Marine Anoxic Carbon Storage
Methodology for CO_2 Removal

Edition 2025 v. 1

Puro Standard
May, 2025

Note that final copy edit will address any inconsistencies in cross-references and rule numbering, and other formatting.

Contents

Glossary of terms

> **REMARK:** This glossary provides only the most important definitions for the current methodology. Please note that further definitions are listed in the Puro Standard General Rules.

Activity – A practice or ensemble of practices that take place on a delineated area resulting in emissions or removals taking place. A Marine Anoxic Carbon Storage activity refers to all operations within the activity boundary of a particular Project, including biomass sourcing, transport, and deposition into a suitable Storage site. An eligible activity is an activity that meets the qualification criteria in a given certification methodology.

Anoxic – Environmental conditions characterized by the absence or near absence of molecular oxygen (O_2), where oxygen levels are insufficient to support aerobic biological processes.

Biomass – Organic matter recently derived from the biosphere, including forestry residue, agricultural residue and biomass originating from landscape management and green waste.

Chemocline – A boundary layer separating two distinct layers within a water body, with different properties characterized by a strong, vertical chemistry gradient. In the context of this methodology, it refers to the boundary separating the oxygen-containing upper water layer from the oxygen-depleted water layer in the bottom.

Dissolved Inorganic Carbon (DIC) – The sum of inorganic carbon components in an aqueous solution, consisting of three main constituents: free CO_2 (aq), bicarbonate ions (HCO_3^-) and carbonate ions (CO_3^{2-}).

Dissolved Organic Carbon (DOC) – The portion of organic carbon found in water that is able to pass through a filter with a pore size between 0.22 and 0.45 µm.

Dissolved Oxygen (DO) – The concentration of oxygen gas dissolved in water, and available for consumption of aquatic organisms.

Environmental and Social Safeguards – Mechanisms to identify, mitigate and prevent adverse environmental and social impacts resulting from implementation of CO_2 removal.

Environmental baseline – The environmental conditions of the storage site prior to biomass deployment, to be established by the CO_2 Removal Supplier prior to deployment through the proper characterization of biological and geochemical properties of the water column and sediment.

External Operator – Any party (such as the biomass sourcing operator, the logistics operators, or the storage site operator), operating on behalf of and at the direction of the CO_2 Removal Supplier for provision of services relating to the Marine Anoxic Carbon Storage activity (however, not including the CO_2 Removal Supplier itself).

Functional anoxia – Seafloor conditions where instead of a total lack of oxygen, the concentration of dissolved oxygen is below 0.03 mg/L. In these conditions, aerobic respiration becomes energetically unfavorable for most microorganisms.

Indirect emissions (Leakage) – An indirect effect associated to a CO_2 removal activity and dependent on the selected Baseline, that may lead to an increase or decrease in greenhouse gas emissions or removals, outside of the system boundaries of the activity, if not avoided or mitigated.

Loss – The definition for loss applies to re-emission pathways known or assumed *a priori*, and which therefore need to be accounted for *at the time of CORC issuance*.

Marine Anoxic Carbon Storage Activity – See Activity.

Output – Volume of CO_2 Removal within a certain Monitoring Period which is eligible to receive CORCs. CORCs are always Issued for Net Carbon Dioxide Removal in the production process, which means that the total volume of Output is determined by subtracting the CO_2 emissions volume (generated directly or indirectly due to the production process or materials used, according to the applicable Methodology) from the CO_2 Removal volume.

Particulate Organic Carbon (POC) – The portion of organic carbon found in water that remains on a filter after separation, typically corresponding to organic matter in particulate form (See also Dissolved Inorganic Carbon (DOC)).

Production Facility – An ensemble of physical assets necessary to perform the end-to-end activities associated with a CO_2 Removal activity, in the context of the Methodology. In the case of Marine Anoxic Carbon Storage, the Production Facility comprises a logistic chain for biomass transport, infrastructure for biomass processing and one or several storage sites (See Storage Site).

Project – A CO_2 Removal Project has a defined scope, start and completion, and assigned resources, aimed at achieving verified net CO_2 removal, i.e. CORCs. It consists of one or multiple CO_2 Removal activities, assessed through a life cycle assessment to quantify total emissions and net CO_2 removal, but also supporting components such as environmental and social safeguards, co-benefits, and monitoring of performance, social and environmental safeguards, and reversal risks. It ensures that the CO_2 removal is effective, durable, and aligned with sustainability principles. A CO_2 Removal Project is represented by a CO_2 Removal Supplier, for a Production Facility, over a Crediting Period.

Reversal – An event which cancels, entirely or in part, the effects of an issued CORC. Reversal is an unaccounted-for event resulting in a situation where at least a part of the removed, quantified and certified carbon represented as a CORC is either released back into the atmosphere (re-emission, loss) or can no longer be considered safely and durably stored for a long term. Note that the concept of Reversal does not refer to the degradation of biomass over time in aquatic environments. That phenomenon is already accounted for in the Methodology and the carbon accounting for the durable storage before issuing the CORC.

Storage site – A specific location within the Production Facility where biomass is deployed. The storage site is defined as a three dimensional space with specific vertical and lateral boundaries based on site-specific radial distance of the deployed biomass and horizontal mixing.

Sustainable biomass – Biomass derived from resources using methods that ensure environmental preservation, social responsibility, and complies with the sustainability requirements of this methodology and other Puro Standard Requirements.

Tonne (t) – A unit of mass equivalent to 1000 kg, also known as ‘metric tonne’. In this methodology, the word ‘tonne’ always refers to metric tonnes.

Acronyms

AOM – Anaerobic Oxidation of Methane

CDR – Carbon Dioxide Removal

CORC – CO_2 Removal Certificate

DIC – Dissolved Inorganic Carbon

DD – Decimal Degree

DO – Dissolved Oxygen

DOC – Dissolved Organic Carbon

DOM – Dissolved Organic Matter

dLUC – Direct Land-Use Conversion

ECS – Extended Continental Shelf

EHS – Environment, Health and Safety plan

eDNA – Environmental DNA

EEZ – Exclusive Economic Zone

EIO-LCA – Economic Input-Output Life Cycle Assessment

GHG – Greenhouse Gas

GNSS – Global Navigation Satellite System

GWP – Global Warming Potential

IPCC – Intergovernmental Panel of Climate Change

LCA – Life Cycle Assessment

LCI – Life Cycle Inventory

MACS – Marine Anoxic Carbon Storage

mCDR – Marine Carbon Dioxide Removal

MHSZ – Methane Hydrate Stability Zone

PAH – Polycyclic Aromatic Hydrocarbon

POC – Particulate Organic Carbon

PTE – Potentially Toxic Element

SDGs – Sustainable Development Goals

tCO_2e – Tonnes of CO_2 equivalents

Note to the reader

Note that final copy edit will address any inconsistencies in cross-references and rule numbering, and other formatting.

> **REMARK:** This methodology provides general information as well as actual requirements which must be met by all projects seeking certification under the Puro Standard. Across the entire methodology, the requirements correspond to numbered rules with formatting conforming to the below example.
>
> 0.0.1 This is an example of a numbered rule. The requirements set within numbered rules must be followed by all projects seeking certification under the Puro Standard.
>
> Please note that in addition to the requirements of this methodology document, all projects seeking certification under the Puro Standard must also comply with the Puro Standard General Rules and other Standard Requirements, as well as any applicable local laws, regulations, and other binding obligations.
>
> For Puro Standard documents, see the Puro Standard document library.

Document history

Edition 2025 v. 1 (May 2025) – Initial Release

1. Introduction

1.1. Overview and scope

This methodology sets the requirements for eligibility and quantification of the net CO_2 removal achieved over two hundred (200)[1] years by storing eligible biomass in anoxic marine basins, in order to prevent biomass decomposition and re-emission of carbon back to the atmosphere.

In this methodology, **Marine Anoxic Carbon Storage (MACS)** refers to the overall process of storing eligible biomass in anoxic seafloor conditions for the purpose of durable CO_2 removal. However, the overall concept of 'ocean storage' is not entirely uniform, but presents several potential variations in scope depending on various factors, such as:

- Type and characteristics of the biomass.
- Biomass treatment and mechanics of the sinking process.
- Type and characteristics of the storage site.

In broad terms, the scope of this methodology includes the following fundamental components: biomass sourcing, processing, transportation, deployment and storage of the eligible biomass. Certain process steps allow several different variations, which are further elaborated in section 3.

While certain biomass types, particularly lignocellulosic biomass, are inherently more resistant to microbial decay, their preservation ultimately depends on the interaction between the organic matter and environmental conditions. Degradation rates are significantly reduced in anoxic environments, which are characterized by the absence of molecular oxygen (O_2) and the presence of reduced chemical species (Mn^{2+}, Fe^{2+}, H_2S, CH_4) (Canfield et al., 2005). Each anoxic storage site is subject to different risks, mitigation measures and monitoring measures. Likewise, biomass selection is subject to different criteria for sustainable sourcing and emission prevention. Therefore, this methodology sets strict requirements for the eligible biomass feedstock, processing of the biomass, as well as for storage site criteria, with the aim to inhibit biomass decomposition and disable the decomposition products (e.g. CO_2, N_2O and CH_4) from entering the atmosphere. Both storage site conditions and biomass characteristics must be sufficiently understood and characterized, as further detailed in sections section 3.6 and section 3.9.

1.2. Natural carbon cycle and mechanism for CO_2 removal

During photosynthesis, plants remove CO_2 from the atmosphere and lock the carbon in the plant tissues.

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[1] CO_2 must be sequestered (on a net basis) for *at least* 200 years.

In natural conditions, decomposition of biomass is a major component of the natural carbon cycle, where physical breakdown and biochemical transformation of the plant material releases products such as CO_2, energy, water and nutrients back to the natural cycle (e.g. atmosphere, geosphere, oceans). Part of the terrestrial biomass produced is naturally transported into the seafloor by river transport, where it accumulates as organic carbon in the seafloor sediments (Hage et al., 2020). However, only a fraction of the suspended organic matter in rivers is naturally deposited in deep-sea sediments, and the transfer efficiency varies globally due to e.g. varying sedimentation rates, post-depositional reworking of the sediment as well as depth (Bradley et al., 2022; Burdige, 2005).

It is important to note that degradability is not an inherent or absolute property of organic matter but is determined by its interaction with environmental conditions (Mayer, 1995). In marine environments, decomposition occurs through different microbially mediated chemical pathways depending on the availability of oxygen. Under oxic conditions, oxygen serves as the primary electron acceptor for organic matter oxidation. In anoxic conditions, decomposition proceeds sequentially, with alternative electron acceptors such as nitrate, manganese oxides, iron oxides, and sulfate being used in order of their energy yields. Once these electron acceptors are depleted, methanogenesis and fermentation become dominant pathways for organic matter breakdown (Arndt et al., 2013). In these processes, biomass may be directly oxidized into CO_2, partly oxidized to intermediate compounds or reduced to methane (CH_4), while a fraction of the carbon is permanently buried in the seafloor sediments (Arndt et al., 2013; LaRowe et al., 2020). The lack of oxygen may enhance the storage capacity. Most eukaryotic organisms, such as animals, plants or fungi, do not survive in anoxic conditions, and therefore in anoxic basins, biomass degradation is principally limited to archaeal and bacterial processes (Fenchel, 2014; Raven et al., 2024). This is especially relevant for woody biomass, which in oxic marine environments is rapidly colonized by specialist Xylophagidae wood-boring bivalves, accelerating the decomposition process (Charles et al., 2022). Therefore, as a re-emission precaution, this methodology is limited to storing biomass into oxygen-deprived basins (see section 1.5).

1.3. Eligible biomass

To ensure durable carbon removal and environmental safety, in the context of this methodology, the eligibility of the biomass feedstock depends on its ability to naturally resist decomposition (recalcitrance) (Zhao et al., 2012). Thus, the eligible biomass is limited to **lignocellulosic biomass** due to its high lignin content, which supports durability in anoxic conditions (Benner & Maccubbin, 1984).

Important variables for evaluating the biomass recalcitrance include:

- The cell wall structure; complex matrices of lignin, cellulose, and hemicellulose contribute to plant biomass recalcitrance (Himmel, 2008; Yousuf et al., 2020).

- The chemical composition of the biomass; especially carbon:nitrogen (C:N) ratio or carbon:nitrogen:phosphorus (C:N:P) (Johnson et al., 2007).
- The physical structure of the biomass; for example, finely divided materials decompose more rapidly than coarse materials. The biodegradability of lignocellulosic materials is directly influenced by the accessible surface area of the substrate, which determines the extent to which cellulases can interact with cellulose (Xu et al., 2019).

Lignin is a complex organic polymer found in the cell walls of vascular plants, including many terrestrial and aquatic plants. It played a crucial role in the evolution of vascular plants by providing structural support and enabling them to withstand the compressive forces of gravity. The composite structure of cellulose, hemicellulose and lignin provides plant cell walls their strength and capacity to resist degradation (Cosgrove, 2005), but the ratio of the individual components varies between different biomass feedstock types (Pauly & Keegstra, 2008; Yousuf et al., 2020) (Table 1.1). A comprehensive list of physical and chemical factors influencing recalcitrance of lignocellulosic biomass may be found in (Zoghlami & Paës, 2019), but overall, the chemical composition and the structure of lignin have a strong impact. Due to its high molecular weight, relative insolubility and complex aromatic structure, lignin is highly recalcitrant against degradation (Vishtal & Kraslawski, 2011; Zhang et al., 2021). Additionally, lignin serves as a physical barrier, which blocks the access of enzymes to cellulose, further enhancing the recalcitrance of the lignocellulosic biomass (Monties & Fukushima, 2001; Zoghlami & Paës, 2019), particularly in oxygen-depleted environments.

In anoxic conditions, anaerobic organisms have a limited capacity to degrade lignin-containing biomass (Marchand et al., 2005). As the aim of a Marine Anoxic Carbon Storage approach is to prevent or limit the degradation of the stored biomass to ensure durable carbon removal, eligible biomass is restricted to lignocellulosic biomass, mainly woody materials and mature or lignified crop residues, which have a combined lignin and cellulose content of 60% (see rule 3.6.5) and a minimum C:N ratio of 50:1 (see rule 3.6.6). A C:N ratio of 50 means that there is 1 g of nitrogen for every 50 g of carbon, i.e. a nitrogen content of roughly 2% of the mass of carbon present.

Importantly, the biomass must not pose any risk for human health or the environment (Faraca et al., 2019) (Agyemang et al., 2024). Further requirements for biomass eligibility can be found in section 3.6 and requirements for biomass sustainability and traceability can be found in section 3.8.

Table 1.1. Composition of lignocellulosic biomass: percentages of Lignin, Cellulose, and Hemicellulose as a proportion of total dry weight. Adapted from (Yousuf et al., 2020).

Raw material	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Grasses	25–40	25–50	10–30

Raw material	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Softwoods	45–50	25–35	25–35
Hardwoods	45–55	24–40	18–25

1.4. Anoxic basins

Anoxic waters are defined as water bodies depleted of dissolved oxygen, leading to virtually no aerobic biological activity (Demaison & Moore, 1980). Anoxia may occur in freshwater and marine environments, as well as in groundwater conditions. In the context of this methodology, anoxic basins are further determined as durably oxygen-depleted marine basins, where both density stratification and physical barriers prevent the anoxic bottom waters from mixing with the overlying, oxygen-containing waters (figure 1.1). Certain anoxic basins may also be *euxinic*, which refers to anoxic conditions where the absence of oxygen is accompanied by high concentrations of dissolved sulfides (e.g. hydrogen sulfide (H_2S)), typically resulting from intense sulfate reduction and organic matter decomposition (Meyer & Kump, 2008).

Anoxic basin may either be a brine-filled depression in a larger water body, such as the Orca Basin in the Gulf of Mexico or the Cariaco Basin off the coast of Venezuela, or extend basin-wide, such as in the Black Sea (Hurtgen et al., 1999; Stanev et al., 2018; Stewart et al., 2007; Tribovillard et al., 2008; Van Cappellen et al., 1998).

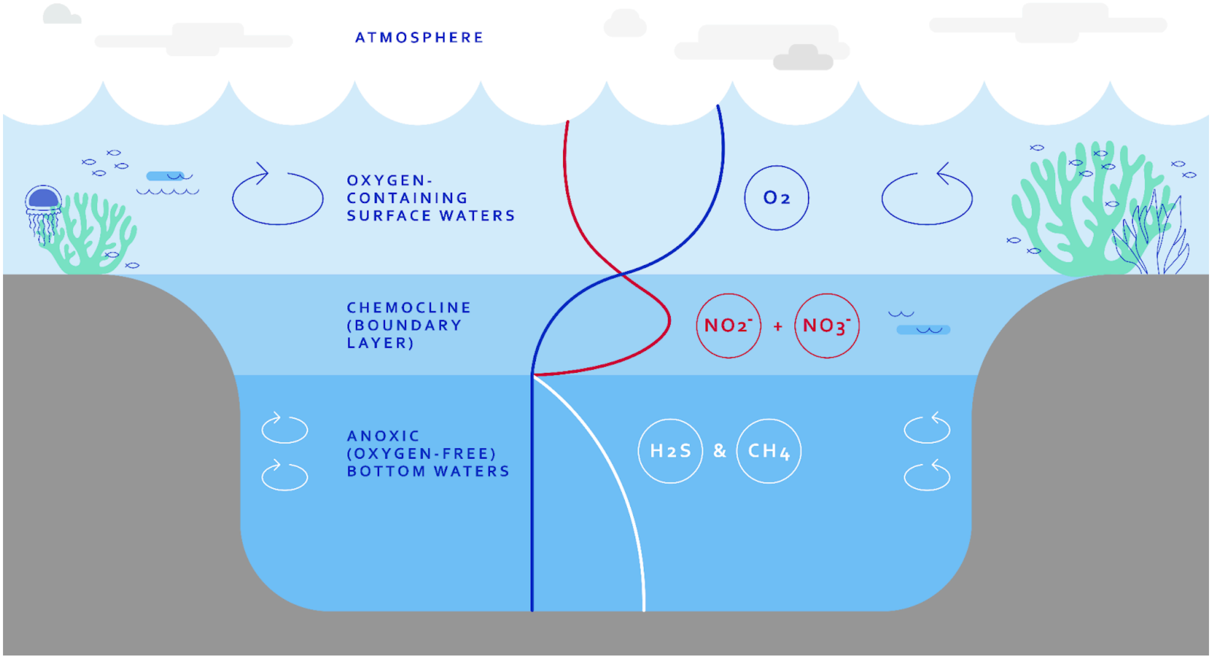

Figure 1.1. A schematic figure of an example anoxic basin, illustrating the stratified water layers: oxygen-containing surface waters, the boundary layer between the oxygen-containing and oxygen-free waters (chemocline) and the anoxic (oxygen-free) bottom waters. The concentrations of oxygen (O_2; dark blue), nitrite+nitrate (NO_2^-+NO_3^-; red) as well as sulfides (H_2S) and methane (CH_4; white) indicate the different characteristics of the respective water masses.

A strong density gradient is responsible for the formation of the chemocline, which prevents the oxygen-containing surface waters from mixing with the oxygen-depleted bottom waters, limiting the water mass circulation within those distinct layers (blue and white arrows).

Preservation for carbon sequestration ultimately depends on both the biomass' composition and the environmental conditions in which it is stored. In marine environments, anoxic basins offer conditions ideal for long-term biomass storage (Raven et al., 2024). These basins are devoid of dissolved oxygen, creating an inhospitable environment for aerobic organisms. Instead, anaerobic microorganisms, such as chemosynthetic bacteria, dominate these areas, sustained by reduced chemical species like Mn^{2+}, Fe^{2+}, H_2S, and CH_4. Due to the limited capacity of anaerobic organisms to degrade complex organic compounds and the low energy yield of available electron acceptors, degradation processes in anoxic environments are significantly slowed (Jessen et al., 2017). Additionally, the lack of oxygen prevents most macroscopic animal life from inhabiting these areas, avoiding the presence of wood-boring organisms like shipworms that typically facilitate the decomposition of wood in oxygenated marine environments (Jones et al., 2019). These facts lead to the accumulation of organic matter and creating conditions where biomass can be preserved over extended periods without decomposition (Thunell et al., 2000). This makes anoxic basins highly relevant for carbon sequestration, as they effectively reduce degradation rates and enhance the stability of organic matter storage.

1.5. Biomass decomposition in anoxic conditions

The majority of studies on the recalcitrance of lignocellulosic biomass has been conducted in terrestrial settings, where fungi have a major role in lignin degradation (Bärlocher & Boddy, 2016). In marine settings, terrestrial biomass may be consumed by multiple eukaryotic organisms (Bienhold et al., 2013; Saeedi et al., 2019). Bacteria is considered to be the dominant species degrading lignin in low-oxygen, deep-ocean environments (Lu et al., 2020; Woo & Hazen, 2018), while it has also been shown, that deep-sea fungi may also have a major role in lignocellulosic biomass degradation in certain deep-ocean environments (Nagano et al., 2019, 2024).

The concept of functional anoxia

When considering optimal conditions for biomass preservation in aquatic environments for this methodology, storage locations are defined as *functionally anoxic* when dissolved oxygen (DO) concentrations are below 0.03 mg/L (Levin, 2002). While this threshold does not represent complete absence of oxygen, it represents conditions where aerobic respiration becomes energetically unfavorable for most microorganisms, leading to a strong dominance of anaerobic processes (Paulmier & Ruiz-Pino, 2009).

At these DO concentrations, most aerobic organisms cannot function effectively, limiting the aerobic decomposition of the stored biomass. This threshold is particularly relevant for field applications, as maintaining strict anoxia in natural systems is challenging due to various environmental factors such as seasonal turnover, wind mixing, and biological activity.

Additionally, this threshold, in combination with nitrate and nitrite thresholds (see rule 3.9.5), also establishes a safeguard for limiting storage sites at or near the boundary of oxic and nitrogenous zones in order to reduce the risk of N_2O production (Canfield & Thamdrup, 2009) (see section 4.5). Therefore, functional anoxia provides a practical and measurable target that balances the theoretical ideal of complete oxygen absence with the realities of implementing and monitoring mCDR systems in natural aquatic environments while still achieving significant reductions in decomposition rates.

1.6. Ocean circulation and its impact on CO_2 removal

The effectiveness of the Marine Anoxic Carbon Storage approach is dependent both on the recalcitrance of the biomass (see section 1.3) and storage site conditions. Specifically, parameters such as depth, downstream circulation patterns and ocean ventilation timescales impact the durability and net efficacy of the Marine Anoxic Carbon Storage approach (Raven et al., 2024; Siegel et al., 2023). In general, deeper storage sites will sequester the stored carbon for much longer timescales than shallow sites, with median sequestration times reaching decadal or centennial timescales (Boyd et al., 2019; Siegel et al., 2021).

In anoxic basins, the stratification further enhances the permanence of carbon storage through multiple mechanisms. First, the density-driven stratification creates distinct water layers that resist vertical mixing, effectively isolating the stored biomass from oxygenated surface waters. Second, this stable stratification often coincides with reduced horizontal transport, limiting the potential displacement of stored carbon to regions where decomposition rates might be higher (G. Li et al., 2020). The combination of these hydrodynamic features not only maintains the anoxic conditions necessary for minimal decomposition but also increases the mean residence time of the sequestered carbon. Even in cases where some anaerobic decomposition occurs, producing dissolved CO_2, CH_4 and N_2O, these gases remain trapped in the deep water masses due to the strong stratification. The ventilation times of these water masses typically exceed centuries, meaning that any decomposition products are effectively sequestered from the atmosphere over climate-relevant timescales (DeVries & Primeau, 2011). In basins where these conditions persist over long timescales, the potential for durable carbon sequestration is significantly enhanced compared to more dynamic ocean environments.

1.7. Biomass processing and sinking

In addition to the biomass selection criteria, pre-processing the biomass prior to deployment may significantly increase its recalcitrance and mitigate negative environmental impacts (Casau et al., 2022). Any processing method selected should be evaluated not only for its effectiveness in enhancing carbon storage but also for its energy requirements and potential emissions, ensuring a positive net carbon removal outcome. Pre-processing should also consider practical aspects of transportation and deployment. For example, standardized bale or pellet sizes facilitate efficient handling and enable the use of automated deployment systems (Tumuluru et al., 2011). Additionally, moisture content management through drying or dewatering reduces transportation costs and allows better control of the final density. Furthermore, low moisture content may reduce the decomposition rate of the biomass prior to deployment, thus increasing the efficiency of the carbon removal approach and decreasing potential methane emissions.

The removal of potential contaminants or impurities during pre-processing is essential to minimize environmental impacts at the storage site and ensure accurate carbon accounting (Faraca et al., 2019). Impurities in the feedstock are defined as non-biodegradable, macroscopic particles of foreign matter, such as plastics, metals, glass, and other mineral aggregates (e.g., sand, clay), mixed with the biomass feedstock. While certain impurities, such as small amounts of sand and clay, may pose minimal environmental risk, their presence must still be detected and assessed to prevent adverse impacts (Agyemang et al., 2024) and ensure proper characterization of the feedstock's carbon storage potential.

Compaction of the biomass into dense bales or pellets serves multiple critical functions in the sequestration process (Kaliyan & Vance Morey, 2009). First, it reduces the surface area to volume ratio of the material, thereby decreasing the exposure to microbial decomposition and potentially slowing degradation rates. Second, compaction increases the overall density of the biomass package, which is essential for ensuring rapid sinking and minimizing horizontal dispersal during descent. This is particularly important as prolonged residence times in the upper water column, where oxygen concentrations and microbial activity are highest, could lead to significant biomass loss before reaching the target storage depth. Additionally, proper compaction prevents the disintegration of biomass during deployment and sinking, which could otherwise result in material loss and reduced sequestration efficiency (Y. Li & Liu, 2000). The increased density from compaction also helps overcome natural buoyancy of some biomass types, particularly those with internal air spaces or high lipid content (Mani et al., 2003), ensuring the material reaches and remains at the intended storage depth.

In addition to biomass processing, the sinking rate of the biomass may minimize carbon loss during the sinking phase. The sinking rate of biomass can be enhanced by using a sinker, a dense material either attached to or embedded in the biomass to increase its density and overcome buoyant forces. Sinkers ensure rapid sinking and precise placement on the seafloor. However, their design and material selection must align with environmental and economic sustainability goals. Long-term impacts of sinkers in marine environments should be carefully assessed, particularly for materials like iron, which may corrode, or minerals that degrade slowly in seawater. Additionally, the production and deployment of sinkers should not generate emissions that negate the carbon removal benefits of the biomass storage.

2. Point of creation of the CO_2 Removal Certificate (CORC)

2.1. The CO_2 Removal Supplier

2.1.1. The CO_2 Removal Supplier is the party authorized to represent the participants necessary to perform the end-to-end activities associated with an Marine Anoxic Carbon Storage activity seeking certification under this methodology (see also section 3.3). Examples of entities which could be identified as the CO_2 Removal Supplier include but are not limited to the following:

- The operator of the biomass deployment system.
- The owner of the biomass deployment system.
- The owner of the stored CO_2.

In particular, the CO_2 Removal Supplier does not need to be the operator of the process creating the CO_2 to be stored (e.g. operating the deployment of the biomass).

2.1.2. The CO_2 Removal Supplier is responsible for making end-to-end data available for 3rd party verification. This includes delivering data needed to assess the eligibility of the activities, quantify the predicted net carbon removal, and monitor the necessary parameters at the storage site after biomass deployment (see section 9).

2.2. Production facility

2.2.1. The production facility is the ensemble of physical assets necessary to perform the end-to-end activities associated with a Marine Anoxic Carbon Storage activity, and subject to the Production Facility Audit as per the terminology defined in the Puro Standard General Rules.[2] For the purposes of this methodology, a Production Facility comprises a logistic chain for biomass transport, infrastructure for biomass processing, and one or several storage sites (see rule 9.3.9) within the activity boundary (figure 2.1), as further detailed in subrules a and b.

a. All storage sites registered under the same Production Facility shall be located in the same jurisdiction. All storage sites shall have broadly consistent:

  - Geographic location.
  - Climatic conditions.

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[2] Available in the Puro Standard document library.

- Oceanographic conditions.
- Risk profile related to storage efficiency and environmental safety.

b. Any change in the definition of the Production Facility requested by the CO_2 Removal Supplier during the Crediting Period will require an update of the Production Facility definition (see also rule 2.2.2 b).

Note that in most cases, the Production Facility is composed of one or several biomass sourcing sites, logistic chain, and one storage site.

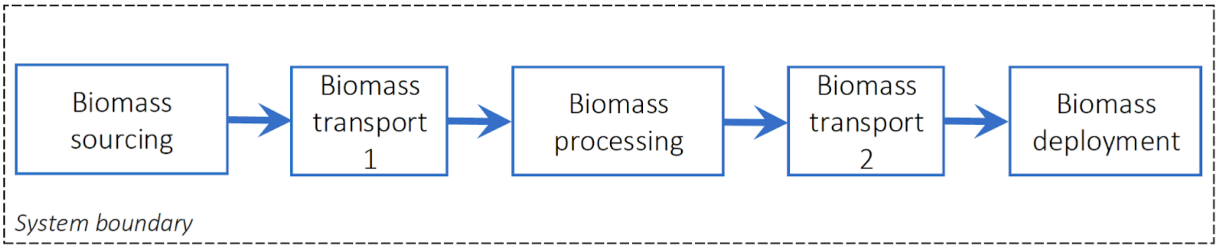

Figure 2.1. Activity boundary in the context of a Marine Anoxic Carbon Storage approach. Note, that transportation of biomass occurs between the stages of the activity. More detailed requirements for the activity boundary are found in section 7.2.

2.2.2. A Production Facility and the associated activity is determined as eligible for issuance of CO_2 Removal Certificates (CORCs) once the Production Facility has successfully undergone a third-party verification by a duly appointed Auditor performing a Facility Audit.

a. The Production Facility Auditor verifies the Production Facility conformity to the requirements for activities under this methodology, and the proofs and evidence needed from the CO_2 Removal Supplier.

b. The CO_2 Removal Supplier may include within the Production Facility additional storage sites conforming to rule 2.1.1 without having to undergo a new Production Facility Audit, provided that such additions comply with the requirements for eligible storage site (section 3.9), and are approved by the Issuing Body and verified during an Output Audit.

2.2.3. The Production Facility Auditor collects and checks the standing data of the CO_2 Removal Supplier and the Production Facility, which includes:

- A certified trade registry extract or similar official document stating that the CO_2 Removal Supplier's organization legitimately exists.
- The CO_2 Removal Supplier registering the Production Facility in the Puro Registry.
- Locations of the storage site(s) forming the Production Facility.

- Whether the Production Facility has benefited from public financial support.
- Date on which the Production Facility becomes eligible to issue CORCs.

2.2.4. The Crediting Period in this methodology is 5 years starting from the first date of the first monitoring period (see rule 5.2.1). The Crediting Period may be renewed twice by successfully undergoing a new Production Facility Audit. The Crediting Period shall not overlap with another Crediting Period.

2.3. Point of creation

2.3.1. The point of creation of the CO_2 Removal Certificates (CORCs) is defined as the earliest point in the CO_2 Removal process when the CORCs can be claimed. For this methodology, the point of creation of the CORC is the moment when the eligible biomass is deposited in anoxic conditions in a manner that prevents re-emissions of GHGs to the atmosphere during the course of an eligible activity, and the data records thereof can be verified.[3]

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[3] Time of deployment is here defined as the point when a complete data trail is available for verification of the end-to-end quantities of biomass sourced and stored.

3. Eligibility requirements

3.1. Overall principles

In broad terms, an eligible activity is capable of permanently increasing the marine carbon stock by safely and durably storing CO_2 captured by plant photosynthesis. In practice, the CO_2 Removal is achieved by deploying sustainable biomass into anoxic ocean storage (figure 3.1).

It is important that the requirements for Marine Anoxic Carbon Storage activities ensure durable, robustly quantifiable CO_2 Removal, conducted in a manner which leads to no net harm[4] to the environment (e.g. deforestation or loss of biodiversity), or to society (through e.g. loss of arable land, decreased food security, chemical emissions or health risks).

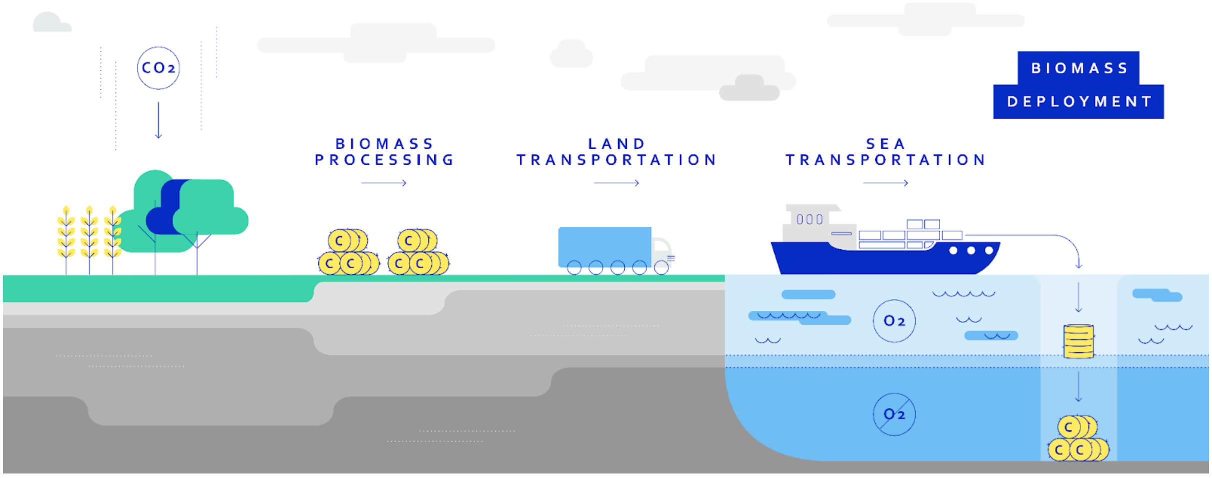

Figure 3.1. A schematic example of a CO_2 removal activity within the scope of this methodology.

There are a few applicable external resources on the design and operation of the Marine Anoxic Carbon Storage activity available to the CO_2 Removal Supplier. The below-listed examples of such resources contain useful information, outlines and recommendations on eligible activities, risk assessment, monitoring and other practicalities. Please note, that the following list is not exhaustive, and contains international agreements which have not yet been ratified, while they may have been recognized as binding agreements in certain jurisdictions.

- International
    - The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters, 1972 (The London Convention)

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[4] While the Marine Anoxic Carbon Storage activity has significant potential to help mitigate the global effects of climate change, it is paramount that the biomass sourcing and storage activities are conducted in a manner such that the benefits overwhelmingly outweigh the disadvantages.

    - The London Protocol, 1996)
        - Guidance for Consideration of Marine Geoengineering Activities.
        - Resolution LP.4(8) On the Amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and Other Marine Geoengineering Activities
    - The United Nations Convention on the Law of the Sea (UNCLOS)
    - International Convention for the Prevention of Pollution from Ships (MARPOL)
        - Annex I Regulations for the Prevention of Pollution by Oil (1983)
        - Annex II Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk (1987)
        - Annex III Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form (1992)
        - Annex IV Prevention of Pollution by Sewage from Ships (2003)
        - Annex V Prevention of Pollution by Garbage from Ships (1988)
        - Annex VI Prevention of Air Pollution from Ships (2005)
    - Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention)
- The United States
    - The Marine Protection, Research and Sanctuaries Act (MPRSA)
    - Environmental Protection Agency's regulations for implementing the MPRSA: 40 Code of Federal Regulations (CFR) 220-229
    - National Marine Carbon Dioxide Removal Research Strategy
    - Clean Water Act, Section 402: National Pollutant Discharge Elimination System
- European Union
    - Directive 2008/56/EC of the European Parliament and of the Council (Marine Strategy Framework Directive (MSFD))
    - Directive 2017/845/EC, amending Directive 2008/56/EC of the European Parliament and of the Council as regards the indicative list of elements to be taken into account for the preparation of marine strategies

While adherence to the above-listed external documents is not required in this methodology (except if/when explicitly stated in a numbered rule, or required by local regulations), they can be a useful source of background information to assist the CO_2 Removal Supplier in creating a well designed and monitored Marine Anoxic Carbon Storage project. The CO_2 Removal Supplier may also use other applicable guidance documents than those listed.

3.2. Requirements for general eligibility

3.2.1. An eligible activity is an activity where eligible biomass is sustainably sourced and subsequently stored in an oceanic storage site under conditions that ensure safe and durable storage, inhibiting carbon to be released back into the atmosphere for at least 200 years.

3.2.2. The CO_2 Removal Supplier shall demonstrate that the biomass is sourced sustainably in accordance with local regulations and other requirements detailed in this methodology (see section 3.8) and following the Puro Biomass Sourcing Criteria[5].

3.2.3. The CO_2 Removal Supplier shall obtain all necessary permits or authorizations to conduct biomass deployment operations prior to introducing biomass to the storage site. All ocean storage sites shall be approved by the competent local authority or regulatory body and hold relevant permits or authorizations for the deployment and storage of biomass.

3.2.4. All installations and operations relating to the Marine Anoxic Carbon Storage activity shall comply with all applicable local, regional, national or international laws, regulations, and other statutory requirements (including, but not limited to requirements for storage site characterization, deployment operations, monitoring and reporting, as well as environmental, ecological, and social requirements).

3.2.5. The deployment of biomass into an applicable storage site shall only take place either within a sovereign state's Exclusive Economic Zone (EEZ) as determined in the United Nations Convention on the Law of the Sea (UNCLOS) Part V[6], or Extended Continental Shelf (ECS) as defined in UNCLOS Part IV[7] *and* Annex II[8] as further detailed in subrules a-c*.*

   a. The EEZ or ECS, or any sector of it, shall not be a subject of a dispute between sovereign states.

   b. In cases where the limits of the ECS have not been established based on the recommendations of the Commission on the Limits of the Continental Shelf[9], operations shall be restricted to the EEZ.

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[5] Available in the Puro Standard document library.

[6] United Nations Convention on the Law of the Sea, Part V, Exclusive Economic Zone

[7] United Nations Convention on the Law of the Sea, Part IV, Continental Shelf

[8] United Nations Convention on the Law of the Sea, Annex II. Commission on the Limits of the Continental Shelf

[9] United Nations Commission on the Limits of the Continental Shelf (CLCS)

c. Additionally, the CO_2 Removal Supplier shall follow any further restrictions on operations within the EEZ or ECS, set by the applicable local, regional, national or international regulations and legislations.

3.2.6. All facilities and equipment used for biomass sourcing, processing, transport, and deployment shall be constructed or installed according to national best practices and in compliance with statutory requirements. All installations shall be approved by local authorities and hold relevant permits for their operation. Examples of such facilities and equipment include warehouses and facilities for chipping/drying/baling the biomass.

3.2.7. The CO_2 Removal Supplier may utilize shared infrastructure for biomass sourcing, transport, processing, or deployment. Shared infrastructure may be utilized even if such infrastructure is also utilized for non-eligible activities, such as port infrastructure.

3.2.8. The CO_2 Removal Supplier shall demonstrate the baseline carbon removal scenario for their intended Marine Anoxic Carbon Storage approach. The baseline is a conservative scenario of what likely would have happened without the Marine Anoxic Carbon Storage activity. For more requirements on the baseline determination, see section 6.2.

3.3. Requirements for the CO_2 Removal Supplier

The activities associated with a particular Marine Anoxic Carbon Storage project can involve multiple site operators collaborating within the project boundary. While the CO_2 Removal Supplier can act as the biomass sourcing operator, logistics operator and the deployment operator, the responsibility of these operations may also be transferred to external operators (see rule 3.3.2) by contractual agreements.

3.3.1. The CO_2 Removal Supplier shall provide a certified trade registry extract or similar official document stating that it is validly existing and in compliance with the legislation of the host jurisdiction.

3.3.2. The CO_2 Removal Supplier shall clearly establish and demonstrate the ownership of the CO_2 Removal project through either proof of direct ownership, or through contracts with external operators[10] where relevant. The CO_2 Removal Supplier shall furthermore prove with contracts or authorization documents its sole ownership of the durably stored carbon.

3.3.3. The CO_2 Removal Supplier shall provide, where applicable, evidence of valid permits, authorizations, licenses, or other equivalent regulatory control documents to operate

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[10] For the purposes of this methodology, an external operator is defined as any party (such as the operator of the biomass harvest, the operator of the biomass sinking system or the logistics operators) operating on behalf and at the direction of the CO_2 Removal Supplier for provision of services relating to the Marine Anoxic Carbon Storage activity.

any industrial facilities within the activity boundary. The CO_2 Removal Supplier shall furthermore provide evidence of possessing the rights to allow for appropriate monitoring at any stage within the activity boundary.

3.3.4. Where any part of the Marine Anoxic Carbon Storage activity is contracted to an external operator, the CO_2 Removal Supplier shall establish a clear division of responsibilities and liabilities between the CO_2 Removal Supplier and the external operator, which shall at least address:

- Conducting the required monitoring activities, such as measuring device set-up, maintenance, and the monitoring of individual parameters.
- Preventive and corrective measures taken in case of a reversal or re-emission.
- Post-deployment and site closure requirements and expenses until the transfer of responsibility.

3.3.5. When any part of the Marine Anoxic Carbon Storage activity is contracted to an external operator, the CO_2 Removal Supplier shall provide the contractual information necessary for assessing compliance with this methodology, the Puro Standard General Rules[11] and other Standard Requirements[12], as well as any applicable local laws, regulations, or other binding obligations. This information shall at least include:

- Certified trade registry extracts or similar official documents stating that any and all external operators are validly existing and in compliance with the legislation of the host jurisdiction.
- Documentation that the CO_2 Removal Supplier is in contractual agreement with the external operator for the purpose of achieving durable CO_2 Removal.
- In the case of an external biomass deployment operator, documentation establishing that the biomass received by the deployment operator will be deployed and durably stored into an eligible anoxic marine storage site.
- Proof of sole ownership to the biomass sourced, transported or stored, and attestation of no claim where necessary as per rule 3.5.1.
- Documentation establishing the right to audit the relevant documents and equipment belonging to the external operator for the purposes of CORC Issuance.

3.3.6. The CO_2 Removal Supplier is responsible for ensuring that sufficient data is available and accessible for auditing and verification that the Marine Anoxic Carbon Storage

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[11] Available in the Puro Standard document library.

[12] Ibid.

activity is compliant with the requirements of this methodology and other applicable Puro Standard Requirements[13], as well as any applicable local laws, regulations, and other binding obligations. This includes but is not limited to delivering the necessary data to assess the eligibility of the activities, and quantify the predicted net carbon removal. In particular, the CO_2 Removal Supplier shall provide all calculation functions and parameters utilized for the quantification of net CO_2 Removal in a clear and consistent manner (see section 11).

3.4. Requirements for additionality

3.4.1. To demonstrate additionality, the CO_2 Removal Supplier shall demonstrate that the Marine Anoxic Carbon Storage activity is not required by existing laws, regulations, or other binding obligations. Further, the CO_2 Removal Supplier shall convincingly demonstrate that the CO_2 removals are a result of carbon finance, as further detailed in the Puro Additionality Assessment Requirements.[14]

3.5. Requirements for prevention of double counting

3.5.1. The CO_2 Removal Supplier shall ensure that the CO_2 removal is not double-counted in a manner which would infringe the Puro Standard General Rules.[15] In particular, the General Rules entail that:

a. The CO_2 Removal Supplier shall evidence that it has the sole right to claim CORCs from the CO_2 placed in storage, and that other parties involved in the supply chain have no such right. This can be evidenced by contracts or attestations exhibiting the relation between the involved parties.

b. The CO_2 Removal Supplier or any party involved in the supply chain shall not associate any CO_2 removal claim (whether a marketing, branding, or footprint claim) to any other products or services delivered by the CO_2 Removal Supplier or involved party (including other types of environmental products, such as renewable energy certificates), unless the issued CORCs have been explicitly retired for this purpose.

c. The CO_2 Removal Supplier or any party involved in the supply chain may still report their direct emissions and removals in other sectoral GHG inventories (e.g. mandatory national reporting for UNFCCC, or voluntary corporate reporting), making adequate disclosures regarding the issuance of CORCs.

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[13] Available in the Puro Standard document library.

[14] Ibid.

[15] Ibid.

3.5.2. The CO_2 Removal Supplier shall decide if CORCs are required for other international mitigation purposes such as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), or other entities operating in the voluntary carbon market. To this end, the CO_2 Removal Supplier shall follow the Puro Standard Article 6 Procedures[16] to ensure proper reporting of the issuance, transfer, and retirement of CORCs, and to avoid double counting.

3.6. Requirements for biomass eligibility and characterization

For the purposes of this methodology, the eligible biomass is limited to lignocellulosic biomass due to its high lignin content (section 1.3), supporting durable storage in anoxic conditions and minimizing the release of methane and other greenhouse gases (GHGs) back to the atmosphere.

3.6.1. The biomass shall be sourced sustainably (see section 3.8) and shall comply with Puro Biomass Sourcing Criteria[17]. The CO_2 Removal Supplier shall categorize the biomass to be used for ocean storage into one of the categories described in rule 3.6.2. Only biomass sourced from eligible feedstock categories are eligible for the issuance of CORCs.

3.6.2. The biomass shall originate from terrestrial sources. Eligible sources of biomass are:

a. Forest biomass: Residues from forest management and timber production activities, including primary (harvested) and secondary (processing) feedstocks (e.g., thinning residues, bark, sawdust). Following *the Puro Biomass Sourcing Criteria category G, with the exception that in the context of this methodology, the forest biomass is limited to residual biomass only*.

b. Agricultural Biomass and Residues: Biomass derived from agricultural activities, including both in-field residues (plant materials remaining after the harvest of food or feed crops, such as straw, stalks, and pruning residues) and non-field residues (by-products from the primary processing of food crops, such as rice husks, maize cobs, nut shells, and bagasse). Additionally, biomass from non-food agricultural crops grown specifically for energy, biomaterials, or other non-food applications is included when sourced from degraded, marginal, or contaminated land, without significant concerns of competition for food or feed production. *Puro Biomass Sourcing Criteria categories I, K, L, M*.

c. Landscape Management and Green Waste: Biomass generated from conservation landscape management and green waste collection, including

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[16] Available in the Puro Standard document library.

[17] Ibid.

materials from the control of invasive species, wildfire mitigation, park and garden maintenance, urban tree cuttings, and river debris. This includes non-hazardous green waste from both rural and urban areas, as well as biomass from the maintenance of protected or managed landscapes. *Puro Biomass Sourcing Criteria categories D and N*.

3.6.3. The CO_2 Removal Supplier shall undertake a chemical analysis of the biomass. The analyses shall be conducted as close as possible to the biomass deployment in order to ensure that the measured properties of the biomass accurately reflect the material being deployed. The analysis shall cover at least:

a. A determination of the quantity and composition of the major structural components of the biomass (cellulose, hemicellulose and lignin). For further details, see rule 3.6.5.

b. A determination of the carbon to nitrogen ratio (C:N). For further details, see rule 3.6.6.

c. A determination of the share of organic carbon (C_{org}). For further requirements, see section 6.1.

3.6.4. The analyses shall be performed for a statistically representative sample of the entire stored biomass (see section 10.5). The experimental analyses shall be conducted as further defined in subrules a and b:

a. The measurements shall be conducted by using appropriate, peer-reviewed scientific best practices or appropriate standard methods.

b. The measurements shall be conducted in laboratories which must be accredited by national authorities and comply with international testing standards (e.g. ASTM, ISO, AS, D).

For initial screening of potentially eligible biomass types, the CO_2 Removal Supplier may utilize e.g. peer-reviewed scientific literature, if available for the type of biomass intended for storage. For literature values, the most conservative values should be used.

3.6.5. Biomass shall have a high lignin and cellulose content, ensuring slower decomposition in anoxic environments. Biomass shall have a combined lignin and cellulose content of at least 60% (by dry weight). Biomass with a lower percentage of lignin and cellulose may be considered as eligible if additional peer-reviewed scientific evidence demonstrates its suitability for long-term carbon storage in anoxic environments, such as relevant pilot studies, pending approval by the Issuing Body.

3.6.6. Eligible biomass shall have a carbon-to-nitrogen (C:N) ratio of at least 50:1. This ensures a low nitrogen content, which reduces the risk of microbial decomposition in anoxic conditions. Biomass with a lower C:N ratio may be considered eligible if additional peer-reviewed scientific evidence demonstrates its suitability for long-term carbon storage in anoxic environments, such as relevant pilot studies, pending approval by the Issuing Body.

3.6.7. The use of chemically treated biomass, such as wood treated with preservatives, fungicides, or other chemicals that could alter its decomposition process, is considered ineligible, unless laboratory tests or comparison with published local, regional, national or international toxicity standards and benchmarks confirm these treatments do not pose environmental hazards at the measured concentrations in submerged conditions.

3.6.8. Prior to deployment, the CO_2 Removal Supplier shall evidence that the concentrations of potentially toxic elements (PTEs) in the biomass do not exceed the limits defined in applicable local, regional, national or international legislation. PTEs are defined as specific chemical elements that can be harmful to living organisms, including plants, animals, and humans, when present in sufficient concentrations. If the biomass may have been exposed to agrochemicals or other treatments which may pose a risk to aquatic ecosystems, the CO_2 Removal Supplier shall provide a chemical analysis of the possible contaminants of the biomass to be stored. To minimize the environmental risks, at least the following parameters shall be analysed:

a. Levels of heavy metals that could leach into the ocean and bioaccumulate in marine organisms, including but not limited to mercury (Hg), lead (Pb), cadmium (Cd), arsenic (As), chromium (Cr), copper (Cu), nickel (Ni), and zinc (Zn). The heavy metal concentrations obtained shall be reported and compared against established regional, national or international safety thresholds.

b. Levels of pesticides, including organophosphates, neonicotinoids, and herbicides, shall be analyzed. The contamination levels obtained shall be reported and compared against established regional, national or international safety thresholds, and the biomass will be considered ineligible when those thresholds are exceeded.

c. Levels of polycyclic aromatic hydrocarbons (PAHs) shall be analyzed. The contamination levels obtained shall be reported and compared against established regional, national or international safety thresholds.

3.6.9. The CO_2 Removal Supplier shall remove harmful impurities from the eligible biomass posing a risk to humans or the environment to the extent required by the local, regional, national or international environmental regulations or other applicable legislation.

3.6.10. The CO_2 Removal Supplier shall ensure that the eligible biomass is free from harmful impurities prior to deployment. Impurities are here defined as unwanted organic or inorganic material present in the biomass feedstock. These impurities shall be categorized and accounted for as follows:

a. Innocuous Impurities in eligible biomass: Impurities considered harmless to aquatic life, such as small amounts of natural mineral aggregates (e.g., sand or clay), may remain in the feedstock provided that the mass fraction of the total deployed biomass due to the innocuous impurities is reliably quantified and deducted from the reported Output volume (see rule 6.1.5).

b. Harmful Impurities in eligible biomass: Prior to deployment, the CO_2 Removal Supplier shall remove from the biomass any foreign objects (such as visible pieces of plastic, glass, metal, and other debris).

3.7. Requirements for biomass processing and deployment

3.7.1. The CO_2 Removal Supplier shall ensure that the biomass maintains structural integrity until it reaches its final storage location.

3.7.2. The CO_2 Removal Supplier shall process the biomass prior to deployment to enhance its density, reduce buoyancy, and minimize dispersion. Acceptable pre-treatment processes include baling, compressing into pellets, or similar techniques that maintain the biomass' long-term stability in aquatic environments.

3.7.3. The CO_2 Removal Supplier shall adhere to industry best practices for baling and handling biomass in terrestrial environments, targeting to obtain the lowest loss rates during transit to the storage site.

3.7.4. The CO_2 Removal Supplier shall evidence that the applied processing of the biomass prevents its dispersion in aquatic environments during deployment and sinking, e.g. via shear stress tests, compression strength tests, submersion tests or similar.

3.7.5. The CO_2 Removal Supplier shall ensure that the material used for baling is either of organic/biogenic origin, or made of inert materials that are innocuous to aquatic life. When the baling material used complies with the rules above (rules 3.7.1 to 3.7.4) and the requirements for biomass sustainability and traceability of origin (section 3.8), the CO_2 Removal Supplier may include the carbon content of the organic baling material as stored carbon (section 6.1).

3.7.6. The CO_2 Removal Supplier may choose to utilize a sinker. A sinker may be either attached to or embedded into the biomass. When a sinker is used, the CO_2 Removal Supplier shall:

a. Ensure that the materials used do not pose a risk to marine ecosystems. For further requirements on environmental risk assessment, see section 4.

b. Account for all emissions – including direct and indirect emissions – related to the use of a sinker (see section 7 and section 8).

3.7.7. The CO_2 Removal Supplier shall ensure that the sinking rate of the biomass is fast enough to minimize the contact time with the oxic water layer while avoiding extremely rapid sinking rates that may disturb pelagic or benthic ecosystems or that create a sediment plume which crosses the chemocline upon impact. For this, a biomass sinking speed shall be a minimum of 0.5 meters per minute.

3.7.8. The CO_2 Removal Supplier shall maintain precise geographic records of all biomass storage sites used in the project (see rule 3.9.1). The CO_2 Removal Supplier shall keep time stamped records of biomass deployment, including:

a. The exact dates of each biomass addition to the storage site or area. Each deployment event shall be linked to its specific location within the storage site to enable accurate monitoring and verification of carbon storage over time.

b. Exact location, boundary, and timeline records, which shall be securely archived and readily available as required for compliance, monitoring, reporting, and verification purposes. Any changes to the storage site locations, boundaries, or deployment schedules shall be reported to the Issuing Body and documented promptly.

The records shall be made available to the Auditor.

3.8. Requirements for biomass sustainability and traceability of origin

3.8.1. The CO_2 Removal Supplier shall demonstrate and keep records (i.e. traceability, chain of custody) of the **origin and type** of the biomass in accordance with the Puro Biomass Sourcing Criteria.[18] Any share of biomass for which origin or type cannot be demonstrated is not considered eligible, and thereby its share of CO_2e will be excluded from the quantification of CORCs (see section 6.1, term $F_{eligible}$).

3.8.2. The CO_2 Removal Supplier shall demonstrate and keep records (i.e. traceability, chain of custody) of the **sustainability** of the biomass in accordance with the Puro Biomass Sourcing Criteria.[19] Any share of biomass for which sustainability cannot be demonstrated is not considered eligible, and thereby its share of CO_2e will be excluded from the quantification of CORCs (see section 6.1, term $F_{eligible}$).

3.8.3. The CO_2 Removal Supplier may utilize a combination of the eligible biomass sources (Rule 3.6.2). However, evidence for the origin, type and sustainability of the biomass

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[18] Available in the Puro Standard document library.

[19] Ibid.

shall be provided separately for each category of biomass source, including the material used for biomass processing, when applicable (see Rule 3.7.5).

REMARK ON THE PURO BIOMASS SOURCING CRITERIA: The Puro Biomass Sourcing Criteria are applicable across all biomass-based CDR methodologies within the Puro Standard. The criteria will be refined and extended over time and the latest version of those criteria shall always be used when reporting CORCs.

The criteria distinguish (at the time of publishing) between 15 categories of biomass feedstocks. For each feedstock category, the document details:

- Required feedstock origin and type disclosures (traceability),
- Required feedstock sustainability criteria,
- Options to evidence the sustainability criteria.

Note, that for the context of this methodology, the eligible biomass sourcing categories categories are limited to specific categories only (see rule 3.6.2). For certain biomass feedstocks where there are risks concerning the introduction of hazardous substances in aquatic environments, additional rules and exclusions may apply.

In practice, the CO_2 Removal Supplier must keep records of the biomass processed, alongside all information needed to demonstrate type, origin and sustainability. This information shall then be synthesized as part of the Output Audit procedures. Puro will make templates available to suppliers, to facilitate the reporting of this information.

Note that the biomass sourcing criteria only address the eligibility of the feedstock, and that the methodology imposes further requirements for eligibility, and other aspects related to the feedstock (e.g. baseline and indirect emissions).

3.9. Requirements for storage site eligibility and characterization

To ensure the stability and minimal decomposition of the deployed biomass, the storage site must meet several critical requirements. This section provides requirements and prerequisites for assessing the environmental conditions of the storage site, aiming to ensure its long-term suitability for carbon storage.

3.9.1. The CO_2 Removal Supplier shall maintain precise geographic records of all biomass storage sites used in the project.

a. The geographic boundaries of a storage site shall be defined and documented as a polygonal perimeter, including latitude and longitude coordinates for all vertices, as well as depth ranges within the area.

b. The storage site boundaries shall be recorded using Global Navigation Satellite System (GNSS) or equivalent geospatial technology, with coordinates expressed in degrees and decimal minutes (DDD° MM.MMM') format and verified for accuracy.

The extent of the storage site shall be determined in the required permits obtained by the CO_2 Removal Supplier (see rule 3.2.3 and rule 3.2.4).

3.9.2. The CO_2 Removal Supplier shall demonstrate the long-term stability of the stratification of the water masses. The storage site shall be situated beneath a stable chemocline, limiting the mixing between oxygen-rich surface waters and the anoxic layers. As evidence, the CO_2 Removal Supplier shall provide:

a. Depth, temperature and salinity data of the full water column, at minimum on a basin-wide coverage. The data shall include multiple spatial and temporal data points for 10 consecutive years if available. Peer-reviewed scientific literature may supplement data where direct measurements are unavailable. The provided data shall portray any seasonal changes within the storage basin. Should there be a lack of 10 consecutive years of full column temperature and salinity data available, then the CO_2 Removal Supplier shall also provide evidence of stable anoxia in the sediments such as the work detailed in (Addy & Behrens, 1980).

b. Evidence of minimal vertical mixing in the full water column, based on both direct measurements and robust atmospheric and ocean response models encompassing, at minimum, the capability of multidecadal hindcasting. Additionally, the model should be capable of forecasting, on a multidecadal scale, the future changes in the physical oceanography in the region. Peer-reviewed scientific literature may be utilized for the direct measurement data.

3.9.3. The CO_2 Removal Supplier shall demonstrate the stability of the seafloor conditions at the storage site, to ensure minimum seabed disturbance. The seafloor conditions shall be homogeneous. As evidence, the CO_2 Removal Supplier shall provide at least:

a. Evidence of low erosion risk out of the storage site. Regions subject to risks for dynamic seabed processes, such as submarine landslides or strong currents that remove material from the storage area, are excluded. Erosion into the target area (e.g., sediment deposition) may be acceptable if it enhances carbon burial rates and permanence without compromising the monitoring.

b. Evidence of geological stability. The storage site shall not be located in a region subject to a significant risk of seismic or volcanic activity of seabed shifts. This shall be evidenced by providing a sufficient assessment of the geological and geophysical characteristics of the seabed.

c. Evidence of little to no anthropogenic disturbances. The storage site shall be located in an area which is not impacted by human activities, such as shipping lanes, fisheries, industrial zones and dredging areas. Similarly, the CO_2 Removal Supplier shall minimize impacts of the Marine Anoxic Carbon Storage activity on maritime and coastal activities (see section 4.4 for further details).

3.9.4. The CO_2 Removal Supplier shall demonstrate that the anoxic conditions at the storage site are stable. The oxygen concentration at the intended storage depth shall not exceed 0.03 mg/L (≈1 μM O_2) (Canfield & Thamdrup, 2009; Paulmier & Ruiz-Pino, 2009). This shall be monitored as follows:

a. Oxygen concentration shall be monitored and verified annually. For further details, see section 9.

b. If the oxygen concentration exceeds 0.03 mg/L for two consecutive annual monitoring events, the CO_2 Removal Supplier shall immediately cease the deployment of biomass and notify the Issuing Body.

3.9.5. In addition to meeting the threshold for oxygen concentration, the CO_2 Removal Supplier shall demonstrate that the storage site is not in an anoxic nitrogenous zone by monitoring the concentration of nitrite and nitrate. Nitrogenous zones are anoxic zones that generally occur near the oxic-anoxic transition zone where the dominant metabolic pathway is the reduction of nitrate and nitrite (Canfield & Thamdrup, 2009). The reduction of nitrate and nitrite results in the production of N_2O, a key environmental risk for a Marine Anoxic Carbon Storage activity (see section 4.5). To limit this risk of N_2O production, the combined nitrate and nitrite concentration at the intended storage depth shall not exceed 0.04 mg/L (≈1 μM). This shall be modified as follows:

a. Nitrate and nitrite concentrations shall be monitored and verified annually. See section 9.3 and section 9.6 for more details on monitoring pre- and post-deployment, respectively.

b. If the combined nitrate and nitrite concentration exceeds 0.04 mg/L for two consecutive annual monitoring events, the site will be considered ineligible.

3.9.6. The CO_2 Removal Supplier shall assess the biological activity at the storage site prior to deployment. The assessment shall be conducted in a manner that represents potential seasonal variability, and follow any additional requirements set in this methodology or relevant local and regional legislation. For further requirements for the assessment and analysis, see rule 9.4.8.

3.9.7. The CO_2 Removal Supplier shall ensure that the storage site is located beneath the photic zone (typically under 200 m) to prevent conditions for photosynthesis. The depth of deployment shall be determined by the CO_2 Removal Supplier, on a case-by-case basis, taking into account the oceanographical conditions, factoring in the stratification and seasonal variability of the water masses (rule 3.9.2). The CO_2 Removal Supplier shall determine:

a. The total water depth at the storage site.

b. The depth of the anoxic layer and its seasonal variability

c. The depth of the chemocline and its seasonal variability.

The storage site depth shall be approved by the Issuing Body.

3.9.8. The CO_2 Removal Supplier shall assess any possible downstream effects occurring due to the Marine Anoxic Carbon Storage activity, which impact the ecosystem and the basin to a larger extent than the storage site (see rule 3.9.1). The assessment shall include, but is not limited to, the following components:

a. Detailed information on the deep sea water mass trajectories and velocities.

b. Assessment of the retention time of the bottom waters, based on the oceanographic measurements and models (see rule 3.9.2).

c. Detailed assessment on any benthic and planktonic ecosystems which may be affected by the potential biomass decomposition products, e.g. elevated dissolved organic carbon (DOC) levels.

3.10. Requirements for positive sustainable development goal impacts

Please note that the Puro Standard General Rules and the associated SDG Assessment Requirements[20] contain the general requirements related to describing and evidencing positive impacts on Sustainable Development Goals (SDGs)[21] that apply to all methodologies. For example, in the context of marine anoxic storage of carbon, positive SDG impacts might be related to targets such as improved sustainability of industries (SDG target 9.4); reduced adverse environmental impact of cities (SDG target 11.6); or enhancing the conservation and sustainable uses of ocean and their resources (SDG target 14.c).[22]

3.10.1. The CO_2 Removal Supplier shall provide descriptions, evidence, and information on the positive impacts of the Marine Anoxic Carbon Storage on Sustainable Development Goals in accordance with the Puro Standard General Rules and other

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[20] Available in the Puro Standard document library.

[21] Resolution adopted by the General Assembly on Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development, G.A. Res 78/206, U.N. Doc. A/RES/71/313 (Jul. 6, 2017). Note that this original SDG indicator framework is subject to regular updates, and has since been revised several times.

[22] For a list of currently up to date SDG targets, see the current official SDG indicator list hosted at the United Nations Statistics Division website. Furthermore, the United Nations Department of Economic and Social Affairs website provides a browsable SDG indicator list.

Standard Requirements (in particular, the SDG Assessment Requirements). Specifically, the Puro Standard General Rules entail that:

a. The CO_2 Removal Supplier shall provide qualitative descriptions of expected positive impacts on Sustainable Development Goals (SDGs) before the Production Facility Audit.
b. The CO_2 Removal Supplier shall provide qualitative and quantitative evidence of positive impacts on SDGs for the Output Audit based on the SDG Assessment Requirements provided by the Issuing Body.
c. The CO_2 Removal Supplier shall, where feasible, provide information on how the Marine Anoxic Carbon Storage activity is consistent with the relevant SDG objectives of the host country.

4. Reversal, environmental and social risks

4.1. Overview

The primary objective of identifying risks is to detect early and ongoing events and ambiguities that could affect the predetermined objectives of the Marine Anoxic Carbon Storage activity. Several risks concerning various mCDR approaches have been identified, concerning climate, ecosystems, human health and the lack of adequate regulatory frameworks (Boettcher et al., 2023; Keating-Bitonti et al., 2024; Levin et al., 2023). While the scope of this methodology eliminates and limits some of these risks, the Marine Anoxic Carbon Storage approach has its own specific risks which need to be identified, accounted for and mitigated. These risks can be categorised into **reversal** risks, **environmental** risks and **social** risks.

In the context of this methodology, *risk* refers to events and situations, whose outcomes are (reasonably well) known in advance and needs to be distinguished from *uncertainty*, which refers to aspects of decision-making which are not easily quantified (Park & Shapira, 2018). The overall risk of an event or situation is often defined as the combination of two parameters: the probability (likelihood) for the event to be realized, and the severity of the event, if realized. Effectively, risk management is composed of four main steps: identification, evaluation, mitigation and control of hazards that could occur within the activity boundary. Therefore, an effective risk assessment takes into account the nature and magnitude of risks in relation to the outcome.

For the purposes of this methodology, the term **reversal** refers to an event which cancels, entirely or in part, the effects of an issued CORC (for further details, see the Puro Standard General Rules[23]). Reversals are therefore considered as unaccounted-for events resulting in a situation where at least a part of the removed, quantified and certified carbon represented as a CORC is either released back into the atmosphere (re-emission) or can no longer be considered safely and durably stored for a long term. It is separated from carbon losses (see section 6.3), which include re-emission pathways identified prior to the CORC issuance, and therefore accounted for in the CORC quantification (see rule 5.3.1).

An eligible Marine Anoxic Carbon Storage activity must also take into consideration multiple **environmental and social risks**, which may negatively impact the terrestrial or marine ecosystems, human health or the local communities. This section outlines the overall criteria to assess, evaluate and mitigate such risks, including certain predetermined risks which all projects seeking for CORC issuance must account for. In addition to the requirements set in this section, further requirements and guidelines are also found in the Puro Stakeholder

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[23] Available in the Puro Standard document library.

Engagement Report Template[24] and the Puro Environmental and Social Safeguards Questionnaire[25].

This methodology, together with applicable local legislation and regulations, sets guidelines and rules to mitigate the possible risks and ensure that the deployed biomass is safely retained in the selected ocean storage site. Appropriate and transparent collection of data as well as regularly updated monitoring plans are key factors in managing and mitigating risks, but effective risk mitigation also requires efficient and transparent communication and collaboration between the CO_2 Removal Supplier and the local authorities and stakeholders.

4.2. General requirements for risk assessment and management

This section focuses on general risk management criteria applicable for reversal risks as well as environmental and social risks. Further assessment criteria specific to each risk type is defined in the following sections:

- Reversal risks (see section 4.3)
- Environmental and social risks (see section 4.4 and section 4.5).

For all types of risk associated with the Marine Anoxic Carbon Storage activity, identifying the key risks is the first step towards a design of an effective monitoring, mitigation and response measures to minimize their likelihood and impact. By proactively managing these risks, the CO_2 Removal Supplier ensures the integrity and safety of the operations.

Risks can be proactively managed by utilizing a mitigation hierarchy framework, which aims to efficiently limit the negative impacts or outcomes of a given risk. Such a hierarchy is based on a sequence of five iterative actions (figure 4.1): anticipating the potential risk, avoiding the risk, minimizing and/or mitigating any negative impacts of the risk, and finally, compensating for any residual impacts. The steps are further characterised as:

- Anticipation: The first step comprises identifying potential risks relevant for a specific Marine Anoxic Carbon Storage activity before they materialize and designing strategies to either avoid, mitigate or minimize their impact.
- Avoidance: Includes measures taken to avoid any negative impacts identified for a given risk. Avoidance measures may include, but are not limited to a careful selection of feedstock sources (see section 3.6) or the storage site (see section 3.9). Effective avoidance measures must be considered during the early stages of the project.
- Minimization: Includes measures to either reduce the duration, intensity or extent of a given risk, in case it cannot be fully avoided. Effective minimization measures may

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[24] Available in the Puro Standard document library.

[25] Ibid.

eliminate some negative impacts, if such measures are planned and executed accordingly.

- Mitigation: Includes measures to mitigate the impacts of a given risk, in case the impacts cannot be fully avoided or minimized. Collectively, avoidance, minimisation and mitigation measures serve to reduce, as much as possible, any negative residual impacts of a given risk.
- Compensation: As the last step, compensation measures are the last resort in case avoidance, minimisation and/or mitigation measures are not capable of fully preventing the negative impacts of a given risk. In the context of this methodology, this applies in the case of a reversal event.

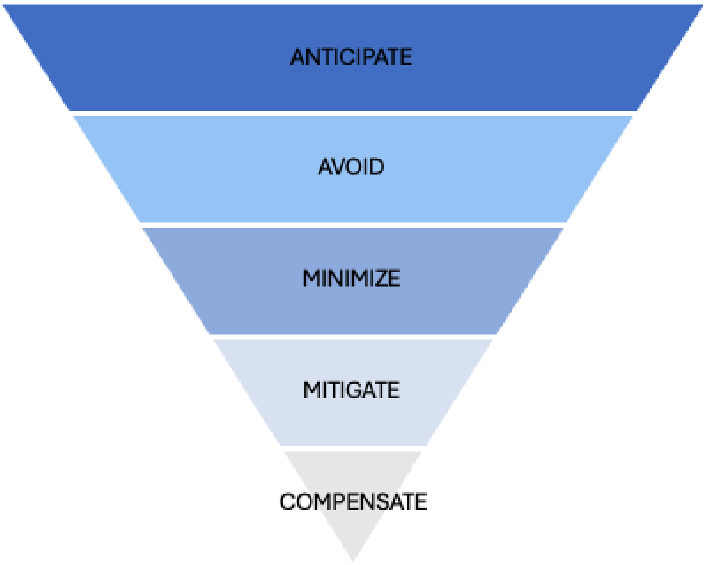

Figure 4.1. Mitigation hierarchy framework for risk assessment in the context of Marine Anoxic Carbon Storage approach.

Note that the Puro Standard General Rules contain requirements on risk assessment and management, particularly in the context of permanence and reversal.

4.2.1. The CO_2 Removal Supplier shall undertake a comprehensive baseline risk assessment prior to project initiation, based on the following criteria:

a. The scope of the assessment shall cover all stages (biomass sourcing, processing, transportation and sinking) within the activity boundary (see rule 7.2.4).

b. The assessment shall be systematic and based on robust, science-based risk assessment criteria, against which the significance of a specific risk/impact is evaluated and measured against.

c. The assessment shall comply with the requirements of this methodology, the Puro Standard General Rules[26] and other Standard Requirements[27], as well as any applicable local laws, regulations, and other binding obligations.

4.2.2. The risk assessment criteria shall include at least the following components:

a. Identification and description of the anticipated risk and its impact, including but not limited to the predetermined risks set in this methodology (see section 4.5).

  - The impacts may include direct, indirect or cumulative risks.
  - The impacts may be either discrete, i.e. isolated events with a clear trigger or a cause, or progressive, i.e. gradual changes that accumulate over time, leading to negative impacts.
  - The potential risks include, but are not limited to risks related to geological instability, oceanographic variability, microbial activity, and anthropogenic disturbances.

b. Analysis and estimation of each identified negative impact a specific risk may have, including the characterization of likelihood and severity, assessing the significance of the risk to the CO_2 Removal Project. The CO_2 Removal Supplier shall use the risk matrix presented in table 4.1 to analyse each risk.

  - The CO_2 Removal Supplier may suggest using another quantitative and/or qualitative risk scoring system, pending approval by the Issuing Body.

c. Assessment of each identified risk, including acceptable, alert and threshold values for each measurable parameter. The CO_2 Removal Supplier shall further design and implement operating procedures in case the alert or threshold value is reached. The values shall be derived from applicable local regulations or, if no such regulations exist, from other relevant sources, such as peer-reviewed scientific literature or industry best practices. The values shall be periodically reviewed to ensure the safety of the operations.

d. Description of the measures to avoid, minimize, mitigate or compensate the negative impacts of identified risks based on the mitigation hierarchy (figure

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[26] Available in the Puro Standard document library.

[27] Ibid.

4.1), including where relevant a description of the parameters and methods utilized to monitor the potential impacts.

- Preventive and corrective measures shall be identified or planned as contingency measures to reduce risks.
- The risk mitigation strategy may include, but is not limited to, data collected from both in-situ sampling and laboratory experiments conducted by the CO_2 Removal Supplier (see section 9.4).
- When the severity or the likelihood of the risk are at an undesirable or intolerable level (table 4.1), the CO_2 Removal Supplier shall either eliminate or reduce the risk to a safe and acceptable level.
- When the severity or the likelihood of the risk are at an inoperable level (table 4.1), the CO_2 Removal Supplier shall immediately cease all operations, prevent further negative impacts from occurring, and notify the Issuing Body.

e. Description of public participation and consultation, as described in the Puro Standard General Rules[28] and the Puro Stakeholder Engagement Requirements.[29]

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[28] Available in the Puro Standard document library.

[29] Ibid.

Table 4.1. A 5x5 risk matrix and descriptions of the risk scores and required actions for the given risk levels.

Risk score	**Risk level**	**Action**
20—25	Inoperable	Critical failure. Requires an immediate seizure of operations. Further avoidance, minimization or mitigation measures are required for the operations to continue.
10–19	Intolerable	High likelihood or severe negative impacts. Requires immediate action to avoid, minimize or mitigate the impacts.
4–9	Undesirable	Manageable risks, which require an active, planned approach for risk avoidance, minimization and mitigation to reduce the negative impacts.
2–3	Acceptable	Minor risks with limited negative impacts. No requirement of immediate action, but effective monitoring and controls are necessary.
1	Negligible	Insignificant risk with negligible consequences. No requirement for immediate action, but requires to avoid future events.

Likelihood → Severity ↓	Very Low (1)	Low (2)	Medium (3)	High (4)	Very High (5)
Minor (1)	1	2	3	4	5
Serious (2)	2	4	6	8	10
Major (3)	3	6	9	12	15
Severe (4)	4	8	12	16	20
Extreme (5)	5	10	15	20	25

4.2.3. The risk assessment shall, to the extent possible, be based on the actual project data acquired during the Marine Anoxic Carbon Storage activity. The risk assessment, including a review of appropriate preventive and corrective safeguards, shall be reviewed and updated periodically together with the Monitoring Plan (see section 9.2). The assessment shall be made available to the Auditor.

4.2.4. To address the above components partly or in full, the CO_2 Removal Supplier may utilize and refer to other documents (e.g. project description documents, stakeholder engagement reports, or legally mandated environmental and social impact assessment documents) containing the required information, provided that such additional documents are also included.

4.2.5. The CO_2 Removal Supplier shall record and disclose to the Issuing Body any negative environmental or social impacts or reversal events (or claims thereof) occurred during the monitoring period, including but not limited to any legal actions and/or other written complaints filed by affected parties.

4.3. Requirements for reversal risk assessment and management

The long-term success of a Marine Anoxic Carbon Storage activity ultimately depends on the stability of the storage site conditions and the integrity of the stored biomass. In this context, a reversal risk is defined as any event or condition that may compromise any (or both) of the abovementioned key factors, resulting in the re-emission of the stored carbon back into the atmosphere. More specifically, in the context of this methodology, the durable storage is considered breached if the carbon stock crosses the chemocline. Please note, that reversal risks are separate from carbon losses (see section 6.3), which result from re-emission pathways known or assumed *a priori*, and which therefore need to be accounted for *at the time of CORC issuance*. Previously unknown or unanticipated re-emissions *after issuance of CORCs* are termed reversals, and are accounted for via a procedure described in the Puro Standard General Rules.[30]

The primary objective of identifying reversal risks is to proactively detect potential events or conditions that could compromise the permanence of the carbon storage, enabling the CO_2 Removal Supplier to define measures to address those risks and compensate for any reversals. A key factor in avoiding or mitigating reversal risks is the concept of a well selected and monitored storage site, of which proper risk management is an integral part. When all of the eligibility (section 3) and risk assessment criteria (section 4.2) set in this methodology are met, the risk of reversal is considered low.

Note that this section is limited to specific assessment criteria for reversal risks. For reversal risk monitoring requirements, see section 9.7.

4.3.1. Prior to the start of the operations, the CO_2 Removal Supplier shall assess any potential sources of a reversal risk, based on the eligibility requirements (see rule

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[30] Available in the Puro Standard document library.

3.9.3) and general risk assessment criteria detailed in section 4.2. The assessment shall include reversal risks arising from:

a. Natural processes, including but not limited to:
    - Discrete events, including geological disturbances such as earthquakes or submarine landslides.
    - Progressive changes, including ocean circulation shifts due to climate change.

b. Anthropogenic interference, including but not limited to:
    - Deep-sea mining.
    - Political or regulatory instability.
    - Fishery operations.

c. Combination of both.

4.4. Requirements for environmental and social risk assessment and management

The Puro Standard General Rules[31] contain the general requirements on environmental and social safeguards that apply to all methodologies (see also rule 4.2.1.), while this section contains further requirements on assessing environmental and social risks and their impacts relevant to Marine Anoxic Carbon Storage activities in particular.

4.4.1. The CO_2 Removal Supplier shall have in place, maintain, and abide by environmental and social safeguards to the extent required by this methodology, the Puro Standard General Rules[32], or any applicable local statutory requirements, in order to ensure that the Marine Anoxic Carbon Storage activities do no net harm to the surrounding natural environment or local communities.

4.4.2. The CO_2 Removal Supplier shall provide all environmental permits, assessments, and other documents related to the analysis and management of environmental and social impacts of the Marine Anoxic Carbon Storage activities that are required by the applicable local laws and regulations.

4.4.3. The CO_2 Removal Supplier shall specifically assess the environmental and social impacts of the Marine Anoxic Carbon Storage activity, following applicable local or national legislative requirements for an Environmental Impact Assessment (EIA).

a. The EIA shall include a comprehensive, project-specific Environmental and Social Risk Assessment, which shall be based on the normal operating

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[31] Available in the Puro Standard document library.

[32] Ibid.

conditions of the Marine Anoxic Carbon Storage activity. In addition to requirements set in section 4.2, the assessment shall include:

- Description of the applicable legal and regulatory framework pertaining to the assessment and management of the environmental and social impacts of the Marine Anoxic Carbon Storage activities.
- Description of the existing local environmental and socio-economic conditions (i.e. background information on the current environmental and socio-economic context in which potential impacts are assessed).
- Description of the Marine Anoxic Carbon Storage activity in detail, including construction, operation, and decommissioning of infrastructure, and other aspects affecting the assessment of environmental and social impacts.
- Identification and description of the anticipated environmental and social impacts, including but not limited to the predetermined risks set in this methodology (see section 4.5). For example, such impacts might include any potential negative effects to:
    - Soil, air, and water quality (e.g., hydrological cycles, physical and biogeochemical properties).
    - Flora and fauna (e.g., biodiversity, habitats).
    - Human health and safety.
    - Socio-economic factors (e.g., related to land use or water resources).
    - Local communities (e.g., due to noise, pollution, limiting access to recreationally significant areas).
    - Sites of cultural or archaeological significance (e.g. shipwrecks).
- Include a disaster management plan, in case of any abrupt situations such as fire, spillages, or natural hazards.

b. In cases where EIA is not required by the applicable local or national legislative requirements, the CO_2 Removal Supplier shall provide documentation that robustly addresses all material environmental and social impacts, following criteria determined in the Puro Standard General Rules[33] and this methodology.

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[33] Available in the Puro Standard document library.

4.4.4. The CO_2 Removal Supplier shall comply with all applicable local laws and regulations relating to access and consumption of water resources. The CO_2 Removal Supplier shall furthermore recognize, respect and promote the human rights to safe drinking water and sanitation[34] as well as the right to water as laid out in the General Comment No. 15 of the United Nations Committee on Economic, Social and Cultural Rights.[35] In particular, the CO_2 Removal Supplier shall not endanger the *availability*, *quality*, or *accessibility* of the local water supply, as defined in article 12 of General Comment No. 15.[36]

4.4.5. The CO_2 Removal Supplier shall prepare and abide by an environment, health and safety (EHS) plan to assess and mitigate exposure to harmful chemicals. The plan shall contain at least the following elements related to environmental risks and human health risks:

a. Identification and listing of any potentially harmful chemical compounds used at any stage within the activity boundary.
b. Risk assessment and mitigation measures for chemical injuries (for example, due to inhalation, ingestion, or skin contact) considering all relevant exposure pathways.
c. Based on the local statutory requirements, a determination of threshold exposure values and/or other limit values to prevent chemically induced diseases (whether through direct exposure, or indirect exposure such as through environmental contamination where relevant), and a description of the measures to limit and monitor the exposure to harmful chemicals.
d. Identification of any potential pathways for chemical spills or leakages, and a description of the measures to prevent leakages and mitigate any harm to the environment or human health.
e. Emergency preparedness plan, including appropriate response procedures in case a chemical spill has occurred. The plan shall at least address:
    - How to prevent any further damage.
    - Equipment and methods for cleanup.
    - Evacuation zones and procedures.
    - First-aid procedures.

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[34] The human rights to safe drinking water and sanitation, G.A. Res 78/206, U.N. Doc. A/RES/78/206 (Dec. 22, 2023).

[35] General Comment No. 15 (2002), The right to water (arts. 11 and 12 of the International Covenant on Economic, Social and Cultural Rights), U.N. Doc. E/C.12/2002/11 (Jan. 20, 2003).

[36] Ibid., p. 5.

4.5. Key environmental risks

The environmental risks associated with a Marine Anoxic Carbon Storage approach can be broadly categorized into terrestrial risks and marine ecosystem risks. While the CO_2 Removal Supplier must identify, assess and evaluate all risks related to the Marine Anoxic Carbon Storage activity within the activity boundary (see rule 4.4.3), this section outlines the key risk predetermined in the context of this methodology (table 4.2) and specific requirements for their assessment, avoidance and mitigation, when applicable.

Table 4.2. Predetermined environmental risks in the context of this methodology. Note, that the list is not exhaustive.

Type of risk	Risk	Description
Terrestrial risk	Nutrient robbing	Nutrients, such as nitrogen, are removed from the terrestrial circulation due to deployment of the biomass.
Marine ecosystem risk	Biodiversity changes and food web disruption	Biomass deployment may lead to biodiversity changes both on species level and as functional traits. Additionally, foreign organisms may be introduced to the storage site.
	Local nutrient cycling	Increasing biomass deployment may release or consume nutrients within the local ecosystem due to biomass decomposition. Changes in local nutrient cycling may have further impacts on the biogeochemistry both at the storage site and downstream.
	Oxygen depletion	Expansion of marine sub-oxic and anoxic environments is a major concern for marine ecosystems and global nutrient cycling.
	Methane production	Methane is the second most abundant GHG, and on a 100-year timescale, almost 30 times more potent than CO_2, and is produced in anaerobic conditions as the biomass decomposes. Methane release into the atmosphere would significantly impact the efficiency of the OSB approach.
	Nitrous oxide production	Nitrous oxide may be produced during biomass decomposition processes if nitrate and nitrite are present. It is approximately 270 times more potent than CO_2 on a 100-year timescale, and therefore, its release would significantly impact the efficiency of an OSB approach.

Nutrient robbing

In addition to carbon, the biomass feedstocks contain additional nutrients, primarily nitrogen, which is removed from the terrestrial circulation due to the deployment of the biomass. The atmosphere is composed of 78% nitrogen (~3.9 quadrillion tonnes) with an additional 3-5 billion tonnes resident within the terrestrial biosphere. While even large scale Marine Anoxic Carbon Storage activity would sequester relatively negligible amounts of global nitrogen, the potential risks must be assessed and possibly mitigated. Project feedstocks, especially agricultural waste, may result in local nitrogen depletion. These depletion levels are consistent with other agricultural practices and are addressed via compliance with the sustainable feedstock sourcing requirements (section 3.8).

4.5.1. The CO_2 Removal Supplier shall assess the risk of local nitrogen depletion at the biomass sourcing area due to the Marine Anoxic Carbon Storage activity.

  a. Additionally, any risks for the global depletion of nitrogen stocks associated with large scale application of the Marine Anoxic Carbon Storage activity shall be assessed.

  b. In cases where the risk of local nitrogen depletion at the biomass sourcing area is considered intolerable, the CO_2 Removal Supplier shall either reduce or mitigate the risk accordingly (see rule 4.4.3).

Biodiversity changes and food web disruption

Biomass deployment may lead to changes in biodiversity, considering both species and functional diversity, by introducing foreign organisms, exterminating existing organisms, or shifting the balance of existing organisms. Changes in the community structure may lead to changes in nutrient cycling, ecosystem stability and economic disruptions (i.e. fisheries). In anoxic basins, the risk for severe negative consequences to the ecosystem is generally decreased due to the lack of eukaryotic organisms. Any introduction of foreign multicellular organisms attached to the biomass, such as plants and animals, will likely not survive in the anoxic conditions. However, the impact on the microbial community is still unknown. Therefore, risks to the ecosystem must be assessed and mitigated, when necessary.

4.5.2. The CO_2 Removal Supplier shall monitor the microbial community composition at the storage site via eDNA analyses. The sampling protocol shall follow the requirements set in rule 9.4.8.

  a. Prior to biomass deployment, the CO_2 Removal Supplier shall determine the environmental baseline for microbial activity as stated in rule 9.3.7.

  b. To track the changes in the microbial communities post-deployment, the CO_2 Removal Supplier shall conduct the measurements on samples collected from the storage site (see section 9.6).

c. When the changes in the microbial community pose a significant risk to the local ecosystem, mitigation protocols shall be utilized (see rule 4.2.2 d) following requirements set by the local, regional or national permitting authority (see rule 4.4.3).

Local nutrient cycling

Increasing biomass deployment may release or consume nutrients within the local ecosystem once the biomass begins to decompose. Changes in local nutrient cycling have the potential to impact the biochemistry of the storage site and have downstream effects due to the water mass circulation and/or potential mixing across the wider ocean. Perturbations to nutrient cycling depend on the decomposition rate, total biomass load, and ventilation. Slower decomposition rates and lower biomass load will result in smaller changes to local chemistry and nutrients, and slower ventilation will isolate the mobility of dissolved species from the wider ocean ecosystem.

In anoxic basins, decomposition rates and ventilation is expected to be low. However, the biomass deployment will result in a significant increase in biomass load compared to natural organic matter deposition. The cumulative impact of Marine Anoxic Carbon Storage activity may impact carbon cycling, the geochemical environment relating to anoxic metabolic pathways, carbonate saturation states, and trace metal cycling. To assess these risks, long-term monitoring is required.

4.5.3. The CO_2 Removal Supplier shall assess the risk of perturbing local nutrient cycling by monitoring the following parameters:

a. The release of mobile carbon species such as DIC and dissolved organic carbon (DOC).

b. Any shift in the dominant redox state at the storage site.

c. Changes to calcite and aragonite saturation state at the storage site. Changes in pH due to the production of DIC and DOC will impact calcite and aragonite saturation states (Ω), where shifts in Ω from ≥ 1 to <1 will lead to calcium carbonate dissolution.

d. The production or consumption of dissolved bioavailable iron, which is a limiting nutrient in the global ocean. In both nitrogenous zones and sulfidic zones of the anoxic basin, dissolved iron is efficiently precipitated out of the water column, limiting bioavailable iron (Scholz et al., 2014). Dissolved iron is released in ferruginous zones where iron oxides are used as the oxidizing agent (Canfield & Thamdrup, 2009).

Monitoring requirements for the above mentioned parameters are further described in section 9.

> **REMARK:** In sulfidic anoxic basins like the Black Sea and the Orca Basin, the predicted risk of perturbing the nutrient cycle is low, though further data is still needed. Decomposition rates of terrestrial biomass in anoxic basins are relatively low with an estimated 50-85% organic matter preservation over 100 years (Keil et al., 2010). Released nutrients are unlikely to cause harm because they will be retained in the anoxic basin due to its slow ventilation (Raven et al., 2024). Perturbation to iron cycling is low because of naturally high rates of iron precipitation due to the high sulfide concentrations. Additionally, sulfidic basins are naturally characterized by a relatively low pH due to the accumulation of DIC, and alkalinity produced during sulfate reduction partially offsets the decrease in pH from further DIC production (Raven et al., 2024).

Oxygen depletion

The expansion of persistent marine sub-oxic and anoxic environments due to human activity is a major concern for marine ecosystems and global nutrient cycling. Such sub-oxic and anoxic zones are already predicted to expand due to rising temperatures which leads to lower oxygen dissolution and increased stratification (Levin, 2018). Therefore, it is essential to limit any further O_2 depletion potentially caused by the Marine Anoxic Carbon Storage activity.

In anoxic basins, where oxygen is already severely depleted, the risk of oxygen consumption is greatly reduced. However, there is still a risk of the expansion of anoxic conditions, for example, resulting from excess sulfide production during the anaerobic metabolic pathway known as sulfate reduction, whereby sulfate is used as the oxidizing agent to break down organic matter. Any excess flux of sulfides into the overlying sub-oxic and oxic layers will be re-oxidized with oxygen, contributing to the depletion of oxygen in these upper layers.

4.5.4. The CO_2 Removal Supplier shall assess the risk of oxygen depletion caused by the oxidation of excess sulfides into sulfate in sub-oxic or oxic layers above anoxic sulfidic basins.

4.5.5. The CO_2 Removal Supplier shall monitor their total biomass load and the resultant sulfide flux in accordance with the monitoring requirements described in rule 9.4.6 and rule 9.5.2.

REMARK: The risk of excess sulfide flux leading to oxygen depletion is dependent on both sulfide production and vertical mixing. For example, Raven et al. have estimated the excess sulfide production from biomass remineralization over centennial timescales (Raven et al., 2024). According to their simplified mass balance exercise, a complete and instantaneous dissolution of 40 Tmol C in the abyssal Black Sea would produce 600-900 µM of excess sulfides (compared to a current concentration of 440 µM). Of this excess sulfide produced, an estimated 0.04% will reach the 500 m depth after 400 years based on a simple vertical diffusivity model. This equates to the introduction of 0.2-0.4 µM of sulfide, or <1% of the current concentration at 500 m, over 400 years. In 1000 years, the share of excess sulfides reaching the 500 m depth increases to 1.26%.

With a predicted biomass preservation efficiency of 50-85% over several centuries in anoxic basins, the dissolution of 40 Tmol C translates to 3.5-11.7 Pg CO_2 sequestered. These rough calculations indicate a low risk of oxygen depletion. However, because observational data for assessing this risk does not yet exist, the true extent of this risk is still uncertain.

Methane production

Methane (CH_4) is a greenhouse gas that has a global warming potential roughly 85 times higher than CO_2 over a 20-year period. Though CH_4 is relatively short-lived in the atmosphere (11.8±1.8 years), its global warming potential is still nearly 30 times that of CO_2 over a 100-year period (Intergovernmental Panel On Climate Change (IPCC), 2023). Therefore, even limited emissions of CH_4 into the atmosphere (CH_4 loss) can result in large inefficiencies with regard to CO_2 removals.

Methane is produced in the ocean during methanogenesis, a process of anaerobic microbial decomposition of organic matter. Methanogenesis is the least energy-favorable out of all microbial metabolic pathways and is therefore limited to chemical zones where other more favorable oxidizing molecules (e.g. O_2, NO_3^-, SO_4^{2-}) are low or depleted (Canfield & Thamdrup, 2009).

In many sulfidic anoxic basins, such as the Black Sea, CH_4 production via methanogenesis, either in the water column or in the underlying sediment, is not negligible. Therefore, there is some risk of CH_4 loss as a result of a Marine Anoxic Carbon Storage activity in anoxic basins when the added biomass is decomposed. However, the risk of CH_4 loss is limited by its potential to be released out into the atmosphere. There are several layers of safeguards in anoxic basins that limit CH_4 loss:

1. CH_4 is anaerobically oxidized to CO_2, a process known as anaerobic oxidation of methane (AOM).
2. CH_4 is aerobically oxidized to CO_2 when circulated into the upper oxic layer.

3. CH_4 can form solid hydrates at depths with high pressure and low temperature, defined as the Methane Hydrate Stability Zone (MHSZ).
4. Anoxic basins are highly stratified which result in ventilation timescales of many thousands of years (Raven et al., 2024), keeping CH_4 produced in these basins from being released into the atmosphere.

Through preliminary site assessments and proper monitoring, the risk of CH_4 loss can be drastically reduced.

4.5.6. The CO_2 Removal Supplier shall place the biomass below the MHSZ. The following criteria shall be followed:

  a. The CO_2 Removal Supplier shall determine the depth of the MHSZ prior to the deployment by using a phase diagram based on temperature and pressure profiles.
  b. After deployment, CH_4 loss shall be monitored based on estimated CH_4 production, CH_4 oxidation, mixing, and measured CH_4 accumulation. These monitoring requirements are further described in section 9.4.

4.5.7. The CO_2 Removal Supplier shall monitor for CH_4 production throughout the monitoring period in accordance with monitoring requirements described in section 9. Any risk of CH_4 loss, accounting for the oxidation rate of CH_4 into CO_2, shall be included in the CORC evaluation as described in section 6.3.

Nitrous oxide production

Nitrous oxide (N_2O) is a GHG with a global warming potential roughly 270 times higher than CO_2 over a 100-year period (Intergovernmental Panel On Climate Change (IPCC), 2023). N_2O is also a dominant contributor to the depletion of stratospheric ozone (Ravishankara et al., 2009). Therefore, any release of N_2O into the atmosphere (N_2O loss) can lead to large inefficiencies in CDR. In anoxic basins, N_2O is produced during denitrification, which is an anaerobic respiration process whereby nitrate is used as the oxidizing agent to breakdown organic matter (Hutchins & Capone, 2022). As nitrate is the second most energetically favorable oxidizing agent after oxygen, denitrification generally occurs in the upper anoxic zones at the oxic-anoxic boundary (Canfield & Thamdrup, 2009). In a strongly stratified anoxic basin, denitrification and the subsequent production of N_2O will be limited if biomass storage is limited to depths where nitrate (and the intermediary product nitrite) concentrations are low.

4.5.8. The CO_2 Removal Supplier shall determine the nitrate and nitrite concentrations at the storage site. Functionally anoxic storage sites with nitrate and nitrite concentrations greater than 0.1 µM prior to biomass deployment are deemed ineligible (see rule 3.9.5). The concentrations shall be monitored throughout the monitoring period in accordance with the monitoring requirements described in section 9.

4.5.9. The CO_2 Removal Supplier shall monitor for N_2O production throughout the monitoring period in accordance with the requirements described in section 9. Any risk of N_2O loss shall be included in the CORC evaluation as described in section 6.3.

5. Quantification of CO_2 Removal Certificates (CORCs)

5.1. General principles

In general, a CORC represents the net removal of 1 tonne CO_2e removed from the atmosphere. In the specific context of Marine Anoxic Carbon Storage, the CO_2 removal results from ensuring the durable storage of the carbon-containing biomass in eligible anoxic conditions.

The overall principle of the CORC calculation (figure 5.1) is that the CO_2 Removal Supplier first determines the gross amount (in metric tonnes) of CO_2e stored as biomass in the ocean storage site over a given monitoring period. Various deductions are then made, such as any potential CO_2e losses, supply chain emissions, the effect of the unmitigated negative ecological, market and activity-shifting leakage and baseline carbon removal, if applicable. The resulting net amount of CO_2e sequestered is credited as CORCs. More details on the method of calculation are given in this section.

$$\underbrace{\text{CORCs}} = \underbrace{C_{\text{stored}}} - \underbrace{C_{\text{baseline removal}}} - \underbrace{C_{\text{loss}}} - \underbrace{E_{\text{project}}} - \underbrace{E_{\text{indirect}}}$$

	CORCs	C_{stored}	$C_{\text{baseline removal}}$	C_{loss}	E_{project}	E_{indirect}
Description	Amount of net CO_2-eq removed by the ocean storage of biomass activity.	Gross amount of CO_2 stored into the ocean storage.	Total amount of CO_2-eq which would have been stored in the absence of the removal activity, if any.	Total GHG emissions from the ocean storage, if any.	Total life cycle emissions arising from the whole supply chain of the ocean storage activity.	Total GHG emissions due to unmitigated negative ecological, market and activity-shifting leakage.
Units	Tonnes of CO_2e	Tonnes of CO_2e	Tonnes of CO_2e	Tonnes of CO_2e	Tonnes of CO_2e	Tonnes of CO_2e

Figure 5.1. CORC calculation equation.

5.2. Requirements for robust quantification of net carbon removal

5.2.1. The length of the monitoring period can be decided by the CO_2 Removal Supplier, but shall not exceed one (1) year.

5.2.2. The CO_2 Removal Supplier shall follow robust and auditable measurement practices and protocols for the data needed for the calculation of the quantity of CORCs resulting from the Marine Anoxic Carbon Storage activity.

5.2.3. The CO_2 Removal Supplier shall provide a life cycle assessment (LCA) quantifying the greenhouse gas emissions related to the Marine Anoxic Carbon Storage activity, as per the scope and system boundaries defined in section 7, and following the general LCA guidelines described in the ISO 14040/44 standards.[37]

5.2.4. The CO_2 Removal Supplier shall quantify the combined uncertainty from the components included in the equation 5.1 and in accordance with the relevant parts of the ISO/IEC Guide 98-3[38] as further described under section 10.6.

5.2.5. The CO_2 Removal Supplier shall calculate the amount of sequestered carbon in the form of CO_2 Removal Certificates (CORCs) for each monitoring period, as per the requirements detailed in section 5.3.

5.2.6. The CO_2 Removal Supplier shall have in place, maintain, and utilize an information system to keep records of any events affecting the amount of CORCs resulting from the Marine Anoxic Carbon Storage of biomass activity.[39] These records shall include time stamped, quantitative information such that their effect on the Output volume of the monitoring period can be quantified. These records shall be available to the Auditor, for the Production Facility Audit and Output Audits.

5.2.7. The CO_2 Removal Supplier shall explicitly show, through comparison of data records, that the amount of CORCs (i.e. the total net amount of CO_2 removed, see rule 5.3.1) during a monitoring period does not exceed the amount (in tCO_2) of eligible CO_2e durably stored during the same monitoring period.

5.2.8. The CO_2 Removal Supplier shall ensure that any instrumentation used for data collection is in place and adequately calibrated at all times (see section 10.5). The data records shall be kept in a reliable data system. See also rule 5.2.6.

5.3. Overall equation

5.3.1. The overall number of CORCs (i.e. the total net amount of CO_2 removed) during a monitoring period shall be calculated as follows (see also figure 5.1 for an illustration):

$$CORCs = C_{stored} - C_{baseline\ removal} - C_{loss} - E_{project} - E_{indirect} \qquad (5.1)$$

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[37] ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework and ISO 14044:2006 Environmental Management - Life cycle assessment - Requirements and guidelines.

[38] ISO/IEC Guide 98-3:2008 Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement.

[39] Examples of such events include any deployment or loss events, as well as the construction or replacement of any facilities, machinery or equipment (which would affect overall supply chain emissions).

Variable	Description	Unit
$CORCs$	Net amount of CO_2 equivalents removed by the removal activity.	tCO_2e
C_{stored}	Gross amount of eligible CO_2 stored into the Marine Anoxic Carbon Storage at the time of the measurement. Further requirements on the calculation of this term are given in section 6.1.	tCO_2e
$C_{baseline\ removal}$	Total amount of CO_2-eq which would have been stored (naturally or man-made) in the business-as-usual case in the absence of the removal activity. Further requirements on the calculation of this term are given in section 6.2.	tCO_2e
C_{loss}	Total amount of CO_2-eq which is re-emitted back to the atmosphere in the format of e.g. CO_2, CH_4 or N_2O, and can no longer be considered durably stored. Further requirements on the calculation of this term are given in section 6.3.	tCO_2e
$E_{indirect}$	The amount of CO_2-eq that is emitted indirectly due to unmitigated negative ecological, market, and activity-shifting leakage resulting from the Marine Anoxic Carbon Storage activity. Further requirements on the calculation of this term are given in section 7.	tCO_2e
$E_{project}$	Total amount of CO_2-eq that is emitted along the supply chain of the removal activity. Further requirements on the calculation of this term are given in section 8.	tCO_2e

6. Determination of stored carbon, baseline carbon removal and carbon loss

6.1. Carbon stored (C_{stored})

6.1.1. The gross amount of eligible carbon stored into an anoxic basin (C_{stored}) shall be calculated as follows:

$$C_{stored} = OM_{wet} \times F_{dry} \times C_{org} \times \frac{44}{12} \times F_{eligible} \quad (6.1)$$

Variable	Description	Unit
C_{stored}	Gross amount of eligible CO_2 stored into the ocean storage at the time of the measurement.	tCO_2e
OM_{wet}	Total mass of the organic matter (OM), based on the wet weight measured prior to deposition. Further requirements for the determination of this term are given in rule 6.1.3.	tonnes
F_{dry}	Fraction of dry matter of the biomass deposited, measured from the sourced biomass. Further requirements for the determination of this term are given in rule 6.1.4.	% mass
C_{org}	Fraction of organic carbon measured from the dry weight (F_{dry}) of the biomass deposited. Further requirements for the determination of this term are given in rule 6.1.4.	% mass
$\frac{44}{12}$	Mass conversion factor from elemental carbon to a corresponding amount of carbon dioxide, calculated as the ratio between the molar masses of carbon dioxide and carbon.	Unitless
$F_{eligible}$	Fraction of the eligible biomass of the total biomass deposited.	% mass

6.1.2. In the case of heterogeneous biomass, the analyzed biomass shall be homogenized and evenly mixed prior to analysis. Further requirements for the proper treatment of the biomass are determined in section 3.7.

6.1.3. The CO_2 Removal Supplier shall measure the total mass of organic matter (OM_{wet}) prior to the deployment of the biomass into the ocean storage. The total mass shall be measured as close in time to the deployment as possible to ensure that the deployed biomass is unaltered by e.g. decomposition in between the measurement and deployment. The total mass shall be measured by direct on-site measurement with reliable, calibrated weighing equipment following industry standards, such as load cells or weighbridges.

6.1.4. The CO_2 Removal Supplier shall collect statistically significant samples (for further requirements on sampling, see section 10.5) of each batch of biomass stored (see rule 6.1.3) to determine the share of dry matter (F_{dry}) and organic carbon content (C_{org}) as further defined in rule 3.6.4.

6.1.5. The CO_2 Removal Supplier shall determine the mass fraction of eligible biomass for every batch of biomass deployed ($F_{eligible}$), by deducting the mass fraction of any innocuous impurities within the eligible feedstock (see rule 3.6.9.a).

$$F_{eligible} = F_{dry} - F_{impurities} \tag{6.2}$$

Variable	Description	Unit
$F_{eligible}$	Fraction of the eligible biomass of the total biomass deposited.	% mass
F_{dry}	Fraction of dry matter of the biomass deposited, measured from the sourced biomass. Further requirements for the determination of this term are given in rule 6.1.4.	% mass
$F_{impurities}$	Mass fraction of impurities within the total mass of the biomass feedstock, as further detailed in rule 3.6.9 a.	% mass

6.2. Baseline ($C_{baseline\ removal}$)

The baseline is a conservative scenario of what durable carbon removal and sequestration likely would have happened without the Marine Anoxic Carbon Storage activity. This section defines requirements for determining a baseline scenario for all eligible biomass sourcing options, as well as considering the potential natural carbon removal occurring at the storage site.

In the baseline scenario, without a Marine Anoxic Carbon Storage approach, the terrestrial biomass would decompose and re-emit to the atmosphere in the form of greenhouse gases e.g. CO_2, N_2O and CH_4. When terrestrial biomass is deployed into anoxic ocean conditions, the stored carbon is effectively sequestered for thousands of years.

6.2.1. The CO_2 Supplier shall demonstrate that the biomass eligibility and sustainability criteria defined in section 3.6 and section 3.8, and as defined in the Puro Biomass Sourcing Criteria[40], is followed.

6.2.2. The CO_2 Removal Supplier shall evidence that in the absence of the Marine Anoxic Carbon Storage activity, the utilized biomass would not have been treated or stored in a manner which would have guaranteed a secure long-term carbon storage. This evidence includes, but is not limited to the following scenarios:

   a. The biomass would have been left unharvested or disposed of on forest land.

   b. The biomass would have been left unharvested or disposed of on agricultural fields.

   Note that alternative uses of the biomass feedstock, such as requirements for market-shifting leakage, do not affect the baseline determination and are further addressed in section 8.

6.2.3. The CO_2 Removal Supplier shall demonstrate that the deployed biomass would not have naturally been stored in the selected storage site due to natural processes, such as riverine transport.

6.2.4. The CO_2 Removal Supplier shall evidence that the Marine Anoxic Carbon Storage activity is not negatively affecting any potential natural carbon sinking process occurring at the storage site. This includes, for example, a natural biochemical cycle in the surface waters and the natural deposition of marine organisms into the seafloor.

6.2.5. When all of the above-mentioned requirements are met, the baseline carbon storage ($C_{baseline\ removal}$) shall be set to 0. In all other cases, the CO_2 Removal Supplier shall quantify the volume of carbon durably stored in the baseline scenario ($C_{baseline\ removal}$).

6.3. Carbon losses (C_{loss})

The definition for losses (C_{loss}) applies to re-emission pathways known or assumed *a priori*, and which therefore need to be accounted for *at the time of CORC issuance*. Previously unknown or unanticipated re-emissions *after issuance of CORCs* are termed reversals, and are accounted for via a procedure described in the Puro Standard General Rules[41] (see section 4.3 and section 9.7).

In the case of Marine Anoxic Carbon Storage, the term losses conservatively refers to CO_2e that cross the chemocline. Therefore, the dissolution of solid carbon into the surrounding water

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[40] Available at the Puro Standard Document Library.

[41] Available in the Puro Standard document library.

masses is not considered as a loss, as long as the mobile carbon and relevant GHG species remain below the chemocline for a minimum of 200 years (see section 4.3 and section 9.5). The total loss arises when biomass decomposes into more mobile components such as DIC, CH_4, and N_2O. The percentage of these unoxidized gases that is mixed across the chemocline over the certification period accounts for the total carbon loss. In anoxic basins the losses due to decomposition and mixing are expected to be negligible over the 200-year storage period.

6.3.1. The CO_2 Removal Supplier shall quantify the total carbon loss.. For the purposes of this methodology, loss is defined as CO_2, CH_4, or N_2O that is released from the ocean storage site that then likely crosses the chemocline over the 200 year storage period.

6.3.2. The total re-emissions due to loss (C_{loss}) shall be calculated as follows:

$$C_{loss} = (CO_{2,loss} + CH_{4,loss} + N_2O_{loss}) * 10^{-6} \tag{6.2}$$

Where:

$$CO_{2,loss} = M_{\% \, loss} * \int_0^t CO_{2,total}(t)\ dt + (1 - e^{-k_{CH4}*t}) * M_{\% \, loss} * \int_0^t CH_{4,total}(t)\ dt \tag{6.3}$$

$$CH_{4,loss} = R_{CH_4} e^{-k_{CH4}*t} * M_{\% \, loss} * \int_0^t CH_{4,\, total}(t) dt \tag{6.4}$$

$$N_2O_{loss} = R_{N_2O} e^{-k_{N_2O}*t} * M_{\% \, loss} * \int_0^t N_2O_{total}(t) dt \tag{6.5}$$

Variable	Description	Unit
C_{loss}	Total mass of GHGs emissions that cross the chemocline after 200 years.	tCO_2e
$CO_{2,loss}$	CO_2e released as DIC or CO_2e produced from oxidized methane at the storage site during the 200 year storage period.	gCO_2e
$CH_{4,loss}$	CO_2e equivalent of unoxidized methane released from the storage site during the 200 year storage period using a global warming potential of 27.0.	gCO_2e
N_2O_{loss}	CO_2e equivalent of unoxidized nitrous oxide released from the storage site during the 200 year storage period using a global warming potential of 273.	gCO_2e
t	Storage period.	years
10^{-6}	Tonne to gram conversion.	t/g

Variable	Description	Unit
$CO_{2,total}$	Total DIC produced from sequestered biomass based upon bottle incubations (rule 9.4.4).	g/year
$M_{\%,\,loss}$	Modeled cumulative percent loss due to mixing (rule 9.5.1) during the 200 year storage period.	%
dt	Change over 200 year storage period.	years
k_{CH4}	The basin specific oxidation rate of CH_4. In the Black Sea k ≈ 0.055/yr[42].	/ year
$CH_{4,total}$	Total CH_4 produced from sequestered biomass based upon bottle incubations (rule 9.4.5).	g/year
R_{CH_4}	CH_4 conversion for CO_2e equivalence.	Unitless
R_{N_2O}	N_2O conversion ratio for CO_2e equivalence.	Unitless
k_{N_2O}	The basin specific reduction rate of N_2O.	/ year
N_2O_{total}	Total N_2O produced from sequestered biomass based upon bottle incubations (rule 9.4.5).	g/years

6.3.3. The CO_2 Removal Supplier shall quantify the total amount of CO_2e released over the 200-year storage period by monitoring decomposition products and rates through incubation experiments (see section 9.4) and by modeling circulation timescales at the site of deployment (see section 9.5).

6.3.4. The CO_2 Removal Supplier shall quantify the basin specific methane oxidation rates, k_{CH4}, below the chemocline through headspace equilibration measurements such as those outlined in (Reeburgh, 2007), isotopic analysis (Kawagucci et al., 2021), other similar analysis, or published literature.

6.3.5. The CO_2 Removal Supplier shall quantify the basin specific nitrous oxide oxidation rates, k_{N_2O}, below the chemocline through isotopic analysis outlined in (Santoro et al., 2020), other similar analysis, or published literature.

6.3.6. The CO_2 Removal Supplier shall annually retrieve a subset of the deployed biomass following requirements set in rule 9.6.7 and measure the carbon content according to rule 6.1.4 for the duration of the CO_2 Removal Activity prior to storage site closure and post-closure monitoring. In cases where the measured value for carbon loss

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[42] See Reeburgh et al. 1991.

differs from the calculated value (see rule 6.3.2), the more conservative value shall be used.

6.3.7. In the case of an intentional loss due to monitoring operations, the CO_2 Removal Supplier shall quantify the mCO_2e_i directly through measurement (e.g. in the context of recovering a batch of biomass for monitoring purposes).

6.3.8. The CO_2 Removal Supplier shall update the quantification of carbon losses annually. The data shall be made available to the Auditor.

6.3.9. The CO_2 Removal Supplier shall calculate the CO_2e equivalence based on the IPCC AR6[43] global warming potential values for 100 year time horizons (GWP100).

REMARK ON CALCULATED AND MEASURED CARBON LOSS: Carbon loss must be calculated (see rule 6.3.2) based on incubation experiments (see section 9.4), modeled mixing regimes (see section 9.5) and subsequently validated with in-field measurements from biomass retrieval (see section 9.6). The following two case examples define the conditions for when to update the CORC calculation.

Case 1. The calculated carbon loss (C_{loss}) based upon incubation experiments and mixing models results in a 2% of CO_2e loss over a 200-year storage period. After retrieving a subset of the deployed biomass, the measured C_{loss} equals 5%. In this case, the CO_2 Removal Supplier shall update their CORC calculation to use the in-field measured value.

Case 2. The calculated carbon loss (C_{loss}) based upon incubation experiments and mixing models results in a 2% of CO_2e loss over a 200-year storage period. After retrieving a subset of the deployed biomass, the measured C_{loss} equals 0.5%. In this case, the CO_2 Removal Supplier shall use the calculated value for their CORC calculation.

As both laboratory incubations and data collected from the in-field biomass retrieval may evolve over time, it is important to update the CORC calculation annually based upon the most conservative estimate of carbon loss.

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[43] Intergovernmental Panel of Climate Change (IPCC) Sixth Assessment Report 2020 (AR6), Section 7.6.1.1 Radiative Properties and Lifetimes.

7. Determination of Project Emissions

7.1. General life cycle assessment requirements

7.1.1. The CO_2 Removal Supplier shall conduct a life cycle assessment (LCA) study for the carbon removal project to quantify the total project emissions from all associated activities within the project's defined boundaries.

7.1.2. The LCA study shall adhere to the general principles defined in ISO 14040/44[44] and the Puro Lifecycle Assessment Guidance for Suppliers.[45]

7.1.3. As part of the LCA study, the CO_2 Removal Supplier shall develop life cycle inventory (LCI) models with the goal of accounting for operational and embodied emissions separately. The LCI models shall identify and quantify emissions from all project-related activities.

7.1.4. The LCA study shall include a report which explains and justifies the data and modeling choices. Supporting calculation files shall be provided to ensure transparency and reproducibility of the CORC calculations..

7.1.5. The LCA study shall quantify the climate impact of the CO_2 removal activity, using 100-year global warming potentials (GWP100) for greenhouse gases, as defined in the IPCC AR6[46]. Other environmental impact categories may be included but are not required.

7.1.6. The CO_2 Removal Supplier shall use relevant emission factors in the development of the LCI models, that:

- Account for major greenhouse gases (fossil CO_2, biogenic non-renewable CO_2, CH_4, N_2O).
- Include a full-scope of emissions (i.e., including upstream and downstream emissions, or so-called supply chain emissions, as opposed to emission factors used for greenhouse gas inventory purposes).
- Reduce bias by avoiding or reducing lack of representativeness of data (see section 10.2).

7.1.7. For transparency, interpretability and auditing purposes (i.e., verification of claims), the climate change impact calculated in the LCA shall be disaggregated into i) contributions from different life cycle stages of the CO_2 removal activity described in

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[44] ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework and ISO 14044:2006 Environmental Management - Life cycle assessment - Requirements and guidelines

[45] Available in the Puro Standard document library.

[46] Intergovernmental Panel of Climate Change (IPCC) Sixth Assessment Report 2020 (AR6), Section 7.6.1.1 Radiative Properties and Lifetimes.

figure 7.1 and table 7.1, as well as the ii) contributions of major greenhouse gases (including total climate impact in tCO_2e but also the specific contributions of CO_2, CH_4, N_2O and other greenhouse gases to this total climate impact).

a. The CO_2 Removal Supplier may use the rules under section 7.6 to define and justify which activities in the Life Cycle Inventory (LCI) are deemed irrelevant or negligible for this calculation process and thus reduce the burden in the data collection process.

b. Reducing the scope of calculation shall be justified in the LCA report and calculation files.

7.1.8. Public disclosure of LCA results in the Puro Registry shall balance confidentiality and transparency. Verified results may be aggregated to protect sensitive or licensed information, in consultation with the Issuing Body. However, the aggregation shall adhere the Puro Life Cycle Assessment Guidance for Suppliers[47], mandating disclosure of level 1 and level 2 contributions, as well as certain level 3 contributions (e.g., direct land use change emissions) as further defined in table 7.1 and in section 7.7.

7.1.9. The LCA cutoff criteria may be used when allocating GHG emissions associated with waste, recycled or secondary resources used as input to the activity, such as recycled steel or plastic.[48] Specifically, the environmental burdens from production of secondary resources may be excluded from the system boundary, but the supply, transformation and handling of the secondary resources shall be included. For more details, see section 7.6.

7.1.10. The CO_2 Removal Supplier shall coordinate data collection and LCA modeling with any external operators[49] to the level necessary to ensure compliance with this methodology and the Puro Standard requirements.

7.2. Methodology-specific life cycle assessment requirements

7.2.1. The functional unit of the LCA shall be “the durable and safe deployment of 1 metric tonne of biomass in an anoxic basin”. Results of the LCA are expressed per metric tonne of carbon dioxide captured, transported, and deployed durably and safely in an anoxic basin.

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[47] Available in the Puro Standard document library.

[48] Description of the cut-off system model is available on the website of the ecoinvent life cycle database.

[49] Data required for performing the LCA of a Marine Anoxic Carbon Storage activity originates from multiple parties, and most importantly from the biomass sourcing operator, the logistics operators, and the biomass deployment operator. See also rule 3.3.5.

7.2.2. The CO_2 removal supplier shall define the **spatial boundaries** of the LCA, including the areas from which biomass is sourced, processed, and transported for durable and safe deployment in an anoxic basin.

7.2.3. The CO_2 removal supplier shall define the **time boundaries** of the LCA, including:

a. Specifying the planned duration and contribution of the biomass sourcing, processing, and deployment activities as they relate to the Monitoring Period.

b. Disclosing both the technical design lifetimes, as well as any useful lifetimes of the Production Facility infrastructure and/or equipment, because useful lifetimes may be shorter than technical design lifetimes. Those lifetimes may affect how embodied emissions are amortized (rule 7.5.4).

7.2.4. The **activity boundaries** that shall be included in the LCA study to represent the carbon capture through biomass sourcing, the processing of biomass, and the safe and durable deployment of biomass as shown in figure 7.1 The LCA report shall include a project-specific process-flow diagram that details each of the main unit processes defined in figure 7.1 These **unit processes** defining the scope and completeness of the LCI models (see also rule 7.2.7).

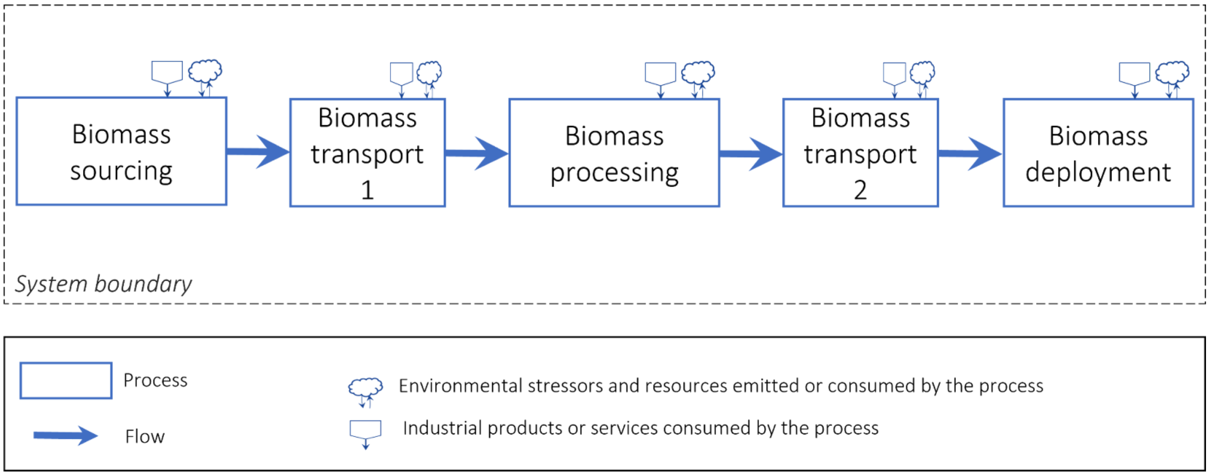

Figure 7.1. System boundaries.

7.2.5. The **system boundary is set cradle-to-grave** and shall include a full scope of emissions from the unit processes in accordance with section 7.3.

7.2.6. Whenever possible, the LCA shall provide disaggregated information on the major greenhouse gases emissions from each unit process.

7.2.7. The three main unit processes or stages are briefly described below and represented in figure 7.1 and detailed in table 7.1:

a. Biomass Sourcing: The process by which biomass may be produced or supplied to be fit for the purpose of biomass deployment. Requirements for eligible biomass are described in section 3.6.

b. Biomass Processing: The process by which biomass is prepared for deployment. Requirements for biomass processing are described in section 3.7.

c. Biomass Deployment: The process by which the processed biomass is durably and safely deployed in an anoxic basin, including its monitoring post-deployment. Requirements for biomass deployment are described in section 3.7.

d. Biomass Transport: The process(es) by which biomass (or any other biomass-derived products resulting from processing, e.g. biochar) is transported from sourcing and processing to deployment. It may be divided into two steps: sourcing to processing and processing to deployment.

7.3. Scope of project emissions

7.3.1. A full scope of emissions implies accounting for the emissions of infrastructure and equipment requirements, material and energy consumption, as well as treatment of waste materials shall be included (i.e., upstream and downstream activities).

7.3.2. Project emissions shall be specified and accounted for in the LCA under two types: operational and embodied emissions, and calculated as follows:

$$E_{Proj} = E_{Ops} + E_{Emb} \tag{7.1}$$

Variable	Description	Unit
E_{Proj}	Lifecycle emissions associated with the operation of the project during the monitoring period and the amortized portion of the lifecycle's embodied emissions.	tCO_2e
E_{Ops}	Lifecycle emissions associated with the operation of the project during the monitoring period.	tCO_2e
E_{Emb}	Sum of lifecycle emissions associated with infrastructure and equipment assets and direct land use changes.	tCO_2e

7.4. Quantification of operational emissions

7.4.1. **Operational emissions** (E_{Ops}) include the greenhouse gas emissions associated with the energy used to operate facilities, machinery, or other types of infrastructure as well as consumable material inputs (e.g., biomass, packaging) and transportation related emissions (e.g., biomass sourcing or biomass deployment) necessary for the carbon removal activity, and shall be measured by the unit processes described in rule 7.2.7. These emissions shall be measured and reported during the monitoring period as follows:

$$E_{Ops} = E_{biomass} + E_{processing} + E_{deployment} + E_{transport} \tag{7.2}$$

Variable	Description	Unit
$E_{Biomass}$	Operational lifecycle emissions associated with biomass sourcing incurred during the monitoring period.	tCO_2e
$E_{processing}$	Operational lifecycle emissions associated with biomass processing incurred during the monitoring period.	tCO_2e
$E_{deployment}$	Operational lifecycle emissions associated with biomass deployment incurred during the monitoring period.	tCO_2e
$E_{transport}$	Operational lifecycle emissions associated with the transport of biomass from sourcing and processing to deployment incurred during the monitoring period.	tCO_2e

7.4.2. For the stage Biomass Sourcing ($E_{Biomass}$) the CO_2 Removal Supplier shall account for the emissions associated with the harvesting, transport, and/or collection of eligible biomass.

7.4.3. For the stage Biomass Processing ($E_{processing}$), the CO_2 Removal Supplier shall account for the emissions associated with processing of eligible biomass to a state that may be used for its final deployment (e.g., chipping and packaging).

7.4.4. For the stage Biomass Deployment ($E_{deployment}$), the CO_2 Removal Supplier shall account for the emissions associated with deployment of eligible biomass in open waters. This shall cover any material assistance in the method of sinking the biomass to the desired depth for durable and safe deployment, as well as the monitoring of reversal and environmental risks as defined in section 4.

7.4.5. For transportation of biomass between project stages ($E_{transport}$), the CO2 Removal Supplier shall account for the emissions of all transport and hub operation activities as they relate to the shipment of eligible biomass from the sourcing site to the processing facility and then to the final deployment site. This stage shall be calculated in accordance with ISO 14083:2023[50] and using the GLEC Framework v3.[51] In addition, material and chemical use, and treatment of any waste arising during transportation should be included.

7.5. Quantification of embodied emissions

7.5.1. **Embodied emissions** (E_{Emb}) represent the carbon emitted in the fabrication, construction, maintenance, and demolition of infrastructure and/or equipment assets (E_{infra}), and in direct land-use conversion (E_{dLUC}) associated with the Production Facility and supporting infrastructure (when applicable). Embodied emissions are calculated as follows:

$$E_{Emb} = E_{infra} + E_{dLUC} \tag{7.3}$$

Variable	Description	Unit
E_{Emb}	Sum of lifecycle emissions associated with infrastructure and equipment assets and direct land use changes.	tCO_2e
E_{infra}	Lifecycle emissions associated with infrastructure and equipment assets.	tCO_2e
E_{dLUC}	Lifecycle emissions associated with direct land use changes.	tCO_2e

7.5.2. Embodied emissions shall account for the life cycle emissions of infrastructure and/or equipment (E_{infra}) as follows:

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[50] ISO 14083:2023 Greenhouse gases - Quantification and reporting of greenhouse gas emissions arising from transport chain operations.

[51] Smart Freight Centre 2023. Global Logistics Emissions Council Framework for Logistics Emissions Accounting and Reporting v3.0, revised and updated. ISBN 978-90-833629-0-8.

a. The calculation shall be cradle-to-grave, including all steps from material extraction to waste disposal. For general guidance, refer to EN 15804+A2[52], EN 15978[53] and ISO 21930:2017.[54]

b. Alternatively, recent monetary emission factors (e.g., kg CO_2e per USD spent) may be used as a proxy for estimating embodied emissions based on capital expenditure (CAPEX), provided that such factors are available in the countries where the facilities are built. This approach may be based on an economic input-output life-cycle assessment, or EIO-LCA.

c. The embodied emissions of pre-existing facilities shall not be accounted for in the project's emissions. However, additional embodied emissions associated with the retrofit and maintenance of the retrofitted facilities shall be accounted for.

d. Emissions associated with the maintenance of the Production Facility shall be estimated based on the expected operational lifetime of the asset and limited to the maximum duration of the project set to 15 years based on rule 2.2.4 and the Puro Standard General Rules.[55]

e. The CO_2 Removal Supplier shall keep records of maintenance, improvements, and repair works performed on the infrastructure, and adjust the estimate of the life cycle emissions accordingly.

f. Processes related to the production of vehicles and transport devices are excluded from the embodied emissions calculations, in alignment with the Global Logistics Emissions Council (GLEC) Framework v3.[56]

7.5.3. **Embodied emissions shall account for direct land-use (dLUC) conversion** if land use has been changed for the construction of the Production Facility e.g., from agriculture or forest land to an industrial site. To this end, the following rules shall apply:

a. dLUC emissions shall be considered and included in the LCA when the construction of the Production Facility and its supporting infrastructure results in land conversion.

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[52] EN 15804:2012+A2:2020 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

[53] EN 15978:2012 Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method.

[54] ISO 21930:2017 Sustainability in buildings and civil engineering works - Core rules for environmental product declarations of construction products and services.

[55] Available in the Puro Standard document library.

[56] Smart Freight Centre 2023. Global Logistics Emissions Council Framework for Logistics Emissions Accounting and Reporting v3.0, revised and updated). ISBN 978-90-833629-0-8.

b. dLUC shall be assessed relative to the land area’s historical state prior to the carbon removal project.

c. dLUC emissions shall account any loss of aboveground and belowground biogenic carbon stocks, relative to the historical state of the land. They shall also include any greenhouse emissions arising during the land conversion such as emissions associated with land clearing by fire as these may release significant amounts of methane (CH_4) and dinitrogen monoxide (N_2O).

d. These emissions shall be quantified using default values for land conversion available in the IPCC Guidelines for National Greenhouse Gas Inventories[57] (Tier 1), country-specific values (Tier 2), or data specific to the project (Tier 3), or a jurisdictional approach when available.

e. The calculation may be performed using the following equations:

$$E_{dLUC} = \frac{44}{12} * (CS_B - CS_P) * A + E_{conversion} \tag{7.4}$$

where the carbon stock per unit area is defined as:

$$CS_X = C_{VEG_X} + C_{DOM_X} + SOC_X \tag{7.5}$$

f. The variables C_{VEG_X}, C_{DOM_X}, and SOC_X should be determined using the equations presented in volume 4 of the IPCC Guidelines for National Greenhouse Gas Inventories[58] and the EU Commission decision on guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC[59] (see also subrule d). In addition, Puro.earth will make calculation tools and data available to the CO_2 Removal Supplier.

Variable	Description	Unit
E_{dLUC}	Absolute direct land use change associated with the construction of infrastructure.	tCO_2e
CS_B	Carbon stock per unit area associated with the baseline land use.	$tC\ ha^{-1}$
CS_P	Carbon stock per unit area associated with the project land use.	$tC\ ha^{-1}$

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[57] 2006 IPCC Guidelines for National Greenhouse Gas Inventories and 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

[58] Ibid.

[59] 2010/335/ Commission Decision of 10 June 2010 on guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC (notified under document C(2010) 3751).

Variable	Description	Unit
A	Area of land converted.	ha
$E_{conversion}$	Greenhouse gas emissions associated with the land use conversion activities, e.g. fuel usage for clearing the land, direct emissions from fire.	tCO_2e
CS_X	Carbon stock per unit area with the project or baseline land use, where subscript X indicates the type of land use.	$tC\ ha^{-1}$
C_{VEG_X}	Above and below ground living biomass carbon stock.	$tC\ ha^{-1}$
C_{DOM_X}	Dead organic matter or litter biomass carbon stock.	$tC\ ha^{-1}$
SOC_X	Soil organic carbon stock.	$tC\ ha^{-1}$

7.5.4. **Embodied emissions shall be amortized** against the project's gross carbon captured, as follows:

a. Embodied emissions shall be apportioned over a period of time in line with its first crediting period (5 years, as specified in rule 2.2.4), or the lifetime assumption of the Production Facility, whichever is shorter.

b. After the initial5-year period, recurring maintenance-related emissions shall be amortized annually and included in the CORC quantification.

REMARK ON BACKGROUND INFRASTRUCTURE EMISSIONS: Rules 7.5.1 and 7.5.2 above deal with foreground infrastructure emissions, as opposed to background infrastructure emissions. Background infrastructure refers to, for instance, the infrastructure needed in production of electricity that is consumed by the project. Background infrastructure emissions are already included in the emission factors used in the LCA, with their own modeling of lifetime, maintenance, etc. The CO_2 Removal Supplier does not need to modify or verify those assumptions; background emission factors can be used as-is.

7.6. LCA cut-off criteria

7.6.1. The LCA model and the data collection process may be simplified by excluding negligible environmental impacts and upstream productions according to this cut-off criteria, as follows:

- Using best judgement, the CO_2 Removal Supplier shall develop preliminary LCI models for operational and embodied emissions that cover approximately 100% of the project emissions associated with each of the project stages (i.e., sourcing, processing, deployment).

- Then, the CO_2 Removal Supplier may exclude the emission flows that represent individually less than 0.5% of the total emissions and up to 5% of the preliminary LCI emissions. Afterwards, these emission flows do not need to be included in the final project emissions data collection and calculations.

7.6.2. The 5% cut-off criteria shall be applied consistently and separately to embodied and operational emissions.

7.6.3. Finally, the following elements are considered to be not relevant for the purposes of LCA modeling, and therefore do not need to be included therein:

- Site selection and feasibility studies.
- Monitoring activities other than storage site monitoring.
- Staff transport (e.g., business travel and employee commuting).

7.7. Summary

7.7.1. The CO_2 Removal Supplier shall collect and organize the elements and processes that contribute to the overall project emissions ($E_{project}$), including both embodied and operational emissions) according to Puro Lifecycle Assessment Guidance for Suppliers[60]. These elements should be organized into the levels of information described in table 7.1 and in subrules a and b:

a. The LCA results shall be provided in a disaggregated, exhibiting the contributions of each main stage (level 1) and substage (level 2). Each sub-stage can be further divided into relevant contributions (level 3)for each project type. If a contribution is deemed irrelevant or equals zero, the CO_2 Removal Supplier shall provide a clear justification based on the cut-off criteria defined in section 7.6.

b. The CO_2 Removal Supplier shall publicly disclose in the Puro Registry, as part of an Output Audit, at least the contributions marked with an asterisk (*) in table 7.1.

Table 7.1. Stages that shall be included in the life cycle assessment of the removal activity (see rule 7.2.7).

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[60] Available in the Puro Standard document library.

Main stages Level 1 contributions	Sub-stages Level 2 contributions	Further sub-stages Level 3 contributions	Comment
$E_{biomass}$	*Operational emissions of biomass sourcing	Supply (e.g., harvest/collection)	Either fully attributed to CORCs or partly allocated to CORCs.
$E_{processing}$	*Operational emissions of biomass processing for deployment	Energy use (heat, electricity, fuel) Material use Conversion	Third-level contributions may be split in sub-stages as relevant for each supply-chain.
	*Embodied emissions of biomass processing facility	Construction, maintenance, and disposal of infrastructure and equipment *Direct land use change (dLUC)[61]	Maintenance can be demonstrated to be neglectable, in annual reporting
$E_{deployment}$	*Operational emissions of biomass deployment *Embodied emissions of deployment/monitoring infrastructure	Energy use (heat, electricity, fuel) Material use Waste treatment	Monitoring of deployment sites is included.
$E_{transport}$	*Transport from biomass sourcing site to processing facility, and to the deployment site.	Energy use (heat, electricity, fuel) based on well-to-wheel transport mode. Material use	

* The contributions marked with an asterisk (*) must be publicly disclosed in the Puro Registry as part of the annual Output Audit (see rule 7.7.1 b).

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[61] Emission contributions associated with direct land use change are described in rule 7.5.3.

8. Determination of indirect emissions (leakage)

The concept of indirect emissions, also termed leakage[62] in the Puro Standard General Rules[63], represent a possible increase or decrease in greenhouse gas emissions or removals that is outside of the system boundaries of the activity. For the purpose of CORC quantification, only the increase in GHG emissions or decrease in carbon stocks are quantified, and the removal activity is penalized if those indirect effects are not avoided or mitigated. Net positive effects are not included in the quantification of CORCs.

Addressing the risks of indirect emissions is crucial to ensuring the integrity of carbon removal interventions. By identifying possible sources of indirect emissions at the project level, the CO_2 Removal Supplier can design and implement strategies to minimize leakage and maximize the positive climate impact of their initiatives. This section defines which leakage sources are relevant to consider for Marine Anoxic Carbon Storage activities, following the three-step approach defined in the Puro Standard General Rules[64]:

1. Identify and characterize sources of indirect emissions.
2. Mitigation of indirect emissions.
3. Quantify unmitigated indirect emissions.

8.1. Identification and characterization of indirect emissions

Unintended consequences, such as indirect emissions or leakage, are present in all types of activities, including CO_2 removal projects. The Core Carbon Principles (CCP) Assessment Framework and Procedure of the Integrity Council for the Voluntary Carbon Markets (ICVCM) defines four types of leakage / indirect emissions: i) activity shifting leakage, ii) ecological leakage, iii) market leakage, and iv) upstream/downstream emissions[65]. Since upstream and downstream emissions are accounted for as part of the project emissions (see section 7), this methodology focuses on the following key sources of indirect emissions: 1) market and activity-shifting leakage, and 2) ecological leakage.

Market and activity-shifting leakage occur when the activity impacts supply or demand for emissions-intensive products or services, thereby increasing or decreasing emissions elsewhere (market leakage), or when the mitigation activity displaces emissions to other locations shifting emissions to locations not targeted, or emissions not monitored, by the activity (activity shifting leakage). In the context of a Marine Anoxic Carbon Storage activity, biomass selected for storage might previously have been used for other purposes, such as bioenergy production,

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[62] Throughout this section, 'leakage' exclusively refers to indirect emissions.

[63] Available in the Puro Standard document library.

[64] Ibid.

[65] Core Carbon Principles Assessment Framework and Procedure, Section 4: Assessment Framework.

livestock bedding, or soil amendment. Diverting this biomass could lead to substitutes like fossil fuels, inorganic fertilizers, or increased logging, all of which may increase GHG emissions elsewhere. Similarly, if timber or agricultural residues with economic value are used for ocean storage, reduced availability could drive increased harvesting, agricultural expansion, or other market responses, resulting in additional emissions.

Ecological Leakage arises when the activity indirectly affects emissions in connected ecosystems. In the context of an Marine Anoxic Carbon Storage approach, biomass removal can indirectly alter GHG fluxes in ecosystems beyond the project boundaries. For instance, large-scale biomass extraction could disrupt local ecosystems by reducing organic inputs to wetlands or rivers, potentially triggering carbon losses from soils or water systems. Such disturbances could also affect nutrient cycling and hydrological dynamics, leading to unintended emissions of CO_2 or CH_4.

The Puro Biomass Sourcing Criteria[66] have been designed to ensure the sustainability of the biomass feedstock used for storage and thus minimize the risk of indirect emissions. Nevertheless, the CO_2 Removal Supplier needs to provide project-specific evidence to prove the sustainability of the stored biomass (see also section 3.8).

8.1.1. For purpose-grown biomass, whether on forested or agricultural land, the CO_2 Removal Supplier shall ensure that the historical use or fate of the land used is documented. The supplier shall assess the leakage relative to this historical baseline including:

   a. Any direct land-use change, including losses of aboveground and belowground biogenic carbon stocks and greenhouse gas emissions resulting from land conversion.
   b. The production and use of crops or products that are no longer produced on the land, including their potential replacements.

8.1.2. For residual biomass, the CO_2 Removal Supplier shall ensure that its historical use or fate is documented with a reasonable estimate. The supplier shall assess the indirect emissions relative to this historical baseline. This assessment shall include any prior use of the biomass for bioenergy services, such as combustion for heat or power, and the need for replacement by alternative energy sources.

8.1.3. The CO_2 Removal Supplier shall identify the key risks of indirect emissions in all steps of the project boundaries (see section 7.2). The identification may be made in a manner similar as suggested in table 8.1.

8.1.4. The CO_2 Removal Supplier shall assess all sources of leakage that are identified in this methodology for the removal activity and the baseline scenario utilized. Each indirect emission source shall be either mitigated according to the rules in section 8.2, or

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[66] Available in the Puro Standard document library.

quantified according to the rules in section 8.3. Furthermore, the CO_2 Removal Supplier shall account for any unmitigated indirect emissions in the quantification of CORCs according to the rules in section 5.3.

Table 8.1. Types and possible sources of indirect emission risks. Note, that the list is non-exhaustive and for guidance purposes only.

Indirect emission type	Biomass sourcing	Biomass processing	Biomass deployment
Market and activity shifting	Displacement of biomass previously used for bioenergy, livestock bedding, or soil amendments.	Demand for specialized equipment or fuels for processing could increase emissions elsewhere.	The use of ships for biomass deployment may lead to displacement effects, such as the need for additional vessels or the reliance on less efficient ships for fishing or cargo transport. .
	Increased demand for economically valuable biomass (e.g., timber) drives logging or agricultural expansion.	Indirect land-use (iLUC) change driven for shift in supply of biomass residues with economic value.	Increased demand for shipping biomass drives the increase of road transport for other goods.
Ecological	Biomass removal disrupts nutrient cycling or hydrological processes in ecosystems (e.g., wetlands, forests).	Emissions from waste/byproducts generated during processing could alter local ecosystem dynamics.	Large-scale biomass deployment alters local ecosystem carbon dynamics (e.g., changes in hydrology or organic input in water bodies).

8.2. Mitigation of indirect emissions

The mitigation of a particular source of indirect emissions refers to the process of demonstrating that it has no significant effect on the overall carbon balance of the project. In this methodology, mitigation of indirect emissions relies on a combination of system-level measures and supplier-level measures. In other words, the CO_2 Removal Supplier may demonstrate that an identified source of indirect emissions has no significant effect on the project by showing that specific system-level conditions apply within the project area (e.g., biomass characteristics, ecosystem dynamics, and logistical arrangements) and by implementing supplier-level actions (e.g., sustainable sourcing and ecosystem protection measures) whenever relevant.

When the requirements set in this section are met, the emissions from the corresponding indirect emission source can be set to zero in the CO_2 removal quantification. In some cases, successfully demonstrating the mitigation of a leakage source is a requirement for project eligibility under this methodology.

Mitigation of ecological indirect emissions

8.2.1. The CO_2 Removal Supplier shall assess ecological leakage sources during the project design phase as part of an Environmental Impact Assessment (EIA) study (see rule 4.4.3) or through a standalone assessment. The following procedure shall be applied to mitigate ecological leakage arising from potential negative effects on nearby marine and coastal ecosystems surrounding the areas where facilities are constructed or biomass is deployed:

a. If the assessment concludes that nearby ecosystems would not be negatively affected, this leakage source is considered mitigated and can be set to zero in the CO_2 removal quantification. Otherwise, the project shall perform an ex-ante quantification of the loss of carbon stocks and emission of greenhouse gases, which shall then be included in the quantification of CO_2 removal. The ex-ante quantification shall use either methods derived from the IPCC Guidelines for National Greenhouse Gas Inventories[67] or site-specific quantification approaches.

b. If the assessment concludes that nearby marine or coastal ecosystems would be negatively affected but quantification is not possible, the project is not eligible in its current design. However, the project design, including construction or deployment plans, may be revised to meet the eligibility requirements (see section 3).

c. If the assessment concludes that nearby ecosystems would not be negatively affected but subsequent events or grievances demonstrate otherwise, penalties shall apply retrospectively following the Puro Standard General Rules[68] for reversals.

8.2.2. The following procedure shall be applied to mitigate ecological leakage related to potential negative effects on ecosystems at biomass sourcing sites:

a. The CO_2 Removal Supplier shall assess this source of indirect emissions as part of biomass procurement planning and the eligibility assessment of

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[67] 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories — IPCC.

[68] Available in the Puro Standard document library.

biomass for each Output Audit, following the latest version of the Puro Biomass Sourcing Criteria.[69]

b. The Puro Biomass Sourcing Criteria[70] are considered sufficient to ensure that biomass sourcing will not significantly disrupt local marine or coastal ecosystems, including hydrodynamics, sediment dynamics, or biodiversity. This assurance is supported by sustainability criteria for biomass feedstocks, particularly those derived from purpose-grown sources or forest residues.

c. If the biomass feedstock is demonstrated to meet the eligibility criteria, this leakage source is considered mitigated and can be set to zero in the CO_2 removal quantification.

d. If the assessment concludes that nearby ecosystems would not be negatively affected but subsequent events or grievances demonstrate otherwise, penalties shall apply retrospectively following the Puro Standard General Rules[71] for reversals.

Mitigation of indirect emissions due to market or activity shifting

8.2.3. The CO_2 Removal Supplier shall assess market and activity-shifting leakage during the project design phase, considering potential shifts in economic or resource-use activities resulting from biomass sourcing or deployment. This assessment shall include, but is not limited to:

a. Market displacement risks: If the biomass feedstock used in the project has alternative high-value applications (e.g., energy generation, agricultural amendments), the project shall demonstrate that its use in the project does not significantly disrupt these markets or lead to increased emissions elsewhere.

b. Activity shifting risks: If biomass sourcing or project activities result in changes to resource use or economic activities in other regions (e.g., displacement of land use, increased harvesting elsewhere), the project shall demonstrate that such shifts do not lead to significant indirect emissions.

c. If the assessment concludes that market or activity-shifting risks are mitigated to a level where they do not significantly impact the project's carbon balance, this leakage source is considered mitigated and can be set to zero in the CO_2 removal quantification.

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[69] Available in the Puro Standard document library.

[70] Ibid.

[71] Ibid.

d. If significant market or activity shifting leakage is identified and cannot be mitigated, the project shall:

- Perform an ex-ante quantification of the resulting emissions, which shall then be included in the CO_2 removal quantification, or
- Redesign the project to address these risks and meet eligibility requirements.

e. If an assessment concludes that market or activity-shifting effects were mitigated, but subsequent evidence (e.g., independent audits, grievances) reveals otherwise, penalties shall apply retrospectively in accordance with the Puro Standard General Rules[72] for reversals.

8.3. Quantification of non-mitigated indirect emissions

8.3.1. The total greenhouse gas emissions due to negative ecological, market, and activity-shifting indirect emissions resulting from the Marine Anoxic Carbon Storage activity shall be calculated as follows:

$$E_{indirect} = E_{ECO} + E_{MAS} \tag{8.3}$$

Variable	Description	Unit
$E_{indirect}$	Total GHG emissions due to unmitigated negative leakage resulting from the Activity.	tCO_2e
E_{ECO}	Total GHG emissions due to unmitigated negative ecological leakage resulting from the Activity.	tCO_2e
E_{MAS}	Total GHG emissions due to unmitigated negative market and/or activity-shifting effects resulting from the Activity.	tCO_2e

Quantifying negative ecological leakage (E_{ECO})

8.3.2. Ex-ante quantification: When ecological leakage sources are identified in the Environmental Impact Assessment (EIA) or a standalone assessment, the emissions impact shall be calculated using:

- Methods derived from the latest version of the IPCC Guidelines for National Greenhouse Gas Inventories[73], or

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[72] Available in the Puro Standard document library.

[73] 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories — IPCC.

- Site-specific quantification approaches supported by robust and transparent data.

8.3.3. Post-implementation adjustments: If subsequent events reveal ecological impacts not identified during the project design phase, emissions from these impacts shall be quantified and included retroactively.

8.3.4. Emissions shall be reported in units of tCO_2e, with all assumptions, data sources, and calculations documented transparently and subject to approval by the Issuing Body.

Quantifying negative market and/or activity shifting leakage (E_{MAS})

8.3.5. The CO_2 Removal Supplier shall estimate the emissions impact of market displacement by analyzing alternative uses for biomass feedstocks and quantifying any additional emissions generated due to resource competition.

8.3.6. The CO_2 Removal Supplier shall identify and quantify emissions resulting from activity shifts using lifecycle assessments, peer-reviewed studies, or equivalent methods.

8.3.7. The total indirect emissions due to market and activity shifting shall include the sum of all identified and quantified impacts, expressed in tCO_2e, with all assumptions, data sources, and calculations documented transparently and subject to approval by the Issuing Body.

9. Monitoring Requirements

9.1. Overall principles

Monitoring, measuring, and reporting the performance of carbon removal activity is essential to ensure that the requirements prescribed in this methodology have been fulfilled. Due to the complexity of the marine ecosystems, substantial risks involved with a poorly chosen or monitored storage site and the yet evolving international and national legal frameworks related to mCDR technologies, it is paramount that the monitoring plan is designed in a robust manner, based on up-to-date scientific knowledge. As a design principle, this methodology aims to rely on —rather than duplicate — local regulations to ensure safe and operationalizable results.

In practice, the monitoring, measuring, and reporting procedures followed in this methodology are the responsibility of the CO_2 Removal Supplier. The verification of the information submitted by the CO_2 Removal Supplier is by a recognized third-party auditor. Finally, the issuance of CO_2 Removal Certificates (CORCs) as a result of the project's performance is the responsibility of the Issuing Body.

A key step in verifying the monitoring data consists of inspection of relevant evidence and corroborating calculations by the auditor. Depending on the requirement, the pieces of evidence themselves can take various forms, such as data records, permits, official documents, or other relevant information which demonstrate compliance with the requirements, and enable claims to be verified. If the auditor concludes, based on the evidence presented, that the carbon removal activity is compliant with the requirements of this methodology, the validated amount of CORCs can then be issued to the CO_2 Removal Supplier.

Note that while this section contains several overarching requirements on the data collection, monitoring, and reporting requirements concerning the Marine Anoxic Carbon Storage activity, additional requirements on these topics are included in other sections of this methodology as well.

While the resolutions or accuracies of individual tools in the monitoring suite may vary, it is the cumulative data from the monitoring approach as a whole that yields the necessary level of detail to determine with a very high degree of certainty that the biomass is effectively stored; that groundwater, surface resources, and the environment are being protected; and that any irregularities can be detected and addressed before they escalate.

9.2. Monitoring Plan

9.2.1. The CO_2 Removal Supplier shall prepare a **Monitoring Plan** to assess the performance of the carbon removal activity by

a. ensuring the conformity of the project with the eligibility requirements (section 3);

b. monitoring environmental and social impacts in support of SDGs (section 3.10) and safeguarding against identified environmental and social risks (section 4);

c. measuring the project's carbon sequestration and GHG emissions (section 5, section 6, section 7 and section 8); and

d. verifying the permanence of the deployed biomass and reporting of any reversal events (section 9, section 10 and section 11).

It is important to note that these goals can be achieved through several routes, and multiple monitoring techniques can often be utilized for the same parameter.

9.2.2. As different approaches might be preferred in different situations, the CO_2 Removal Supplier shall always consider site-specific needs and choose a suite of monitoring technologies that enable the verification of the quantity and location of the deployed biomass at the levels of resolution and certainty required by the applicable local regulations and this methodology, and in accordance with 10. Measuring Requirements, in particular, the quality control requirements presented in section 10.7.

9.2.3. The CO_2 Removal Supplier shall submit the Monitoring Plan with the project description for its validation during the Production Facility Audit, as described in the Puro Standard General Rules.[74]

9.2.4. The Monitoring Plan shall describe the procedures by which the CO_2 Removal Supplier will collect data and evidence in accordance with ISO 14064-2:2019[75] and Puro Standard requirements.[76]

9.2.5. The Monitoring Plan shall include the following:

a. purpose of monitoring (rule 9.2.1);

b. project boundaries and monitoring system diagram;

c. description of the monitoring practices based on their purpose (e.g., conformity, GHG measurement, risk assessment, etc.);

d. monitoring frequency;

e. monitoring roles and responsibilities of the project personnel;

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[74] Available in the Puro Standard document library.

[75] ISO 14064-2:2019 Greenhouse gases, Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emissions reductions or removal enhancements.

[76] Available in the Puro Standard document library.

f. data collection plan, including list of parameters and their attributes and data sources (table 10.1);

g. uncertainty assessment and measurement procedures;

h. data quality control (QC) plan;

i. information management system for record keeping and data sharing.

j. definition of threshold values for environmental and social safeguards and follow up procedures for responsible parties involved in the carbon removal activity.

9.2.6. The monitoring system shall include one or several diagrams clearly identifying all points of monitoring and measurement.

9.2.7. The monitoring system may be organized by project stage as summarized in table 9.1.

Table 9.1. Summary of required monitoring and relevant subsections organized by project stage.

Monitoring focus	Sourcing of Biomass	Processing of Biomass	Deployment of Biomass	Post-deployment and storage site closure
Eligibility requirements	Section 3.6 Requirements for biomass eligibility and characterization Section 3.8 Requirements for biomass sustainability and traceability of origin	Section 3.7 Requirements for biomass processing and sinking	Section 3.9 Requirements for storage site eligibility and characterization	n/a
Environmental and social impacts	Section 3.10 Requirements for positive sustainable development goal impacts Section 4.4 Requirements for environmental and social risk	Section 3.10 Requirements for positive sustainable development goal impacts	Section 3.10 Requirements for positive sustainable development goal impacts Section 4.4 Requirements for environmental and social risk	Section 3.10 Requirements for positive sustainable development goal impacts Section 4.4 Requirements for environmental and social risk assessment and management

Monitoring focus	Sourcing of Biomass	Processing of Biomass	Deployment of Biomass	Post-deployment and storage site closure
	assessment and management Section 4.5 Key environmental risks		assessment and management Section 4.5 Key environmental risks	Section 4.5 Key environmental risks
GHG emissions and carbon sequestration	Section 7 Determination of project emissions	Section 7 Determination of project emissions Section 6.1 Carbon stored	Section 7 Determination of project emissions Section 6.3 Carbon losses	Section 7 Determination of project emissions
Reversal risks	n/a	n/a	n/a	Section 9.6 Monitoring for CO_2 release and reversal risks

9.2.8. Unless otherwise specified, all monitoring shall be based on activity data specific to the CO_2 Removal activity and sites of operation (e.g. biomass sourcing/deployment site).

9.2.9. The CO_2 Removal Supplier shall prepare, maintain, and comply with the validated Monitoring Plan for the Marine Anoxic Carbon Storage activity, as further described in subrules a-d.

a. The monitoring plan shall be tailored to the specific characteristics and requirements of all stages (biomass sourcing, processing, deployment, and post-storage closure) within the activity boundary.

b. The monitoring plan shall describe procedures for measuring, calculating and analyzing data and information to ensure that the storage site conforms to expected behavior, and that the deployed biomass remains securely contained. To this end, the monitoring plan shall at least:

- Identify potential vulnerabilities and propose solutions to mitigate recognized vulnerabilities.
- Specify monitoring parameters and define monitoring tasks.

c. The monitoring plan shall cover activities throughout the duration of the Marine Anoxic Carbon Storage activity, including:

  - Baseline data gathering and storage site characterization (pre-deployment period).
  - Biomass sourcing and processing performance in accordance with the corresponding eligibility requirements.
  - Performance of the storage site during operations (deployment and post-deployment period).
  - Closure of the storage site and post-closure monitoring (post-deployment period).

d. The monitoring plan shall be periodically evaluated and updated to ensure that the monitoring practices continue to be appropriate and effective. The evaluation shall include a re-assessment of the site-specific monitoring requirements and risks. For example, updates to the monitoring plan might be necessary due to:

  - Monitoring and site performance data.
  - New scientific knowledge.
  - Improvements in best available technology.

9.2.10. The monitoring plan shall describe how the CO_2 Removal Supplier plans to respond to any significant irregularities in the performance of the monitoring or storage systems during the biomass sourcing, deployment and storage operations (contingency monitoring).

9.3. Monitoring eligibility compliance

9.3.1. The CO_2 Removal Supplier shall comply with the eligibility requirements described in this Methodology and Puro Standard General Rules.[77]

9.3.2. In case of any deviation or non-conformity with the eligibility requirements and validated Production Facility design detected during a monitoring period, the CO_2 Removal Supplier shall notify the Issuing Body and develop a plan to solve the situation at the earliest possible and demonstrate actions to meet the eligibility requirements. The non-conformity with the eligibility requirements may:

a. Impact the verification of the Output of the Production Facility and the corresponding CORC issuance for that period.

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[77] Available in the Puro Standard document library.

b. Require the Issuing Body to suspend the Production Facility in accordance with the Puro Standard General Rules.[78]

9.3.3. The CO_2 Removal Supplier shall prepare a sampling plan to conform with the requirements for biomass eligibility and characterization (section 3.6), specifically following requirements to determine the chemical composition of the sourced biomass (see section 10.5) prior to biomass processing or deployment (see rule 3.6.4 and rule 3.6.5). In particular, the CO_2 Removal Supplier shall determine:

a. The carbon content by drying a statistically representative sample of the biomass according to best practice such as those outlined in (Bell & Siegel, 2022) before processing for CNH analysis with the Pregl-Dumas combustion method (Yargicoglu et al., 2015) or similar analysis.

b. Other chemical components associated with the environmental safeguards by determining *a priori* the ranges and/or thresholds of those chemical elements that need to be monitored to meet regulatory and safety conditions.

9.3.4. The CO_2 Removal Supplier shall ensure that the sampling plan conforms with the requirements set for biomass processing and deployment (see section 3.7), to determine the structural integrity of the sourced biomass prior to deployment.

9.3.5. The CO_2 Removal Supplier shall develop a sampling plan to conform with the requirements for storage site eligibility and characterization (section 3.9), specifically following the requirements to assess the baseline environmental conditions prior to biomass deployment and to detect potential environmental impacts post-deployment (see section 10.5).

9.3.6. The CO_2 Removal Supplier shall keep a record of the documentation that supports the chain of custody of the eligible sources of biomass in accordance with requirements for biomass sustainability and traceability of origin (see section 3.8) and Puro Biomass Sourcing Criteria[79] and make that documentation available for third-party verification upon request.

9.3.7. The CO_2 Removal Supplier shall comprehensively characterize the storage site prior to biomass deployment for two purposes:

a. To evaluate site eligibility (see section 3.9).

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[78] Ibid.

[79] Available in the Puro Standard document library.

b. To establish the environmental conditions of the storage site prior to biomass deployment, referred to as *environmental baseline* (see also rule 9.3.8 and table 9.2).[80]

9.3.8. The CO_2 Removal Supplier shall conduct measurements to establish the environmental baseline included in table 9.2 in a manner which properly accounts for seasonal variability. Measurements shall be conducted at least quarterly for a minimum of one full year before the first deployment within the storage site boundary. Peer-reviewed scientific literature, when available, may be used to supplement the quarterly environmental baseline measurements if the following conditions are met:

a. The published data was taken within the storage site boundary in the last 10 years.

b. At least one of the quarterly environmental baseline measurements shall be taken within one year before the first deployment.

The CO_2 Removal Supplier may deem that certain parameters in table 9.2 are not relevant for their study site. In this case, the CO_2 Removal Supplier shall provide a justification of their omission with evidence from peer-reviewed scientific literature, pending approval by the Issuing Body.

Table 9.2. Required measurements for characterizing the storage site prior to biomass deployment.

Parameter	General purpose	Where to measure
Dissolved oxygen	Site eligibility: <0.03 mg/L (1μM) (rule 3.9.4)	Full water column
NO_2^-+NO_3^-	Site eligibility: <0.004 mg/L (0.1 μM) (rule 3.9.5)	Full water column
Temperature	Long-term monitoring of environmental risks and mixing stability	Full water column
Salinity	Long-term monitoring of environmental risks and mixing stability	Full water column
DIC	Long-term monitoring of environmental risks	Full water column, sediment
Alkalinity	Assessing site geochemistry	Full water column, sediment

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[80] While many of the required environmental priors directly link to eligibility rules and post-deployment monitoring requirements, those that are not directly linked provide information for e.g. understanding the geochemistry of the storage site or unforeseen events.

Parameter	General purpose	Where to measure
Aragonite and calcite saturation state	Long-term monitoring of environmental risks	Full water column, sediment
pH	Long-term monitoring of environmental risks	Full water column, sediment
POC, DOC	Assessing site geochemistry	Full water column, sediment
CH_4	Long-term monitoring of environmental risks and CORC evaluation	Full water column, sediment
N_2O	Long-term monitoring of environmental risks and CORC evaluation	Full water column, sediment
Sulfate	Assessing site geochemistry	Full water column, sediment
Sulfides	Assessing site geochemistry	Full water column, sediment
Site relevant trace metals (e.g. Fe^{2+})	Assessing site geochemistry	Full water column, sediment
Live cell staining	Long-term monitoring of environmental risks	Storage site, sediment
Microbial diversity	Long-term monitoring of environmental risks	Storage site, sediment

9.3.9. Sampling and measurement protocols shall follow those determined by internationally recognized global ocean observing programs whenever possible. These protocols include the most up-to-date versions of:

- GO-SHIP Repeat Hydrography Manual.[81]
- Guide to Best Practices for Ocean CO_2 Measurements.[82]
- Sampling and Sample-handling Protocols for GEOTRACES Cruises.[83]

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[81] GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and Guidelines. IOCCP Report No. 14, IPCO Publication Series No. 134, Updated version 1.1. 2019.

[82] Dickson, A.G., Sabine, C.L. and Christian, J.R. (Eds.) 2007. Guide to Best Practices for Ocean CO_2 Measurements. PICES Special Publication 3, 191 pp.

[83] Sampling and Sample-handling Protocols for GEOTRACES Cruises (Cookbook, version 4.0, 2024).

Parameters listed in table 9.2 that do not have established protocols in the above-listed documents shall use applicable peer-reviewed scientific practices and enclose details of the specific method used in the Monitoring Plan pending approval by the Issuing Body.

9.3.10. The CO_2 Removal Supplier shall define the storage site boundary as a three dimensional space governed by set vertical and horizontal distances from the location of biomass storage complying with the following criteria:

a. The vertical boundary shall be defined as the greatest of 50 m from the seafloor or the extent of the bottom mixed layer as defined in (Huang et al., 2018) or (Chen et al., 2023).

b. The horizontal distance is the radial distance from the center of biomass deployment based on the horizontal mixing for a 10-day period:

$$R = \sqrt{\frac{K_H t}{\pi}} \times 10^{-3} \tag{9.1}$$

Variable	Description	Unit
R	Radial distance	km
K_H	Horizontal eddy diffusivity	m^2/s
t	Mixing timescale of 10 days = 864 000 s	s

REMARK: As an example, the radial distance for the Black Sea, based on K_H of 400 m^2/s (Stanev, 1990) is approximately 10 km. Thus, the storage site is defined as a cylinder with a radius of 10 km and a height of 60-400 m, based on the range of bottom mixed layer depths in the deep Black Sea (Eremeev & Kushnir, 1999), centered at the deployment location.

9.4. Laboratory-based monitoring

While in-field measurements are necessary for monitoring the storage site for environmental and social risks, carbon accounting, and reversal events in the post-deployment stage, many parameters of interest for assessing changes in the storage site may be too small to detect against natural variability, occur in irregular pulses, or be rapidly diluted out of the storage site. Furthermore, scientific research on the long-term impacts of terrestrial biomass storage in anoxic basins are still limited, and the impacts may differ significantly based on the specific storage site geochemistry and the biomass composition. Thus, laboratory-based, long-term experiments are crucial in understanding the magnitude of environmental and social risks and unidentified risks. Laboratory-based experiments will also inform the predicted carbon loss due to biomass decomposition to assess CORC evaluations (see section 6.3) with as much accuracy as possible.

9.4.1. The CO_2 Removal Supplier shall conduct laboratory-based bottle incubation experiments that begin prior to biomass deployment. The incubation setup shall represent in-field conditions as much as possible and shall be conducted using the best peer-reviewed scientific practice available at the time of design, and detailed in the Monitoring Plan (see section 9.2). The incubation results shall be used as a proxy for in-field conditions and shall be utilized to inform CORC evaluations.

9.4.2. The minimum requirements for the bottle incubation experiments are as follows:

a. Incubations shall begin at least 12 months before the first biomass deployment.

b. Incubations shall last at least 2 years or 6 months after peak biomass remineralization.

c. During the incubation period, care shall be taken to maintain stable incubation conditions such as anoxia, temperature and the absence of light.

d. Unless otherwise stated, all incubations shall be performed with seawater from the storage site and a representative sample of the biomass being deployed, referred to as seawater sample and biomass sample, respectively.

e. For the incubation, a mixture of 90% filtered seawater sample and 10% whole seawater sample shall be amended with a standard amount of sediment taken from the storage site to inoculate the incubation solution with a microbial community representative of in-field conditions.

f. The initial dry weight of each biomass sample shall be measured and recorded. The biomass samples shall be reasonably consistent across all bottles.

g. Incubation containers, referred to as bottles, shall not be gas or liquid permeable.

h. Two control groups are required with five replicates for gas measurements and three replicates for other measurements:

    - Bottles with incubation solution (see rule 9.4.2.e) but no biomass sample.
    - Bottles with sterilized incubation solution (see rule 9.4.2.e) and sterilized biomass sample. The CO_2 Removal Supplier shall take care to ensure that the control bottle is fully sterilized.

i. A 16-day pre-trial incubation with surface seawater and biomass sample is strongly recommended if the CO_2 Removal Supplier has not performed any previous decomposition experiments for their specific biomass. For the pre-trial, a doubling frequency sampling scheme shall be used (i.e. Day 1, 2, 4, 8, and 16). This pre-trial allows the CO_2 Removal Supplier to establish proof-of-concept for the incubation experiments and test sampling methods and instrumentation. The biomass decomposition rate assessed from the pre-trial helps inform the sampling frequency of the multi-year incubation experiments and provide an estimate for the maximum possible decomposition rate.

j. Control and experimental bottles for measuring gases and seawater constituents shall be separate with different requirements. For minimum measurements required, see rule 9.4.3.

  - For measuring CH_4 and N_2O, 500 mL bottles or larger shall be used with a standard headspace of known volume for all bottles. There shall be a minimum of five replicates, including for Time 0, but gas sampling may be done continuously without sacrificing bottles.
  - For all other measurements, 500 mL bottles or larger shall be used with no headspace. Bottles shall be sacrificed for sampling at each time point. There shall be a minimum of three replicates per time point, including for Time 0.

k. Sampling frequency throughout the incubation shall be determined by the CO_2 Removal Supplier based on prior information such as the redox state of the storage site, biomass composition, previous experiments, and peer-reviewed scientific literature. In determining the sampling frequency, care shall be taken to catch peak decomposition activity as much as possible. All measurements specified in rule 9.4.3 shall follow the same sampling frequency. The sampling frequency shall be recorded and be made available to the Auditor.

9.4.3. The CO_2 Removal Supplier shall monitor the following parameters during incubations:

a. DIC production and biomass carbon loss, for further details see rule 9.4.4.

b. CH_4 and N_2O production, for further details see rule 9.4.5.

c. Sulfide production, for further details see rule 9.4.6.

d. Carbonate saturation state for calcite and aragonite, for further details see rule 9.4.7.

e. Microbial abundance and functional diversity, for further details see rule 9.4.8.

9.4.4. DIC production and biomass carbon loss shall be monitored during the incubations as further described in subrules a-d.

a. DIC measurements shall be taken from each sacrificial bottle at each time point using industry best practices. Measurement precision for DIC shall be within 1.5 µmol/kg[84], based on the standard deviation of random duplicate analysis from the same bottle.

b. A function of DIC production over time as a function of biomass organic carbon shall be determined based on best fit to the data. DIC production ($CO_2(t)$) shall be in units of g C per g biomass C per year.

c. Carbon in the form of solid biomass ($C_{biomass}$), particulate organic carbon (POC), dissolved organic carbon (DOC), and particulate inorganic carbon (PIC) shall be measured for each sacrificial bottle to check that the carbon budget is balanced to within measurement uncertainty based on the following equation:

$$C_{biomass} = C_{solid} + POC + DOC + PIC + DIC + CH_4 \tag{9.2}$$

d. Determination of $C_{biomass}$ shall be based on an initial analysis of the percent carbon content by dry weight of the biomass sample from at least five replicates.

Variable	Description	Unit
$C_{biomass}$	Initial total carbon content of the biomass.	g C
C_{solid}	Carbon remaining as solid biomass.	g C
POC	Particulate Organic Carbon produced.	g C
DOC	Dissolved Organic Carbon produced.	g C
PIC	Particulate Inorganic Carbon produced.	g C
DIC	Dissolved Inorganic Carbon produced.	g C
CH_4	Methane produced.	g C

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[84] Dickson, A.G., Sabine, C.L. and Christian, J.R. (Eds.) 2007. Guide to Best Practices for Ocean CO_2 Measurements. PICES Special Publication 3, 191 pp. SOP2 - Total dissolved inorganic carbon.

9.4.5. CH_4 and N_2O production shall be monitored during the incubations as further described in subrules a-c.

a. CH_4 and N_2O shall be sampled from the bottle headspace of the non-sacrificial bottles using industry best practices. The volume of the headspace shall be reasonably small and known. The headspace from a single bottle may be sampled to measure both CH_4 and N_2O. Throughout the incubation period, the CO_2 Removal Supplier shall take care to maintain a headspace pressure well above atmospheric pressure. Bottles shall be maintained in a temperature controlled room and kept at the same temperature during sampling. The data shall be made available to the Auditor.

b. A function for CH_4 production over time as a function of biomass organic carbon shall be determined based on best fit to the data. CH_4 production ($CH_4(t)$) shall be in units of g CH_4 per g biomass C per year.

c. A function for N_2O production over time as a function of biomass organic carbon shall be determined based on best fit to the data. N_2O production ($N_2O(t)$) shall be in units of g N_2O per g biomass C per year.

9.4.6. Sulfide production shall be monitored during the incubations as further described in subrules a-c.

a. Total sulfide measurements shall be taken from a sample of sufficient volume of incubated seawater to allow for accurate analysis from each sacrificial bottle using industry best practices.

b. A function for sulfide production as a function of biomass organic carbon shall be determined based on best fit to the data. Sulfide production ($H_2S(t)$) shall be in units of g S per g biomass C per year.

9.4.7. Carbonate saturation state Ω for calcite and aragonite shall be calculated as follows, based on measured Ca^{2+} concentration and CO_3^{2-} concentration determined from DIC and pH measurements from each sacrificial bottle at each time point.

$$\Omega = \frac{[Ca^{2+}][CO_3^{2-}]}{K_{sp}} \tag{9.3}$$

Variable	Description	Unit
$[Ca^{2+}]$	Calcium ion concentration	μM
$[CO_3^{2-}]$	Carbonate ion concentration	μM
K_{sp}	Solubility constant for calcite or aragonite as a function of temperature, salinity, and pressure	μM^2

9.4.8. Microbial abundance in the bottles shall be monitored via live cell staining using cell sorting techniques such as redox sensor green dye (Kalyuzhnaya et al., 2008) BONCAT (Hatzenpichler et al., 2014), or similar. Microbial diversity shall be monitored using eDNA measurements such as 16S.

> **REMARK:** Ideally, the CO_2 Removal Supplier should monitor for the diversity of known and biogeochemically relevant functional traits, such as:
>
> - Sulfate reducers.
> - Methanotrophs.
> - Methanogens.
> - Denitrifiers.
> - Anammox bacteria.
>
> The CO_2 Removal Supplier should determine which metabolic function and microbial groups are expected from a suite of geochemical and biological analysis of the study site.

9.5. Model-based monitoring

In addition to laboratory-based experiments and in-field measurements, site specific ocean models are necessary for predicting downstream environmental impacts and estimating carbon loss over the 200-year permanence timescale.

9.5.1. The CO_2 Removal Supplier shall assess the mixing loss of DIC, CH_4, and N_2O for each storage site using a circulation model for the chosen anoxic basin, in accordance with subrules a-f.

a. Mixing loss ($M_{\%loss}$) shall be defined as the cumulative percent loss of DIC, CH_4, or N_2O produced at Time 0 removed above the chemocline over the permanence period, using the following equation:

$$M_{\%loss} = \frac{X_{chemo,200}}{X_o} \times 100\% \tag{9.4}$$

Variable	Description	Unit
$M_{\%loss}$	Cumulative percent loss due to mixing over the permanence period.	%
$X_{chemo,200}$	Total DIC, CH_4, or N_2O produced at the seafloor that is removed above the chemocline depth after the 200-year storage period.	µM

Variable	Description	Unit
X_0	Total DIC, CH_4, or N_2O produced at the seafloor at Time 0.	μM

b. $M_{\%loss}$ shall be modeled using an eddy-resolving circulation model of the storage site and a particle release simulation with an imposed boundary condition of zero above the chemocline.

c. The eddy-resolving circulation model shall be validated to the storage site with published, quality controlled in-field observational datasets.

d. It is important to note that the estimate of $M_{\%loss}$ throughout the 200-year storage period is a major source of uncertainty in the risk assessments and CORC evaluations. This uncertainty is largely due to the uncertainty in emissions pathways and the availability of accurate climate forecasts beyond the next 50–100 years. Therefore, at the time of CORC issuance, the uncertainty of $M_{\%loss}$ shall be evaluated based on the uncertainty of the circulation model with present-day parameters. However, the uncertainty of $M_{\%loss}$ shall be re-evaluated whenever the value of $M_{\%loss}$ is re-calculated. Furthermore, the method of quantifying the uncertainty of $M_{\%loss}$ may be updated as climate and ocean circulation models advance.

e. The mixing regime for the circulation model shall be updated with new data, if available, every 10 years for stable basins ($M_{\%loss} \leq 25\%$) and every 5 years for less stable basins ($M_{\%loss} > 25\%$)

f. For shallow anoxic basins (total anoxic zone depth <500 m) that exhibit a uniform vertical potential density profile within the anoxic zone, an $M_{\%loss}$ value of 0 may be justified if the mean radiocarbon age of the top 5 cm sediment layer at the seafloor of the anoxic zone is ≥200 years. The mean radiocarbon age shall be determined from three sampling locations with two replicates for one randomly chosen location to assess measurement error.

9.5.2. Downstream processing of sulfides shall be accounted for by creating a site-specific model that estimates what percent of sulfides are precipitated out by forming metal sulfides before reaching the chemocline. Based on a typical geochemical environment for anoxic basins, the most common dissolved trace metals that form sulfide precipitates include Fe^{2+}, Fe^{3+}, and Cu^{2+} (Lewis, 2010). Model inputs may include relevant data from the incubation experiments or peer-reviewed scientific literature, when available.

9.5.3. Downstream processing of CH_4 shall be accounted for by creating a site-specific model that estimates what percent of CH_4 is oxidized to CO_2 before reaching the chemocline. Model inputs may include relevant data from the incubation experiments or peer-reviewed scientific literature, when available.

9.6. Field-based monitoring

In addition to laboratory-based experiments and model-based monitoring, regular field measurements are required to validate the results of the incubation experiments (see section 9.4) and to monitor for predetermined and unforeseen environmental impacts (see section 9.8) throughout the biomass deployment and post-deployment stages. The requirements set in this section closely resemble those set for monitoring eligibility compliance (see section 9.3) but instead of measurement and monitoring conducted prior to and during the biomass deployment phase, these requirements apply also during the post-deployment phase.

Monitoring during the biomass deployment stage

9.6.1. The CO_2 Removal Supplier shall periodically monitor the storage site as detailed in the Monitoring Plan (see section 9.2), following predetermined procedures to monitor the permanence of the deployed biomass and the storage site characteristics.

9.6.2. The CO_2 Removal Supplier shall monitor the water column and sediment characteristics at the storage site after biomass deployment for the parameters listed in table 9.3. All parameters shall be measured at minimum annually starting from one year after the initial biomass deployment. The data shall be made available to the Auditor.

Table 9.3. Required measurements for long-term monitoring of the storage site after biomass deployment with designated threshold values.

Parameter	Purpose	Threshold	Where to measure
Dissolved oxygen	Site eligibility	<0.03 mg/L (1 µM)	Storage site
$NO_2^-+NO_3^-$	Site eligibility	<0.004 mg/L (0.1 µM)	Storage site
Temperature	General site characteristic useful for quantifying mixing and geochemical processes	n/a	Full water column
Salinity	General site characteristic useful for quantifying mixing and geochemical processes	n/a	Full water column
DIC	Assess changes in carbonate	n/a	Storage site,

	saturation		sediment
pH	Assess changes in carbonate saturation and characterize geochemical processes	Based on original saturation states (see rule 9.6.6 for more details)	Storage site, sediment
Aragonite and calcite saturation states	Assess change in nutrient cycling	Shift from oversaturated to undersaturated (see rule 9.6.6 for more details)	Storage site, sediment
CH_4	Monitor for CH_4 accumulation for CORC evaluation	n/a	Storage site
N_2O	Monitor for N_2O accumulation for CORC evaluation	n/a	Storage site
Live cell staining	Assess change in microbial community	Decrease in viable cells by >30% for two consecutive years (see rule 9.6.6 for more details)	Storage site, sediment
Microbial functional diversity	Assess change in microbial community	n/a	Storage site, Sediment

9.6.3. Sampling and measurement protocols shall follow internationally recognized global ocean observing programs, as detailed in rule 9.3.9. Parameters listed in table 9.3 that do not have established protocols in the above-listed documents shall use practices from appropriate, peer-reviewed scientific literature and enclose details of the specific method used in the Monitoring Plan.

9.6.4. Measurements for the full water column shall follow the requirements set in section 10.5. While sampling near the “approximate center” of the storage site will not be possible in the post-deployment stage due to the presence of the deployed biomass, the CO_2 Removal Supplier shall take samples as close to the biomass as possible.

9.6.5. Sediment samples shall be collected following the requirements set in section 10.5. While sampling directly below the biomass will not be possible, the CO_2 Removal Supplier shall take samples as close to the biomass as possible.

9.6.6. At any point during the monitoring period, if established thresholds for environmental safeguards are exceeded, the CO_2 Removal Supplier shall immediately cease biomass deployment to the given storage site and notify the Issuing Body. The evaluation of environmental change against the thresholds shall be based on the parameter mean value for within the storage site boundary. The Issuing Body reserves the right to determine whether the continuation of deployments, pending the environmental parameters to return to within the established threshold, and may require additional mitigation protocols to be implemented in order to limit further changes. The established thresholds are as follows:

a. Dissolved oxygen or NO_2^-+ NO_3^- concentrations at the storage site shall not exceed the designated threshold for site eligibility (see table 9.3, rule 3.9.4 and rule 3.9.5).

b. If aragonite and/or calcite is determined to be oversaturated ($\Omega>1$), any shifts in saturation states of aragonite and/or calcite shall not transition from an original state of oversaturation ($\Omega>1$) to undersaturation ($\Omega<1$).

c. If both aragonite and calcite are determined to be undersaturated before deployment, a decrease in pH shall not exceed 0.2 pH relative to the environmental baseline.

d. Microbial activity based on live cell staining shall not decrease by over 30% relative to the environmental baseline for two consecutive years.

9.6.7. The CO_2 Removal Supplier shall annually retrieve a subset of the deployed biomass from the first deployment to assess the carbon loss. The subset shall consist of at least 5 samples of sufficient size to allow for accurate analysis. The samples shall be analysed according to the requirements set in rule 3.6.4, and the resulting dry weight and carbon content (in % mass) shall be compared to the values measured prior to biomass deployment. The measured values shall be taken into consideration for quantifying carbon losses as determined in rule 6.3.6.

Monitoring during the post-deployment and storage closure stage

9.6.8. The CO_2 Removal Supplier shall retain access to the storage site for monitoring purposes throughout the post-closure period, according to the long-term monitoring requirements described in rule 9.6.2. Monitoring post-deployment shall occur at least on years 1, 2, 5, 10 and 15 after the deployment of the final batch of biomass.

9.6.9. After storage closure, the CO_2 Removal Supplier shall create a storage closure report including relevant information for the future uses of the storage site. Such information may for example include:

a. Information of the relevant entities and authorities relevant to any possible future activities.

b. Documentation and maps indicating the location and quantity of the deployed biomass.

c. Documentation of the timeline of the operations (e.g. deployment-phase, post-deployment phase, site closure).

d. Information on the storage site characteristics.

9.7. Monitoring for CO_2 release and reversal

9.7.1. The CO_2 Removal Supplier shall assess the reversal risk according to the general requirements for risk assessment set in section 4.2, requirements for reversal risk assessment in section 4.3 and the Puro Standard General Rules.[85] Note, that only previously unknown or unanticipated re-emissions *after issuance of CORCs* are termed reversals, and separated from carbon losses which are accounted for *at the time of CORC issuance* (see section 6.3).

9.7.2. The CO_2 Removal Supplier shall continue monitoring the permanence of the carbon removal activity during and after site closure (post-deployment and storage closure stages) following requirements set in rule 9.6.8. In cases where the post-closure monitoring shows that the permanence of the carbon storage has been compromised, the CO_2 Removal Supplier shall follow the procedure regarding permanence and risk of reversal described in the Puro Standard General Rules, section 6.7.[86]

9.8. Monitoring for environmental and social impacts

9.8.1. For monitoring of social and environmental impacts, the CO_2 Removal Supplier shall conduct an inclusive stakeholder engagement process in accordance with the Puro Stakeholder Engagement Requirements.[87] Stakeholders may include, but are not limited to:

a. Local communities.

b. Nongovernmental organizations (NGOs).

c. Independent experts.

The result of the process shall be reported and included with the Project Description for the validation of the Production Facility. Any potential risk identified through this process shall be incorporated in the Monitoring Plan.

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[85] Available in the Puro Standard document library.

[86] Ibid.

[87] Ibid.

9.8.2. The Monitoring Plan shall include the following monitoring procedures:

a. Environmental risks including, but not limited to, the predetermined risks identified in section 4.5, in accordance with the general requirements for risk assessment (see section 4.2), requirements for environmental and social risk assessment (see section 4.4) and the environmental safeguards defined in the Puro Standard General Rules.[88]

b. The social risks identified in the Puro Stakeholder Engagement Report[89], in accordance with the general requirements for risk assessment (see section 4.2), requirements for environmental and social risk assessment (see section 4.4) and the social safeguards defined in the Puro Standard General Rules and the Puro Stakeholder Engagement Requirements.[90]

c. The environmental and social impacts that may contribute to the Sustainable Development Goals (see section 3.10) pursued by the CO_2 Removal Supplier in accordance with the Puro Standard General Rules and Puro SDG Assessment Requirements.[91]

9.8.3. The CO_2 Removal Supplier shall monitor the environmental impacts by a combination of laboratory-based monitoring (see section 9.4), model-based monitoring (see section 9.5) and field-based monitoring (see section 9.6) for characterization of the environmental baseline at the storage site (see rule 9.3.6 b), and monitor changes to the initial conditions.

9.8.4. The CO_2 Removal Supplier shall design and implement an “Ongoing feedback and grievance mechanism” as described under the Puro Stakeholder Engagement Requirements[92] to facilitate the continuous engagement between the project stakeholders for the identification and resolution of any issue or grievance associated with the carbon removal activity.

9.8.5. The CO_2 Removal Supplier shall maintain a record of the stakeholder feedback and follow-up actions, and report the status and actions associated with this process in the corresponding Output Report until its adequate resolution.

9.8.6. The CO_2 Removal Supplier shall address any grievances in accordance with the mitigation hierarchy described in section 4.2.

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[88] Available in the Puro Standard document library.

[89] Ibid.

[90] Ibid.

[91] Ibid.

[92] Ibid.

9.9. Monitoring for greenhouse gas accounting

9.9.1. The CO_2 Removal Supplier shall monitor project activities to collect activity data for the measuring and calculation of GHG emissions and carbon removals to determine the net carbon removal in accordance with the CORC quantification equation presented in this Methodology.

9.9.2. The CO_2 Removal Supplier should become familiar with the requirements described in section 10 and section 11 when preparing the monitoring plan. In particular, special attention should be given to the uncertainty assessment of the carbon removal activity (section 10.2).

10. Measuring Requirements

10.1. General Requirements

10.1.1. The estimate of net carbon removal following the quantification of CORCs (see equation 5.1) shall be *accurate* and *precise*.

10.1.2. Accuracy and precision depend on the uncertainty associated with the processes and data inputs involved in quantification of GHG emissions and the resulting net carbon removal from the implementation of the Marine Anoxic Carbon Storage activity.

10.2. Uncertainty Assessment

10.2.1. The CO_2 Removal Supplier shall perform an uncertainty assessment of the implementation of the Marine Anoxic Carbon Storage activity to:

a. Identify the possible causes of uncertainty.

b. Establish actions to reduce that uncertainty through the design of the Production Facility (or project) and improve the accuracy and precision of the net carbon removal calculation.

10.2.2. The process of producing an uncertainty assessment follows these steps:

a. Specification of the parameters that contribute to the measuring model described by the overall CORC equation (see section 10.3).

b. Identification of uncertainty sources based on the likely causes of uncertainty (random errors) associated with each component of the CORC equation (see section 10.4).

c. Quantification of uncertainty estimates for the parameters used in the data collection process for the quantification of the net carbon removal process (see rule 10.6.1 c).

d. Calculating the combined uncertainty (see rule 10.6.1 d) based on the mathematical combination of those estimates when used as inputs to a statistical model (i.e., linear propagation or Monte Carlo method). For more detailed requirements, see section 10.6.

e. If applicable, the CO_2 Removal Supplier should take steps to improve the quantification of the inventory of GHG emissions and carbon removal based on the experience obtained from steps a to c. This step should be designed in accordance with the QC plan (section 10.7).

10.2.3. In this Methodology, there are significant sources of uncertainty associated with the "lack of completeness" and "model" of the carbon loss component of the CORC equation (see section 6.3). This component includes a bias or systematic error as the uncertainty is linked to the understanding of the decomposition processes and challenges in monitoring and measuring changes in the carbon stored in the storage site. As a consequence, the CO_2 Removal Supplier should strive to reduce this uncertainty (see section 10.4 and section 10.7), report it in a qualitative way when submitting the CORC quantification with the Output Report (see section 11), and report the combined uncertainty of the random errors for all other parameters in CORC quantification.

10.2.4. The CO_2 Removal Supplier should utilize the requirements for the laboratory-based monitoring (see section 9.4), model-based monitoring (see section 9.5) and field-based monitoring (see section 9.6) to reduce the uncertainty associated with the conceptualization and modeling of the carbon loss process after the biomass deployment.

10.3. Data Collection

10.3.1. For the calculation of the net carbon removal and associated uncertainty of measurement, the sources of data and information on the carbon removal activity are:

a. **Measured** or **calculated**. Empirical data associated with measurements of emissions and activity data. This is applicable to measurements obtained via tools specifically designed for this purpose and the calculations based on the measured inputs using equations.

b. **Estimated**. Quantified estimates based upon expert judgement. This is applicable to emission factors (EF) and average activity (AD) data based on surveys or other peer reviewed studies.

10.3.2. The data for the CORC quantification and/or environmental and social impacts shall be collected with the attributes described in table 10.1.

Table 10.1. Information to be compiled in the monitoring plan for each relevant parameter involved in the LCA calculations.

Field name	Description
ID	A unique identifier of the parameter.
Parameter	The name of the parameter.
Unit	The measurement unit of the parameter.

Field name	Description
Value	The value of the parameter.
Equation	Reference to the equation where this parameter contributes to.
Description	A brief text describing what the parameter is about, and how it is used in calculations.
Source of data	A brief text describing where the data is sourced from: measured (m), calculated (c), or estimated (e).
Monitoring frequency	The frequency of monitoring of the parameter.
QC procedures	A brief text describing how the data is obtained, via what measurements, and why the value selected is conservative in light of possible error or uncertainty.
Measurement uncertainty (%)	An estimation of the ***random error*** component associated with the measurement, and estimated as percentage uncertainty in the parameter.
Comments	Free text comments

10.3.3. The CO_2 Removal Supplier shall collect data according to the Monitoring Plan, and update the net carbon removal calculation for each monitoring period. The result shall be included in the report (see section 11) and shall be available to the Auditor for the Production Facility Audit and Output Audit.

10.4. Determination of Causes of Uncertainty

10.4.1. For the purposes of this methodology, two types of uncertainty are defined as follows:

a. **Bias or systematic errors** may arise from conceptual errors or from an incomplete understanding of the processes included in the CORC quantification equation (measuring model) and its main components. This type of uncertainty impacts the accuracy of the net carbon removal estimation.

b. **Random errors** may arise based on the inherent variability of the system, the representativeness of the data used to make the calculations, the measurement errors, and uncertainty obtained from expert judgement. This type of uncertainty can be estimated following requirements set in section 10.6 and it impacts the precision of the net carbon removal estimation.

10.4.2. The CO_2 Removal Supplier shall define the actions to be taken to reduce the causes of uncertainty in the implementation of the Marine Anoxic Carbon Storage activity.

10.4.3. The CO_2 Removal Supplier may refer to the IPCC Guidelines for National Greenhouse Gas Inventories[93] and General Guidance and Reporting for information on the treatment of uncertainty (IPCC 2006, 2019). The causes of uncertainty can be summarized as follows in table 10.2.

Table 10.2. Causes of Uncertainty (after IPCC 2006, 2019).[94]

Cause of uncertainty	Type	Mitigation
Lack of completeness	Bias	Concept, QA/QC
Model	Bias and random errors	Concept, QA/QC
Lack of data	Bias and random errors	Experts, QA/QC
Lack of representativeness of data	Bias	QA/QC, verification
Statistical random sampling errors	Random errors	Statistics sizes
Measurement error; random component	Bias and random errors	QA/QC, verification
Misreporting	Bias	QA/QC
Data gaps	Bias and random errors	Statistics, experts

10.5. Sampling Procedures

The purpose of these sampling procedures is to obtain a representative sample for measurement of relevant parameters for the calculation of the net carbon removal or other requirements in this methodology.

10.5.1. The CO_2 Removal Supplier shall determine the materials to sample according to the requirements set in this methodology.

10.5.2. The CO_2 Removal Supplier shall prepare a sampling report form for biomass sampling, and water column and sediment sampling in accordance with ISO 18135:2017[95], ISO 5667-9:1992[96], and ISO 5667-1919:2004[97] (also known as a sampling certificate, see e.g. Annex A of ISO 18135:2017). The certificate shall be made available to the Auditor.

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[93] 2006 IPCC Guidelines for National Greenhouse Gas Inventories and 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

[94] Ibid.

[95] ISO 18135:2017 Solid Biofuels - Sampling.

[96] ISO 5667-9:1992 Water Quality - Sampling. Part 9: Guidance on sampling from marine waters.

[97] ISO 5667-19:2004 Water Quality - Sampling. Part 19: Guidance on sampling of marine sediments.

Biomass sampling

10.5.3. The CO_2 Removal Supplier shall prepare a full sampling plan of biomass sources in accordance with ISO 18135:2017[98] (figure 10.1) as part of the Monitoring Plan data collection (see rule 9.2.5.f).

10.5.4. The biomass sampling plan shall be prepared with a clear objective, such as quantifying carbon content or other relevant parameters.

10.5.5. In the case of a new feedstock or feedstock supplier, the existing sampling plan shall be reviewed and updated accordingly, or a new full sampling plan shall be prepared. The new feedstock shall meet the requirements of the Production Facility definition as defined in rule 2.2.1 a. The new sampling plan shall be incorporated with the first Output Report for verification by the third party auditor.

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[98] ISO 18135:2017 Solid Biofuels - Sampling.

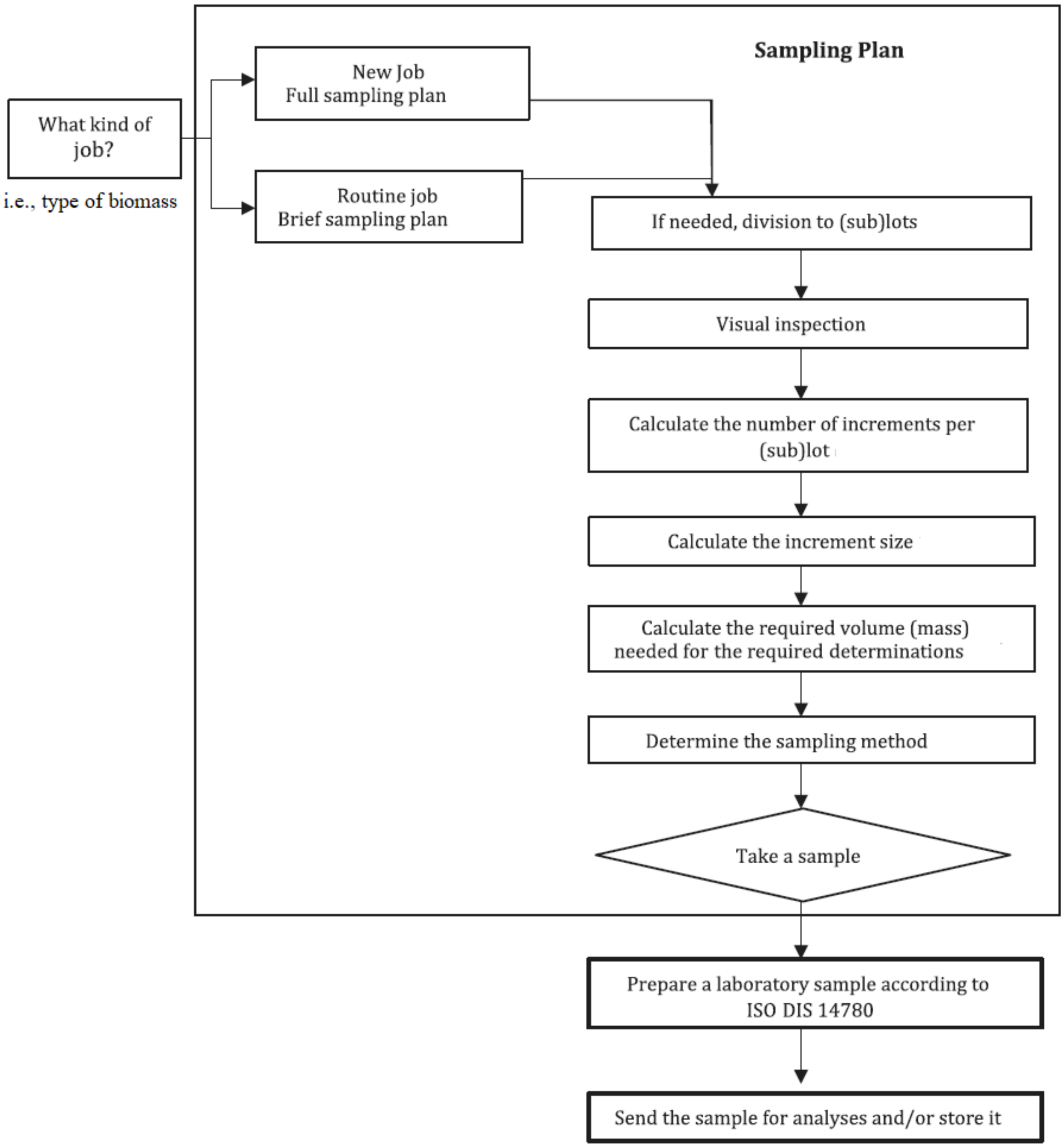

Figure 10.1. Procedure for sampling, modified after ISO 18135:2017.[99]

Water column and sediment sampling

10.5.6. The CO_2 Removal Supplier shall prepare a full sampling plan of water column and sediment samples as part of the Monitoring Plan data collection (see rule 9.2.5.f), and in accordance with the applicable protocols as defined in:

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[99] ISO 18135:2017 Solid Biofuels - Sampling.

a. ISO 5667-1:2023[100] for both water column and sediment sampling

b. ISO 5667-9:1992[101] for water column sampling.

c. ISO 5667-19:2004[102] for sediment sampling.

The sampling plan shall be reviewed and updated periodically as part of the Monitoring Plan data collection (see rule 9.2.5.f). Further requirements for water column sampling are set in rules 10.5.9 and 10.5.10, and for sediment sampling in rule 10.5.11.

10.5.7. The sampling plan shall clearly state the objective of sampling, such as determining the eligibility of the storage site or monitoring for environmental impacts. The sampling plan shall include detailed protocols for sample collection for all relevant parameters listed in table 9.2. and table 9.3.

10.5.8. Measurements for the full water column shall be taken from the surface (<10 m deep) to as close to the seafloor as possible. The vertical sampling resolution may vary based on the basin, but the CO_2 Removal Supplier shall properly characterize the vertical variability of the geochemical properties of the basin, in particular the oxic to anoxic transition and the water mass within the storage site. At each of at least two randomly chosen depths, at least two replicate measurements shall be taken to assess measurement error.

10.5.9. Water column measurements shall be taken from at least 5 locations along a transect of the storage site running through the approximate center of the storage site from boundary to boundary (see rule 9.3.10) as follows:

a. One sample shall be taken at the approximate center.

b. Two samples shall be taken at the opposite edges of the storage site. At one randomly chosen location, at least two replicate measurements shall be taken to assess measurement error.

10.5.10. Sediment samples shall be collected from at least 5 locations within the storage site boundary, considering the approximate center of the storage site boundary (see rule 9.3.10) as further specified in subrules a-d.

a. The sampling shall be conducted in a manner representative of the storage site, based on one or several of the following principles, as further detailed in ISO 5667-19:2004[103]:

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[100] ISO 5667-1:2023 Water Quality - Sampling. Part 1: Guidance on the design of sampling programme and sampling techniques.

[101] ISO 5667-9:1992 Water Quality - Sampling. Part 9: Guidance on sampling from marine waters.

[102] ISO 5667-19:2004 Water Quality - Sampling. Part 19: Guidance on sampling of marine sediments.

[103] ISO 5667-19:2004 Water Quality - Sampling. Part 19: Guidance on sampling of marine sediments.

- Random sampling.
- Grid sampling.
- Gradient sampling

b. The CO_2 Removal Supplier shall select the appropriate sampling principle based on the objective of the sampling (rule 10.5.8), which may vary between the project stages (table 9.1).

c. Regardless of the sampling technique used, the CO_2 Removal Supplier shall collect replicate measurements from at least 5% of the samples collected, or always at least from one randomly selected sampling location, to assess measurement error.

d. Each sediment core shall be at least 30 cm long, and preferably recovered via a multicore sediment sampling device to ensure appropriate replicates. Solid phase extraction of POC and microbes shall be conducted from the solid sediment while all other measurements listed in table 9.2 shall be conducted from the extracted pore water.

REMARK: The time and frequency of sampling and number of samples must be determined based on site-specific data (see e.g. rule 9.2.2). Essentially, a higher sampling frequency and an increased number of samples is often necessary when assessing the storage site eligibility (section 3.9), and determining the environmental baselines of the storage site (rule 9.3.7). Furthermore, an increased sampling frequency prior to biomass deployment is necessary to determine the representative sampling frequency during the monitoring period based on statistical approaches.

A well-planned sampling strategy aims to minimize the risk of inadequate sampling or unnecessarily frequent sampling. Marine Anoxic Carbon Storage is a relatively novel CDR approach, and with limited peer-reviewed data available to fully assess the sampling frequency or necessary number of samples. This methodology sets requirements for the CO_2 Removal Supplier to utilize multiple approaches for monitoring, including laboratory-based monitoring (section 9.4), model-based monitoring (section 9.5) and field-based monitoring (section 9.6). The purpose of these requirements is to ensure the collection of sufficient samples and data to determine the durability of the stored carbon, and to detect potential environmental impacts.

As the biogeochemical changes in the anoxic basin are nonlinear through time, and the signals may be too weak to detect via in-situ monitoring, it is essential that the sampling protocol is designed and conducted in a manner that these signals may be detected. Puro.earth acknowledges that future advances in e.g. numerical oceanographic modeling may provide additional information for developing an improved sampling plan which may better represent the site-specific characteristics.

10.6. Estimation of Measurement Uncertainty

Knowledge of the uncertainty of measurement implies increased confidence in the validity of a result (EURACHEM/CITAC Guide CG 4[104]). In the context of this methodology, the object of the estimation of the uncertainty of measurement is the net carbon dioxide removal based on the elements that contribute to the CORC calculation equation 5.1.

The uncertainty of the net carbon dioxide removal activity is the result of combining the standard uncertainty of all the parameters identified in the measurement model and its calculation processes and expanding it to cover a confidence interval of approximately 95%. This section serves as guidance and should be used in conjunction with other relevant Puro Standard guidelines and templates.[105]

10.6.1. The process of building a measurement model for uncertainty estimation shall follow the steps described under ISO/IEC Guide 98-6[106]. Alternatively, the process of measurement uncertainty estimated described in EURACHEM/CITAC Guide CG 4[107] may be used. These steps are adapted and summarized for the Marine Anoxic Carbon Storage approach as follows:

a. Step 1: Specification of the parameter(s)

- The net carbon dioxide removal for the issuance of CORC is calculated with equation 5.1, which represents the project's measurement model. The parameters in this equation are considered Level 0 components and may include other input parameters calculated from other models (i.e., Level 1, 2 or more), constants, calibration standard values, etc. Figure 10.2 represents the hierarchy of variables found in the measurement model.
- The CO_2 Removal Supplier shall describe each parameter under this measurement model following the form presented in table 10.1 and include them in the Monitoring Plan.
- Depending on the system boundaries, it is possible that the CO_2 Removal Supplier may be required to expand the list of parameters to better capture the processes of the carbon removal activity. Therefore, it is possible to include additional levels of parameters to define the contributions to this measurement model.

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[104] S L R Ellison and A Williams (Eds). Eurachem/CITAC guide: Quantifying Uncertainty in Analytical Measurement, Third edition, (2012) ISBN 978-0-948926-30-3. Available from www.eurachem.org

[105] Available in the Puro Standard document library.

[106] ISO/IEC Guide 98-6:2021 Uncertainty of measurement - Part 6: Developing and using measurement models.

[107] Eurachem/CITAC guide: Quantifying Uncertainty in Analytical Measurement, Third edition, 2012.

- Finally, the CO_2 Removal Supplier shall ensure that the Monitoring Plan includes all parameters serving the measurement model and that the data is collected according to section 10.3 of this document.

b. Step 2: Identification of uncertainty sources.

- The sources of uncertainty should be determined based on the type of data as defined under rule 10.3.1, considering the following:
    - For measured data, representative sampling and measuring tool calibration shall be considered in the calculation of uncertainty.
    - For estimated data, uncertainty sources may be found in the referenced peer-review documentation or provided by the database supplier. Alternatively, uncertainty for emission factors may be estimated following a qualitative assessment using the pedigree matrix (see rule 10.6.1.c).
    - For calculated data, the sources of uncertainty depend on the types of data used in the calculation, i.e., measured and/or estimated, and shall include their corresponding sources of uncertainty.
- Alternatively, the CO2 Removal Supplier may follow the guidance in Appendix C “Analysing Uncertainty Sources” of the EURACHEM/CITAC Guide CG 4.

c. Step 3: Quantification of the uncertainty.

- The estimate of standard of uncertainty of a given parameter may be obtained from information included in:
    - Evaluation of the dispersion of repeated measurements.
    - Previous measurement data.
    - Expert knowledge or judgement.
    - Manufacturer’s specifications.
    - Data provided in calibration and other certificates.
    - Uncertainties assigned to reference data taken from peer-reviewed publications.
- The uncertainty of a parameter shall be expressed as a percentage uncertainty derived from standard uncertainty or standard deviation before proceeding to combine it with other uncertainty contributions.

- In case the single parameter uncertainties of a parameter are unknown, for example in the case of emission factors, it is possible to estimate the uncertainty using the GHG Protocol guidance for “Quantitative Inventory Uncertainty”[108] This involves using the pedigree matrix approach based on qualitative indicators to compute the parameter's geometric standard deviation and propagating its uncertainty using a Taylor series expansion.

d. Step 4: Calculating the combined uncertainty

- When a parameter is calculated from other parameters, its uncertainty is the result of the combination of the uncertainty of the contributing parameters.
- According to ISO/IEC Guide 98-1:2024[109], the two principal methods for propagating measurement uncertainty are:
    1. The law of propagation of uncertainty is defined as Approach 1 and described in greater detail in this document.
    2. The propagation of distributions by means of the Monte Carlo method is defined as Approach 2. This approach is not covered in this document. For further details, refer to ISO/IEC Guide 98-3:2008/Suppl. 1.
- For the purpose of this methodology, the CO_2 Removal Supplier may use the “law of propagation of uncertainty”, Approach 1. This entails that the combined standard uncertainty of the net carbon dioxide removal process may be estimated by the positive square root of the total variance obtained by combining all the uncertainty components. There are two rules for the combination of uncorrelated uncertainty under addition and multiplication.
- The CO_2 Removal Supplier may follow the rules described in the IPCC Guidelines for National Greenhouse Gas Inventories (2006, 2019)[110], summarized below for ease of reference:
    - Convert uncertainty values into percentage uncertainty prior to combining them.

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[108] https://ghgprotocol.org/sites/default/files/2022-12/Quantitative%20Uncertainty%20Guidance.pdf

[109] ISO/IEC Guide 98-1:2024 Uncertainty of measurement - Part 1: Introduction.

[110] 2006 IPCC Guidelines for National Greenhouse Gas Inventories

- Where the percentage uncertainty are to be combined by multiplication, the combination shall be calculated as follows:

$$U_{total} = \sqrt{U_1^2 + U_2^2 + ... + U_n^2} \tag{10.1}$$

Variable	Description	Unit
U_{Total}	The percentage uncertainty in the product	%
U_i	The percentage uncertainties associated with each of the quantities.	%

- Where uncertainty quantities are to be combined by addition or subtraction, the combination shall be calculated as follows:

$$U_{total} = \frac{\sqrt{(U_1 \bullet x_1)^2 + (U_2 \bullet x_2)^2 + ... + (U_n \bullet x_n)^2}}{|x_1 + x_2 + ... + x_n|} \tag{10.2}$$

Variable	Description	Unit
U_{Total}	The percentage uncertainty in the sum of the quantities.	%
x_i	The uncertain quantities associated with each of the quantities.	Unitless
U_i	The percentage uncertainties associated with each of the quantities.	%

- Alternatively, the CO_2 Removal Supplier may reference the EURACHEM / CITAC Guide CG 4[111]. See section 8.2 for a detailed procedure on the calculation of uncertainty and its combination.

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[111] Eurachem/CITAC guide: Quantifying Uncertainty in Analytical Measurement, Third edition, 2012.

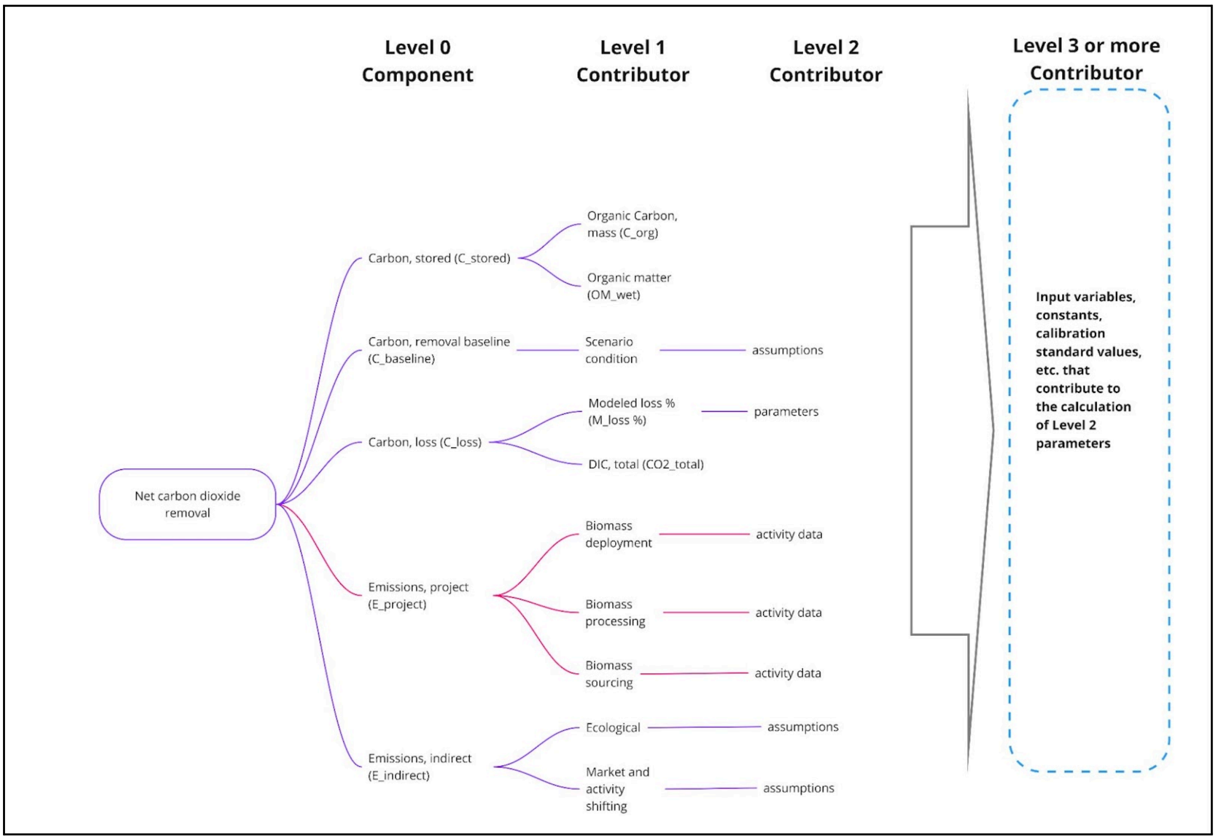

Figure 10.2. Hierarchy of parameters of the measurement model

10.7. Quality Control (QC) System and Procedures

10.7.1. The CO_2 Removal Supplier shall develop a quality control (QC) system that includes procedures to measure and control the quality of the GHG inventory for the calculation of the net carbon removal that will be included in the Output Report. The QC system is designed to:

a. Ensure the data is presented in accordance with the principles described under ISO 14064-2[112], namely, relevance, completeness, consistency, accuracy, transparency, and conservativeness.

b. Identify and address errors and omissions.

c. Document and archive all inventory material and records in accordance with rule 11.1.6.

10.7.2. Information provided by the CO_2 Removal Supplier shall be verified by a third-party Auditor, who will provide the quality assurance (QA) of the performance of the carbon

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[112] ISO 14064-2:2019 Greenhouse gases, Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emissions reductions or removal enhancements.

removal activity in accordance with the Puro Standard General Rules[113] and the requirements set in this methodology.

10.7.3. The CO_2 Removal Supplier shall provide a quality control (QC) plan, which is to be included in the Monitoring Plan. The plan shall at minimum:

a. Identify the parties involved in coordinating the implementation of the quality control procedures.

b. Define the quality control procedures.

c. Ensure availability and access to information on activity data and emission factors, including data quality and measurement uncertainty in accordance with the requirements for data collection (section 10.3).

d. Ensure confidentiality of inventory and source category information, when required.

e. Define requirements for archiving information.

f. Define frequency of QC checks on different parts of the inventory.

10.7.4. The CO_2 Removal Supplier should consider the feedback from the third-party verification of the Output Report and incorporate the corresponding improvements in the next Output Report. The feedback may include but it is not limited to:

a. Improve the estimates of emissions and/or removals.

b. Reassess of inventory compilation processes and uncertainty estimates, when required.

10.7.5. The QC procedures shall include at minimum the calibration of the measuring tools.

a. All measurement devices shall be installed, operated and calibrated according to the device manufacturer's specifications or according to an appropriate industry consensus standard.

b. All measurement devices shall be calibrated to an accuracy of at least 5% (i.e. the calibration error of any measurement device shall not exceed 5%). Calibration records shall be made available for third-party verification.

c. This requirement does not apply to energy (heat, electricity, fuel) billing meters, provided that the energy supplier and the CO_2 Removal Supplier do not have any common owners and are not owned by subsidiaries or affiliates of the same company.

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[113] Available in the Puro Standard document library.

11. Reporting Requirements

11.1.1. The CO_2 Removal Supplier shall prepare and make available an Output Report to provide evidence of the Production Facility performance for the monitoring period covering the scope of monitoring as described in rule 9.2.1 and demonstrates conformity of the Marine Anoxic Carbon Storage activity with the requirements of this methodology, as well as the Puro Standard General Rules[114] and other Standard Requirements.[115]

11.1.2. The Output Report shall include supporting documented evidence for each monitoring period described in the Monitoring Plan, in accordance with ISO 14064-2:2019, clause 6.13 “Reporting the GHG project”.[116]

11.1.3. The Output Report shall include, as a minimum:

a. The name of the CO_2 Removal Supplier and operational partners.

b. A brief description of the Production Facility, including size, location, crediting period, type of carbon removal activity, and Puro-approved Methodology version being followed.

c. The date of the report and the time covered by it.

d. A CORC Summary with supporting detailed GHG calculations and evidence. The GHG emission reductions and removals are stated in tonnes of CO_2e. The detailed information may be redacted to protect sensitive commercial information and comply with data providers' end-user license agreements.

e. If applicable, a description of the GHG baseline and demonstration that the GHG emission removals are not over-estimated.

f. The combined percentage uncertainty of measurement of the CORCs issued in the CORC Summary statement. The estimate shall be at an approximate 95% confidence interval or two standard deviations.

g. As applicable, an assessment of permanence including any reversal event.

h. If required by the CO_2 Removal Supplier, changes to the Production Facility and Monitoring Plan shall be clearly stated, and evidence of conformity with

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[114] Available in the Puro Standard document library.

[115] Ibid.

[116] ISO 14064-2:2019 Greenhouse gases, Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emissions reductions or removal enhancements.

Puro General Rules[117], the requirements set in this methodology, and other Puro Standard[118] requirements shall be provided for validation by the third-party Validation and Verification Body.

i. Report the appropriate IPCC inventory sector based on the source of biomass used:
   - "Agriculture" for carbon captured from agricultural residues.
   - "Land-use change and forestry" for carbon captured from forest residues.

11.1.4. Delays or changes in the reporting frequency shall be in conformity with Puro Standard General Rules.[119]

11.1.5. The CO_2 Removal Supplier shall have in place, maintain, and utilize an information system to keep records of all monitoring activities associated with the Marine Anoxic Carbon Storage activity (see rule 9.2.5.i). In addition:

a. These records shall include information on the parameter or process monitored (i.e. what was monitored and how), as well as results of any measurements performed.[120]

b. The information shall be time-stamped and quantitative (where applicable).

c. These records shall be available to the Auditor, for the Output Audits.

d. These records shall be kept for at least two years after the end of the crediting period or the last issuance of CORCs for this project activity, whatever occurs later.

11.1.6. The terminology used in this methodology in relation to monitoring frequency shall be interpreted as detailed in subrules a and b:

a. The following definitions apply to the description of monitoring frequency:
   - Monthly monitoring is defined as at least once per calendar month.
   - Quarterly monitoring is defined as at least four times per calendar year (once every three months).
   - Semi-annual monitoring is defined as at least twice per calendar year (once every six months).

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[117] Available in the Puro Standard document library.

[118] Ibid.

[119] Available in the Puro Standard document library.

[120] Note also rule 5.2.6 on keeping records of events that affect the quantification of CORCs. Note that these records are at least partly separate, as not all monitoring activities or results thereof necessarily affect the number of CORCs.

- Annual monitoring is defined as at least once per calendar year.
- Periodical monitoring is defined as monitoring at predetermined, regular temporal intervals decided by the CO_2 Removal Supplier based on site-specific needs as well as any applicable regulations. The monitoring frequency and rationale thereof shall be explained in the monitoring plan.

b. Monitoring activities with a predefined cadence (e.g. quarterly monitoring) shall be evenly distributed throughout the monitoring period (e.g. once every three months for quarterly monitoring). The CO_2 Removal Supplier may make reasonable adjustments to the monitoring schedule for reasons of necessity or practicality, but such adjustment shall not result in any undue or disproportionate delays to the monitoring activities.

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