthropogenic disturbances. The former are exacerbated by climate change, while the latter increase in case of regulatory uncertainty and social instability (FAO 2024).

Stakeholders remain divided on how to treat carbon credits with non-permanence risks. Some argue that if reversal risks are minimised and any reversals are addressed over sufficiently long timeframes, such credits should be considered to deliver equivalent climate mitigation benefits to those without non-permanence risks. Others, however, advocate for a like-for-like approach, in which only carbon credits without non-permanence risks are used to offset permanent emissions.

Carbon crediting programmes usually permit the crediting of mitigation activities with non-permanence risks, as long as mechanisms are implemented to address and compensate for potential reversals. Thereby, credits are set aside to offset any reversals once those occur. Approaches to address and compensate for reversal risks include the following:

- **Temporary credits**: Under this approach, credits are issued on a temporary basis and expire if a reversal occurs. Users are to replace the expired credits. This method, which is simple and credible, was used under the Clean Development Mechanism (CDM) for afforestation and reforestation activities. However, it proved unattractive to buyers and has not been adopted by other programmes.
- **Mandatory insurance**: Each activity that has a reversal risk needs to prove that it is insured against reversals. Insurance premiums will depend on the assessment of risks by the

insurance provider; activities with high reversal risks may be deemed uninsurable. The insurance needs to provide replacement credits as soon as a reversal is occurring. The type of acceptable replacement credits is debated, with proposals ranging from like-for-like to any credits that meet programme requirements. A critical aspect of an insurance solution is the duration of the insurance coverage required by the programme.

- **Buffer pools**: In this approach, a portion of issued credits is set aside in a buffer pool instead of being sold, with contributions differentiated by the risk profile of the activity (e.g. forestry activities generally face higher reversal risks than geological storage). If a reversal occurs, an equivalent number of credits is cancelled from the buffer pool to compensate. Such pools are managed by the crediting programmes and are typically applied across multiple mitigation activities ("pooled buffer pool") rather than for individual ones. Many of the same considerations that apply to insurance – such as the nature of replacement credits – also apply.

Another approach to address reversal risks that does not build on compensation of reversals is **tonne-year accounting**. This approach claims to resolve the reversal risk by only annually crediting the contribution to mitigation achieved considering that a full reversal could take place tomorrow. It builds on the idea that an "equivalence period" can be defined where a temporary storage equals permanent mitigation. The approach is the subject of significant scientific controversy, as it is considered inconsistent with the Paris Agreement's temperature goal (FAO 2024). It was formally rejected by the Supervisory Body of the Article 6.4 mechanism (SBM), the PACM's oversight body.

Compensating for reversals requires a preliminary step: conducting risk assessments, which is mandated by most carbon crediting programmes. These programmes have developed various categorisation approaches to identify the key factors contributing to reversal risk. In many cases, reversal risk assessments are closely linked to efforts aimed at reducing these risks. Based on the resulting scores or rating of the risk assessment, compensation measures are implemented including monitoring requirements.

Regarding treatment of reversal risks in the context of the PACM, one needs to look at standards, tools and methodologies that are adopted by the SBM. In October 2024, the SBM adopted the Methodologies Standard and **Removals Standard**. The latter (UNFCCC 2024) sets out the requirements for activities involving removals and provides provisions for addressing reversals. These requirements also apply to emission reductions that are subject to reversal risk. The standard:

- Lists **drivers** of reversal risks (para. 37):
  - Activity finance and management, asset ownership, rising opportunity costs
  - Regulatory uncertainty and social instability, political, governance and legal risks, acts of terrorism, crime, and war
  - Natural disturbances and extreme events such as fires, pests and droughts, hurricanes, floods and landslides, earthquakes, volcanic eruptions, geological faults and fractures
  - Climate change impacts exacerbating any of the above risks

- Differentiates between **avoidable** and **unavoidable** risk types (para. 9e, f)
  - Avoidable reversals are reversals caused by factors over which the activity participants have **influence or control**
  - Unavoidable reversals are all other reversals
- Specifies a **process** for addressing reversals including (para. 38 – 62):
  - Conducting a **reversal risk assessment**, which must include a **risk mitigation plan**, using the reversal risk assessment **tool** to identify, assess and mitigate reversal risks, and calculate an **overall percentage-based risk rating**.
  - Unless the risk is classified as "negligible", the activity is required to contribute a specific percentage of A6.4ERs according to the risk rating to a **Reversal Risk Buffer Pool Account (RRBPA) at each issuance**. These are called "Buffer A6.4ERs". The RRBPA is administered by the UNFCCC Secretariat and aggregates all Buffer A6.4ERs.
  - Remediating any avoidable and unavoidable reversals in full by **cancelling an equivalent amount of Buffer A6.4ERs** from the RRBPA. An equivalent volume of A6.4Rs must be fed into the RRBPA by the activity participant if the reversal was classified as avoidable.

The requirements of the Removals Standard will be further elaborated in a **Non-Permanence Standard** and a **Reversal Risk Assessment Tool**. The former will cover post-crediting period monitoring, reporting, and remediation of reversals, post-reversal action, and host Party roles; handling of late, incomplete or missing monitoring report submissions when reversals occur; reversal risk assessment and avoidable and unavoidable reversals, and reversal compensation. The latter will address the following aspects (UNFCCC 2025a):

- Whether upper limits are needed in respect of the risk rating (overall) or specific risk factors (within the tool), including options and science-based rationales for upper limit(s)
- Risk rating that constitutes a negligible risk
- Any further categorization of risk
- How remediation measures are taken into account in the risk assessment tool

Given that the Removals Standard mainly applies the buffer pool approach, this study focuses on buffer pools contributions and the underlying risk ratings and assessments. Section 2 provides a comprehensive overview of the current practices and requirements in independent carbon crediting programmes within the voluntary carbon market (VCM), focusing on the assessment and reduction of reversals risks (section 2.1), related monitoring and reporting (section 2.2.) and approaches for compensating reversals (section 2.3). It also compares the requirements of these independent programmes with those set out in the Removals Standard. Section 3 explores options for operationalising reversal risk assessment and compensation under the PACM, with the aim of ensuring environmental integrity. Finally, section 4 presents key recommendations based on the findings of this report.

2. Stocktake of reversal risk and buffer pool approaches applied by carbon crediting programmes

This section provides an overview of how carbon crediting programmes address reversals risks. Most programmes aim to: (i) ensure that reversal risks are properly assessed; (ii) reduce those risks through targeted mitigation measures; and (iii) compensate for reversals, if they occur, through dedicated mechanisms. In most of the cases, the reversal risk assessment determines the proportion of issued credits that must be allocated to a buffer pool. Most carbon crediting programmes require ongoing monitoring of reversal risks and the reporting of any reversals that occur. However, the frequency and timing of these obligations vary between programmes.

The analysis focuses on the requirements and procedures established by the following programmes and their standards: American Carbon Registry (ACR), Climate Action Reserve (CAR), Gold Standard for the Global Goals (GS4GG), Verified Carbon Standard (VCS), Isometric and Puro.earth. The programme documents that serve as the basis for this analysis are listed in Annex A. In addition to programme-specific requirements, this analysis also considers the non-permanence criteria outlined in the Assessment Framework of the Integrity Council for the Voluntary Carbon Market (ICVCM), which seeks to promote high integrity across the VCM.

The following sub-section begins by examining which activity types are subject to reversal risk requirements across various carbon crediting programmes. It then analyses each programme's provisions for assessing and mitigating reversal risks, followed by their monitoring and reporting obligations, and finally, the requirements for addressing and compensating for reversals when they occur.

2.1. Requirements for assessing and reducing risks of reversals

Carbon crediting programmes conduct risk assessments to examine and reduce reversal risks. The assessments can be tailored to certain groups of activity types or reservoirs. Carbon crediting programmes apply different categorisation of risks as well as approaches to the risk assessments. Table 1 below summarises the activity types eligible under each programme for certification and indicates whether reversal risks must be addressed for those activities.

Table 1: Risk assessment requirements for specific activity types with an existing methodology (Programme-eligible activity types with an existing methodology are highlighted in blue, while the presence of reversal risk assessment requirements is indicated by a checkmark)

Activity category	Activity type	ACR	CAR	GS4 GG	VCS	Iso-metric	Puro.earth
Land use, land use change and forestry	Soil carbon		✓	✓	✓		
	Improved forest management	✓	✓	✓	✓		
	Afforestation/reforestation	✓	✓	✓	✓	✓	
	Avoided Conversion/REDD	✓	✓		✓		
	Blue carbon	✓		✓	✓		
Biomass carbon capture and storage (CCS)	Bioenergy with carbon capture and storage (BECCS)				✓	✓	
	Subsurface biomass carbon removal and storage					✓	
	Terrestrial storage of biomass						✓
	Biomass (fermentation) & bio-oil geological storage			✓		✓	
	Biochar production and storage		✓		✓	✓	✓
Geological carbon storage (GCS)	CO_2 storage in saline aquifers				✓	✓	✓
	CO_2 storage in depleted hydrocarbon reservoir	✓*			✓		✓
	CO_2 storage via mineralisation				✓	✓	✓
Mineralisation / carbonates						✓	✓
Enhanced weathering						✓	✓
Oceans & rivers	Ocean, river, and wastewater alkalinity					✓	
	Electrolytic seawater mineralisation					✓	

** Under ACR, geologic sequestration projects do not require a reversal risk assessment, but 10% of the max. total GHG emission reductions and removals must be contributed to an ACR-managed reserve account*

Table 2: ICVCM categorisation of activity types based on their reversal risk

	Activities
Activities with a material risk of reversal	• Storage and protection of carbon in biogenic reservoirs: conservation and avoided conversion (e.g., grassland/rangeland management, avoided deforestation) • Agriculture soil carbon sequestration • Forestry sequestration (improved forest management, afforestation/reforestation, agroforestry) • Wetland and marine ecosystem restoration/management including seagrasses, saltmarshes, mangroves, peatlands
Activities with *potential* material risk of reversals	• Mitigation activities involving the displacement of non-renewable biomass • Biochar • CCS with geological storage • Enhanced weathering • CCS with mineralisation; and CO_2 in concrete utilisation

While risk assessments and mechanisms for addressing reversals were initially developed for forestry sector activities – including both emission reduction and removal activities – some programmes also mandate them for storage activities and other activities. **ACR**, **GS4GG** and **VCS** differentiate between reversal risk tools for Agriculture, Forestry and Other Land Use (AFOLU) and geological storage activities. **ICVCM** distinguishes between activities with a material risk of reversal and those with a potential material risk. Compared to others, the initiative identifies additional activity types with a potential risk of reversal: Mitigation activities involving the displacement of non-renewable biomass such as cookstove activities.

Table 3 presents an overview of the requirements established by independent carbon crediting programmes to assess and reduce reversal risks. For illustrative purposes, we have grouped activities with reversal risks into two main categories:

- AFOLU (excluding activities that inherently lack reversal risk)[1]
- Geological storage and other activities (e.g., final three categories in Table 1)

The table uses a colour-coding scheme to indicate the stringency of each programme's approach with respect to environmental integrity:

- **Green** indicates an ambitious and robust approach
- **Yellow** represents a mixed or moderate level of stringency
- **Orange** denotes a lenient or minimal approach, and
- **Grey** indicates that the activity type falls outside the programme's scope

[1] Some agricultural activities, such as enteric fermentation and rice cultivation, are not subject to reversal risks

Table 3: Overview of requirements for assessing and reducing reversal risks

		ACR	CAR	GS4GG	VCS	Isometric	Puro.earth	ICVCM
Risk assessment requirements	**AFOLU**	Risk assessment mandatory (dedicated tool)	Risk assessment mandatory (defined in each meth.)	Risk assessment mandatory (dedicated tool)	Risk assessment mandatory (dedicated tool)	Risk assessment mandatory (defined in each methodology)	Not applicable	Estimation of reversal risk required
	Geological storage + others	Risk assessment not required for GCS	Not applicable	Tool currently under development	Risk assessment mandatory	Standard risk assessment questionnaire	Risk assessment required – material risk	Risk assessment required to identify material risk
Risks covered by risk assessments	**AFOLU**	Management and Governance risks (Financial Risk, Social and political risk); Natural disaster risk	Defined in each methodology (e.g., Mexican Forest protocol: Financial, management, social and political, natural disturbance)	Main categories: Natural disturbance risks; Political risks; Project management risks; Financial risks; Market risks, others	Risk factors are classified into three categories: internal risks, external risks, and natural risks. Climate change risks covered	Defined in each methodology. Where absent, Isometric applies risk questionnaire. Reforestation: proponent capacity, financial viability, social governance, disturbance risks	Not applicable	No specification included
	Geological storage + others	Risk assessment not required for GCS	Not applicable	Under development	Regulatory framework risk, Political risk, land and resource tenure risk, closure financial risk, design risk	Risks covered by questionnaire: Physical or chemical measurement, Impermeability, (In)organic carbon, Conditions for methane production, Material risk of reversal – natural/ human, Trapping mechanisms, Monitoring and/or lab data duration,	Nature-induced risks, Human-induced risks, Geopolitical risks, any additional risks mentioned in the methodologies	No specification included

		ACR	CAR	GS4GG	VCS	Isometric	Puro.earth	ICVCM
						History of reversals		
Time horizon of the risk assessment	**AFOLU**	Not addressed	Not addressed	Long-term implementation risk of the project to be considered	100-year time horizon	Not addressed	Not applicable	No requirements included
	Geological storage+ others	Risk assessment not required for GGS	Not applicable	Tool currently under development	Durability of sequestered CO_2 through injection period and the post-injection assessment period	Not addressed	Not addressed	No requirements included
Approaches for quantifying risks *(*requires further analysis to clarify differences between approaches)*	**AFOLU**	Risks are calculated using equations that generate a percentage-based risk rating for each type	Descriptive/qualitative answers to a questionnaire trigger a score; Mix of project-specific risk and default risk values	Descriptive/qualitative + quantitative answers to a questionnaire trigger a score	Descriptive/qualitative + quantitative answers to a questionnaire trigger a score	Descriptive/qualitative answers to a questionnaire trigger a score	Not applicable	Require estimation of the reversal risk using a clearly defined approach that is made publicly available (no further specification)
	Geological storage+ others	Risk assessment not required for GGS	Not applicable	Tool currently under development	Descriptive/qualitative + quantitative answers to questionnaire trigger a score	Descriptive/qualitative answers to questionnaire trigger a score	A qualitative and/or quantitative analysis based on scientifically justifiable methods incl. characterisation of risk likelihood and severity	No requirements included
Re-evaluation of risk rating	**AFOLU**	At least every 5 years, at verification and/or if reversals occur	At least every 5 years, at verification and/or if reversals occur	At the time of renewal of certification	At every verification event and/or if reversals occur	At least every 5 years and verification	Not applicable	No requirements included

		ACR	CAR	GS4GG	VCS	Isometric	Puro.earth	ICVCM
	Geological storage+ others	Not addressed	Not applicable	Tool currently under development	At every verification event and/or if reversals occur	At least every 5 years and verification	Risk assessments reviewed at annual third-party audits	No requirements included
Risk reduction measures	**AFOLU**	Project Proponents shall enter into a legally binding Reversal Risk Mitigation Agreement with ACR that details the risk mitigation option selected. Risk assessment specifies mitigation options	For certain risks, if developers include specific risk mitigation activities, overall risk rating could be reduced (e.g., communal projects have conducted social risk mitigation activities)	Depending on the score, risk mitigation measures must be developed and detailed in a risk and capacities report. The corrected scores (incl. mitigation measures) determines whether projects can proceed to certification	Adaptive management plan, including risk mitigation measures, is required. Risk ratings are lowered if proponent demonstrates mitigation measures are planned (at validation) or implemented (at verification)	Reforestation methodology: Aspects of the project which have higher risk exposure must be accompanied by an appropriate risk mitigation plan	Not applicable	Requires or incentivises mitigation activity
	Geological storage+ others	Project proponents are required to complete a Risk Mitigation Covenant	Not applicable	Tool currently under development	Indirectly addressed	Not addressed	Pre-emptive risk mitigation required if material risks are identified	Appropriate measures to avoid material risks of reversals
Exclusion of high-risk activities	**AFOLU**	Not addressed	Not addressed	High-risk activities excluded	High-risk activities excluded	Regulated in methodologies. Eg., Reforestation methodology: Project must be below indicated thresholds to be eligible for crediting	Not applicable	No requirements included

		ACR	CAR	GS4GG	VCS	Isometric	Puro.earth	ICVCM
	Geological storage+ others	Risk assessment not required for GGS	Not applicable	Tool currently under development	High-risk activities excluded	Not addressed	Not addressed	No requirements included
Conservativeness in risk assessments	**AFOLU**	For calculation of the specific risks per sub-category, the use of conservative values is encouraged	Conservativeness not explicitly addressed	Conservativeness not explicitly addressed	For some risks, there is an explicit requirement to use conservative estimates	In general, a conservative estimate is required for removals	Not applicable	No requirements included
	Geological storage+ others	Risk assessment not required for GGS	Not applicable	Tool currently under development	Conservativeness not explicitly addressed	In general, a conservative estimate is required for removals.	Conservativeness not explicitly addressed	No requirements included

Reversal risk assessment requirements and scope

All major programmes analysed require a risk assessment for AFOLU activities, although approaches differ in several aspects. Regarding geological carbon storage and others, **ACR** is the only programme that, despite covering such activities, does not require a risk assessment.

All the programmes analysed have specific, differing guidelines or frameworks for conducting risk assessments. Currently, **VCS** has one specific risk assessment for AFOLU activities and another for geological carbon storage, and **GS4GG** is also in the process of developing a dedicated framework for geological storage in addition to its AFOLU one. **Puro.earth** focuses on crediting engineered carbon removals and therefore requires a risk assessment to identify the potential material risks of engineered carbon removal methods, although it has not developed a dedicated risk assessment tool. The frameworks differ in the risk categories and aspects considered. In most cases, the specific frameworks apply to all their corresponding activities, i.e. the AFOLU framework for all AFOLU activities or the geological storage framework for all geological storage activities. However, for example, **CAR** defines specific risks in each of its protocols (methodologies), and **Puro.earth** has additional factors mentioned in the applicable methodologies.

Programmes categorise the reversal risks in various ways (also see section 3.1). Some risks are associated with the overall country-level situation (e.g., political or governance risks), and others are specific to the project (e.g., financial management, land and resource tenure). Experts usually distinguish between natural versus human-induced risks. Natural risks stem from inherently uncontrollable forces like wildfires, floods, pest outbreaks, or seismic events. Human-induced risks encompass what **VCS**, for example, has categorised as internal and external risks. Internal risks arise from within the project itself — parameters like operational missteps, weak governance, or budget shortfalls. External risks originate outside the project's daily operations, such as changing regulations, legal challenges, or contracting counterparty insolvency. **VCS** and **GS4GG** consider climate change risks in their AFOLU risk assessments.

Regarding **PACM**'s approach to the reversal risk assessment, the SBM's Methodological Expert Panel (MEP) is planning to develop standardised tools for each GHG reservoir type (UNFCCC 2025a). To which extent the risk assessment is standardised or activity specific will be a key question to be tackled by the MEP in the operationalisation of the PACM's assessment approach. This is further discussed in section 3.2.

Time horizon of the reversal risk assessment

The time horizon that should be considered when assessing the potential reversal risks associated with a project is critical for environmental integrity. Importantly, this period is not to be equated with the crediting period. In most cases, carbon crediting programmes do not address this point, or, as in the case of **GS4GG** keep it overly generic: long-term implementation risk of the project should be considered. For AFOLU projects, **VCS** is the only programme that specifies a numerical time horizon – 100 years based on present conditions and the information available at the time of the risk analysis. For CCS projects, the intended permanence is on geological timescales (e.g., thousands of years). As it is not feasible to monitor on this timescale, **VCS** assesses the durability of sequestered CO_2 through the injection period and post-injection assessment period.

A **best practice** in current programme requirements is to **clearly define the time horizon** for reversal risk assessments, as this can significantly affect the resulting score or rating. The **PACM** Removals Standard requires that risk assessments account for the nature, magnitude, likelihood, and **duration of risks**. Accordingly, its reversal risk assessment tool should specify a clear assessment horizon. This is further discussed in section 3.5.

Approaches for quantifying risks

Carbon crediting programmes follow widely different approaches in assigning a numerical value to the risks.

GS4GG and **Puro.earth** indicate that the approach used to determine the risk is mainly quantitative. Puro.earth requires that reversal risk estimates be scientifically justified and clearly documented, including the methods and data sources used—such as statistical tools, peer-reviewed literature, or relevant regulations. **GS4GG** requires justification to be objective and based on credible sources (e.g., peer-reviewed journals, maps, climate modelling, etc.). Under **Verra** and **Isometric**, risks are estimated using a questionnaire-based approach, where specific scores are assigned depending on the responses provided. **VCS** requires that the risk scores be clearly documented and substantiated including by providing relevant assumptions, parameters and data sources to ensure the results can be easily reproduced.

ACR uses a formula-based approach across all risk subcategories. These formulas incorporate specific data sources and define a maximum potential risk for each activity. **CAR** employs a simpler, methodology-specific approach. For example, in its Mexico Forest Protocol, risk is determined using both project-specific factors (e.g., land ownership type, with private land risks ranging from 6% to 8% and communal ownership from 4% to 6%) and default values (e.g., a 4% political risk for private lands). **VCS**'s GCS Non-Permanence Risk Tool evaluates risks based on jurisdiction and project characteristics. For example, if the jurisdiction prioritises CO_2 storage in the event of competing pore space use, the risk score is zero. Conversely, if all project injection wells fail to meet VCS design guidelines, a risk score of 2 is assigned.

In the case of **VCS** risk analysis (AFOLU and geological storage), Verra also conducts periodic reviews. This process reviews a sample of AFOLU and GCS project risk reports to identify inconsistencies in the application of the AFOLU and GCS Non-Permanence Risk Tools, and their assessment by validation/verification bodies.

The **PACM** Removals Standard specifies that the reversal risk assessment is to calculate a percentage-based risk rating. Further details are still to be worked out. Section 3.2 discusses the quantification of reversal risks in more detail.

Re-evaluation of the risk rating

Most carbon crediting programmes require the risk assessment to be regularly updated. Programmes such as **ACR, CAR** and **Isometric** specifically indicate a reassessment at least every 5 years. Under **Puro.earth**, risk assessments are reviewed as part of the annual third-party audits required for facility verification. This suggests risk assessments are revisited at least annually during these audits. Likewise, for most of the programmes, a full verification and or reversal triggers the need to update the risk assessment **(ACR, CAR, VCS, Puro.earth)**.

Current practices in the VCM suggest that re-evaluations of the risk rating should occur at least every five years and immediately following any reversal and/or the identification of additional risk factors. This is in line with the **PACM** Removals Standard which specifies that the risk assessment must be reviewed and revised every five years from the start of the first crediting period as well as whenever the monitoring plan must be updated.

Risk reduction measures

The implementation of risk reduction measures typically results in a lower risk rating, which in turn requires lower contributions to the pooled buffer reserve.

In the case of **ACR**, reduction measures are integrated into risk assessments through quantified percentage reductions to specific risk subcategories (e.g., wildfire, biotic) or as general adjustments. Regarding the latter, risks can be reduced by 2% or 3% if a project provides verifiable evidence of a legally binding and enforceable conservation commitment. Also, if aggregated projects and programmatic approaches, demonstrate sufficient diversification across ecological regions, non-adjacent parcels and acreage, projects can reduce risks by up to 6%. To reduce specific subcategory risks, projects may lower wildfire risk by 25% by demonstrating recent fuel reduction treatments, mitigate biotic risks through targeted treatments, and address hydrologic risks by incorporating flood-tolerant species.

In the case of **GS4GG**, it **mandates** adequate risk mitigation to be identified and planned after the risk assessment has been conducted. Once mitigation measures have been identified and planned a "corrected score" must be calculated. The corrected score determines whether the project can proceed to design certification (score must be lower than 6). Risks and proposed mitigation measures are assessed at design certification, included in the initial risk and capacities report.

Puro.earth specifies that methodologies **require** CO_2 removal suppliers to pre-emptively mitigate material reversal risks.

The **VCS** AFOLU risk tool **allows for** reducing the sub-category risk rating if risk mitigation measures are applied (e.g., management team includes individuals with significant (i.e., more than five years) experience in AFOLU project design and implementation). Furthermore, as part of its general requirements, VCS **mandates** an adaptive management plan, which requires having in place a mitigation plan for potential risks to the project, including those identified through the AFOLU risk assessment tool. For **VCS** GCS projects, the financial closure risk can be reduced if funding is secured for post-injection site care—covering long-term monitoring, well plugging, remediation, and corrective actions. A fully funded post-injection care plan corresponds to a risk score of 1, whereas lack of funding results in the highest score of 5. Similarly, the well design risk score can be reduced to 0 if the injection well meets specific technical standards; non-compliance leads to a higher risk rating of 2.

A comparison of programme requirements indicates that **best practice** involves **integrating risk reduction measures** including the assessment of proposed reduction measures at activity's validation or design certification based on a **detailed plan or report** outlining measures. The implementation of risk reduction measures **should be a mandatory requirement** for all identified risks. The **PACM** Removals Standard aligns with this approach by requiring the risk assessment tool to include a risk mitigation plan.

High-risk activities

Few carbon crediting programmes include specific provisions for activities or sub-risks classified as high risk. **GS4GG** and **VCS** set maximum acceptable risk levels based on project-specific assessments. For **GS4GG**, a risk score above 6 triggers mandatory mitigation measures to reduce the score; otherwise, the project is deemed unacceptable for certification. Under **VCS**, any unacceptably high risk in a category renders the project ineligible for crediting. The AFOLU risk assessment under **VCS** has a default minimum risk of 12% and a maximum of 60%, with critical thresholds at 35% for internal risks, 20% for external risks, and 35% for natural risks. Projects exceeding 60% risk fail the assessment and can only qualify for crediting if adequate mitigation lowers the overall risk.

In the VCM, best practice involves establishing high-risk thresholds that, if exceeded, lead to the exclusion of the activity from crediting. These risk thresholds are not directly comparable, as each programme employs a different approach. The **PACM** Removals Standard does not specify requirements for excluding high-risk activities.

Conservativeness

Conservativeness is characterised by deliberately adopting assumptions or parameters that err on the side of caution, often by overestimating risks or underestimating benefits, to ensure that decisions are made with a safety margin that protects against unforeseen adverse outcomes.

In the **VCS** AFOLU risk assessment tool, some risks require conservative estimates for their determination. For example, in the case of natural risks with less than 100 years of data, conservative extrapolation is required. Where data are unavailable for the project area, likelihood and significance shall be determined based on conservative estimates (i.e., not underestimating the possible frequency or severity) of historical events in the project region" (VCS 2024, p.17). Regarding risk on financial viability, it is indicated that "the assumptions made for revenue from both carbon and other commercial sources must be conservative" (VCS 2024 p.17).

In the case of **ACR**, for the calculation of the specific risks per sub-category, the use of conservative values is encouraged. For example, for the quantification of biotic risks (ACR 2024a).

While the **PACM** Removals Standard refers to the use of conservative assumptions in monitoring, it does not set specific requirements for the reversal risk assessment or the derivation of risk ratings. We recommend that the principle of conservativeness be systematically integrated into the risk assessment tool. Additional considerations are discussed in Section 3.3.

2.2. Monitoring, reporting and reversal notification requirements

An important permanence requirement is the length of the monitoring period also beyond crediting periods because it ensures that carbon storage is maintained over time and that any reversals are detected. In Table 4 we compare the requirements of various independent carbon crediting programmes regarding monitoring, reporting and reversal notification requirements.

Duration and cessation of monitoring for activities involving reversals

The duration of monitoring and remediation periods for activities involving reversals remains one of the weakest aspects of most carbon crediting programmes, falling short of the longer timeframes typically recommended in the scientific literature. Monitoring requirements vary across programmes, generally ranging from 40 to 100 years. The **ICVCM** sets a minimum 40-year monitoring period for AFOLU projects starting from the first crediting period – a requirement we do not consider ambitious (see Kessler et al. 2024). **ACR** and **VCS** also adopt a 40-year monitoring period from the start of the crediting period for AFOLU activities, although VCS allows shorter durations for projects registered before 1 January 2024, noting that such projects would not qualify for ICVCM's Core Carbon Principles eligibility. Among the programmes reviewed, **CAR** takes one of the most stringent approaches, requiring monitoring for 100 years after the last issuance of carbon credits.

For geological storage, most programmes do not prescribe a fixed number of monitoring years but instead require monitoring throughout both the injection and post-injection periods. For example, **VCS** mandates a minimum of seven years of post-injection site care. **ACR**, **Puro.earth**, and **Isometric** require post-injection monitoring until it can be demonstrated that the CO_2 plume has stabilised, particularly for storage in saline aquifers. Additionally, geological storage projects must comply with applicable legal frameworks, which often determine the post-injection monitoring duration. For instance, the US Environmental Protection Agency requires 50 years of monitoring, while Switzerland mandates only 30 years under its CO_2 Ordinance. In the US, a site becomes eligible for a plume stabilisation assessment after a minimum of 15 years, and in the EU after 20 years; once stabilisation is confirmed, the site can move toward decommissioning. Where no regulatory timeframe is specified, **Isometric** sets a default post-injection monitoring period of 50 years.

The carbon crediting programmes analysed also include provisions for cases where project developers fail to submit or discontinue submission of monitoring reports, generally aligning with **ICVCM**'s requirement to treat such failures as avoidable reversals.

Table 4: Monitoring, reporting and notification requirements

		ACR	CAR	GS4GG	VCS	Isometric	Puro.earth	ICVCM
Duration of monitoring for activities involving reversals	**AFOLU**	At least 40 years from **start** of the crediting period	100 years following **issuance** of CAR credits	30-50 years	At least 40 years from **start** of crediting period	Specified in each methodology - E.g., reforestation: At least 40 years from **end** of crediting period	Not applicable	At least 40 years from start of first crediting period
	Geological storage + others	Duration of project + post-injection monitoring until CO_2 plume stabilised and CO_2 will remain contained within the storage volume	Not applicable	Tool currently under development	Duration of project + post-injection until storage site closure. Post-injection site care should not be less than 7 years for geological carbon storage	Specified in each meth.: Duration of project+50 years of post-injection monitoring unless relevant regulatory authority has different protocol	Post-injection monitoring required until plume stabilisation demonstrated; applicable local regulations, Between 20-50 years	No requirements
Cessation of monitoring	**AFOLU**	Activities deemed ceased (early project termination)	Deemed avoidable reversal – full remediation	Failure to provide annual reports requires full remediation and results in decertification of project	Consequences depend on missed timeframe (e.g., 5, 10 or 15 years)	Deemed avoidable reversal	Not applicable	Deemed avoidable reversal
	Geological storage + others	Not regulated	Not applicable	Tool currently under development	Consequences depend on missed timeframe (e.g., 5, 10 or 15 years)	Deemed avoidable reversal	Production facility deregistered	No requirements
Frequency of	**AFOLU**	Requires a monitoring	Defined in methodologies. E.g., soil	Annual reports required (summary of	No minimum requirements specified.	Frequency of measurement and	Not applicable	No minimum requirements specified

		ACR	CAR	GS4GG	VCS	Isometric	Puro.earth	ICVCM
submitting monitoring reports		report at each verification	enrichment: Annual monitoring reports to document updates + Monitoring report at verification	monitoring information) + monitoring report at verification	Defined by project proponent in monitoring plan based on the corresponding methodology	reporting, as specified in the relevant Protocol		regarding frequency of reporting
	Geological storage + others	Requires a monitoring report at each verification	Not applicable	Annual reports required (summary of monitoring information) +monitoring report at verification	No minimum requirements specified. Defined by the project proponent in monitoring plan based on corresponding methodology	Frequency of measurement and reporting, as specified in the relevant Protocol	Output report must be submitted annually	No minimum requirement specified regarding frequency of reporting
Reversal-related notifications and associated deadlines	**AFOLU** **Geological storage + others**	Within 10 business days of becoming aware of a potential unintentional or intentional reversal	Regulated in each protocol. E.g., soil enrichment protocol, for avoidable and unavoidable reversal, notification must be in writing within 30 days	Notification (via email) within 30 days of discovering the reversal/loss event	Notification (via email) within 30 days of discovering the reversal/loss event	Expectation for it to be made within 1 business day of having been identified, but it must be made within a max. of 3 business days	Notify Issuing Body of any reversal event within 5 days of detection *Notification must include failure that caused reversal, and quantifica.	Only a general reference that reversals must be reported, no additional guidance provided
Consequences of reversal notification	**AFOLU** **Geological storage + others**	Full monitoring report to be submitted within 6 months if a significant event occurred	Submission of a detailed report within one year	Submission of a detailed report within three months of the initial notification date	Submission of a detailed report within two years	*Time for submission of full report not specified *Reversal subject to verification	*No additional submission of report required	Only a general reference that reversals must be reported, no additional guidance provided

For AFOLU activities, **CAR** has set a clear best practice in the VCM by requiring a 100-year monitoring period. The **PACM** Removals Standard does not specify the duration of the (post-crediting) monitoring period. It is specified that the activity developers may request the SBM to permit the termination of the post-crediting period if they can demonstrate that the stored GHGs are at negligible risk of reversal or that potential future reversals are remediated (UNFCCC 2024, para. 28). We recommend that further PACM permanence requirements in both the standard and tool align with this monitoring best practice for land-based carbon storage activities (i.e., 100 year-period). PACM guidance should also clearly define the consequences of failing to submit a monitoring report on time, treating it as an avoidable reversal – requiring full replacement of, or replenishment to, the buffer pool for all credits issued during the affected monitoring period.

Frequency of submitting monitoring reports

Carbon crediting programmes vary in how frequently they require the submission of monitoring reports. For example, under **GS4GG**, project developers must submit both monitoring and annual reports. Monitoring reports are prepared for each verification, which must occur at least once within the five-year certification cycle. Annual reports, due by the end of the following calendar year, provide a summary of monitoring data collected throughout the year. Similarly, **Puro.earth** also requires annual reporting. **VCS** mandates that projects facing reversal or loss risks maintain continuous monitoring without gaps between reporting periods.

A best practice by some programmes is an annual report that also covers any updates regarding reversals. Regarding monitoring reports, the **PACM** Removals Standard requires that there is no gap between two consecutive monitoring period. Besides, the frequency of monitoring report submission under the mechanism is determined by the methodology based on the activity's nature and reversal risk. However, the interval between the start of the crediting period and the first report – and between any two consecutive reports – must not exceed five years. Use of shorter time periods by activity developers is encouraged. PACM requirements link the frequency of monitoring report submission to the reporting period and the associated reversal risk.

Reversal-related notifications and associated deadlines

Carbon crediting programmes usually require a notification in the event of a reversal. **GS4GG** and **VCS** require a notification (via email) within 30 days of discovering the reversal/loss event. **ACR** requires it within 10 business days. **Isometric** suggests the reversal to be notified within the same day, and max within 3 days and **Puro.earth** within 5 days.

Under **PACM**, the activity developer must notify the SBM in case of **any observed event** involving the release of stored GHGs within 30 days.

Consequences of reversal notification

After the notification of the reversals, project developers are usually required to submit a detailed report. For **GS4GG**, an assessment report must be submitted within three months of the initial notification date; for **CAR**, within one year; and for **VCS**, a loss event report must be submitted within two years of discovering the loss event, provided that VCUs have previously been issued. Under VCS, if the loss is discovered during the verification, the project developer must submit a loss event report before the review of the verification is requested.

Other consequences include the suspension of related actions by the programme. For example, **GS4GG** requires freezing the project registry account that is affected by the reversal event. **CAR** does not allow transactions to take place until the reversals are verified, and in some cases, it might also require onsite verification of the reversals. Under **VCS**, if a loss event report is not submitted within two years of the event's discovery, respective projects cannot issue further VCUs until report submission. In addition, buffer account credits are put on hold equivalent to the estimated loss. **VCS** also requires the verification of the occurred losses by a VVB. VCS applies a tiered approach to non-submission of a verification report following the last verification. If no verification is submitted within 5 years, 50% of the project's buffer credits are put on hold. If no submission occurs within 10 years, all remaining buffer credits are put on hold. After 15 years without submission, buffer credits are cancelled from the AFOLU pooled buffer account in an amount equal to the total number of VCUs issued to the project (including those previously put on hold), and the project is designated as inactive. The monitoring report at the verification after the loss event is to restate the loss event to reflect it in the net GHG benefit for the monitoring period.

Best practice in the VCM for post-reversal notification includes suspending all activity-specific operations and requiring detailed reports assessing the reversal event and its extent. Identified reversals should be promptly reflected in a subsequent monitoring report. Operations should only resume once remediation has been completed. Also, the risk rating should be revised.

The **PACM** Removals Standard specifies that, following a reversal event, all operations related to the affected mitigation outcomes must be suspended. The activity developer is required to prepare a preliminary assessment report of the event. If a reversal is confirmed, a monitoring report must be submitted to the SBM within one year, followed by a review of the activity's risk rating and a potential increase in its contribution to the RRBPA.

2.3. Requirements for the remediation of reversals

In the event of reversals, carbon crediting programmes apply different remediation approaches, typically distinguishing between avoidable (intentional) and unavoidable (unintentional) reversals. For example, buffer pools are commonly used to compensate for unavoidable reversals. Table 5 first outlines the differentiated treatment of avoidable and unavoidable reversals, followed by a detailed description of the mechanisms prescribed to address them.

Table 5: Requirements for the remediation of reversals

		ACR	CAR	GS4GG	VCS	Isometric	Puro.earth	ICVCM
Avoidable vs unavoidable reversals requirements	**AFOLU**	**Avoidable**: Project developers must cancel credits and also deposit credits into the buffer pool **Unavoidable**: buffer pool	**Avoidable**: compensate for intentional reversals with non-buffer reserve credits by surrendering credits from their reserve account **Unavoidable**: buffer pool	**Avoidable**: Compensate with credits from project's registry account; compensate using an equivalent number of credits purchased from other GS projects **Unavoidable**: buffer pool	**Avoidable**: buffer pool, replenish the pool in full **Unavoidable**: buffer pool replenishment only required if credits used exceeds the amount originally contributed by developers	**Avoidable**: project proponent must reimburse buffer pool **Unavoidable**: not required to reimburse buffer pool	Not applicable	Determine whether avoidable or unavoidable; compensate for avoidable reversals (no further issuance until compensated)
	Geological storage + others	Recognises that avoidable and unavoidable reversals can impact geological storage, but no specific requirements outlined	Not applicable	Tool currently under development	**Avoidable**: buffer pool, replenish the pool in full **Unavoidable**: buffer pool replenishment only required if credits used exceed once contributed by developers	**Avoidable**: project proponent must reimburse buffer pool **Unavoidable**: not required to reimburse buffer pool	A small amount of CO_2 released during monitoring that is planned, controlled, and unavoidable is not counted as a reversal	No requirements
Mechanism	**AFOLU**	Buffer pool only allowed for unavoidable reversals	Buffer pool only allowed for unavoidable reversals	Buffer pool only allowed for unavoidable reversals	Buffer pool, avoidable and unavoidable reversals, but different approaches	*Buffer pool for avoidable + unavoidable *Only against reversals that may be observed because of monitoring	Not applicable	Buffer pool, but not detailed requirements and definitions provided

		ACR	CAR	GS4GG	VCS	Isometric	Puro.earth	ICVCM
						*Buffer pool not allowed for open system (e.g., the ocean) or where direct observation would not be possible		
	Geological storage + others	Reserve Account managed by ACR	Not applicable	Tool currently under development	Geological carbon storage pooled buffer account	Buffer pool for avoidable + unavoidable *only against reversals that may be observed as a result of monitoring *Buffer pool not allowed for open system or where direct observation would not be possible	No buffer pool, but Compensation involves withdrawing equivalent credits or depositing comparable ones	No compensation mechanism required. Activities with material risks must have appropriate measures in place to avoid material risks
Buffer pool/reserves contribution	**AFOLU**	Dependent on the results of risk assessment	Dependent on results of risk assessment	20% fixed contribution	Dependent on the results of the risk assessment	Dependent on the Risk of Reversals (very low, 2%; low, 5%; Medium, 7%; High, 10-20%)	Not applicable	20% min. of total carbon credits issued, **or** carbon credits proportional to the reversal risk
	Geological storage+ others	10% of the annual max. GHG emission reductions and removals	Not applicable	Tool currently under development	Dependent on the results of the risk assessment	Dependent on the Risk of Reversals (very low, 2%; low, 5%; Medium, 7%; High, 10-20%)	Not applicable	No requirements

		ACR	CAR	GS4GG	VCS	Isometric	Puro.earth	ICVCM
		to a Reserve Account						
Buffer credits use criteria	**AFOLU** **Geological storage+ others**	CORSIA[2] with CORSIA; AFOLU with AFOLU; Non-AFOLU with credits within vintage of 5 years or most recent vintage available	Grassland credits with grassland; forest with forest; credits with granted eligible status for use in programmes outside the Reserve with credits same status; in case of not sufficient credits of same type CAR can retire credits from any other type	Developer must ensure that the credits offered for compensation have the same eligibility compliance as the lost credits due the reversal event (e.g., CORSIA with CORSIA)	Not addressed specifically, but there is a dedicated buffer pool for AFOLU and other one for geological carbon storage	CORSIA with CORSIA	Developer must deposit credits of the same type, or if unavailable of comparable permanence	No requirements
Other compensation mechanisms or Tonne Year Accounting	**AFOLU**	Permits insurance as a substitute for a buffer pool	Tonne-year accounting	No other compensation mechanism available	No other compensation mechanism available	Third-party insurance permitted; does not alter buffer pool size	Not applicable	Work program in place for insurance products and mechanisms
	Geological storage+ others	Permits the use of insurance	Not applicable	Tool currently under development	No other compensation mechanism available	Third-party insurance permitted but does not alter buffer pool size	Compensation involves withdrawing equivalent credits or depositing comparable ones	Work program in place for insurance products and mechanisms

[2] Carbon Offsetting and Reduction Scheme for International Aviation

Remediation of avoidable and unavoidable reversals

Typically, carbon crediting programmes differentiate between avoidable (intentional) and unavoidable (unintentional) reversals. **GS4GG** differentiates between force (intentional) and non-force (unintentional) majeure. The following table showcases what the different credit programmes considered under both categories:

Table 6: Programmes' categorisation into avoidable and unavoidable reversals

	Unavoidable (unintentional)	Avoidable (intentional)
ACR	No definition included	No definition included but references to it across several documents: • The loss of carbon stocks through illegal logging by outside actors is considered an intentional reversal • Early project termination (i.e., discontinuing MRV before end of the minimum 40-year project term) • Other: over-harvesting, forest conversion
CAR	• Not due to the Project Owner' negligence, gross negligence or wilful intent)	• Due to the Project Owner's negligence, gross negligence or wilful intent • Failure to meet the monitoring, reporting, and verification requirements considered an avoidable reversal
GS4GG	(Force majeure) • Any act of war (whether declared or not), invasion, revolution, insurrection, terrorism, or any other acts of a similar nature or force, that prevents DOE travel to project site • Natural disaster like flood, earthquake, etc. • Change in governmental requirements, policy, etc. that affect the project implementation and operation • Any event beyond the control of the project developer and not involving the developer's fault or negligence and not foreseeable • Force majeure does not include shortage of personnel, industrial action, economic downfall, sickness of personnel, breach of contract by subcontractors and liquidity or solvency problems. • An event may qualify as "Force majeure" while it was assessed as no or low risk for project implementation	(Non-force majeure) • Any other cause that is not covered under force majeure
VCS	A reversal over which the project proponent has no control. Examples include natural disasters such as hurricanes,	A reversal over which the project proponent has influence or control. Examples include poor project management, removal of a portion of the project

	Unavoidable (unintentional)	Avoidable (intentional)
	earthquakes, flooding, drought, fires, tornados and winter storms, and human-induced events such as acts of terrorism, crime, or war. Encroachment by outside actors (e.g., logging, mining, or fuelwood collection) are considered unavoidable when demonstrably unforeseeable and out of the project proponent's control.	area from participation, harvesting/over-harvesting, or tillage events.
Isometric	• Project proponent has no control, including natural disasters, encroachment by outside actors, or occurrence of other demonstrably unforeseeable factors reasonably considered to be outside of the Project Proponent's control,	• Cease of ongoing monitoring • Reversals over which the project proponent has influence or control, e.g., poor project management or operational negligence
Puro.earth	Not addressed	
ICVCM	No definition included but requires programmes to define and apply clear criteria for determining whether a reversal is avoidable or unavoidable. In a future version of the initiative's Assessment Framework, it is likely that a definition of avoidable and unavoidable reversals is included in line with the recommendation of its permanence work program (ICVCM 2025).	

The type of reversal experienced prompts different compensation approaches. For unavoidable (unintentional) reversals, carbon crediting programmes typically use buffer pools to compensate for reversals. In the case of a reversal, credits allocated to the pool are cancelled to compensate for the reversals. Programmes have different ways of managing compensation. For example, **ACR** and **Isometric** do not require replenishing the pool after a compensation. **VCS** requires a replenishment only if credits used exceed the credits allocated by the project developer to the buffer pool (e.g., contributed with 100 credits, 150 were cancelled, 50 credits must be deposited). For **ACR**, if the loss from the reversal exceeds the project proponent's buffer pool contributions, the proponent shall pay a "deductible" of 10% of the lost credit amount.

Regarding avoidable (intentional) reversals, **ACR, CAR**, and **GS4GG**, do not allow reliance on the buffer pool to compensate for the reversals. **ACR** mandates that project developers cancel credits and deposit credits into the buffer pool. **CAR** requires activity developers to compensate for intentional reversals by surrendering non-buffer credits from their account. If an avoidable reversal is not compensated by the activity owner, CAR will retire credits from the buffer pool to cover the loss. Conversely, **VCS** allows buffer pool credits to compensate for avoidable reversals; however, it requires project developers to replenish the buffer pool in full once new credits have been issued after a reversal. A similar approach is also followed by **Isometric**, which requires project developers to reimburse the buffer pool with an equal number of credits.

Best practice in the VCM limits the use of buffer pool credits to remediating unavoidable reversals. Avoidable reversals are directly to be compensated through non-buffer credits by the activity developer. Another best practice is for the programme to intervene if the activity owner fails to fulfil their obligation to remediate avoidable reversals. The **PACM** Removals Standard, permits the use of "Buffer A6.4ERs" for avoidable reversals but requires full replenishment of the RRBPA with an equivalent volume of A6.4ERs of comparable quality (i.e., same activity type and authorisation status). The standard mandates stress-testing the RRBPA at least every three years, though.

Buffer pool contribution

Pooled buffer pools operate by combining the contributions of various mitigation activities into a single reserve. Most of the programmes determine the buffer pool contribution based on the results of the risk assessments. Conversely, for AFOLU, **GS4GG** requires a 20% fixed contribution of the credits issued. The guidelines document[3] outlines a risk assessment procedure to identify the risks associated with an activity and the corresponding mitigation required. The risk assessment is thus used to determine the need for risk mitigation measures (score range: 7-27), but it does no serve to calculate a buffer pool percentage. To derive the overall risk per subcategory three factors are combined: Exposure of the project to an event, vulnerability of carbon pools and spatial scale. Each of these factors can be rated high (sore 3), medium (score 2) low (score 1) or no impact (score 0).

Both options for buffer pool contribution are allowed by the **ICVCM**. **ICVCM** also requires making publicly available information on the pooled buffer reserve contents, including the origin of carbon credits. Risk assessment-based buffer pool contributions are further discussed in section 3.2.

Use of insurance

Some carbon crediting programmes allow the use of insurance products to cover unavoidable reversals which are, however, rarely used (FAO 2024). **ACR** permits using insurance products (e.g., insurance, bonds, letters of credit) as a substitute for buffer pool contributions if they are grounded in an actuarial assessment of project risk, considering factors like the location, potential threats, and risk mitigation strategies factors. **ACR** either needs to receive a sufficient volume of credits or adequate funds, as determined by ACR, to offset the reversal via credits cancellation. Under **Isometric**, third-party insurance is permitted but does not alter buffer pool size. **ICVCM** has set a work programme on insurance products and mechanisms and other approaches to address permanence.

While not frequently in use yet, the use of insurance products can replace or complement buffer pool contributions. The latter is the case for **PACM**. The **PACM** Removals Standard encourages activity developers to obtain and maintain sufficient coverage under an insurance policy or comparable guarantee products to cover risks from avoidable reversals.

[3] Guidelines "Risks & Capacities for Agriculture & Forestry Activities" (GS 2025b)

3. Operationalising the reversal risk assessment approach

3.1. Systematic categorisation of reversal risks

Reversal risks can be classified into various categories and sub-categories, which serve as the basis for assessing and determining the corresponding risk factors and scores.

In its recently released "Guidelines: Risks & Capacities for Agriculture & Forestry" (2025b), GS differentiates between the following risk categories and types:

Table 7: GS risk categorisation for agriculture & forestry activities (GS 2025b)

Risk category	Risk types
Natural Disturbance	Fire damage; wind damage; temperature extremes; water extremes; climate variability; geological extreme events; animals; pest and disease outbreaks
Political	Political interventions; land acquisition; non-regularised resettlement; exploitation of natural resources
Project Management	Technical capacity (availability); technical capacity (dependency); financial capacity (availability); financial capacity (dependency); legal capacity (availability); legal capacity (dependency); capacity to maintain GS4GG certification (availability); capacity to maintain GS4GG certification (dependency); constraints in technical equipment
Financial risks	Lack of secured, continued financial resources for activity implementation until the activity's cumulative break-even cash flow
Market risks	Lack of liquidity/financial resources due to price variations; risk of competing commodities; risk of competing infrastructure
Other risks	Any other specific risks that endanger the viability of the activity

In comparison, Verra differentiates between internal, external and natural risks with the following risk types (Verra 2024a):

Table 8: VCS categorisation of risks in AFOLU non-permanence risk tool (Verra 2024a)

Risk category	Risk types
Internal risks	Project management; financial viability; opportunity cost; project longevity
External risks	Land and resource tenure; stakeholder engagement; political risk
Natural risks	Historical natural risk; projected future climate change impact; sea-level rise impact

In its geological carbon storage non-permanence risk tool under VCS, Verra differentiates between regulatory framework risks, political risks, land and resource tenure risks, closure financial risks and design risks (Verra 2025a).

ACR (2024) differentiates the following categories and types:

Table 9: ACR categorisation of risks in its reversal risk tool (ACR 2024)

Risk category	Risk types
Management and governance risks	Financial (e.g., failure); social and political (e.g., corruption, shifts in politics, legal frameworks etc.); illegal logging
Natural disaster risks	Wildfire; biotic (e.g., insects and diseases); hydrologic (e.g., flood events); other natural disasters (e.g., hurricanes, tornadoes, drought etc.)
General risk adjustments	Conservation and commitment adjustment; diversified risk adjustment

ACR's tools further specifies that some of the risk types are not applicable to all projects. For example, the illegal logging and biotic is only applicable to forest projects while the hydrological risk is applicable to forest, wetland and grassland projects.

For PACM (2024) we propose the following categorisation of risks:

Table 10: Proposed reversal risk categorisation

Risk category	Risk types
Natural disturbances and climate hazards	There are two principal approaches to defining sub-categories, neither of which is inherently superior: **Trigger of specific event that then leads to reversal** Geophysical extreme event (earthquakes, tsunamis, volcanic eruptions) Meteorological extreme event (drought, rainfall, windstorm, hailstorm) **Actual event leading to reversal** Fire Water stress Pests Flooding Wind Landslide Opening of crack/fault in the earth (for geological storage) Change in characteristics of waterbody *Climate change-induced intensification of the sub-categories above**
Political, social and governance risks	Land tenure and resource rights, Regulatory and policy uncertainty, Crime, social instability, conflict (terrorism, civil war, war), Bad governance, corruption and legal system weakness, leading to illegal activities (e.g., logging, mining) and related land use change Harvesting
Project management and	Technical expertise and technology availability, Institutional and legal capacity, Monitoring continuity,

Risk category	Risk types
operational capacity risks	Asset ownership
Financial and market risks	Financial sustainability (incl. solvency and liquidity issues), Rising opportunity costs

Regarding climate change-induced intensification*, we propose to base it on peer-reviewed and publicly available data sets and integrate it in each type of natural disturbances and climate hazards rather than treating it as a standalone category. It then should be applied as a multiplier in these sub-categories.

As discussed in section 2, the classification of the identified risk types into avoidable (or intentional) and unavoidable (or unintentional) is key. The MEP is currently proposing the following:

- Avoidable risks: (Mis)management of the activity, neglect, illegal action, insolvency, use of products (where applicable), any factors not identified in risk assessment, stop of monitoring etc.
- Unavoidable risks: Natural disturbances, extreme events, war, acts of terrorism

Generally, the number of unavoidable risks should be kept to a minimum and include the risk category "Natural disturbances and climate hazards" as well as the risk type "Crime, social instability, conflict (terrorism, civil war, war)".

If additional risks are identified that do not fall within the specified sub-categories above, we propose that, for the sake of conservativeness, these be classified as 'avoidable'. Also, any cessation of monitoring and verification should immediately be treated as an avoidable reversal which we identified to be best practice in ongoing VCM practices.

3.2. Determination of risk ratings and buffer pool contributions

As outlined in section 2.3, the buffer pool contributions are either determined based on a fixed share of credits (GS) or a share based on the risk assessment and the resulting rating. The PACM Removals Standard states that an overall contribution to the RRBPA (we use the term **buffer pool percentage** for the remainder of our study) needs to be calculated as result of the risk rating, considering, inter alia, the nature, magnitude, likelihood, and duration of the risks.

Unlike most independent programmes, the PACM's Removals Standard requires percentage-based risk ratings to account for both avoidable and unavoidable reversals. While activity participants must fully replenish the RRBPA with equivalent A6.4ERs for avoidable reversals, the responsibility is ultimately assigned to the RRBPA rather than the activity proponent. While we would generally advocate for a different approach to address avoidable reversals in line with best practice, the Removals Standard has already been adopted. Against this background, we recommend **limiting the percentage-based risk rating to cover only specific avoidable reversals**. For other avoidable reversals, responsibility for remediation could be assigned directly to the activity proponent or addressed through mandatory insurance coverage

Most of the programmes discussed in chapter 2 have developed individual approaches to quantify the risk of reversals and to derive a risk rating. Thereby, they assign ratings to risk types and usually aggregate these to receive an overall risk score or rating. Subsequently those programmes that apply buffer pool approaches calculate the buffer pool percentage based on the aggregate risk score/rating. We would like to note that in the budget-constrained context of this assignment we cannot evaluate whether the buffer pool percentages specified by the programmes are conservatively reflecting the reversal risk or not. The methodologies used to determine the risk ratings differ considerably among programmes. Accordingly, this sub-section prioritises the identification of key considerations for deriving risk ratings, rather than proposing specific percentage-based values. First, we assess programmes' methodologies in more detail.

ACR in its tool for terrestrial sequestration projects builds on several equations at risk sub-category level to derive a buffer pool percentage which is multiplied by total GHG mitigation outcomes to calculate the buffer pool contribution for each issuance (ACR 2024a). To calculate the financial risk, it builds on the credit rating of the activity developer. The social and political risk is derived from the World Bank Worldwide Governance Indicators based on the project's location and calculated based on an equation that assumes a maximum risk of 8%. Illegal logging risk is calculated using data from the Forest Trends Global Illegal Logging and Associated Trade Risk Data Tool, it is capped at 4.25%. Other core input types for calculations of other sub-category risks include GIS datasets, project geography and biodiversity metrics. For information that is not available in predefined datasets, such as wildfire risk outside US, ACR requests the project developer to provide a risk assessment based on publicly available data, peer reviewed literature, or other verifiable sources.

Under CAR, buffer pool contributions are established by each methodology (protocol). According to its "Mexico Forest Protocol" (CAR 2025), a default deduction is used to determine the projects contribution to the buffer pool. Thereby, the reversal risk is calculated based on a mix of project-specific risk values (e.g., for financial and management risk categories, wildfire risk) and default risk values (e.g., for political, disease or catastrophic event risks). A matrix is used to identify project-specific risk values by assessing factors that influence risks, such as financial risks (e.g., projects occurring on public land have lower risks). These ratings per category are then used to calculate the buffer pool contribution rate. However, the scientific basis for the assigned risk ratings is not clearly explained.

Verra has developed a questionnaire with specific binary questions that approximate certain risks in its AFOLU non-permanence risk tool (Verra 2024a). Most of the sub-questions are linked to specific, provided positive or negative scores, which are then summed to calculate the overall score for the risk type. The risk type-specific scores are, in turn, summed to get a category-specific rate. The value of the risk score for the respective question is not further explained by Verra.

A comparison of these widely different methodologies to deriving risk ratings and buffer pool percentages, reveals that programmes generally do not explain the **scientific basis for the specific risk scores or ratings** assigned at the risk category or risk type level. According to Haya et al. (2023), an analysis of 67 Verra REDD+ projects found that contributions to the buffer pool to cover all natural risk categories averaged 2%. In addition, most projects allocated just the lowest allowable share – 10% to the buffer pool to cover natural and human- induced risks (Haya et al. 2023). As a result, it is difficult to evaluate the robustness of these scores and ratings. This is reinforced by a recent scientific publication that questions the scientific methodological foundation of the natural risk assessment in Verra's AFOLU tool (see Anderegg et al. 2025). The authors argue that the buffer pool contribution does not sufficiently account for natural disturbance scenarios and the impacts of climate change. Badgley et al. (2022) identified the same lack of analysis to justify natural, financial and management risk rates for California's forest carbon offsets buffer pool.

To ensure credibility and robustness, reversal risk scores and ratings should be transparently derived and **grounded in scientific evidence**. Current practices lack sufficient transparency regarding how risk ratings are determined. Under the PACM, we recommend that an initial buffer pool percentage be established for each activity type by an independent expert body. To support this, we propose the establishment of a **Risk Assessment Panel** under the authority of the SBM, composed of independent risk experts. This panel should review and validate proposed risk ratings using a conservative and unbiased approach. Additionally, targeted research should be undertaken to improve the evidence base for natural disturbance-related risks given their increasing importance in the context of climate change.

The specification of risk scores by carbon crediting programmes appears to follow relatively unstructured approaches. Some risks are assessed solely based on likelihood, others only on consequences, and some implicitly combine both without clearly stating the underlying assumptions. In our view, a consistent and transparent approach that explicitly **evaluates both likelihood and consequences** is needed (see Kaplan and Garrick 1981; Rausand and Stein 2020). This approach requires a prior classification of likelihood (e.g., frequency or probability) and consequence (e.g., magnitude, severity). Many classifications of likelihood and consequence follow approximate logarithmic scales instead of linear scales (e.g., damages tend to increase in an exponential, not linear fashion). As the logarithm of a product is the sum of logarithms, for logarithmic scales following equation is more suitable (Rausand and Stein 2020): $Risk = \sum_{i=1}^{n}(likeli_i) + (conseq_i)$. It is important to note that a low-impact, high-probability risk can receive the same rating as a high-impact, low-probability risk. Whether this equivalence is appropriate for ranking reversal risks – particularly over long timeframes – warrants further discussion. Individual risk thresholds for both dimensions can be defined. Defining thresholds for both dimensions and applying weights can better reflect their relative importance. Weighting also plays a key role when aggregating individual risk criteria into a total score, especially if the rating is converted into a buffer pool percentage.

Also, none of the programmes considers "**cascading**" risk where an initially small event triggers a series of interconnected, progressively worsening impacts or failures across multiple systems or sectors (Pescaroli and Alexander 2018). An option to account for cascading risks is to define minimum values for all interconnected risks when at least one of them has a high probability. Similarly, "**compound**" risks can generate an overall impact beyond what would be expected from each risk individually (Pescaroli and Alexander 2018). As an example, droughts and heat waves are individual risk factors for wildfires, but if both occur at the same time, the risk for wildfires increases exponentially. The risk assessment thus needs to include additional interaction parameters for high impact cascading and compound risks that account for the likelihood that two or more risk factors happen simultaneously or sequentially. Therefore, methodologies need to consider which risks are independent, and which ones are compound and cascading and thus need to be weighted more highly.

Most independent programmes have separate tools and approaches for AFOLU and geological activities. Generally, risk assessment should be differentiated by the **type of reservoir,** as many risks are directly related to it. A geological reservoir in basaltic rocks has generally different risk characteristics compared to a geological reservoir in a saline aquifer. The former has much lower reservoir leakage risks than the latter. Well integrity failure risks at injection may be comparable for both reservoir types, but post-injection will differ as per the characteristics of the reservoir. Risks of reservoirs in crushed rocks generated by enhanced rock weathering will be linked to the final deposit of the crushed rock, and the likelihood of it being disturbed. Risks will also differ between standing forests and soil, the former being much more exposed to fire risk than the latter. So, first, the reservoir types need to be differentiated regarding their risks. Here a standardisation can be undertaken.

Once reservoir-specific risks have been defined, activity type-specific risks need to be defined; these apply only to one or a subset of activity types. Subsequently, a specific risk assessment methodology needs to be applied to each reservoir type. This methodology needs to consider differences in site conditions. While for example fire risk may be comparable for forest reservoirs in the same climate zone, risks of pests may differ according to the altitude level of the forest. The use of alternative methodologies for the same reservoir type should be restricted to prevent selective application.

The higher the level of aggregation of the risk in question, the higher the potential for standardisation of the risk assessment. Because some risks span multiple activity classes while others are specific to a single activity type, **a modular risk framework** is recommended. A common module evaluates cross-cutting risks – such as management or political risks – to ensure consistency across all activities, while separate modules address risks unique to each activity type.

When developers conduct the risk assessment, the framework must limit opportunities to understate risks without imposing excessive transaction costs. **Clear, precise questions** minimise room for interpretation, reducing bias and preventing risk underestimation. With appropriate incentives, the framework can also allow expert judgment to account for site-specific factors that fall outside predefined criteria.

3.3. Impact of risk reduction measures

Most carbon crediting programmes require or incentivise the consideration of risk reduction measures in the risk assessment. The more ambitious approaches require the development of a detailed risk reduction plan or report that explains how specific risk factors are addressed. In most programmes, the implementation of risk reduction measures leads to an improved overall risk rating and, consequently, a lower buffer pool percentage. However, in the case of natural disturbances, researchers (Anderegg et al. 2025) have noted that reductions in buffer pool contributions based on such measures should be applied more conservatively, as their effectiveness is still an open scientific question (Anderegg et al. 2025).

For the PACM, we propose to incorporate best practices in further guidance including:

- **Proactive integration at design stage:** Risk mitigation must be addressed proactively at the time of design certification or validation, based on recent and verifiable measures
- **Risk type-specific mitigation:** Measures should be tailored to individual risk types and clearly outlined in the mitigation plan
- **Justified and evidence-based measures:** While some flexibility in mitigation approaches can be allowed, all measures must be supported by credible evidence — such as peer-reviewed scientific literature and expert judgment
- **Transparent risk scoring:** Both pre- and post-mitigation risk ratings should be provided in the plan or report for enhanced transparency
- **Verification requirement:** The mitigation plan must be subject to independent third-party verification including to check whether the risk measures remain effective
- **Ongoing updates:** The risk assessment must be updated in response to any changes and at each renewal

3.4. Considering conservativeness in deriving risk ratings

Uncertainty poses a fundamental challenge to risk assessments (Price et al. 2007). Effective risk assessments must account for both aleatory (randomness) and epistemic (lack of information) uncertainties, while the former can only be better characterised but is not reducible (Dabra 2008). To address uncertainty, the risk can be re-calculated assuming varying parameter values, leading to a set of risk values (Kaplan and Garrick 1981). Also, samples created by Monte Carlo simulations and the use of Bayesian Inference are tools that are commonly employed for risk assessment under uncertainty but may be too complex and cumbersome to apply for assessing the risk of reversals for individual carbon crediting activities. However, risk assessments can make use of regional studies that employ such techniques to model certain risks, e.g. regional exposure to wildfires.

Generally, in the context of reversal risk assessments, conservativeness can be used as a guiding principle to address uncertainty, ensuring that risk ratings and buffer pool percentages err on the side of caution when scientific evidence is limited or inconclusive. Most risk tools and guidelines applied by independent programmes do not systematically apply conservative approaches. Some make a reference to choose conservative values when deriving the rating for a specific risk type.

We propose to clearly enshrine conservativeness as one of the guiding principles for conducting the risk assessment under PACM to ensure that the derivation of a risk rating for each risk type is based on conservative parameter values, regardless of whether they are measured, estimated or defaults are used. The relevance of such an approach is demonstrated by the fact that buffer pools that have been operated for less than a decade in the context of the Californian cap-and-trade programme for AFOLU activities are already close to exhaustion because the forest buffer pool is severely under-capitalised due to non-conservative ratings (Badgley et al. 2022).

3.5. Time frame for risk assessments

The risk assessment time horizon should ideally match the post-crediting monitoring and remediation period, at least for AFOLU activities. 100 years is an often referred to time horizon for monitoring and remediation of AFOLU activities. In case a crediting period of a removal activity is 10 years, but 100 years without reversals are required for permanence, the reversal risk for at least the 90-years after the end of the crediting period needs to be monitored and addressed either by the activity developer or a responsible authority. It should be noted that only a small share of human institutions survives for 100 years.

Most carbon crediting programmes adopt monitoring time horizons spanning several decades, with 40 years being a common benchmark. For example, the EU's CCS Directive permits the transfer of the responsibility to state authorities already 20 years after storage site closing (Cames et al. 2024). However, this falls short of the long-term permanence requirements, highlighting a significant gap between actual practice and the durability needed. Given that removal activities under the PACM may have crediting periods of up to 45 years, we recommend that the transfer of reversal risk liability to the host country government be permitted no earlier than 55 years after the end of the crediting period – that is, 100 years from its start.

It is important to recognise that risk can change over time, both during and after the crediting period. In many cases, risk increases may be driven by climate change, but risks can also decline as project conditions evolve. Consider, for example, an afforestation project with a uniform species mix and consistent annual carbon removals across the entire area. If 50% of it the project area burns during the 45-year crediting period, a 50% reversal event has occurred. However, if the same area burns 80 years after project start, but the remaining 50% has accumulated twice the carbon stock relative to the end of the crediting period, then no net reversal has taken place.

When a reservoir is supplied by multiple activities over time, an important question arises: which activity is held liable in the event of a reversal? Consider a geological storage facility filled by five developers – A though E – in equal, sequential instalments over the crediting period. If a leak occurs in the final monitoring year, resulting in 10% reversal, how should liability be allocated? Should it be based on each developer's proportional contribution to the total storage, or according to a "last in, first out" or "first-in, first out" principle? Under proportional attribution, each developer would be responsible for 10% of the reversals. Under "last in, first out", developer E would lose 50% of its share. In the third case, developer A would have to replace 50% of its share.

4. Recommendations

Drawing on a comparison of practices across independent carbon crediting programmes and PACM's reversal risk approach, we propose the following key recommendations for further operationalising the PACM requirements:

- The SBM should consider establishing a Risk Assessment Panel. This independent panel of risk experts should be established to review and validate proposed risk ratings and ensure that ratings are calculated based on science and conservatively.
- The SBM's MEP should implement a reversal risk assessment approach in the respective tool that applies a standardised approach to reservoir-specific risks, builds on a module for cross-cutting risks (e.g., political, management) and activity type-specific modules for risks specific to an activity type, ensuring consistency and tailored evaluations. Higher standardisation for broadly applicable risk factors should be enabled.
- PACM's Non-Permanence Standard should:
  - For avoidable reversals, limit buffer pool coverage to a subset of those avoidable reversals and assign the responsibility for non-covered avoidable reversals directly to the activity proponent. Non-covered avoidable reversals should include those that are reasonability quantifiable such as solvency.
  - Determine the monitoring period length to align with best practice for land-based carbon storage activities (i.e., 100 year-period).
  - Mandate monitoring reports for all activity types at least every 5 years and require annual updates that provide a summary of monitoring data collected throughout the year including on any reversal event.
  - Clearly define the consequences of failing to submit a monitoring report on time, treating it as an avoidable reversal – requiring full replenishment of the buffer pool for all credits issued during the affected monitoring period.
  - Require detailed, risk type-specific mitigation plans at the design stage, supported by credible evidence, independently verified, and updated at each verification to ensure effectiveness. Require transparent reporting of pre- and post-mitigation risk ratings in the context of mitigation plans.
  - Define clear time horizons for risk assessments, aligned with post-crediting monitoring periods.
- PACM's reversal risk assessment tool should:
  - Set initial buffer pool percentages for each activity/reservoir type based on expert analysis, reviewed by the Risk Assessment Panel.

- Ensure that all risk ratings must be scientifically grounded, with clear methodologies and documented assumptions.
- Incorporate climate change-induced intensification as a multiplier for natural disturbance risk types, using peer-reviewed, publicly available datasets to enhance accuracy and relevance.
- Adopt a consistent and transparent framework that evaluates both likelihood and consequence of reversal risks using clearly defined, possibly logarithmic scales.
- Use clear, closed-ended questions in the risk assessment to reduce subjectivity and limit opportunities to understate risk.
- Aggregate risk ratings in a structured manner using transparent weightings.
- Include interaction parameters in risk assessments to account for cascading (e.g., small events triggering larger impacts) and compound risks (e.g., simultaneous drought and heat waves), setting minimum values for interconnected risks.
- Establish clear reversal risk thresholds to exclude high-risk activities from crediting unless mitigated below acceptable levels, ensuring only projects with acceptable risk profiles proceed to registration.
- Enshrine conservativeness as a guiding principle, using conservative parameter values for risk ratings to prevent underestimation and ensure buffer pool adequacy.

Next to these policy recommendations, further research is required on:

- Scientific basis for reversal risk ratings, including a comparative assessment of the methodologies and scores used by independent carbon crediting programmes.
- Evidence base for natural disturbance risks, including climate change impacts.

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Annex A: Overview of relevant programme documents

	ACR	CAR	GS4GG	VCS	Isometric	Puro
AFOLU	• Reversal risk analysis and buffer pool contribution determination (2024 a) • ACR Buffer Pool Terms and Condition (2024 b) • ACR Standard v8.0 (2023) • ACR AFOLU Carbon Project Reversal Risk Mitigation Agreement • Specific methodologies	• Reserve Offset Program Manual (2024) • Specific protocols (methodologies) • Project implementation agreement	• Principles and requirements (2025c) • Land Use & Forestry Activity requirements (2020) • Risks & Capacity Guideline for Land Use & Forest projects (2025b) • GHG emission reduction & sequestration product requirements (2025a) • Performance shortfall guidelines, requirements and procedure (2024)	• AFOLU Non-Permanence Risk Tool (2024a) • VCS Standard (2024b) • Registration and Issuance Process (2024c)	• Isometric Standard (2025a) • Risk Reversal Questionnaire (2025) • Reforestation Protocol (2024)	Not applicable
Geological storage + others	• ACR Standard v8.0 (2023) • Specific methodologies	-	• Principles and requirements (2025c) • GHG emission reduction & sequestration product requirements (2025a) • Reversal Risk Calculations for Geological Storage (under development) (2025d)	• Geologic Carbon Storage Non-Permanence Risk Tool (2025a) • Geologic Carbon Storage (GCS) Requirements (2025b) • VCS Standard (2024) • Registration and Issuance Process (2024c)	• Isometric Standard (2025a) • CO2 Storage in Saline Aquifers (2025b)	• Puro Standard (2024a) • Geologically stored carbon methodology (2024b)

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