[Relae] Microsoft

Criteria for High-Quality Carbon Dioxide Removal

RELAE + MICROSOFT
2026 EDITION

Criteria for High-Quality Carbon Dioxide Removal: 2026 Edition

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Introduction

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The science is clear: ambitious action is needed to reduce greenhouse gas (GHG) emissions while also rapidly scaling carbon dioxide removal (CDR). Effective and equitable climate action can both reduce climate loss and damage and provide wider benefits to society. The AR6 WIII report from the Intergovernmental Panel on Climate Change (IPCC) estimates the global community must remove 100-1,000 giga tonnes (Gt) of carbon dioxide (CO_2) by 2100 to limit persistent warming to no more than 1.5°C. To reach this goal, large-scale CDR projects must annually remove 7-9 $GtCO_2$ by midcentury. Achieving this goal will require rapid scale-up and deployment of **all** viable CDR methods.

Microsoft and Relae are committed to the development of this essential market.[1]

Relae is the trusted advisor in energy and climate, delivering scientifically rigorous, technically advanced, and commercially grounded solutions. Our scientists, engineers, and policy experts pair systems-level knowledge with project-level understanding to help clients achieve their energy and climate goals. Founded in 2020 as Carbon Direct, Relae has supported over 150 companies, including Microsoft, Mitsubishi, and JPMorganChase, in navigating today's most pressing challenges across energy systems, greenhouse gas emissions accounting, carbon markets, climate policy, natural capital, environmental markets, and emerging technologies. To learn more, visit www.relae.co.

Microsoft has committed to being carbon negative by 2030. By 2050, Microsoft aims to remove the equivalent of all cumulative GHGs emitted since Microsoft was founded. Since we announced our first portfolio of 1.3 million tonnes of CDR in January 2021, Microsoft has continued to ambitiously grow its CDR portfolio year-on-year. As we shared in a recent portfolio update, we have contracted to purchase over 78 million tonnes of CDR from more than 60 projects in 10 unique CDR pathways.

Over the past six years, Microsoft and Relae have observed a critical challenge in the emerging CDR industry: while there are many CDR projects on the market, many have quality gaps, ranging from establishing a baseline to ongoing monitoring, reporting, and verification. A major challenge in assessing quality is the lack of a common framework for CDR project developers and purchasers to define a best-in-class CDR project. To address that challenge, Microsoft and Relae have annually published these *Criteria for High-Quality Carbon Dioxide Removal* based on emerging science and hard-fought lessons from conducting diligence on real-world projects. Along the way, we have augmented the criteria with sector-focused perspectives that help CDR developers and industry stakeholders navigate complex considerations. In 2021, Microsoft elaborated on the need for a common framework in a white paper, noting the need for clear carbon accounting standards and the development of rigorous guidelines for additionality, durability, and leakage. Microsoft updated these insights in a 2022 white paper, where we discussed the lack of common standards, high prices, and insufficient supply of high-quality CDR credits. In a 2023 briefing paper, Microsoft demonstrated a commitment to signing long-term CDR offtake purchase agreements to help accelerate development of large-scale, quality CDR projects while progressing toward our 2030 goal. In another white paper, collaboratively written with Ørsted and Relae (formerly known as Carbon Direct), Microsoft explored the challenge in determining who gets to claim the carbon removal in their inventory when countries and the private sector coinvest in projects. Relae has provided buyers with guidelines for sustainably sourcing agricultural and forestry biomass for biomass-based CDR projects. Microsoft anticipates continuing to transparently share due diligence and contracting learnings on topics that could use explication, such as dynamic baselining in forestry projects and sustainable rock sourcing for enhanced rock weathering and ocean alkalinity enhancement projects.

Recent policy announcements also highlight the pressing need for evidence-based CDR criteria to guide action by both public- and private-sector actors. In the United States (US), the Inflation Reduction Act and the Infrastructure Investment and Jobs Act both

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continue to provide funding for CDR project development, as well as procurement of CDR. Revisions to Environmental Protection Agency (EPA) Greenhouse Gas Reporting Program influence how captured CO_2 is measured and disclosed; permitting reforms may accelerate project timelines but compress time available for environmental review; and continued reliance on tax credits without harmonized durability standards leaves critical questions like monitoring duration, reversal liability, and life cycle boundaries only partially defined. Across Europe, policy support for CDR continues to advance. In the European Union (EU), the Carbon Removal Certification Framework (CRCF) has moved from proposal to implementation, with methodologies and delegated acts under development to establish quality thresholds for certified removals. Concurrently, the EU has also announced intentions to launch an EU Buyer's Club, as a voluntary initiative to kickstart demand for CDR under the CRCF framework. Japan is similarly primed to scale demand as the nation's carbon market shifts into its compliance phase in 2026, and enables emitters to offset a portion of their emissions using eligible CDR credits from a range of approved pathways. Globally, more than 75 countries have submitted long-term, low-emissions development strategies to the United Nations Framework Convention on Climate Change (UNFCCC), most of which include nature-based strategies and with approximately one-third mentioning engineered CDR. At COP30, Parties moved from rule-setting toward operationalizing international carbon market infrastructure, with further progress in implementing the Article 6.4 Paris Agreement Crediting Mechanism and continued technical work toward global consensus on how removals are defined, accounted for, and authorized for international transfer.

Together, these developments underscore the urgency for just, scientifically grounded, high-quality CDR principles that ensure effective climate action across sectors and borders and serve as an anchor across shifting policy environments. However, much more is needed than quality criteria. First and foremost, more buyers must step forward to grow the nascent CDR market. Early compliance markets must formalize standards and regulations. Project developers must reach higher levels of technical maturity, build real projects, and make transactions easy—all subjects of Relae's recent white paper, CDR 2.0: Five Pillars of Successful Project Deployment and Delivery. These developments need to rest on a foundation of scientific and technical rigor.

Microsoft and Relae seek to be at the cutting edge of the CDR industry's advancement and actively create a market for high-quality projects by translating quality frameworks into commercial actions. Over the first part of this decade, Relae's in-depth, project-level due diligence has routinely identified key areas where project developers' plans may not result in measurable and verifiable carbon sequestration. Microsoft's procurement contracts incorporate these diligence findings—most often in the form of developmental milestones or contractual safeguards during delivery periods—to ensure that the resulting carbon credits meet the standards set in these criteria for high-quality CDR. To the extent that this document's perspectives can be built into registry standards and suppliers' development plans, the CDR market can continue to expand quickly and with high integrity.

Updates in the 2026 Edition

To help rapidly scale development of high-quality CDR, we developed the inaugural *Criteria for High-Quality Carbon Dioxide Removal* in 2021. This 2026 update is intended to achieve two key objectives:

- ↳ The updated criteria support and guide submissions to Microsoft for CDR procurement.
- ↳ More broadly, the updated criteria help advance a common definition of high-quality CDR by providing widely applicable quality benchmarks. We hope to catalyze CDR market maturation that facilitates just, effective climate action at scale.

We emphasize that the following criteria are not a substitute for due diligence to demonstrate scientific efficacy, validation, and ongoing assurance as the project progresses. Nor are the criteria intended to replace existing industry standards, which provide important—though in some cases imperfect or underdeveloped—quality assurance. We encourage existing standard-setting bodies to consider how these criteria could inform their protocols and principles.

The science of CDR is evolving, and these criteria will progress with this evolution. The 2026 edition provides updates across the essential principles as well as to each of the CDR methods. This year, we added an *Appendix* on delivery risk that covers criteria that can reduce the risk of project underperformance for CDR projects, as defined for open- and closed-system projects. In subsequent iterations, we plan to add additional detail to define delivery risk considerations based on the CDR approach. We look forward to collaboratively refining this guidance in a way that is consistent with our understanding of the market's quality needs over the coming years.

Essential Principles for High-Quality Carbon Dioxide Removal

Essential Principles for High-Quality Carbon Dioxide Removal

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The following common set of shared principles are intended to help characterize high-quality CDR projects. Note that we distinguish between principles that "must" or "should" be considered during project development and implementation. We use these terms to differentiate between minimum viable project characteristics (must) versus ideal project characteristics (should). These principles are not exhaustive but are intended to describe key considerations across all CDR pathways.

A "project" is a cohesive set of activities that are relevant to generating CDR credits. In some cases, CDR activities may be a part or extension of a larger body of activity. For these cases, the "project" refers to the component that is relevant to generating CDR credits. CDR developers and buyers typically evaluate the quality of individual projects. It is also important to consider potential environmental, social, and other impacts across a CDR portfolio. While impacts of individual projects are often relatively small, collective impacts from each CDR pathway at scale may be significant.

High-quality CDR projects must remove CO_2 from the atmosphere for a project's contracted duration, which is the core environmental service buyers purchase. The principles of additionality, durability, limited leakage, and measurement, monitoring, reporting and verification determine whether or not that service has been delivered. High-quality projects also must safeguard the wellbeing of people and ecosystems impacted by the project. These are detailed below and for each CDR pathway in this report.

Effective project management is essential to deliver high-quality CDR projects. While project developers must first design projects that will result in high-quality CDR, as defined by the criteria detailed here, effective project management is essential to translating the intent behind "must" and "should" criteria into concrete product requirements and real-world applications. Project developers need to incorporate the technical, economic, commercial, organizational, and political facets of a project into project design and management to ensure projects are able to deliver credits as planned. Fundamentally, the criteria provided here are intended for project developers to use as guidelines as they pursue detailed project requirements. Successful project management involves comprehensive coordination of tasks and resources, adherence to project specifications and standards, economic optimization, skilled commercial negotiation, and smooth operational flows from ideation through handover to operations. High-quality project management navigates stakeholder expectations and political landscapes, uniting diverse stakeholder viewpoints to work toward common goals. See more criteria that projects should follow to minimize delivery risks in the *Appendix*.

We engage with developers at every stage of the project life cycle, from concept development to ongoing operations to final closure and post-project monitoring. We acknowledge that early-stage projects may not yet have the resources to demonstrate full adherence, but should nonetheless commit the necessary resources to achieve criteria compliance as quickly as possible. Early-stage projects must align their planning accordingly and demonstrate clear pathways to criteria adherence prior to operations. Developers are also encouraged to engage with ongoing project monitoring and assurance activities that build confidence in implementation throughout the project life cycle.

The principles for specific CDR pathways build upon the common principles described on the following pages.

Social Harms, Benefits, and Environmental Justice

High-quality CDR projects contain strong elements of harm prevention, harm reduction, and meaningful benefits distribution. High-quality CDR projects prevent new **social harms** to people and communities and support a reduction in existing harms. Because concerns vary by CDR pathway and project, the harms that follow are not exhaustive, but are intended to describe some of the common and potentially negative impacts across all CDR pathways. Beyond preventing and reducing harm, high-quality CDR projects can provide additional **social benefits** to local communities by advancing environmental justice, building climate resilience, and supporting livelihoods.

Environmental justice focuses on improvements in the material conditions of front-line communities who experience disproportionate pollution exposure and other environmental burdens. This includes the equitable distribution of environmental benefits and harms resulting from CDR project development, implementation, and ongoing measurement, monitoring, reporting, and validation. Environmentally-just CDR projects facilitate meaningful participation and collaboration with local communities throughout the project life cycle. It is important that community involvement is equitable, inclusive, accessible, and centers perspectives from vulnerable or marginalized communities. This collaboration and shared project leadership starts by acknowledging past and present harms to front-line communities.

Social and environmental harms and benefits are closely interwoven. Harms and benefits that primarily impact ecosystems are discussed under the *Environmental Harms and Benefits* section.

PROJECT DEVELOPERS MUST

- Document direct social harms resulting from the project, including evidence of a low risk of negative community health impacts, and assess whether the project might materially exacerbate existing burdens on proximate and marginalized communities.
- Reduce any project-specific social harms, and document related mitigation and prevention measures the project has or will implement.
- Adhere to any country, state, and/or local protocols of community consultation in and near the project area in the early stages of project development (e.g., United Nations Free, Prior, and Informed Consent, State of California Tribal Consultation Laws, Government of Canada Public Consultations, etc.).
- Comply with any country, state, or local laws, including those related to benefit-sharing agreements with local communities.
- Guarantee that communities within and proximate to the project area will not be physically displaced as a result of project activities.
- Quantify the displacement of income-generating activities and local livelihoods caused by project activities (e.g., agricultural practices) and, where appropriate, identify pathways for supporting a just transition to new employment opportunities.
- Document ongoing direct and transparent engagement with directly impacted communities, including marginalized and Indigenous peoples, if present, throughout the project lifetime. This must include outlining pathways for integrating community needs/input across project phases at the "Involve" level, as defined by the Movement Strategy Center's *Spectrum of Community Engagement to Ownership* for evaluating procedural equity.
- Avoid developing, disturbing, or restricting access to lands or waters legally designated as culturally sensitive and provide a mitigation plan for lands or waters that communities and local stakeholders have identified as culturally and ecologically significant and that may be impacted by project activities.
- Explicitly describe worker compensation in project proposals, detail how this compensation fits within the microeconomics of the region (e.g., whether wages are meaningfully above poverty wages), and ensure workers receive a living wage for that region.
- Explicitly describe how the project approaches benefit sharing with local communities, including information about the percentage of project revenues or profits paid to project stakeholders (e.g., community members, landowners, and other local partners); the form of these payments (e.g., cash payments, in-kind payments, or funding for community services); the timing of these payments; and assumptions used to value non-cash benefits. If there is no benefits-sharing program, plainly state so.

- Explicitly describe any worker-related health and safety impacts and provide best-in-practice training and reporting channels.
- Conduct and disclose diligence on all direct counterparties,[2] demonstrating that direct counterparties do not have a significant history or ongoing pattern of legal or regulatory violations, questionable conduct, or human rights concerns.

PROJECT DEVELOPERS SHOULD

- Engage with local communities at the level of “Collaborate” as defined by the Movement Strategy Center’s *Spectrum of Community Engagement to Ownership*.
- Promote long-term sustainable livelihoods and economic opportunities for local communities. This can include providing additional non-monetary benefits, such as training and education opportunities, improvements to local facilities, and access to the voluntary carbon market.
- Ensure that any social benefits the project claims are being tracked with qualitative and quantitative indicators that reflect project dimensions (e.g., revenue sharing, workforce development goals, community investment funds, etc.). Provide robust evidence to support any claims of social benefits resulting from the project.
- Clearly articulate distributive equity of project benefits to ensure underserved, marginalized, and vulnerable populations are involved, economically empowered, and generating wealth for themselves during the lifetime of the project.
- Design projects with community-centered approaches that do not restrict the current use of or access to land. Where possible, increase community land use or access over the course of the project lifetime.
- Promote context-appropriate social inclusion by ensuring equitable participation of women, low-income communities, and other marginalized groups in project implementation and benefits.
- Prioritize engagement with direct counterparties that demonstrate strong community relationships where the project is sited, a clear understanding of local contexts, and compliance with applicable human health regulations.
- Provide training, technical assistance, or resources to help direct counterparties meet labor, safety, and community engagement standards when possible.
- Develop, and require direct counterparties to adhere to, a written code of conduct or operating standards covering labor rights, health and safety, anti-corruption, and community engagement.

2. *A direct counterparty is defined as a facility, organization, or entity that a CDR project directly contracts with and is structurally dependent on to generate credits, including for its location (e.g., landowners that make up a significant proportion of project land or existing facilities), provision of key materials (e.g., mines or nurseries), or project implementation (e.g., key implementation partners or service providers).*

Environmental Harms and Benefits

Environmental harm is defined as any impact on the environment as a result of human activity that has the effect of degrading the environment, whether temporarily or permanently. Minimizing environmental harms involves preventing and mitigating negative impacts on environmental systems. Common classes of harms seen across CDR project types include release of pollutants into air, soil, and water; thermal pollution; disruption of nutrient cycling; introduction of invasive species; and habitat fragmentation. Because concerns vary by CDR pathway and context, the harms that follow are not exhaustive, but are intended to describe some of the common and potentially negative impacts across all CDR pathways. In addition to preventing and mitigating harms, high-quality projects strive to promote **environmental benefits** that extend beyond the environmental benefits of carbon removal. Environmental benefits can include enhancing ecosystem services and underlying ecological and environmental functions, such as maintaining or increasing biodiversity.

Social and environmental harms and benefits are closely interwoven. Harms and benefits that primarily impact communities and people are discussed under the *Social Harms, Benefits, and Environmental Justice* section. Impacts that have a significant bearing on both ecosystems and communities are addressed in both sections.

PROJECT DEVELOPERS MUST

- Obtain all required legal permits and operating permissions from the appropriate local, state/providence, and federal authorities.
- Avoiding siting projects in or near environmentally sensitive areas (e.g., protected habitats, critical ecosystems, or designated conservation areas) if there is a credible risk of adverse environmental impacts.
- Document all potential negative impacts to surrounding ecosystems, including acute, chronic, and accumulated impacts.
- Implement and document a strategy for mitigating, monitoring, and remediating negative environmental impacts.
- Transparently report any use of toxic and/or persistent environmental pollutants, including agrochemicals, and the risk of their release into the environment.
- Regularly inform the local community about the results of environmental risk assessments and monitoring activities, including any material findings and corresponding mitigation measures.
- Implement supply-chain strategies that seek to minimize or mitigate air, water, and land impacts, including waste handling and disposal activities associated with the project.
- Avoid using industrial chemicals and pesticides banned in the United States or the European Union (regardless of project geography) unless a comprehensive, public risk management plan accompanies the proposed chemical's use in the project.
- Conduct and disclose diligence on all direct counterparties, demonstrating that direct counterparties do not have a repeated and/or significant history, or ongoing pattern, of questionable environmental conduct or environmental permit violations.

PROJECT DEVELOPERS SHOULD

- Implement activities that promote ecosystem services, such as clean air, water, or habitat restoration, and the ecological and environmental functions that underpin them.
- Implement a plan for tracking and reporting on relevant environmental metrics to substantiate any claims of environmental benefits resulting from the project.
- Prioritize partnering with local organizations and industries to reduce emissions and environmental risks associated with the project's upstream and downstream supply chains.
- Make and report progress on public carbon reduction targets and/or clean energy transition commitments.
- Prioritize engagement with direct counterparties that demonstrate understanding of applicable regional and local environmental systems and adherence to environmental health regulations.

Additionality and Baselines

Removal credits are **additional** if they would not have occurred without carbon finance. The baseline of a project is a conservative estimate of the carbon and other GHG impacts that would have occurred without carbon finance (the "counterfactual").

PROJECT DEVELOPERS MUST

- Show that carbon finance is required to implement the project. When multiple finance streams support a project, projects are considered additional if revenue from the sale of carbon credits is required to build, manage, and execute the CDR project.
- Provide project financial information sufficient to demonstrate financial additionality (including any national or state support), particularly where multiple revenue streams are present.
- Demonstrate how variation in key financial assumptions (through sensitivity analysis or similar methods) affects project viability with and without carbon credit revenue.
- Show that the project is not required by existing laws, regulations, or other binding obligations. If current laws or regulations mandate the project's proposed activities, but are not being actively enforced, projects must provide justification for why enforcement is not expected to happen during the project's crediting period.
- Show that project activities are not common practice in the absence of financial or regulatory incentives.
- Quantify the project's claimed carbon removal relative to the most scientifically-, economically-, and legally-plausible baseline for carbon stocks and flows (i.e., the counterfactual in the absence of carbon finance).
  - ↳ Baselines must account for both recent and projected changes in carbon and other GHG stocks and flows.
  - ↳ Baselines must be conservative, project specific, and site specific.

PROJECT DEVELOPERS SHOULD

- Document a rationale for the assumptions used for cost of debt and cost of equity when demonstrating financial additionality.
- Identify and report any potential conflicts or overlap between project activities and national or subnational policies for climate mitigation.

Measurement, Monitoring, Reporting, and Verification

Carbon measurement, or project-level carbon accounting, reports all GHG emissions associated with a CDR project using repeatable and verifiable GHG quantification methods. In general, this requires the use of a cradle-to-grave life cycle assessment (LCA) and/or models that accurately estimate CDR, calibrated by periodic direct measurement.

Monitoring, reporting, and verification (MRV) involves developing and adhering to a plan for long-term monitoring of the project. Measurement and MRV are often closely linked. Developers should consider the interactions between these two criteria during project planning and execution.

PROJECT DEVELOPERS MUST

- Develop and document an MRV plan prior to the start of the project that is sufficient to substantiate all credited project performance claims over the crediting period and to support reasonable projections beyond the active monitoring period.
- Adapt the MRV plan throughout the project by incorporating the best available science and evolving industry practices.
- Use scientifically supported and technically recognized measurement methods, appropriate to the project context, to quantify the net volume of removals the project claims and disclose the specific methods used.
- Adhere to best practices (e.g., ISO standards 14040 and 14044) when preparing and submitting a project LCA, including using a cradle-to-grave system boundary that is inclusive of the relevant MRV time window and end-of-life project activities, conservatively quantifying all GHG emissions associated with the project, and disclosing the allocation method when multiple products exist.
- Disclose all sources of and conservatively discount for uncertainty to avoid overstating the estimated CDR from a project, both overall and by time period (e.g., annual CDR).
- Design schedule or trigger conditions for LCA updates into the MRV plan, to reflect material operational, methodological, or data changes over the project lifetime.
- Separately quantify and report emissions removal, reductions, and other avoided emissions, and delineate by GHG type.
- Use models that are calibrated and validated for the specific conditions the project will operate in, if applicable. Within each evaluation step, ensure validation is conducted using separate data (i.e., not data used for model calibration).
- Specify model assumptions that cannot be calibrated or revised due to practice constraints, if applicable. Developers must periodically review MRV measurements and other scientific advancements to revise all other assumptions.
- Ensure there is no double issuance or double use of credits by following best-in-class carbon accounting guidelines, including allocating GHGs at the project level.
- Ensure that the project's MRV plan and corresponding calculated net removal volumes are or will be verified by an independent third party and certified by a standards body.

PROJECT DEVELOPERS SHOULD

- Use regionally appropriate sampling and data collection methods to quantify GHG emissions and removals associated with a project, instead of using solely model-based or statistical methods.
- Directly measure carbon removed and stored throughout the duration of the project, to the maximum practical extent possible. Store this data in a shared repository or facilitate data access to advance MRV for CDR projects and accelerate CDR market development.
- Contribute data and/or project learnings to advance the development and improvement of robust global datasets and models.

Durability

Durability is the capacity for stored carbon to withstand reversal, or reemission, to the atmosphere. We use the term "durability" because it is less absolute than "permanence" and acknowledges the temporal variability inherent to most forms of carbon storage. The durability of stored carbon is limited by both natural and anthropogenic risks of reversal, which can prematurely release carbon from storage. Reversals can be either intentional (e.g., changing management practices) or unintentional (e.g., natural disturbances). Longer and more durable storage terms are preferable (until widely accepted methods enable comparison of varied durability terms).

PROJECT DEVELOPERS MUST

- Document and substantiate the projected duration (in years) over which removed carbon will be stored using a combination of the best available science and relevant system performance metrics.
- Implement an MRV plan to monitor the stored carbon, reliably detect reversal events over the monitoring period, and, as applicable, collect enough evidence to reliably predict the likelihood of reversal events after the active monitoring period up to the stated durability term.
- Conservatively estimate a project's risk of reversal using the best available science, including planning for present and future climate change.
- Identify who is liable for remediating the reversal of stored carbon and the length of this liability (e.g., number of years), including any intended transfer of liability.

PROJECT DEVELOPERS SHOULD

- Site projects in areas with a low risk of reversal and implement ongoing risk-mitigation measures to minimize the impact of future reversal events, including future risks associated with climate change.
- Mitigate the risk of reversals throughout and beyond the project operational lifetime.
- Rely on insurance-type products, such as a buffer pool, that address the risk of reversal and satisfy the following criteria.
  - ↳ Reflect a scientifically substantiated, conservative risk of reversal, including possible increases in risks associated with climate change.
  - ↳ Dictate that intentional reversals must be entirely remediated, even exceeding all buffer pool contributions from the project.
  - ↳ Retire a project's buffer pool credit contributions at the end of the project monitoring period.
  - ↳ Draw upon like-for-like CDR for compensation, where possible.

Leakage

Economic leakage ("leakage") is the displacement of GHG emissions from the project site to another geographic location. Economic leakage typically occurs because market demand for the output of the emitting activity is unchanged, while the CDR project decreases local supply. Leakage must not be confused with *physical leakage* of stored CO_2, which is discussed in the Durability principle.

There are two forms of economic leakage: activity-shifting and market. Activity-shifting leakage occurs when agents operating within a project boundary shift production to outside the project boundary. Market leakage occurs when a project reduces the production of a good, and this local reduction induces increased production of that good or a replacement good elsewhere to meet demand. Market leakage can be very difficult to predict and measure.

PROJECT DEVELOPERS MUST

- Assess the likelihood and potential magnitude of market leakage and conservatively account for the associated carbon impacts, including both domestic and international leakage. Alternatively, compellingly demonstrate that the project avoids any leakage.
- Design projects to avoid directly inducing activity-shifting leakage, and conservatively account for and mitigate any such leakage that occurs.
- Document all significant sources of leakage and implement mitigation strategies to minimize unwanted leakage outcomes over the lifetime of the project.
- Justify the assumptions, methods, and data sources used to quantify leakage.

PROJECT DEVELOPERS SHOULD

- Design project activities to reduce the probability of inducing market leakage.
- Document positive leakage when project activities are expected to lead to additional carbon benefits beyond the project boundaries, and provide supporting evidence even if the methodology does not require it.

Green leaves with clusters of small green buds.

Glossary of Technical Terms for the Essential Principles

Activity-shifting leakage: Occurs when agents operating within a project boundary shift production to outside the project boundary, thereby displacing GHG emissions from the project site to another geographic location.

Crediting period: The period of time during which CDR projects can generate and issue credits under an approved methodology.

Direct counterparty: A facility, organization, or entity that a CDR project directly contracts with and is structurally dependent on to generate credits, including for its location (e.g., landowners that make up a significant proportion of project land or existing facilities), provision of key materials (e.g., mines or nurseries), or project implementation (e.g., key implementation partners or service providers).

Durability period: The period of time that a CDR project states that the carbon it removes will remain out of the atmosphere, without reversal.

Flows (carbon): The movement of carbon between reservoirs (e.g., land-ocean-atmosphere carbon exchange).

Front-line communities: Communities of color, low-income communities, women and gender-diverse groups, Indigenous peoples, and other vulnerable communities affected by the intersecting crises of climate and racial injustice.

Life cycle assessment (LCA): A methodology used to evaluate the environmental impacts of a product, process, or service across its entire life cycle, from raw material extraction to end-of-life disposal or recycling.

Market leakage: Occurs when project activities reduce production of a good, thereby inducing increased production of that good (or a replacement good elsewhere) to meet demand. Ultimately, market leakage causes displacement of GHG emissions from the project site to another geographic location.

Mitigation strategy: Planned actions and approaches designed to reduce or prevent GHG emissions and other negative environmental, social, or economic impacts of a project.

Model calibration: The process of adjusting model parameters to improve agreement between model outputs and observed real-world data.

Model validation: The process of assessing how well a model's outputs match real-world data or expected behaviors to ensure its accuracy and reliability.

Model uncertainty: The degree of confidence or potential error in a model's predictions due to limitations in data, assumptions, or parameter estimations.

Monitoring methodology: All methodologies for predicting and monitoring relevant elements and properties for carbon accounting and environmental harms, including documenting and reporting all uncertainties and assumptions made in data analysis and calculations.

Monitoring period: The period of time over which a CDR project actively collects, aggregates, and reports data to quantify removals, emissions, storage status, and other required parameters for a specific verification or reporting cycle.

Positive leakage: A beneficial effect of project activities that are expected to lead to additional carbon benefits beyond the project boundaries (e.g., established project woodlots will result in reduced fuelwood collection in existing forests).

Project activities: All relevant processes, facilities, and land used throughout the scope of the project, such as industrial operations, feedstock sourcing and processing, seed sourcing and planting, stakeholder engagement, chemical manufacturing, and waste disposal.

Stocks (carbon): The amount of carbon held in a reservoir (e.g., atmosphere, technosphere, biosphere) at a given point in time.

System boundary: The defined limits—physical, geographical, temporal, and conceptual—within which an LCA is conducted, identifying which elements are included or excluded.

Third party: An independent individual or organization that is not directly involved in the project's development or operation but is engaged for auditing, verification, certification, or other forms of external review.

Afforestation, Reforestation, and Revegetation

Forestation is the process of planting or replanting trees to enhance carbon storage and other ecosystem services. Agroforestry integrates trees within agriculture production systems. These approaches are collectively known as **Afforestation, reforestation, and revegetation (ARR)**. We include criteria for *Improved Forest Management* and *Mangrove Forestation* in separate sections below. Given the large amount of degraded land around the globe, ARR approaches offer substantial opportunities to remove carbon from the atmosphere while simultaneously providing important co-benefits to communities and nature. ARR projects have complex social, ecological, and economic land-use dynamics, which are place based. Given this, it is essential to site projects in socially as well as environmentally appropriate areas. The following principles for ARR projects build upon those described previously under the *Essential Principles for High-Quality Carbon Dioxide Removal* section.

Afforestation, Reforestation, and Revegetation

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Social Harms, Benefits, and Environmental Justice

These criteria build on and extend the social harms, benefits, and environmental justice considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Develop projects only on land where tenure (including communal or customary rights) is clearly and broadly recognized by the relevant parties to minimize the risk of tenure conflicts, disenfranchisement, and displacement of local communities.
- Work with a land rights specialist to develop a process to verify the land tenure of target lands.
- Avoid violence when establishing or protecting forested areas.
- Respect local or traditional approaches to landownership and management, decision-making, and benefit distribution.
- Work with experienced partners, including those with relevant local expertise, to select project locations, species, and planting approaches.
- Select species for agroforestry systems in consultation with the local communities who will be caring for or benefiting from the trees.
- Where project activities displace existing activities, ensure that alternative livelihoods substitute for displaced activities (including activities deemed destructive or illicit).
- When project activities displace subsistence agriculture, ensure that this does not increase food insecurity.
- Provide a fair and transparent mechanism for communities or individuals to opt out of or terminate lease agreements when they no longer wish to participate.
- Codevelop benefit-sharing arrangements that are appropriate for the type of local land tenure, including negotiating terms before carbon credits are sold, transparently disclosing what portion of revenue the rights holders will receive, and indicating how and when funds are apportioned.
- Provide sufficient training and technical support to ensure that project trees are properly established and managed and, in agroforestry projects, to ensure that project trees are integrated in ways that support crop productivity.

PROJECT DEVELOPERS SHOULD

- Submit the tenure verification process to audit by a credible third party.
- Promote locally relevant and equitable integration of women, low-income, and other marginalized communities into project activities.
- Proactively plan for the job security and economic stability of workers to mitigate the short duration of many forestation activities (e.g., through longer-term employment across multiple parcels in a region).
- Actively promote long-term sustainable livelihoods and economic opportunities for local communities (e.g., support local workforce development programs and initiatives).

Environmental Harms and Benefits

These criteria build on and extend the environmental harms and benefits considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Site projects only in places that are ecologically suitable for self-sustaining forest growth and will not cause environmental harm (e.g., water stress).
- Avoid the destruction of historically non-forested native ecosystems such as wetlands, grasslands, and savannas. If targeting these ecosystems for afforestation, provide documentary evidence that they are severely degraded and no longer support critical ecosystem functions.
- Select a forestation strategy based on a scientifically defensible interpretation of the site's ecological and social context. For ecological restoration projects, use a scientifically defensible reference model as a guide to benchmark forest recovery.
- For reforestation projects, promote biodiversity and resilience by growing an ecologically appropriate diversity of mostly native species and pursuing ecological restoration or natural regeneration of formerly forested areas where conditions allow.
- For agroforestry projects that use non-native trees, prioritize planting known locally naturalized multi-purpose species and provide justification (e.g., community preference, site amelioration).
- Avoid using species that have the potential to become invasive and follow the Precautionary Principle.
- Prioritize local seed stock collection methods that do not harm natural forests, do not reduce the production of non-timber forest products, and utilize local infrastructure and seed supply chains.
- Avoid damaging, destroying, or harvesting existing trees during site preparation, unless those trees are non-native or diseased, or there is a valid silvicultural justification to remove them.

PROJECT DEVELOPERS SHOULD

- Expand and diversify the coffer of native seeds or germplasm available to ensure adequate supply to meet preexisting demand and to accommodate demand from new CDR project activity, prioritizing local job creation whenever possible.
- Prioritize cost-effective forestation techniques that harness the site's natural recovery potential such as applied nucleation, direct seeding, or assisted natural regeneration.
- Work to abide by Kew Gardens' 10 Golden Rules for Reforestation.

Additionality and Baselines

These criteria build on and extend the additionality and baselines considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- For reforestation projects, use a dynamic baseline with statistically matched controls. For agroforestry projects, use a dynamic baseline if project conditions allow, or present a valid justification if they do not.
- For agroforestry projects not using a dynamic baseline, provide other analyses, such as historical time series of remotely sensed data, to ensure that pre-project natural regeneration is incorporated into the baseline calculations and not credited to removals.
- Evaluate the natural regeneration baseline using the best available science to predict natural seedling establishment and forest growth in the absence of tree planting, and to select the most adequate forestation approach.
- Ensure that pre-project trees are monitored and credited throughout the monitoring period only if their growth is directly attributable to project activities.
- If using a dynamic baseline, use remote sensing protocols that ensure representative selection (i.e., based on relevant covariates) and matching (i.e., statistical similarity) of project plots to control plots.
- If using a dynamic baseline, select a stocking index that correlates closely with in situ forest carbon or biomass as validated by relevant field data, and that can detect trends in above ground biomass stocks over time with sufficiently low uncertainty, noise, and bias. Prioritize stocking indices based on structural data.
- When making the case for common practice additionality, present credible evidence of the barriers to implementing agroforestry systems—particularly where established local or regional markets for agroforestry products already exist.

PROJECT DEVELOPERS SHOULD

Use a crediting approach that adjusts dynamically if legal requirements or other land-use dynamics change over time, especially where the project area is legally required to be forested, but it is generally not, or where future land use is uncertain.

Measurement, Monitoring, Reporting, and Verification

These criteria build on and extend the measurement and MRV considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Specify key assumptions that materially affect modeled ex ante carbon accumulation rates, such as the geographic and environmental variables, choice of allometric models, and expected seedling survival rates.
- Use statistical samples and the best-available models to quantify above-ground carbon (e.g., context appropriate and statistically robust allometric equations) ex post. For all models provide a science-based justification and transparent methodology for the selected approach.
- Conduct uncertainty analyses, conservatively incorporate results into ex ante models, and transparently disclose all sources of uncertainty.
- Stratify the project area and determine sampling intensity using statistical analysis to ensure the sampling approach is representative of the project area and meets predefined uncertainty thresholds.
- For ex post sampling design, use a probability-based selection process with documented randomization procedures to minimize risk of plot selection bias.
- Use ground inventories to validate remotely sensed measurements of above-ground biomass changes.
- Quantify changes in below-ground carbon, where this pool is included, using the most conservative root:shoot ratios (i.e., use smaller ratios to mitigate uncertainty) or using well-supported species- or forest-specific ratios, to reduce the risk of overcrediting.
- Measure and monitor changes in soil carbon using the criteria listed in the Soil Carbon section for any projects that are claiming removals in soils or where project activities are likely to decrease soil carbon.
- Quantify any GHG fluxes associated with site preparation, including removal of existing vegetation or long-distance transportation of seeds and seedlings. If GHG fluxes are determined to be insignificant, provide a justification.
- Explicitly account for agroforestry design features (e.g., planting density, regular coppicing) that are likely to influence tree growth in the carbon accumulation model.

PROJECT DEVELOPERS SHOULD

- Use site-specific data, including but not limited to data collected by the project developer, to better parametrize models used to estimate biomass changes (e.g., species-specific allometries and wood density measurements).
- Use permanent sampling plots to facilitate a data-driven understanding of change over time and more efficiently achieve required statistical precision, unless there is valid justification for temporary plots (i.e. known location of plots could influence farmer management decisions).
- Ensure that projects are sited on lands where the net impact on soil carbon is expected to be positive (e.g., degraded lands).
- Include a cradle-to-farm gate LCA of harvested agroforestry and plantation products if the project will produce wood products or agricultural commodities from trees included in its carbon accounting.
- Quantify applicable and appreciable indirect climate impacts and include them in project carbon accounting. For example, projects sited in high-altitude or high-latitude areas should include estimated changes in albedo due to establishment of tree cover in the project's carbon accounting.
- Publish or share monitoring data sets whenever possible, especially when working in poorly known ecosystems or where quality information is lacking.

← AFFORESTATION, REFORESTATION, AND REVEGETATION

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Durability

These criteria build on and extend the durability considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Use the best available information to forecast future risks of disturbance to planted forests and situate projects in areas of low risk. Salient disturbance risks include, but are not limited to, direct and indirect impacts of climate change, drought, fire, pests and diseases, financial insolvency of the project operator, land theft, timber theft, and social disturbances.
- For ecological restoration projects, identify the human and/or environmental drivers of forest loss or degradation and ensure that the proposed interventions properly address them.
- Actively mitigate identified risks throughout the project duration (e.g., forest thinning in fire-prone areas).
- Select species adapted to future climate conditions and use planting patterns that foster resistance to disturbance, where appropriate.
- Implement seedling planting and monitoring plans to maximize the probability of tree survival during the critical three- to five-year establishment period, factoring in physical infrastructure and human capacity needs.
- Implement a long-term plan to reduce avoidable reversal risks and ensure that carbon stocks are maintained for the duration of the crediting period.
- Leverage early-warning systems to detect and respond to reversals, particularly wildfire.
- For projects introducing new commodities, demonstrate adequate planning and resourcing to implement the supply infrastructure and demand offtake needed to support the long-term viability of the new commodity crop.
- When leasing land, align the leasing terms to the project's durability terms or add provisions that show a clear path in that direction (e.g., renewal clauses).

PROJECT DEVELOPERS SHOULD

- Select plant material with genetic and provenance variability, sourced from areas likely to match the future site conditions, to promote resilience.
- Include a plan and earmark the necessary resources to replace agroforestry trees that are projected to reach the end of their productive life before the crediting period expires. If replanting is a landowner obligation, specify this in the landowner agreement.
- Incorporate harvested timber or biomass into long-lived wood products, either traditional (e.g., lumber, oriented strand board) or emerging (e.g., biochar, cross-laminated timber).
- Encourage additional productive uses of land such as sustainable wood production, sustainable harvest of non-timber forest products, and ecotourism to ensure that forests are protected and maintained over time.
- Pilot new methods in small areas and use monitoring results to inform scaling when interventions are first-in-kind locally.
- Leverage existing legal or policy instruments (e.g., conservation easements, protected area designation) to secure the durability of the carbon stocks beyond the crediting period.
- When leasing land, include measures to support intergenerational decision-making and facilitate landownership transitions that safeguard long-term project continuity.

Leakage

These criteria build on and extend the leakage considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- When claiming low leakage rates, provide evidence that project lands are degraded, that project lands have low economic value, or that project activities do not significantly displace existing land uses. The evidence must show that one of the following scenarios is true.
  - ↳ The project is sited in an area where agricultural land use and active land cover change have been minimal over the preceding decade, and there is a low likelihood of future agricultural use.
  - ↳ Tree planting is integrated into ongoing agricultural practices through sustainable agroforestry systems that can reliably support or enhance existing yields.
- When determining activity-shifting leakage, use a combination of remotely sensed land-use data to characterize land cover changes with production records or other credible data to ensure that leakage accounting is conservative.
- When activity-shifting leakage is likely, establish contractual agreements and/or implement project-specific activities that mitigate leakage and adequately monitor the impacts of the mitigation plan.

Glossary of Technical Terms for Afforestation, Reforestation and Revegetation

Afforestation: Planting trees or seeding in areas that have not been forested historically.

Agroforestry: A land-use management system that intentionally integrates trees or shrubs into agricultural lands.

Dynamic baseline: A baseline that compares the project area to matched control plots outside of the project area. Control plots are located in areas with similar characteristics to the project area but are not subjected to project activities. A dynamic baseline is updated regularly to reflect changes in land use and forest conditions over time.

Precautionary Principle: An approach to risk management that promotes caution and prevention when scientific certainty about cause-and-effect relationships is not fully established.

Recruitment: The process by which new individuals are added to a plant population, whether by germination and maturation or by dispersal.

Reference model: A model that describes the expected condition of a site without degradation and that accounts for background and predicted changes in environmental conditions.

Reforestation: The process of replanting trees in areas where forests once existed but were lost or degraded.

Mangrove Forestation

Mangrove forestation, including ARR, is the process of growing mangrove tree species to establish forest cover. Located within the intertidal zones of tropical and subtropical coastlines, mangroves are highly productive forests capable of stocking large amounts of carbon in their biomass and soils. However, intertidal ecology also necessitates specific forestation considerations, such as potential hydrological restoration of the site. Given the unique ecology of mangroves, we provide specific guidance for mangrove forestation here. The following principles build upon those described previously under the *Essential Principles for High-Quality Carbon Dioxide Removal* section.

Mangrove Forestation

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Social Harms, Benefits, and Environmental Justice

These criteria build on and extend the social harms, benefits, and environmental justice considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Implement projects on land where tenure (including communal, informal, or customary rights) is clearly and broadly recognized, and appropriately documented, by the relevant parties to minimize the risk of tenure conflicts and exclusion of local stakeholders.
- Incorporate local or traditional approaches into landownership and management.
- Use equitable and livelihood-sensitive approaches to addressing anthropogenic drivers of deforestation and barriers to natural regeneration or reforestation, particularly where forest use (e.g., fuelwood collection or grazing) supports local livelihoods.
- Provide a fair and transparent mechanism for stakeholders to opt out of agreements if they no longer wish to participate.
- Codevelop benefit-sharing arrangements with local communities, including negotiating terms before carbon credits are sold, transparently disclosing what portion of revenues the communities will receive, and indicating how and when funds are apportioned in culturally appropriate terms.
- Prioritize mangrove forestation in areas that protect communities from storm surge, prevent coastal erosion, and support fish nursery habitat.

PROJECT DEVELOPERS SHOULD

- Promote locally relevant and equitable integration of women, low-income, and other marginalized communities into project activities.
- Proactively plan for worker job security and longer-term economic stability to mitigate the short duration of many forestation activities (e.g., through longer-term employment across multiple parcels in a region).
- Actively promote long-term sustainable livelihoods and economic opportunities for local communities (e.g., support local workforce development programs and initiatives).

Environmental Harms and Benefits

These criteria build on and extend the environmental harms and benefits considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Avoid the destruction of other coastal ecosystems, such as seagrass meadows and natural tidal mudflats, which are globally important and threatened ecosystems.
- Avoid damaging or destroying any existing mature mangroves during site preparation activities.
- Prioritize biodiversity by planting an appropriately justified variety of native species suited to current and future environmental conditions.

PROJECT DEVELOPERS SHOULD

- Prioritize restoration methods that re-establish natural hydrological conditions and support natural mangrove regeneration, rather than solely rely primarily on large-scale planting.
- Assess the project's effects on groundwater levels and the associated impacts on groundwater-dependent ecosystems, including adjacent wetlands, beyond the project boundary. Where monitoring detects a measurable change in adjacent groundwater ecosystem hydroperiod, salinity, or vegetation composition that exceeds natural seasonal or interannual variability and is attributable to the project, implement adaptive management to mitigate further impact, or document the rationale for a decision not to mitigate.

Additionality and Baselines

These criteria build on and extend the additionality and baselines considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Identify the human and/or environmental drivers of mangrove loss or degradation, and ensure that the proposed interventions mitigate the impacts of these drivers.
- Ensure only biomass gains attributed to the project activities are credited.
- Establish control plots to directly measure natural regeneration over the course of the project. These control plots must be selected from a donor pool area that is ecologically comparable to project plots across biophysical dimensions, including vegetation type, tidal regime, soil type, salinity gradient, geomorphic position, and land use history. If it is not possible to identify statistically significant and spatially appropriate control plots, justify how the project is demonstrating that natural regeneration is not occurring on an ongoing basis.
- If using dynamic baselines, use remote sensing protocols that: (1) measure multiple times within each year to reduce intra-annual variability driven by tidal flooding and cloud cover, and (2) are validated against field-measured plot data at representative sites.
- Identify constraints to natural recruitment/regeneration and either mitigate these constraints or provide evidence that site conditions are appropriate for planting.
- Distinguish between autochthonous and allochthonous soil carbon when establishing the baseline for soil carbon removals. Only include autochthonous removals that are demonstrably attributable to project activities and exclude externally derived (allochthonous) inputs that would occur under the business-as-usual scenario.
- Use historical time series of remotely sensed data to show that natural recovery of mangrove forest is very unlikely to occur when claiming a negligible natural regeneration baseline.

PROJECT DEVELOPERS SHOULD

Use a dynamic baseline with statistically matched controls if project conditions allow, even if not required by the methodology, to ensure that the project is not crediting carbon removals due to natural regrowth.

Measurement, Monitoring, Reporting, and Verification

These criteria build on and extend the measurement and MRV considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Justify the models and assumptions used to quantify expected carbon accumulation in the above-ground biomass, below-ground biomass, and organic soil pools. Include key determinants of carbon accumulation such as the environmental setting of forestation areas (e.g., fringe versus deltaic settings), species-specific allometries, and survival rates of seedlings.
- Conduct uncertainty analysis, conservatively incorporate results into ex ante models, and transparently disclose all sources of uncertainty.
- Use statistically robust sampling methods for quantifying above-ground carbon, including stratifying by site hydrogeomorphology (e.g., tidal inundation regime, salinity, sediment deposition, and microtopography) to capture spatial variability in biomass.
- When including below-ground carbon in project accounting, quantify the changes using the most conservative root:shoot ratios (i.e., use smaller ratios to mitigate uncertainty) or using well-supported species- or forest-specific ratios to reduce the risk of overcrediting.

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- Measure and monitor changes in soil carbon when claiming removals in soils, using the criteria listed in the *Soil Carbon* section and stratifying by site hydrogeomorphology (i.e., project developers must rely on empirical site-level data or models, not default soil carbon factors).
- Separate between allochthonous and autochthonous sources of soil carbon, if crediting soil carbon removals, and appropriately deduct the contribution of allochthonous carbon.
- Quantify and appropriately deduct any GHG fluxes associated with site preparation including removal of existing vegetation. If applicable, explain why any GHG fluxes are expected to be insignificant.
- Implement monitoring plans that measure changes in carbon stocks using some or all these approaches: mapping, remote sensing, relative sediment elevation table methods, long-term field plot measurements, and/or field-validated modeling.
- Use ground inventories to validate remotely sensed measurements of above-ground biomass changes.
- Compare and justify expected carbon accumulation numbers against benchmark figures, such as standing carbon stocks in proximal mature mangrove stands, global maps of mangrove carbon, or meta-analyses of carbon accumulation in planted mangroves from scientific literature.

PROJECT DEVELOPERS SHOULD

- To account for and deduct allochthonous carbon contributions, collect field sediment samples down to a depth defined by a temporal marker (e.g., a feldspar horizon), measure bulk density and total carbon content through laboratory analysis, and apply conservative baseline projection and monitoring methods consistent with best practice.
- Implement projects on lands where the net impact of forestation or agroforestry on soil carbon is likely to be net positive, unless soil carbon is directly measured.
- To quantify additional GHG fluxes, measure porewater salinity over the project's lifetime to model methane and nitrous oxide emissions.
- Quantify any indirect climate impacts (e.g., methane emissions potentially resulting from hydrologic restoration or soil disturbance).

Durability

These criteria build on and extend the durability considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Plant mangroves in appropriate locations with site-appropriate species where mangroves are likely to persist and flourish. For example, mudflats are often considered for mangrove planting but are unsuitable, as vegetation growth is limited in these areas.
- Prioritize planting strategies that mimic natural propagule establishment patterns, including planting in clusters or groups within the intertidal zone and planting in grids or with increased spacing outside the intertidal zone.
- Integrate projections and scientific models of sea level rise and increasing impacts of climate change over multiple timescales when choosing sites for forestation and species stratification. Projections must include SSP5-8.5 (i.e., the Intergovernmental Panel on Climate Change's high-emissions, high-warming scenario) to capture uncertainties in durability.
- Ensure proper site assessment and preparation, including reestablishing hydrological connectivity where necessary and testing for appropriate soil quality (e.g., redox potential, sulfides/sulfates).
- Implement active and ongoing measures (i.e., adaptive management plans) to mitigate identified risks to the durability of carbon held in mangrove forests (e.g., direct and indirect impacts from sea level rise, storm surge, or watershed management).
- Determine the hydrological status of the site and mitigate any impacts to site hydrology that might prevent successful mangrove forestation.
- Identify and mitigate anthropogenic drivers of mangrove loss throughout the project life.
- Implement seedling planting and monitoring plans to maximize the probability of seedling survival during the critical three- to five-year establishment phase, including physical infrastructure and human capacity considerations.
- Monitor and document seedling survival at multiple time points (e.g., at year one, three, and five), as well as any additional planting to replace dead seedlings in subsequent years.

- Unless justified as ecologically appropriate, avoid planting monocultures of generalist species, such as Rhizophora spp., particularly if or when project areas span a breadth of geomorphic strata and tidal regimes.

PROJECT DEVELOPERS SHOULD

- Continually monitor for potential policy conflicts for long-term management of forests due to unclear demarcations of intertidal zones and overlapping jurisdictions of national or local governments (e.g., Ministry of Marine Resources and Ministry of Forests).
- When initiating projects that involve harvesting for purposes other than fuelwood, incorporate harvested biomass into long-lived wood products, either traditional (e.g., lumber or polewood) or emerging (e.g., biochar). Where the project displaces existing fuelwood harvesting, establish woodlots or collection sites to absorb that demand within the project boundary; any displaced demand that cannot be redirected must be quantified and deducted as leakage.
- Plant species adapted to current conditions and resilient to future conditions and use planting patterns that foster resistance to disturbance, including plans to mitigate coastal squeeze (i.e., the phenomenon by which mangroves cannot migrate toward land in response to sea level rise due to impermeable surfaces such as paved urban areas).
- Incorporate appropriate flood management techniques to support early planting, such as restoring hydrological connectivity and only planting within a species' known tolerance for tidal inundation.

Leakage

These criteria build on and extend the leakage considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- When claiming low leakage rates, demonstrate and document that project activities do not displace existing livelihood uses (e.g., aquaculture, timber harvest, and fishing), and provide evidence that alternative livelihoods or resource access have been secured for affected communities where such uses are restricted.
- Where forestation converts active aquaculture or other productive coastal land uses, quantify and account for the associated emissions.
- Undertake ongoing leakage monitoring to verify and report that project activities remain unchanged, no new displaced activities emerge outside the project boundary, and that there are no changes to hydrology and sediment dynamics, where relevant to leakage risk.

PROJECT DEVELOPERS SHOULD

Use remotely sensed land-use data to determine leakage estimates, especially when coupled with models of land-use change.

Glossary of Technical Terms for Mangrove Forestation

Allochthonous carbon: Organic material contributions to carbon pools from neighboring ecosystems (e.g., leaf litter in a neighboring ecosystem falling into waterways and being transported to the project area).

Autochthonous carbon: Organic material contributions to carbon pools derived from within an ecosystem; in this case, mangrove species (e.g., mangroves photosynthesizing and sequestering carbon).

Hydrogeomorphology: The interaction(s) between hydrological processes (e.g., groundwater flow and precipitation) and landforms/earth minerals, as well as the interaction between geomorphic processes (e.g., soil formation and erosion) and surface/subsurface waters.

Hydrological restoration: The (re)establishment of appropriate site hydrology.

Recruitment: The process by which new individuals are added to a plant population, whether by germination and maturation or by dispersal.

A dense mangrove forest with tangled roots growing into calm water.

Improved Forest Management

Improved forest management (IFM) changes the management of existing forested landscapes to increase carbon storage. IFM includes a broad range of practices that increase carbon stocks in forests and forest products, such as deferred timber harvest, reduced impact logging, and other silvicultural adjustments. IFM project design is rapidly evolving as registries release new dynamic baseline methodologies, but general uncertainty remains concerning additionality and market leakage. These uncertainties make accurate quantification of CDR from IFM projects challenging, resulting in a tendency for project developers to overestimate carbon benefits. Exemplary IFM projects use the most up-to-date methods and transparently utilize accurate data to conservatively estimate carbon sequestration. The following principles for IFM build upon those described previously under the *Essential Principles for High-Quality Carbon Dioxide Removal* section.

Improved Forest Management

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Social Harms, Benefits, and Environmental Justice

These criteria build on and extend the social harms, benefits, and environmental justice considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Ensure that the project minimizes major risks to the health and safety of workers, especially risks present in forest management operations.
- Include landowners and forest rights holders in project planning, execution, and operation.
- Codevelop benefit-sharing arrangements with participating landowners, including negotiating terms before carbon credits are sold, transparently disclosing what portion of revenues stakeholders will receive, and indicating how and when funds are apportioned.
- Avoid increasing the risk of natural disturbances that may directly or indirectly impact local communities.
- Support Indigenous Peoples' and local communities' access to their customary resources, where applicable.

PROJECT DEVELOPERS SHOULD

- Provide a fair and transparent mechanism for private non-industrial landowners to opt out of or terminate lease agreements when they no longer wish to participate.
- Demonstrate and document how activities and direct benefits sustain stable, long-term, forest-based livelihoods and access to forest resources.
- Design the project to respect or integrate traditional ecological knowledge and forest resource use.

Environmental Harms and Benefits

These criteria build on and extend the environmental harms and benefits considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Transparently document any use of toxic and/or persistent environmental pollutants, including agrochemicals used for suppression of unwanted vegetation, and the risk of releasing these pollutants into the environment.
- Implement forest management practices that are appropriate to the local forest ecosystem and maintain or increase biodiversity.
- Implement forest management practices that protect extant populations and maintain habitat for regionally threatened or endangered species, or species that are in decline, and maintain ecosystem connectivity.
- Enroll properties with third-party certification bodies such as the Forest Stewardship Council, Sustainable Forestry Initiative, or the American Tree Farm System.

PROJECT DEVELOPERS SHOULD

- Implement forest management practices that generate environmental benefits beyond carbon sequestration and business-as-usual practices.
- Avoid increasing the risk of natural disturbances that may directly or indirectly harm local ecosystems.

Additionality and Baselines

These criteria build on and extend the additionality and baselines considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Implement conservative baselines as defined by the following two criteria.
  - ↳ Baselines must reflect initial standing carbon stocks and historical forest management practices unless a regional assessment is more appropriate, in which case the baseline must reflect typical forest management on lands of similar ownership and forest type.
  - ↳ Baselines must account for recent or projected changes in forest product demand. For example, projects located in regions with decreasing harvesting trends (e.g., mill closures) can be expected to have increasing baseline stocks.
- Use a methodology that generates credits using a dynamic baseline when: (1) regional forest inventory or remote sensing data have low biomass uncertainty, (2) reference areas with similar management history are available and identifiable, and (3) a suitable dynamic baseline methodology exists for the project jurisdiction.
- Use a common practice baseline constraint, such that credits are only issued for carbon above the average stocking level found on comparable properties.
- For projects with multiple revenue streams, such as timber harvest or conservation investments, demonstrate that IFM activities are unequivocally a result of carbon finance by documenting inputs to financial models (e.g., those used to calculate net present value).
- Demonstrate that project activities are not a result of current or anticipated legal requirements, economic incentives and trends, social drivers, or other non-carbon drivers which could influence management activity.

Measurement, Monitoring, Reporting, and Verification

These criteria build on and extend the measurement and MRV considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Use the best available forest measurement tools to measure and verify changes in carbon storage.
- Use statistically representative field inventories and/or remote sensing. If remote sensing models are used, calibrate and validate remote sensing models with ground-truth measurements. Continuously improve model performance over time as better data sources and modeling techniques become available.
- Conservatively account for uncertainty in baselines and ex post monitoring.
- Utilize allometry that is context appropriate and statistically robust.
- Include monitoring and reporting only on carbon pools with increased storage and where data and measurements can be well substantiated (e.g., excluding increases in soil carbon when uncertainty is high).
- Include monitoring and reporting on all carbon pools where project activities result in decreased carbon storage (e.g., harvesting or site preparation for planting).

PROJECT DEVELOPERS SHOULD

- Include potential effects of climate change on tree growth and stand development when modeling ex ante credit estimates.

Durability

These criteria build on and extend the durability considerations included under the [Essential Principles for High-Quality Carbon Dioxide Removal](#) section.

PROJECT DEVELOPERS MUST

- Actively identify, monitor, and mitigate risks throughout the project duration (e.g., forest thinning in fire-prone areas).
- Design projects so that forest-dependent livelihoods, and cultural, ecological, and economic values are self-reinforcing and incentivize durability through the project period (e.g., increased forest thinning schedule and labor promotes local livelihoods and increases social license for carbon).
- Include likely effects of climate change on stand development and forest health when accounting for reversal risks and planning project activities.

PROJECT DEVELOPERS SHOULD

Improve forest health and reduce disturbance hazards (e.g., wildfire, insects, etc.) on project lands, including those associated with historical management practices, such as fire suppression and adverse species selection.

Leakage

These criteria build on and extend the leakage considerations included under the [Essential Principles for High-Quality Carbon Dioxide Removal](#) section.

PROJECT DEVELOPERS MUST

- Use conservative market leakage deductions, justified by analysis of how the project affects timber supply and affected markets. Consider key leakage drivers in these markets, including timber supply responsiveness, demand elasticity, product substitutability, and market integration (e.g., global trade exposure and product commoditization).
- Establish contractual agreements or use certification schemes that prevent activity-shifting leakage and fully disclose all landholdings.

PROJECT DEVELOPERS SHOULD

- Design projects so they are less likely to induce market leakage (e.g., focus on reduced-impact logging, silviculture, and other approaches that increase carbon sequestration, reduce emissions, and maintain wood product supply).
- Deduct market leakage at the same time that increased carbon stocks are credited, even if existing offset protocols do not require this standard.

Glossary of Technical Terms for Improved Forest Management

Allometry: A method for establishing quantitative relationships between measurable dimensions of trees and other tree properties (e.g., diameter and height measurements can be used to estimate a tree's biomass).

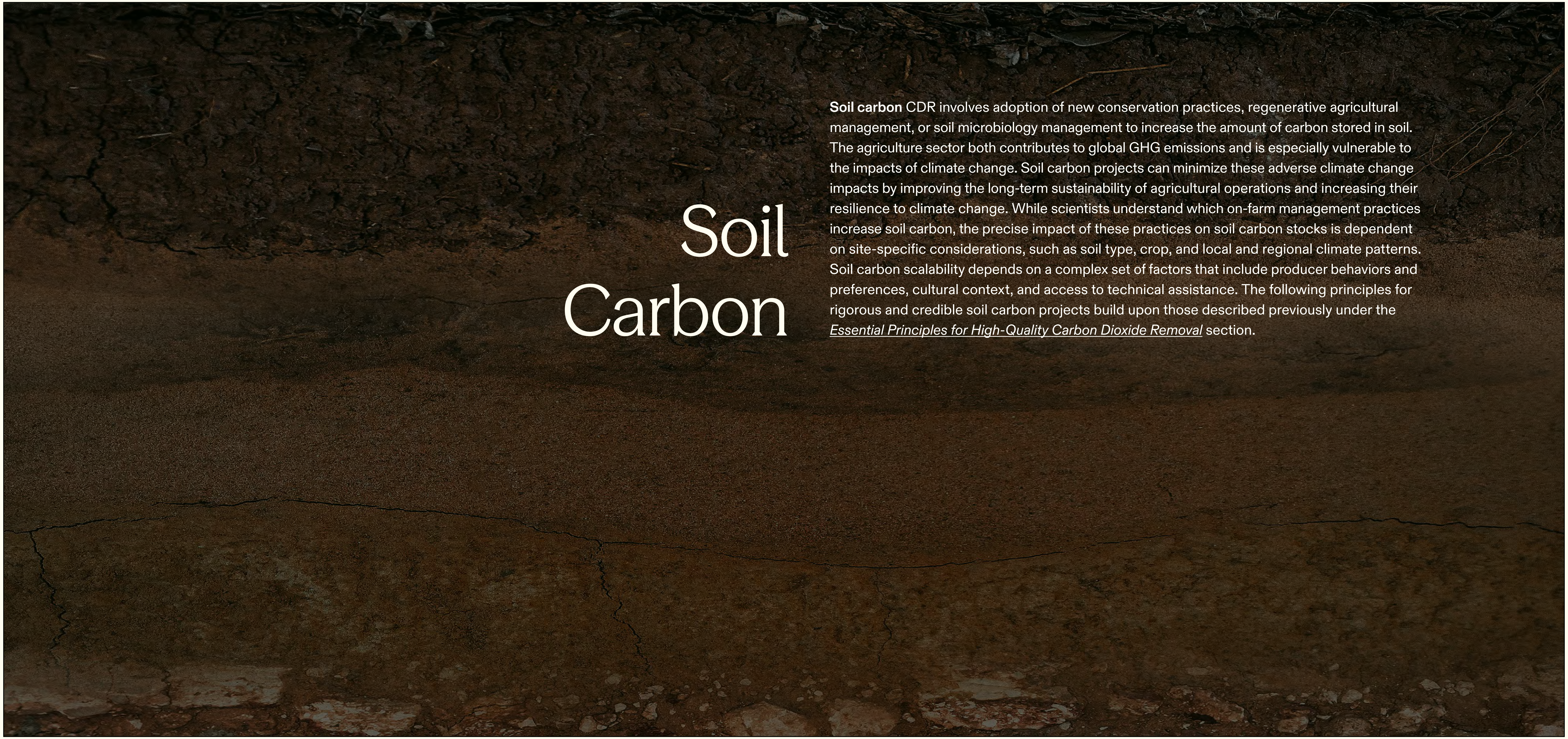
Dynamic baseline: A baseline that compares the project area to matched control plots outside of the project area. Control plots are located in areas with similar characteristics to the project area but are not subjected to project activities. A dynamic baseline is updated regularly to reflect changes in land use and forest conditions over time.

Forest management: Any planned human intervention in a forest ecosystem to achieve specific goals and objectives, which can typically be grouped as environmental, economic, and social.

Long-lived wood products: Wood products generated from timber harvests that persist for decades or centuries.

Natural disturbance: Any non-human-induced event that changes forest canopy structure, species composition, or age-class distribution, such as storm events, natural fire, insect pest outbreaks, and disease outbreaks.

A vast forest landscape with trees of different size and maturation.



Soil Carbon

Soil carbon CDR involves adoption of new conservation practices, regenerative agricultural management, or soil microbiology management to increase the amount of carbon stored in soil. The agriculture sector both contributes to global GHG emissions and is especially vulnerable to the impacts of climate change. Soil carbon projects can minimize these adverse climate change impacts by improving the long-term sustainability of agricultural operations and increasing their resilience to climate change. While scientists understand which on-farm management practices increase soil carbon, the precise impact of these practices on soil carbon stocks is dependent on site-specific considerations, such as soil type, crop, and local and regional climate patterns. Soil carbon scalability depends on a complex set of factors that include producer behaviors and preferences, cultural context, and access to technical assistance. The following principles for rigorous and credible soil carbon projects build upon those described previously under the *Essential Principles for High-Quality Carbon Dioxide Removal* section.

Soil Carbon

← SOIL CARBON
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Social Harms, Benefits, and Environmental Justice

These criteria build on and extend the social harms, benefits, and environmental justice considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Show that projects have a low risk of community health impacts from changing agricultural practices and inputs (e.g., fertilizer, herbicides, etc.), including the health and welfare of agricultural producers (e.g., farmers and ranchers).
- Articulate and, if necessary, implement a strategy for mitigating negative economic impacts on producers resulting from changes in crop yields or management costs, particularly in early project years.

PROJECT DEVELOPERS SHOULD

- Allow flexibility in producer practices, as allowed by the chosen methodology, given variable climate, environmental, and market conditions.
- Ensure contracts allow flexibility across allowed practice changes so producers are not locked into inadvisable practices.
- Design projects to accommodate participants who both own and lease land. This should include contractual provisions to ensure that lessees do not inadvertently experience adverse financial effects as a result of improving soil health through regenerative practices (i.e., being charged higher rent for more desirable land).
- Actively promote long-term sustainable livelihoods and economic opportunities for local communities.
- Publicly disclose the expected percentage of project revenues, profits, and any other financial benefits paid to agricultural producers (e.g., farmers and ranchers).
- Identify how project labor will be distributed and compensated, considering that agricultural operations often rely on migrant labor.

Environmental Harms and Benefits

These criteria build on and extend the environmental harms and benefits considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Show that projects have a low risk of directly or indirectly causing negative ecosystem impacts from changing agricultural practices, including from changes in inputs (e.g., fertilizer, herbicides, etc.). Negative ecosystem impacts can include, but are not limited to, lower air quality, degraded water quality, negative impact to soil water holding capacity, land degradation, biodiversity loss, downstream waterway pollution, and noise pollution.

PROJECT DEVELOPERS SHOULD

- Monitor and quantify ecosystem co-benefits, where possible. Ecosystem co-benefits can include, but are not limited to, improved soil health, erosion control, increased biodiversity, improved water quality and retention, and higher air quality.
- Design projects to provide quantifiable ecosystem co-benefits that result in net positive impacts.
- Support grower partners in reducing or eliminating the use of toxic or persistent chemicals by providing educational materials and/or agronomic support.

Additionality and Baselines

These criteria build on and extend the additionality and baselines considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Document dynamic baseline emissions from business-as-usual management in one of two ways:
  - ↳ Use control plots that represent project field geography and land management practices to directly measure baseline fluctuations in soil carbon due to climate variability or other non-management drivers.
  - ↳ Use a peer-reviewed model to estimate baseline fluctuations in soil carbon based on historical management practices and soil carbon measurements from a pre-project time period encompassing at least one full crop rotation or three years, whichever is longer. If modeled baselines show decreasing soil carbon stocks, projects must conservatively assume a stable baseline or provide appropriate physical validation measurements to justify a decreasing baseline.
- Gather management history to demonstrate that any new practice is not already a common management practice across the farm or ranch, as defined by the applicable methodology.
- Use baselines that are specific to the project region and agricultural system to quantify the change in soil carbon resulting from new management practices.
- Assess the barriers that prevent farmers from implementing planned project practices. These may include financial barriers, lack of available equipment, knowledge gaps, or other barriers.
- Require farmers to disclose participation in parallel insetting, carbon, or other programs that pose a risk of double counting project carbon benefits. Document the approach to prevent double counting.

Measurement, Monitoring, Reporting, and Verification

These criteria build on and extend the measurement and MRV considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Quantify net project carbon removals including any material emissions increases (e.g., from increased fertilizer applications, increased herd stocking density as a result of greater forage availability).
- Document sampling design, including any stratification by practice, soil type, crop, and other relevant environmental factors.
- Document the analytical and calculation methods used to quantify changes in soil carbon stocks, including the mass/depth basis and any correction applied.
- When using modeling to estimate soil carbon changes, implement project-specific direct soil sampling prior to initiation of project activities, and at least once every five years, to validate modeled estimates of soil organic carbon stocks and reconcile modeled projections with empirical measurements if discrepancies emerge.
- Take a representative set of soil cores to a sufficient depth to represent the impact of the implemented practice (e.g., a minimum of 30 centimeters depth below the organic layer for cover crops, up to one meter or more of soil depth for some types of tillage change). Core collection depths must be justified based on expected outcomes of specific practice changes.
- Use the best available laboratory analysis practices to measure carbon, such as dry combustion in a carbon and nitrogen analyzer.
  - ↳ Project developers may use novel technological approaches to measure soil carbon directly if such approaches have been validated against more established methods in the specific setting where they will be applied.

↳ Project developers may use legacy analytical approaches in regions where best available methods are not geographically available yet, provided they run a subset of samples via the best available approaches to demonstrate a statistically robust calibration between the analytical methods. Paired analyses must continue as long as legacy methods are used. Projects must transition to using the best available methods when they become available.

- Measure both organic and inorganic carbon in soil, and discount credit volumes appropriately if project activities result in losses of inorganic carbon (e.g., if project activities acidify soils with carbonates present). If measurements show the absence of inorganic carbon in soil, further monitoring may be reduced.
- Calculate carbon content using appropriate methods for bulk density measurement or an equivalent soil mass basis.
- Use models that have been developed and published in peer-reviewed literature for a specific soil, climate, or management context.
- Use modeling best practices, including appropriate calibration and validation with region- and practice-appropriate independent datasets. Comprehensively assess and transparently disclose model prediction uncertainty.
- Document model procedures and sources of validation data.
- Quantify, account for, and transparently disclose sampling error and error associated with lab processing, instrumentation, carbon stock quantification methods, and model prediction uncertainty. Make appropriate adjustments to credit volumes prior to issuing credits to conservatively account for error.

PROJECT DEVELOPERS SHOULD

- Take soil cores as deeply as possible, ideally to one meter.
- Provide comprehensive documentation of all soil carbon quantification methods that have been reviewed by a qualified third party.
- Develop and disclose a plan to share soil carbon data in a public repository, which could be used to improve model-based quantification approaches. This is particularly relevant for projects in areas with limited soil carbon data availability.
- Use remote sensing primarily for stratification and practice verification (e.g., confirming cover crop presence) rather than for direct quantification of soil carbon stock change, unless the remote sensing method has been rigorously validated against direct measurements that are appropriate to the project's region, cropping system, practice changes, and any other relevant context.
- Disclose both discrete sources of error and a consolidated value, ideally developed using Bayesian approaches to combine sources of error.
- Perform model recalibration when significant discrepancies appear between modeled and true-up results based on physical sampling.

Durability

These criteria build on and extend the durability considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Commit to fulfilling a durability term supported by a detailed monitoring and verification plan. The plan must monitor changes in management practices and subsequent reversals across the entire project area for the full duration of the project's crediting period and its durability monitoring period.
- Use verification methods and contracting mechanisms that maximize the likelihood that new practices will be implemented and maintained for the full durability term.
- Document robust strategies to monitor and mitigate reversal risks, both during and beyond the project crediting period. This must include appropriate buffer or risk pool contributions that can mitigate reversals due to changes in land management or ownership, changes in management practices, and impacts of natural hazards.

PROJECT DEVELOPERS SHOULD

- Identify and implement durability mechanisms (e.g., financial incentives, agronomic support, permanence trusts, conservation easements) to minimize producer attrition prior to the fulfillment of the durability term.

- Estimate the economic burden that participating producers will take on when adopting new agricultural practices (e.g., purchasing new machinery) to inform the risk that producers will leave programs for economic reasons and manage producer enrollment accordingly.
- Support the generation of commercial-scale, long-term data to better understand biophysical reversal rates that occur when project practice changes revert.
- Seek and support implementation of policy incentives that promote durability, where possible.

Leakage

These criteria build on and extend the leakage considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Conservatively quantify leakage, including the impacts of reduced herd numbers or crop yields following implementation of new practices, and deduct credits appropriately.
- Quantify and discount credit volumes for leakage associated with organic amendments (e.g., manure, compost, biosolids, or sludge), where carbon-containing inputs are transferred from a neighboring site to a project field, resulting in no net carbon removal.

Glossary of Technical Terms for Soil Carbon

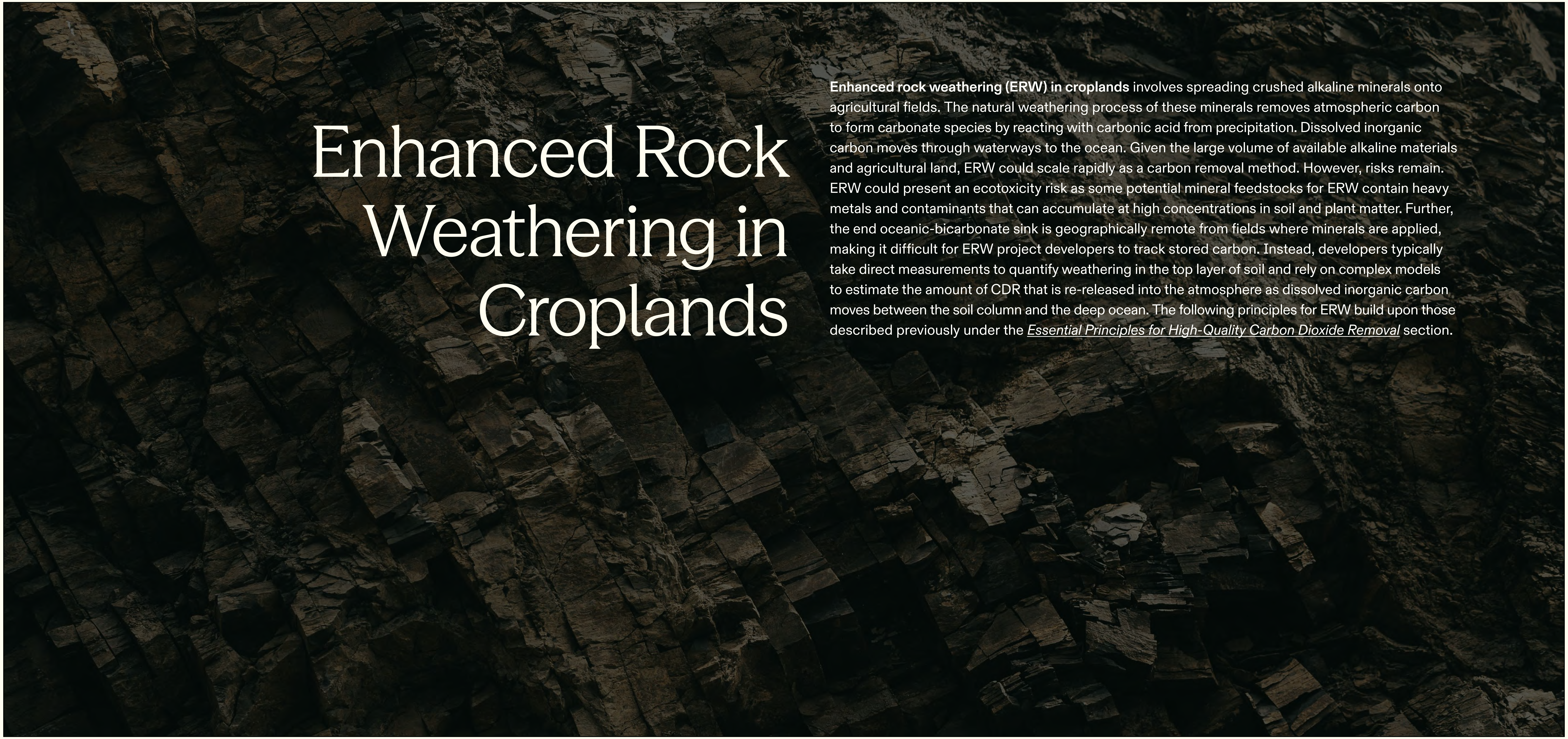
Equivalent soil mass: A method of calculating soil carbon stocks that corrects for change in soil bulk density (e.g., compaction or expansion) by referencing a fixed mass of soil rather than a fixed depth.

Microbial inoculum: Soil amendment containing a collection of live microorganisms selected for specific functional traits and applied to soil with the intent of altering nutrient cycling or other soil functions.

Regenerative agriculture: A broad term encompassing a set of agricultural practices, like cover cropping or reduced tillage, that are aimed at enhancing soil health and increasing stores of soil carbon. Regenerative agriculture is also called conservation agriculture or climate-smart agriculture.

Soil inorganic carbon: Carbon stored in soil in the form of carbonate species, including aqueous bicarbonate (HCO_3^-) or carbonic acid (H_2CO_3) in soil pore water and solid carbonate minerals like calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$).

Soil organic carbon: Carbon stored in soil in the form of organic matter or organic compounds, generally derived from the breakdown of plant matter by microorganisms.



Enhanced Rock Weathering in Croplands

Enhanced rock weathering (ERW) in croplands involves spreading crushed alkaline minerals onto agricultural fields. The natural weathering process of these minerals removes atmospheric carbon to form carbonate species by reacting with carbonic acid from precipitation. Dissolved inorganic carbon moves through waterways to the ocean. Given the large volume of available alkaline materials and agricultural land, ERW could scale rapidly as a carbon removal method. However, risks remain. ERW could present an ecotoxicity risk as some potential mineral feedstocks for ERW contain heavy metals and contaminants that can accumulate at high concentrations in soil and plant matter. Further, the end oceanic-bicarbonate sink is geographically remote from fields where minerals are applied, making it difficult for ERW project developers to track stored carbon. Instead, developers typically take direct measurements to quantify weathering in the top layer of soil and rely on complex models to estimate the amount of CDR that is re-released into the atmosphere as dissolved inorganic carbon moves between the soil column and the deep ocean. The following principles for ERW build upon those described previously under the *Essential Principles for High-Quality Carbon Dioxide Removal* section.

Enhanced Rock Weathering in Croplands

【 Hybrid 】

← ENHANCED ROCK WEATHERING IN CROPLANDS

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Social Harms, Benefits, and Environmental Justice

These criteria build on and extend the social harms, benefits, and environmental justice considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Characterize and mitigate risks of human exposure to contaminants via soils, groundwater, and uptake in crops:
  - ↳ Quantify mineral amendment dissolution rates and potentially toxic element (PTE) concentrations and speciation, where appropriate (e.g., hexavalent chromium).
  - ↳ Quantify the total concentration of PTEs in baseline soils. Where harms are dependent on the specific chemical form (e.g., chromium), also quantify the relevant PTE speciation.
  - ↳ Conservatively assess potential PTE transformation and transport pathways (e.g., oxidation of trivalent chromium to hexavalent chromium).
  - ↳ Identify relevant regulatory limits for PTE mass loading and soil-feedstock mixture endpoint concentrations. Establish conservative and compliant nonexceedance thresholds for PTE mass loading and endpoint concentrations and avoid applying feedstock quantities that would exceed any PTE threshold.
  - ↳ Actively implement ongoing quality control processes for sampling and analyzing mineral feedstocks, soils, and plant matter.
- Avoid the risk of asbestos exposure through feedstock screening and selection.
- Implement safety protocols required during feedstock quarrying, processing, transport, and application, including measures for the individual worker (e.g., personal protective equipment and material handling procedures) and project-level measures (e.g., limiting spreading during high-wind conditions).
- Avoid contaminating drinking water supplies by documenting points of potable water supply withdrawals from down-gradient aquifers and surface waters and monitoring PTE concentrations for potentially impacted potable sources, as possible.
- Require safety protocols that use best practices to minimize adverse impacts of project activities on local air and water quality, inclusive of project activities executed by direct counterparties.
- Prior to feedstock application, inform local stakeholders and communities of potential adverse environmental impacts (e.g., increased PTE loading, airborne dust).
- Avoid negative direct impacts from project activities on grower fields, such as compaction from tractors.

PROJECT DEVELOPERS SHOULD

- Quantify the impacts of mineral application on crop yield, soil chemistry (e.g., organic carbon, mineral nutrients), and farming practices (e.g., lime and fertilizer application) and inform growers of data collected from their fields.
- Preferentially use source materials that maximize net carbon removal (e.g., existing particle size distribution does not require additional processing and is close to application sites).
- Limit the impacts of material extraction by prioritizing use of mineral waste that does not require new or expanded mining. When sufficient waste material is unavailable, prioritize expanding existing mining over opening new mines to minimize environmental impacts on local communities.

Environmental Harms and Benefits

These criteria build on and extend the environmental harms and benefits considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Minimize environmental harms related to PTEs (see the Social Harms, Benefits, and Environmental Justice section for ERW).
- Disclose whether mineral amendments are sourced from unused quarry fines, expanded activity at existing quarries, or dedicated new quarry locations. In the case of new or expanded quarrying activity, forecast the environmental impact from the new quarrying activities and include those predictions in an analysis of the project's net impacts.
- Prior to feedstock application, proactively implement environmental harm mitigation and response plans specific to feedstock and land application areas.

PROJECT DEVELOPERS SHOULD

- Quantify impacts of project activities on biodiversity and soil health indicators.
- Document and, where possible, measure both positive and negative impacts of mineral application for adjacent ecosystems, including down gradient waterways.
- Avoid creation or expansion of mining operations that result in conversion of natural lands. In the event that mining activities attributable to the project result in land conversion, restore the same amount of land area that was converted for mining within an equivalent or similar biome.

Additionality and Baselines

These criteria build on and extend the additionality and baselines considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Provide documentation of any revenue streams beyond carbon credits. This includes, for example, revenue from growers paying for application of project feedstocks to croplands as an alternative to lime.
- Explain assumptions underlying the project baseline, including assumptions about counter-factual feedstock weathering; characterize inorganic carbon content in mineral feedstocks; and document mineral and waste handling practices.
- Use control plots to measure the baseline soil processes and chemistry on agricultural land, including counterfactual lime application when appropriate.
- Quantify historical baseline agricultural lime use at the field level that would be displaced by project activities using a pre-project period encompassing at least one typical lime application cycle for the region (e.g., every four years).
  - ↳ In areas with recent agricultural lime application, both limed and unlimed control plots may be required to track baseline soil processes.
  - ↳ If historical lime use is displaced by project activities, quantify any counterfactual carbon removals associated with historical lime based on field-specific factors (e.g., soil pH) and deduct appropriately. Conservatively exclude avoided emissions from agricultural lime application.
  - ↳ In lieu of precisely quantifying counterfactual carbon removals, calculate a conservative deduction based on displaced lime stoichiometry.
- Quantify the cost and availability of ERW feedstocks and lime for soil pH management independent of carbon projects. Project financial additionality requires that ERW feedstocks are not a cost competitive alternative to existing lime use in the absence of carbon finance.
  - ↳ Review factors driving costs associated with each amendment (e.g., distances to ERW feedstock and lime sources and amounts of each amendment required) at the most granular level possible, ideally the field level.

- Require growers to provide sufficient management history to demonstrate that project activities are not already a common management practice across the farm or ranch.
- Require growers to disclose participation in parallel insetting, carbon, or other programs that pose a risk of double counting project carbon benefits.

PROJECT DEVELOPERS SHOULD

Prior to project initiation, confirm clear parameters and any necessary restrictions on agricultural management practices with grower partners while prioritizing grower flexibility.

Measurement, Monitoring, Reporting, and Verification

These criteria build on and extend the measurement and MRV considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Ensure that carbon removal claims are consistent with a net carbon-negative outcome based on a quarry-to-ocean LCA that includes mineral feedstock quarrying, processing, transportation, application, and impact on other non-CO_2 GHG sources.
- Provide detailed accounting and justification of counterfactuals for waste or residue feedstocks.
- Design sampling strategies to differentiate project and baseline conditions in a statistically robust manner, including any stratification by feedstock source, agricultural practice, soil type, crop, and other relevant environmental factors.
- Implement procedures for control plot selection to optimize representativeness and avoid bias, using randomization when appropriate.
- Conservatively quantify gross feedstock weathering in-field based on spatially and temporally representative physical measurements.
- Document the analytical and calculation methods used to quantify feedstock weathering and gross carbon dioxide removal, including how feedstock weathering is differentiated from background soil weathering.
- Validate gross feedstock weathering with an independent secondary method based on physical measurements. Secondary methods must be based on those that are established in the peer-reviewed literature, appropriate to the deployment area, and calibrated for the project site.
- Proactively assess lags in alkalinity transport from the near-field zone (e.g., cation exchange capacity).
- Quantify processes that decrease net carbon dioxide removal, prioritizing physical measurements where feasible, and discount credit volumes appropriately. Loss terms must include at least the following: non-carbonic acid weathering, plant cation uptake, river offgassing, and ocean losses.
- Assess and monitor processes that may further decrease net carbon dioxide removal and discount credit volumes appropriately, including secondary mineral precipitation, decreases in soil organic carbon stocks, impacts to natural weathering in the far-field zone (e.g., in areas with carbonate bedrock), and the risk of reversal due to irrigation from groundwater that may contain weathering products.
- Use modeling best practices when using models to quantify loss terms:
  - ↳ Use models that are established in peer-reviewed literature and/or other applications with third-party evaluation.
  - ↳ Document how models link biogeochemical and hydrologic processes.
  - ↳ Perform calibration and validation with appropriate independent datasets, ideally from the same regions and feedstock/soil combinations, for the target variable(s).
  - ↳ Document model initialization assumptions and how model uncertainty is incorporated into conservative carbon removal estimates (e.g., through appropriately conservative deductions for uncertainty).
- Quantify and adjust credit volumes to account for the following sources of error: sampling and measurement error, laboratory processing and instrumentation error, feedstock weathering quantification error, and model prediction uncertainty for modeled loss term processes.
- Archive samples sufficient for auditing and reanalysis of claimed project outcomes.
- Use direct measurements of multiple variables to ground-truth models wherever possible.

- Establish the quality of laboratory analyses through either use of certified external laboratories or third-party certification of project-controlled laboratories.

PROJECT DEVELOPERS SHOULD

- Strive to source renewable energy to power operations for mining, grinding, and transporting feedstock.
- Use the best available measurement methods to quantify changes in soil health and any other claimed co-benefits following mineral feedstock application.
- Collect data, share it in a public repository, and contribute to key research questions within the field, including far-field zone losses, feedstock impacts on soil organic carbon change, impacts of baseline agricultural lime use, agricultural management impacts on feedstock weathering rates, and agronomic impacts of feedstock application, where possible.
- Avoid deployments in areas with high risk of significant far-field zone losses.
- Quantify the enhanced weathering potential and expected weathering rate of all feedstocks based on mineralogy, elemental composition, and specific surface area.
- On an ongoing basis, monitor the particle size distribution, mineralogy, and particle morphology of feedstock material applied to cropland from all feedstock sources.

Durability

These criteria build on and extend the durability considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Provide a durability term that is supported by the MRV plan, and that accounts for the expected reactions and subsequent transport of aqueous ions to ocean storage.
- List carbon release risk scenarios for both precipitated and dissolved carbon (these risks must be reflected in the MRV plan).
- Justify credit deductions for losses in the far-field zone according to the procedures outlined in the MRV plan.

PROJECT DEVELOPERS SHOULD

- Collaborate with local research groups with expertise in the project's geography to accurately quantify far-field zone losses and other location-specific durability considerations.
- Prioritize deployments in locations where groundwater residence time, from fields to surface water, is short.

Leakage

These criteria build on and extend the leakage considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Document the impact of applied minerals on crop yields. Quantify and deduct for leakage if yields decline because of project activities.
- Quantify, and include in the MRV plan, any carbon emissions incurred by feedstock sourcing, such as from potential land-use change or impacts to mineral feedstock supply chains (e.g., expanded quarrying).

PROJECT DEVELOPERS SHOULD

- Quantify valuable minerals and materials in source rock.
- Avoid feedstock sourcing (i.e., type and volume) that could divert supply away from and constrain inputs to other decarbonization efforts and supply chains (e.g., mineral applications in low-carbon commodities).

← ENHANCED ROCK WEATHERING IN CROPLANDS

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Glossary of Technical Terms for Enhanced Rock Weathering in Croplands

Alkaline mineral: Material which contains alkali or alkaline-earth metals such as calcium, magnesium, sodium, and potassium and is used as a mineral feedstock for ERW.

Carbon mineralization: A broad term encompassing all pathways (and associated timescales) through which CO_2 reacts with ions derived from alkaline minerals to form carbonate minerals. Also called "mineral carbonation."

Carbonate species: Chemicals and materials containing the carbonate ion (CO_3^{2-}); in aqueous systems, often in the form of bicarbonate (HCO_3^-), carbonic acid (H_2CO_3), or dissolved CO_2 gas depending on the pH; in solid systems, often in the form of carbonate minerals, such as calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), and magnesite ($MgCO_3$).

Enhanced weathering potential: The maximum amount of gross CO_2 removal possible from weathering a given feedstock, expressed on a basis of mass CO_2 removed per mass feedstock.

Far-field zone: Locations where reactions related to project activities occur, from the bottom of the near-field zone to the final storage location in the ocean.

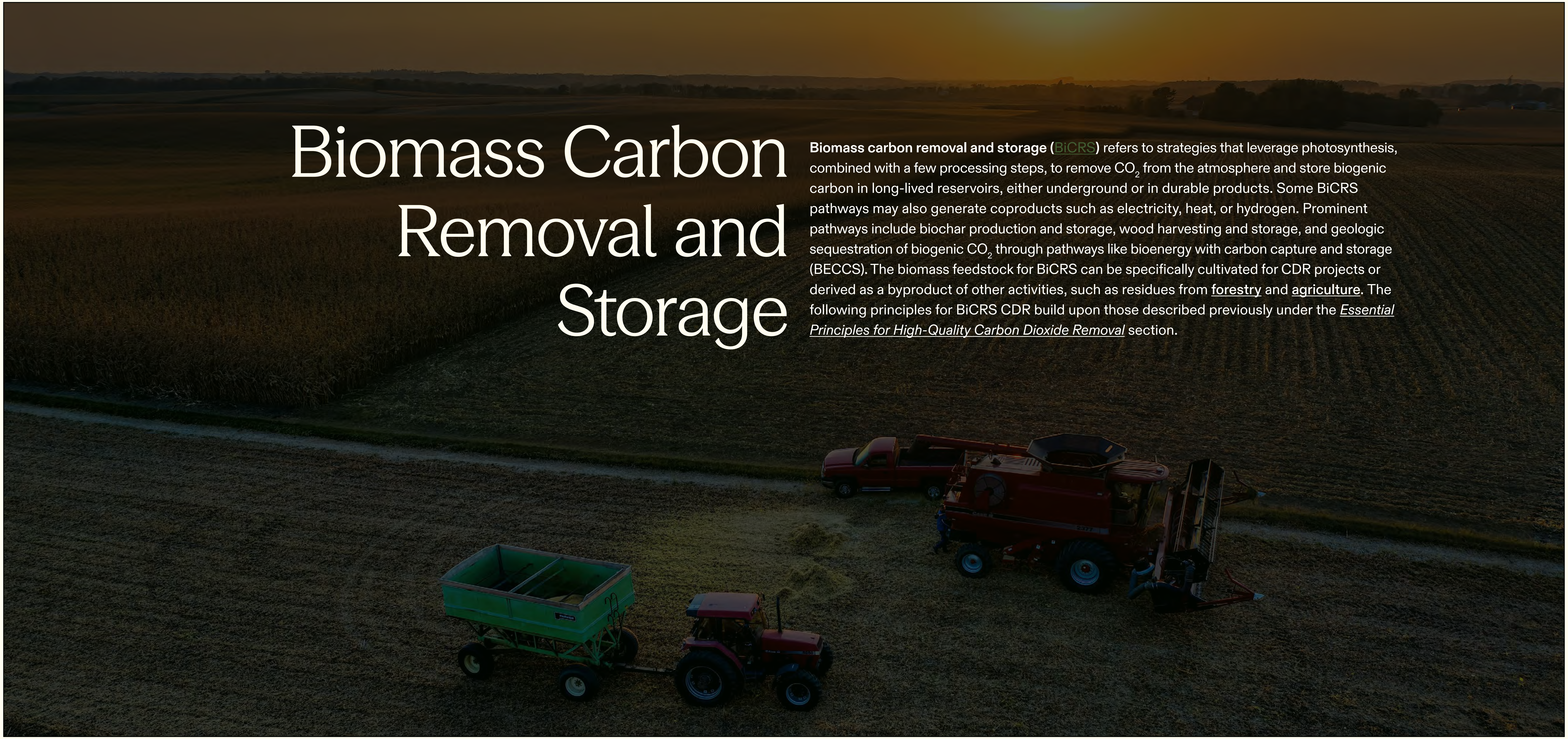
Natural mineral weathering: In the context of ERW, this involves the slow breakdown of minerals due to dissolution in water (e.g., rainwater, pore water, or groundwater) containing dissolved carbonate species derived from atmospheric CO_2.

Near-field zone: The soil zone where feedstock is applied to croplands and where weathering, and measurements of weathering, occur.

Oceanic bicarbonate sink: The channel by which the ocean absorbs and stores atmospheric CO_2 in the form of bicarbonate ions (HCO_3^-), helping to buffer changes in atmospheric CO_2 over time.

Potentially toxic elements (PTEs): Naturally occurring elements that can be toxic to humans or ecosystems, even at low concentrations (e.g., arsenic, cadmium, chromium, lead and nickel).

Natural limestone rock with layered erosion patterns.



Biomass Carbon Removal and Storage

Biomass carbon removal and storage (BiCRS) refers to strategies that leverage photosynthesis, combined with a few processing steps, to remove CO_2 from the atmosphere and store biogenic carbon in long-lived reservoirs, either underground or in durable products. Some BiCRS pathways may also generate coproducts such as electricity, heat, or hydrogen. Prominent pathways include biochar production and storage, wood harvesting and storage, and geologic sequestration of biogenic CO_2 through pathways like bioenergy with carbon capture and storage (BECCS). The biomass feedstock for BiCRS can be specifically cultivated for CDR projects or derived as a byproduct of other activities, such as residues from forestry and agriculture. The following principles for BiCRS CDR build upon those described previously under the *Essential Principles for High-Quality Carbon Dioxide Removal* section.

Biomass Carbon Removal and Storage

【 Hybrid 】

← BIOMASS CARBON REMOVAL AND STORAGE

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Social Harms, Benefits, and Environmental Justice

These criteria build on and extend the social harms, benefits, and environmental justice considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Ensure that biomass feedstock sourcing does not compromise local communities' essential resource access, such as for cultural and customary purposes.
- Document clear and legitimate rights to biomass supply and associated land use.
- Educate end users about the potential benefits and risks associated with project coproducts, such as biochar.

PROJECT DEVELOPERS SHOULD

Articulate how project activities, like feedstock production and product or coproduct sales, will benefit under-resourced and marginalized populations, including benefits like wealth generation and economic empowerment.

Environmental Harms and Benefits

These criteria build on and extend the environmental harms and benefits considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Show that feedstock procurement, biomass conversion, and carbon storage operations have a low risk of any major negative impacts on the surrounding ecosystems (including soil health, biodiversity, water quality, and air quality).
- Monitor any use of toxic and/or persistent environmental pollutants.
- Provide a detailed strategy for ensuring—through tracking, mitigating, monitoring, and other methods—that the physical coproducts and wastes of the project (e.g., biochar, wood, liquids, gases, emissions, etc.) have a low risk of negative impacts on ecosystems.

PROJECT DEVELOPERS SHOULD

- Maximize and substantiate environmental co-benefits (e.g., fire suppression from feedstock procurement).
- Implement measures to improve industrial sustainability, such as water recycling/reuse, heat recovery, and waste valorization, to minimize adverse non-carbon environmental impacts.

Additionality and Baselines

These criteria build on and extend the additionality and baselines considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Document, monitor, and quantify any carbon accounting impacts of the most likely counterfactual scenario for the biomass resources in question, throughout the duration of the project. Include their current use, assumed counterfactual carbon storage, and any potential future uses in the absence of the project.
- Document landscape carbon stock changes, relative to a conservative baseline, when biomass feedstocks are sourced directly from land management activities, such as ecological restoration or vegetation management. Include both above- and below-ground carbon stocks in this assessment.
- Document the financial viability of the project, with and without revenue from carbon credits, using a financial or techno-economic model. The model must include the impact of coproducts, tax deductions and credits, regulations, policy incentives, and other financial factors. Examples of policy incentives in the United States include the 45Q tax credit, Clean Fuel Standards, and federal grants or loan guarantees.
- Include and justify the cost of the biomass feedstock, delineating transportation and procurement costs, and the per-unit pricing of all project products such as biochar, bio-oil, electricity, ethanol, or steam.

PROJECT DEVELOPERS SHOULD

Justify the current project cost estimate, and quantify and support its potential for change based on cost curve projections.

Measurement, Monitoring, Reporting, and Verification

These criteria build on and extend the measurement and MRV considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Ensure that CDR claims are consistent with a net carbon-negative outcome against a credible baseline, based on cradle-to-grave LCAs that include biomass feedstock procurement (including land-use change for purpose-grown feedstocks), land management activities (e.g., ecological restoration, vegetation management, land clearing, etc.), process emissions, carbon storage operations, environmental disturbances, and embodied emissions.
- Conduct an attributional LCA based on primary data where available. Justify values used in the LCA that are derived from literature or databases and conduct sensitivity analyses for values with high uncertainty.
- Quantify the consequential GHG impacts of project implementation, including the impacts of feedstock sourcing, energy procurement, and leakage. Justify values used in the LCA that are derived from literature or databases and conduct sensitivity analyses for values with high uncertainty.
- Clearly outline emission allocation methods for coproducts, including a sensitivity analysis on allocation assumptions and different product scenarios.
- Provide detailed accounting and justification of counterfactuals for waste or residue feedstocks.
- Provide the implementation and operational details of any internal or third-party MRV platforms the project will use, including access permissions, personnel responsible for making updates, approach to integration of automated inputs, and the process for platform quality checks.
- Select energy and material sources with the lowest fossil GHG emissions per gross tonne of CO_2 removed, where multiple viable configurations are available.
- If project activities introduce a reasonable risk of decreasing soil carbon, quantify changes in soil carbon using the criteria listed in the Soil Carbon section and/or deduct credits conservatively for any decreases in soil carbon.

PROJECT DEVELOPERS SHOULD

- Document the rationale for selecting the project registry and affiliated protocol, and highlight where the project exceeds protocol requirements.
- Maintain robust biomass feedstock supply records that track biomass type, supplier, origin point or sourcing area, mass, volume, and certification references by batch or shipment.

Durability

These criteria build on and extend the durability considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Use geologic storage sites, where applicable, created under established permitting processes (e.g., EPA Class permitting for deep injection wells in the United States or meet ISO 27914:2017 standard for CO_2 storage).
- Quantify and document expected changes in the amount of carbon sequestered over time (e.g., through decay or physical leakage).
- Use guidance set forth for durability in the Direct Air Capture section when storing gaseous CO_2 (e.g., BECCS).
- Rely on empirical measurements for durability claims, rather than models, whenever possible.
- Establish procedures and rights to notify relevant parties of any storage-site reversals and to quantify impacted CDR credits (i.e. mass-balance for shared storage sites) and applicable reversal management mechanisms (e.g., buffer pools or compliance surrender).

Leakage

These criteria build on and extend the leakage considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Quantify and include, in carbon accounting and MRV, the carbon emissions that may result from the project's consumption or displacement of feedstock, regional materials, and energy supplies (e.g., energy diverted for capture and compression of CO_2 at retrofitted facilities).
- Quantify the market impacts and carbon emissions resulting from biomass procured at a price that exceeds the cost incurred by the supplier, including potential biomass market distortions and associated resource diversion.
- Quantify and include, in carbon accounting and MRV, any carbon emissions from potential land-use change or impacts to bioeconomy product supply (e.g. biofuels or biochemicals displacement) incurred by feedstock sourcing.

PROJECT DEVELOPERS SHOULD

Avoid relying on feedstocks with potential land-use change impacts or bioeconomy product supply impacts (i.e., by following the guidance on sustainable biomass sourcing in the Biomass sustainability section.

Other Considerations

Biomass sustainability

PROJECT DEVELOPERS MUST

- Source biomass feedstock following the guidelines outlined in *Sustainable Forest Biomass Sourcing for CDR: A Buyer's Guide* and *Agricultural Biomass Sourcing for CDR: A Buyer's Guide*, where applicable. Biomass must come from sources that adhere to the following guidelines:
  - ↳ Operate with integrity and oversight through strong governance, standards, and supply-chain transparency.
  - ↳ Minimize negative impacts on Indigenous Peoples, workers, and local communities.
  - ↳ Produce biomass without threatening protected areas or reducing regional carbon stocks.
  - ↳ Do not distort markets for agriculture or forestry products.

PROJECT DEVELOPERS SHOULD

Forecast future biomass sustainability (using the "must" criteria above, as appropriate) given the existing and planned projects in the developer's intended biomass sourcing area.

Pathway-Specific Considerations

Biochar

PROJECT DEVELOPERS MUST

- Verify, through end-to-end tracking and auditable chain-of-custody records, that all biochar generating CDR credits is durably stored in a long-term sink. Biochar storage must minimize reversal risk and prevent biochar use in combustion, incineration, energy recovery, or any other applications that would rapidly release CO_2 to the atmosphere.
- Ensure that all biochar offtakers and end-users have binding agreements in place that restrict use to approved pathways, prohibit diversion or resale for non-approved purposes, require cooperation with monitoring and verification activities, and provide audit access sufficient for independent compliance review.
- Develop a protocol for responding to failed or terminated end-use arrangements, or to potential diversion of credited biochar. The protocol must address the suspension of CDR credit issuance, buyer notification, and redirection or exclusion of affected volumes.
- Conduct biochar elemental analysis (e.g., carbon, hydrogen, oxygen) and apply the best available models to predict and substantiate the durability of stored carbon, quantify biochar recalcitrance, and estimate carbon loss over at least a 100-year time frame.
- Ensure that biochar is regularly tested for heavy metals, toxins (e.g., tar), and polycyclic aromatic hydrocarbons (PAHs) to minimize environmental harms (e.g., adhere to the European Biochar Certificate or World Biochar Certificate guidelines, as well as local regulations). Test on a routine schedule and whenever production conditions change materially including significant shifts in pyrolysis temperature, feedstock composition, or processing methods.
- Document that the project results in the production of biochar that is additional to a verifiable and established baseline production scenario.
- Measure, and include in an LCA or carbon accounting model, any methane emissions from the biochar production process.
- Account for end-of-life scenarios for manufactured materials that utilize biochar as an additive or component (e.g., cement, asphalt, concrete, building products etc.), to prevent potential carbon reversals once those materials reach the end of their useful life.
- Demonstrate that the total biochar produced is equal to the total biochar durably stored minus documented and explained losses on dry-mass balance.
- Maintain auditable batch and annual biomass-to-biochar mass-balance records (e.g., weighbridge tickets, feedstock receipts, production logs, moisture loss accounting) and calculate conversion yields on a dry-mass basis. Expected losses should align with the facility's expected yield range, and any material deviations shall be documented and explained.
- All biochar offtakers and end users must disclose participation in parallel insetting, carbon crediting, or other environmental attribute programs that pose a risk of double counting project carbon benefits. Project developers must obtain and retain these disclosures as part of their MRV protocols.

PROJECT DEVELOPERS SHOULD

- Measure biochar decomposition rates after application, differentiating between labile and recalcitrant fractions, to refine existing decay models.
- Monitor biochar application sites for safe application practices (e.g., application rates, incorporation methods, and worker safety measures), potential reversal events, and rigor in reporting mechanisms for landowners and applicators (e.g., traceability of volumes applied, mechanisms to document reversals).
- Consider energy efficiency and water-use mitigation measures in project design, such as by exploring the utilization of waste heat from the pyrolysis process, where feasible and supportive of the primary CDR objectives.

BECCS

PROJECT DEVELOPERS MUST

- Ensure that all emissions and environmental releases, such as sorbent or solvent slip, are adequately monitored and transparently disclosed, for identification of potential hazards and confirmation that emissions remain below harmful and applicable regulatory thresholds. Consider worldwide permitting requirements to identify the most stringent requirements on environmental impacts (e.g., air emissions, water discharge) as guidance on best practices.
- Implement rigorous safety and community outreach plans to mitigate risks associated with uncontrolled CO_2 release during transportation and storage.
- Describe in detail the energy requirements (including sources) for retrofitting and operating a carbon capture system, and quantify the associated emissions within the project's carbon accounting (such as in the leakage assessment or the overall LCA).

Biomass Storage

PROJECT DEVELOPERS MUST

- Design storage methods to minimize decomposition, inhibit biological degradation, and mitigate the risk of external disturbances, such as intrusion by biotic agents, geological events, and weather events.
- Provide a cradle-to-grave LCA that includes all relevant portions of the project, including topsoil disturbance and transport of biomass feedstock.
- Use in situ sensors and gas sampling in the biomass storage environment to monitor for sealing integrity and indicators of degradation.
- Use in situ sensors and gas sampling of methane for MRV.

PROJECT DEVELOPERS SHOULD

- Maintain a buffer pool of credits to mitigate uncertainty in factors like durability and methanogenesis, until MRV substantiates modeled outcomes.
- Ensure the storage site is securely established, both physically and legally, to prevent disturbances from human interference and activities over time frames relevant for durability, to the extent possible.
- Use sample excavations, from either the actual project storage site or a representative test storage site, to enhance MRV. In cases where direct sampling could compromise sealed areas, establish a dedicated MRV subplot for systematic testing.

Waste-to-Energy with Carbon Capture and Storage

While waste-to-energy (WtE) with carbon capture and storage (CCS) falls under the broader category of BECCS, the specific characteristics and nuances of this project type warrant its classification as a distinct subcategory.

PROJECT DEVELOPERS MUST

- Distinguish and quantify fossil and biogenic carbon fractions of carbon flows using established standards and methods, such as carbon-14 isotope analysis on feedstocks, products, and emissions, with sufficiently frequent monitoring across metering locations. Such verification must be done at the capture facility on at least a quarterly basis.
- Ensure that the WtE facility tracks all incoming waste by charging gate fees and requiring bills of loading or gate tickets to document quantities, origin, and local provenance in order to substantiate chain-of-custody claims.
- Ensure that the WtE facility prioritizes feedstocks that are verifiable waste streams without higher-value applications, does not incinerate waste that would otherwise be recycled or reused, and demonstrates that further waste sortation is economically or operationally unfavorable where applicable.
- Ensure that any additional waste sourced to enable operation of the capture unit is fully accounted for in the project's LCA, including associated transportation and handling emissions.
- When emissions from such a facility may be taxed, ensure that project effects on taxation are accounted for when demonstrating that the facility meets all additionality criteria, including regulatory and financial additionality.
- If biogenic feedstock is used to increase the heating value of the feedstock, the feedstock must adhere to *Biomass Sustainability* criteria, including that it was not grown specifically for energy production or incineration.

PROJECT DEVELOPERS SHOULD

- Ensure waste is sorted to remove recyclable or reusable material and that sorting is conducted by an entity other than the WtE facility owner, where possible. If the operator is responsible for sorting waste, ensure this is done in an objective manner.
- Use waste that is primarily sourced from the surrounding area with defined transportation distances, and limit the use of imported waste, importing only from exporting countries that have relevant waste targets.

Glossary of Technical Terms for Biomass Carbon Removal and Storage

Biochar: Stable solid, rich in carbon, that is produced by heating biomass in the absence of oxygen (pyrolysis), or in limited oxygen that does not permit full combustion (gasification and partial combustion). Biochar must be stored in a reservoir or application that prevents storage reversal (i.e., it must not be combusted). Applications include using biochar as a soil amendment or incorporating it into long-lived materials, such as cement.

Bioenergy with carbon capture and storage (BECCS): A CDR method that involves using biomass to generate energy or fuels while capturing and storing the biogenic CO_2 emissions produced from combustion, gasification, fermentation, or other biomass conversion pathways. This can include processes like biopower or WtE with CCS, ethanol CCS, and pulp and paper CCS.

Biomass burial: A CDR method that involves storing biomass in engineered or naturally suitable environments, such as underground vaults or in sediment, to slow decomposition and sequester carbon for long periods of time.

Coproduct emission allocation: Method used in an LCA to distribute GHG emissions among multiple products derived from the same process, such as on the basis of coproduct mass or energy contents.

Cradle-to-grave LCA: LCA with a broad system boundary, which includes all emissions from energy and material sourcing and consumption, waste treatment, construction and decommissioning, compression, transportation, and storage or reuse of captured carbon.

Elemental analysis: A scientific testing method used to determine the composition of a material in terms of its chemical elements (e.g., carbon, hydrogen, oxygen).

Labile: Organic carbon in biomass and biochar that is readily decomposed, such that stored carbon is cycled back into the atmosphere.

Recalcitrant: Organic carbon in biochar and biomass that resists decomposition, preventing the loss of stored carbon to the atmosphere.

Waste-to-energy with carbon capture and storage (WtE with CCS): A subset of the BECCS CDR method that often involves combusting mixed biogenic and fossil waste (e.g., municipal solid waste) to generate energy (i.e., heat or electricity), capturing the resulting CO_2 emissions, and providing long-term geologic storage for the captured CO_2.

Biomass harvesting from sugarcane field.

Abiotic Marine Carbon Dioxide Removal

Marine carbon dioxide removal (mCDR) pathways utilize the ocean's physical circulation, biogeochemical processes, and marine ecosystems to remove atmospheric CO_2 and durably store it in various forms. To safely deploy mCDR technologies and ensure precise carbon accounting, advanced forecasting and monitoring methodologies are essential, as these pathways both affect and rely on the dynamic ocean regime and marine life, including its intrinsic uncertainties. High-quality mCDR projects prioritize rigorous carbon **measurement, monitoring, reporting, and verification (MMRV)** in addition to equally rigorous MMRV of the ocean ecosystem and marine life to mitigate harm. The methodologies and protocols required for mCDR projects are under active development and are being continuously refined as new data emerges.

Among the suite of mCDR pathways under development, this set of criteria focuses on the abiotic pathways of ocean alkalinity enhancement, which captures and stores atmospheric CO_2 as bicarbonate dissolved in the ocean, and direct ocean removal, which removes CO_2 from ocean waters and stores it externally. These methods offer the potential for durable, large-scale CDR. The following principles for abiotic mCDR build upon those described previously under the *Essential Principles for High-Quality Carbon Dioxide Removal* section.

Abiotic Marine Carbon Dioxide Removal

【 Hybrid 】

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Social Harms, Benefits, and Environmental Justice

These criteria build on and extend the social harms, benefits, and environmental justice considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Develop a social harms and benefits plan that considers potential impacts on fisheries, aquaculture, and existing coastal industries.
- Implement community engagement strategies to address misperceptions regarding potential risks associated with project activities.
- Minimize disruption of coastal businesses or those relying on the ocean.
- Ensure local traditional and Indigenous practices are considered and not disrupted by project activities.

PROJECT DEVELOPERS SHOULD

- Actively engage with local communities and provide education on the regional ocean, ocean stewardship, risks and benefits associated with the project, and how project activities interact with the coastal and oceanic ecosystem.
- Address significant concerns from local communities, stakeholders, and fisheries through community education, conduct research and development with a third party, and/or modify the project plans prior to large-scale project implementation.
- Design project activities to improve existing climate and social inequities, including near major feedstock sources and processing facilities (e.g., mines, wastewater facilities, etc.).
- Support local fisheries and aquaculture through partnerships like profit sharing.
- Provide employment opportunities to local communities including those that have been historically marginalized.

Environmental Harms and Benefits

These criteria build on and extend the environmental harms and benefits considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Develop eMRV protocols with consideration of the regional and relevant global oceanic regime, ecosystem health, all effluents discharged from project activities, and ecosystem responses. This must include monitoring the health of the ecosystem for a defined period after project completion or operational shutdown, with the monitoring duration determined by project- and site-specific conditions.
- Implement strategies to mitigate potential harm caused by project activities.
- Monitor all effluents, site-specific reactions, and ecosystem responses from project activities at clearly defined intervals and on an ongoing basis.
- Develop and integrate specific eMRV plans for all keystone, vulnerable, sensitive, and endangered species that could be affected by project activities.
- Identify and define thresholds of harm for any changes to the oceanic regime and ecosystem caused by project activities.
- Implement plans for suspending project activities if the project causes harm or exceeds established thresholds. Include timely reporting and communication with local authorities and communities.
- Establish a baseline assessment of the health of the marine ecosystem and relevant global and regional oceanic regime. Report all assumptions and uncertainties.
- Establish the baseline impacts on the marine ecosystem from all relevant pre-existing base facilities (e.g., desalination facility) processes, emissions, and disturbances, prior to project initiation.

- Use scientific studies, protocols, and monitoring methodologies to ensure sufficiently high accuracy (e.g., high-resolution ocean models, remote sensing, and autonomous platforms).
- Transparently disclose uncertainties, include them in eMRV plans, and specify methods to reduce them, where feasible.
- Assess potential impacts from project activities using available data and by conducting studies through an approved third party. Transparently share essential data relating to environmental impacts with the local community and broader scientific community.

PROJECT DEVELOPERS SHOULD

- Transparently share all data relating to the project with local communities and the broader scientific community.
- Use data from field trials and mesocosm studies to gather insights into potential large-scale impacts on and responses resulting from the project's activities.
- Evaluate and incorporate climate change impacts on the oceanic regime and ecosystem into assessments for establishing potential acceptable risk levels for project activities.
- Collaborate with local research institutions to advance studies on sustainable ocean management, eMRV methodologies, and the protection of marine food systems.
- Consult with pre-existing facilities and other relevant local industries to identify potential opportunities to increase the environmental safety of external processes.

Additionality and Baselines

These criteria build on and extend the Additionality and Baselines considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Establish a baseline of the relevant oceanic regime through historical data and monitoring methodologies that includes variability ranges, significant outlier events, and inherent uncertainties. Document and transparently share assumptions, uncertainties, and model limitations.
- Establish relevant baseline data for all pre-existing base facilities and processes, prior to initiating the project.

A single frond of giant kelp floating in turquoise ocean water.

Measurement, Monitoring, Reporting, and Verification

These criteria build on and extend the measurement and MRV considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Conduct an LCA with consideration of processes such as mineral dissolution and gas exchange.
- Implement an MRV plan that accounts for region-specific and relevant global processes such as ocean circulation and biogeochemical cycles.
- Document information regarding the monitoring methodologies used to quantify CDR, such as the models used, assumption, resolution, uncertainty, and known limitations.
- Regularly update the project's MRV plan to incorporate the best available science and monitoring tools and techniques.
- Directly monitor the relevant properties and chemical composition of project feedstocks, products, intermediates, and by-products. Predict and assess any potential responses upon discharge into seawater that could impact the project's CDR efficacy.
- Ensure proper carbon accounting for all end uses and fates of captured CO_2 to avoid double counting.

PROJECT DEVELOPERS SHOULD

Use energy with low associated emissions and provide the electricity emissions factor and the latest emissions factor for the local electrical grid, if purchasing electricity from the grid. The use of marginal emissions factors may be appropriate, depending on grid conditions.

Durability

These criteria build on and extend the durability considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Predict and monitor relevant global and regional changes to the oceanic regime that pose a risk of releasing carbon stored within the ocean.
- Regularly update durability calculations with project data and the latest scientific research.
- Monitor for conditions and processes, at all relevant points in the project's facility, that could result in CO_2 outgassing and/or secondary carbonate precipitation.
- Document details of the models used to predict the fate of the captured CO_2, including input data, resolution, uncertainty, and known limitations.
- Disclose the use of CO_2 as a feedstock, and the risk of CO_2 reversal from any non-durable product or commodity.
- Follow guidance set forth for durability in the *Direct Air Capture* section when storing pure CO_2 (e.g., as in direct ocean removal projects).

PROJECT DEVELOPERS SHOULD

- Implement long-term plans for monitoring the durability of captured CO_2 well after project completion. Transparently share relevant data with the scientific community.
- Seek long-term monitoring solutions for storage, such as through regulatory takeover as envisioned by the European Union Carbon Capture and Storage Directive.

Leakage

These criteria build on and extend the leakage considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Predict, monitor, and report changes in the oceanic regime, regionally and globally, that could result in the release of CO_2 or unfavorably impact the carbon cycle elsewhere.
- Monitor and mitigate disruptions to local coastal businesses or those relying on the ocean in a way that could lead to increased emissions outside the project boundary, including land-based and maritime activities.
- Account for energy use induced by project activities and evaluate potential leakage from: (1) upstream and downstream use of fossil-fuel energy sources, and (2) electricity powering operations, including grid-related emissions from power purchase and use.
- Account for the counterfactual use of feedstocks and any increased production demand induced by consuming those feedstocks for project activities.

Other Considerations

Permits and Law

PROJECT DEVELOPERS MUST

- Conduct the project in accordance with all applicable regional, national, and international laws, regulations, and best practices for ocean-based activities that are not necessarily legally binding.
- Adhere to any applicable regulations from the London Convention and London Protocol regarding marine geoengineering activities and any non-coastal discharge into the ocean, the principles laid out in the United Nations Convention on the Law of the Sea (even if the host country has not ratified it), maritime zone regulations, regulations on exploitation of ocean resources, exclusive economic zones, and high seas boundaries and use rights.
- Mitigate negative impacts on international maritime activities.
- Consult with relevant agencies regarding all applicable coastal zone management plans, new or existing permits, and certifications.
- Engage in public comment periods and stakeholder consultations as part of the permitting process.

PROJECT DEVELOPERS SHOULD

- Work with national and international governmental bodies to cooperatively share relevant information and establish clear, sustainable, and equitable governance for the deployment of mCDR.
- Demonstrate consistency with coastal zone management plans of adjacent coastal states, where applicable.
- Assess project compliance with evolving governance frameworks, including the potential impact of the new Agreement on Marine Biodiversity of Areas beyond National Jurisdiction (BBNJ Agreement) for activities in international waters.
- Consult with local permitting agencies and identify any areas where the project should go above and beyond requirements to mitigate environmental harm and ensure the durability of mCDR.

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Scale-Up Readiness

PROJECT DEVELOPERS MUST

- Evaluate and incorporate any necessary adjustments to the MRV plan that may result from increasing the scale of the mCDR project, such as a decrease in the signal-to-noise ratio or increased uncertainty.
- Predict and mitigate potential social and environmental harms and benefits associated with increasing the scale of the project, including those linked to increased feedstock consumption.
- Predict and evaluate the potential impacts of halting project operations (at scale) to the environment and durability of stored carbon.
- Develop plans to stop project operations if ecosystem harm is detected or harmful thresholds are exceeded. Incorporate a risk assessment of termination shock and a remediation strategy for the project at anticipated scales.
- Follow the guidance set forth in this document for scalability of *direct air capture* when applicable.

Glossary of Technical Terms for Abiotic Marine Carbon Dioxide Removal

Environmental monitoring, reporting and verification (eMRV): Rigorously predicting and monitoring all potential acute, chronic, and cumulative impacts of project activities on the oceanic regime and the health of the ecosystem.

Marine life: All living organisms in the ocean, through the food chain, and species directly dependent on the ocean (e.g., migration patterns of birds).

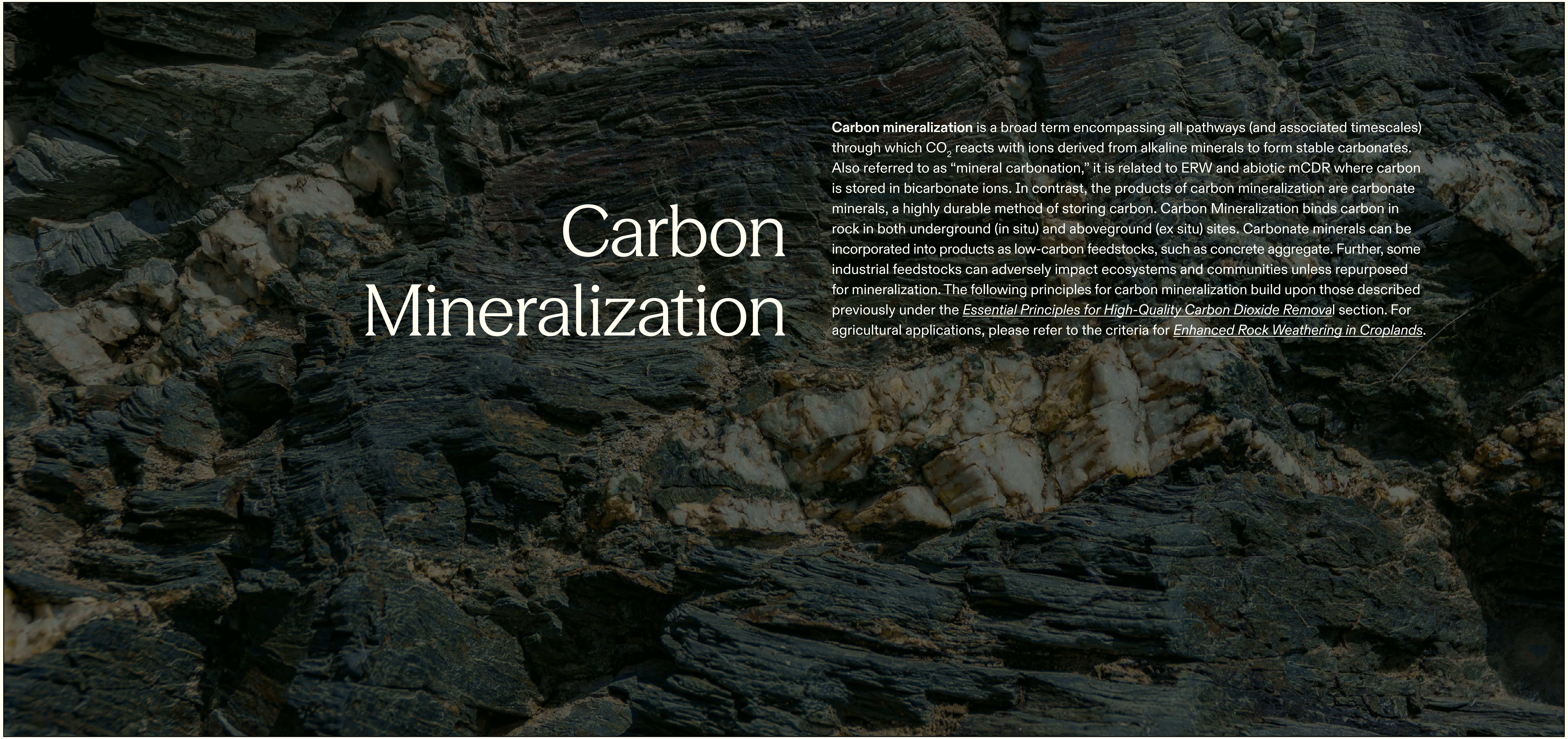
Ocean biogeochemistry: The processes and interactions that regulate the cycling of elements in the ocean. This includes all parameters and processes that pertain to marine life (e.g., photosynthetic processes and biogenic calcification), all mechanisms that relate to sedimentation at the sea floor, and all physical and chemical properties and processes within the ocean (e.g., nutrient cycling and air-sea-gas exchange).

Ocean circulation: All movement of ocean water.

Ocean modeling: Numerical modeling relevant to mCDR, including ocean biogeochemistry and physical processes.

Oceanic ecosystem: The interaction between living and non-living components within marine environments. This includes all marine life and their interconnected relationships such as community responses and biodiversity.

Oceanic regime: All conditions and processes of the oceans. This includes ocean biogeochemistry and circulation.



Carbon Mineralization

Carbon mineralization is a broad term encompassing all pathways (and associated timescales) through which CO_2 reacts with ions derived from alkaline minerals to form stable carbonates. Also referred to as "mineral carbonation," it is related to ERW and abiotic mCDR where carbon is stored in bicarbonate ions. In contrast, the products of carbon mineralization are carbonate minerals, a highly durable method of storing carbon. Carbon Mineralization binds carbon in rock in both underground (in situ) and aboveground (ex situ) sites. Carbonate minerals can be incorporated into products as low-carbon feedstocks, such as concrete aggregate. Further, some industrial feedstocks can adversely impact ecosystems and communities unless repurposed for mineralization. The following principles for carbon mineralization build upon those described previously under the *Essential Principles for High-Quality Carbon Dioxide Removal* section. For agricultural applications, please refer to the criteria for *Enhanced Rock Weathering in Croplands*.

Carbon Mineralization

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Social Harms, Benefits, and Environmental Justice

These criteria build on and extend the social harms, benefits, and environmental justice considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Minimize risk of adverse impacts on ecosystems, communities, and workers (e.g., changes in water quality, land use, pollutant use, and exposure to harmful materials).
- Document how a facility's established community engagement processes are expanded when CDR activities are added onto existing industrial processes (e.g., concrete production or active mine site).
- Characterize risk of contaminant mobility to soils and groundwater by quantifying potentially toxic elements (PTEs) concentrations and speciation, where appropriate.
- Avoid the risk of asbestos exposure to workers and communities through feedstock screening, selection, and safety measures.

PROJECT DEVELOPERS SHOULD

- Where possible, remediate past negative environmental impacts on communities and ecosystems, and document these efforts.
- Prioritize the sustainable sourcing of mineral feedstocks, such as using mineral waste that does not require new mining and results in minimal environmental impact to local communities.

Environmental Harms and Benefits

These criteria build on and extend the environmental harms and benefits considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Measure and disclose the mass, volume, composition, hazard classification, and disposal methods of waste streams, at a minimum including all on-site operations and upstream material and energy inputs.
- Disclose whether ex situ mineralization projects source raw materials and inputs from existing mines and industrial by-products, or if they require new mining activities. In the case of new mining activity, measure and mitigate any environmental impacts from the new mine or quarry.
- Quantify the net amount of water, potable and non-potable, that the project consumes during mineralization.
- For in situ mineralization projects, quantify the risk to local seismicity and implement mitigation actions used to prevent those risks.
- Implement mitigation and remediation plans for unintended release of a waste stream into the environment.

Additionality and Baselines

These criteria build on and extend the additionality and baselines considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Include a closed mass balance accounting for all states of carbon (e.g., solid, dissolved or aqueous, and gas), any metals that contribute to mineral carbonate formation, and all alkalinity imported or exported from the project boundaries when quantifying project baselines and changes in mineralization rates.
- Measure the rate of atmospheric CO_2 drawdown from counterfactual mineral weathering under project-relevant conditions when calculating the project baseline.
- Quantify the initial inorganic carbon content in feedstocks prior to project operations.
- Document all revenue streams for the project including the sale of refined metals, material products, and any cost savings from adopting mineralization technology at existing facilities.

PROJECT DEVELOPERS SHOULD

- Characterize baseline carbonate mineral content and use validated measurement of modeling approaches sufficient to distinguish net carbonate formation from background variability, with conservative treatment of uncertainty where phase-level attribution is not feasible.
- Monitor feedstock carbonate mineral content throughout the project duration.
- Implement control plots to measure natural mineral weathering rates before, during, and after project deployment, when relevant.
- Measure changes in mineralization reaction rates over time due to consumption of highly reactive material and feedstock passivation.

Measurement, Monitoring, Reporting, and Verification

These criteria build on and extend the measurement and MRV considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Use the best available measurement methods and tools to directly measure carbon stocks and fluxes in materials.
- Disclose any modeling tools used to supplement and inform measurements, along with information on model validation, calibration, and uncertainty.
- Measure and monitor, where appropriate, the impact of the project on other GHG pathways (e.g., methanogenesis, nitrogen cycle).
- Identify the source of metals, such as calcium and magnesium, that are contributing to mineral formation. Include the carbon impact of the metal source in the project's MRV plan.
- Document the spatial and compositional variability in industrial waste or mineral feedstocks and demonstrate how this variability is incorporated into measurement design, quantification uncertainty, and life cycle impact assessment.

PROJECT DEVELOPERS SHOULD

- Identify all carbon reservoirs and monitor carbon movement between reservoirs with appropriate tools (e.g., tracer, isotopic studies).
- Use cost assessments and LCAs that clearly identify and differentiate continuously produced and stockpiled industrial feedstocks.
- Include cross verification with redundancy (e.g., cross referencing gas, liquid, and solid phase fluxes with mass balances).
- Supplement and calibrate modeling with direct physical and/or chemical evidence of mineralization.

Durability

These criteria build on and extend the durability considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Implement downstream use and/or storage pathways that maintain the geochemical stability of carbonated materials and avoid foreseeable exposure scenarios that would materially increase reversal risk.
- Quantify the fraction of carbon stored aqueously in dissolved form versus the fraction stored in physical mineral form through carbonate precipitation.

PROJECT DEVELOPERS SHOULD

- Include reversal risks for both solid and aqueous carbon in MRV plans.
- Implement release scenarios and mitigation plans that reflect the anticipated impacts of climate change and changes in land use or water reservoir development, when relevant.
- Include feedstock supply and/or subsurface reservoir capacity and injectivity when planning large-scale mineralization projects.

Leakage

These criteria build on and extend the leakage considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Quantify the impact of the project on land use, especially when project infrastructure encroaches on high-value land use.
- Demonstrate, through project design and energy sourcing contracts, that any new energy needed for mineralization operations does not extend demand or create new demand for emissions-intensive energy.
- Integrate project activities into active mining processes in a way that causes minimal disruption to or influence on current or future mining outputs, where applicable.

PROJECT DEVELOPERS SHOULD

- Quantify the project's production of valuable coproducts and, for retrofits to pre-existing industrial facilities, provide evidence of the historic volume of production.
- Include the size and distance to market or area of application for projects in the built environment.

Glossary of Technical Terms for Carbon Mineralization

Alkaline mineral: Mineral which contains alkali or alkaline-earth metals such as calcium, magnesium, sodium, and potassium and is used as a mineral feedstock.

Built environment: The constructed physical world, including buildings, infrastructures, and urban spaces.

Carbonate species: Chemicals and materials containing the carbonate ion (CO_3^{2-}); in aqueous systems, often in the form of bicarbonate (HCO_3^-) or carbonic acid (H_2CO_3), or dissolved CO_2 gas depending on the pH; in solid systems, often in the form of carbonate minerals, such as calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), and magnesite ($MgCO_3$).

Ex situ mineralization: Mineralization as a result of the chemical reaction between CO_2 and industrial waste resources or excavated alkaline minerals, typically in a dedicated reactor or industrial process.

In situ mineralization: Mineralization as a result of the chemical reaction between CO_2 and minerals in naturally occurring geologic formations, deep underground; typically, aqueous or supercritical CO_2 is injected into a deep geologic formation, where it mineralizes to form solid carbonate minerals over time.

Mass balance: Systematic way to track and quantify all mass flows entering or exiting a system to follow the Law of Conservation of Matter.

Natural mineral weathering: Slow breakdown of minerals due to atmospheric conditions where CO_2 reacts with the minerals in rocks to form carbonate species.

Potentially toxic elements (PTEs): Naturally occurring elements that can be toxic to humans or ecosystems, even at low concentrations (e.g., arsenic, cadmium, chromium, lead, and nickel).

Volcanic basalt rock columns.

Direct Air Capture

Direct air capture (DAC) projects involve mechanical and chemical systems that remove and concentrate CO_2 from ambient air. This CO_2 is then disposed of in a long-term carbon sink or used as a feedstock. DAC projects typically do not require rare or critical materials and could be sited in many geographies, including near CO_2 storage resources and low-cost or stranded low-carbon energy assets. Net-negative DAC projects rely on large amounts of low-carbon energy, both heat and electricity, which may limit the speed and scale of deployment. The following principles for DAC build upon those detailed previously under the *Essential Principles for High-Quality Carbon Dioxide Removal section*.

Direct Air Capture

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Social Harms, Benefits, and Environmental Justice

These criteria build on and extend the social harms, benefits, and environmental justice considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Quantify potential impacts from sorbent or solvent slip downwind of the facility, even if the project is compliant with general health and safety guidelines and all applicable local/regional regulations.
- Articulate a strategy to measure and mitigate any material impacts to air, water, and land quality, including emissions from solvent or sorbent slip and discharge into local air, water, and land.
- Avoid developing, disturbing, or restricting access to land legally designated as culturally sensitive or ecologically important by community members or local stakeholders. This includes land the project directly uses for DAC facilities, renewable energy installations to power DAC facilities, or other utilities required for operations (e.g., local water resources, land for CO_2 transport, land for geological storage).
- Prevent community displacement by ensuring that any new or expanded pipelines, roads, wells, or other infrastructure do not inequitably impact historically disadvantaged or marginalized communities.
- Measure and mitigate any adverse impacts on local communities from increased water consumption. These impacts may include increased water and wastewater treatment prices and/or decreased local water quality, including discharges from capture facilities and sorbent/solvent manufacturing facilities.
- Document all land-use changes required for project deployment, including new infrastructure.

PROJECT DEVELOPERS SHOULD

- Minimize the need for new inputs (e.g., energy, construction materials, sorbents/solvents) by monitoring and improving material and process efficiency, including application of best practices in reuse and circularity.
- Prioritize material sourcing that minimizes disproportionate impacts on front-line communities.
- Actively promote long-term economic opportunities for local communities by providing training programs that implement a pipeline of local workers skilled at DAC management and operation.
- Minimize land-use changes that could have negative community consequences, including any new infrastructure required for project deployment.
- Publicly disclose air emissions monitoring results related to solvent/sorbent degradation products and other criteria pollutants that may not be explicitly listed in the project air permit.

Environmental Harms and Benefits

These criteria build on and extend the Environmental Harms and Benefits considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Measure the amount and type of material released to the air, water, and soil—including reagents, process byproducts, degradation products, and any substances not native to the receiving environment—during the project's construction and startup/commissioning phase, as well as during its steady state operations.
- Measure and mitigate any adverse impacts from increased water consumption, including decreased local water quality due to discharges from capture facilities and sorbent/solvent manufacturing facilities.

- Articulate a strategy to measure and mitigate any material impacts to air, water, and land quality, including emissions from solvent or sorbent slip and discharge into local air, water, and land.
- Implement a remediation plan for unintended releases of chemicals to the environment.

PROJECT DEVELOPERS SHOULD

Benchmark environmental impact practices against the most protective permitting standards globally, rather than defaulting to the requirements of the operating jurisdiction alone.

Additionality and Baselines

These criteria build on and extend the additionality and baselines considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Explain the economic viability of the project with or without the requested investment and/or CDR procurement, and the role of tax or policy incentives (e.g., the 45Q tax credit in the United States or, in some European Union countries, state auctions for carbon removals).
- Quantify baseline GHG fluxes and expected GHG fluxes from induced material and energy consumption to serve as a reference for leakage-related emission impacts.

Measurement, Monitoring, Reporting, and Verification

These criteria build on and extend the measurement and MRV considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Ensure that carbon removal claims are consistent with a net carbon-negative outcome based on a cradle-to-grave LCA.
- Conservatively quantify all life cycle GHG emissions, such as direct and indirect land-use change, concrete and steel production and construction, procurement of capture media and chemicals, disposal of waste products, and energy use during DAC operations.
- When a project uses fossil-fuel energy sources, include full life cycle impacts, encompassing both upstream natural gas leakage and downstream usage, in carbon measurement considerations.
- Measure the relative fraction of atmospheric and fossil CO_2 sent to storage and validate any discrete measurements (e.g., C-14 sampling) with continuous measurements of all carbon flows within the system, including fossil fuel consumption, when projects co-capture fossil and atmospheric CO_2.
- Include full life cycle impacts of the electricity powering operations, including grid-related emissions from grid-connected power purchase and use.
- When purchasing electricity from a grid, provide substantive details of the power purchase agreement, including the electricity emissions factor of the generating resource under contract where applicable, the latest emissions factor for the local electrical grid, and related RECs.
- Present a viable MRV plan that adheres to key regulatory requirements (e.g., Class VI well permits) for any subsurface storage and CO_2 transportation activities that are part of the project.
- Model displacement of high carbon-intensity products or processes for DAC projects coupled to CO_2 utilization.

- Where DAC-sourced CO_2 is used as a feedstock, ensure that removal credits are not double counted against environmental attributes of carbon-containing products.
- Disclose if CO_2 storage is physically connected to a reservoir where CO_2-based enhanced oil recovery is practiced. If so, the project developer must ensure that DAC-based removals are not double counted against oil production with a lower carbon intensity.
- Include documentation or the status of permit applications for storage sites.
- Design a project that emits less than 0.3 tonnes of fossil GHG emissions per gross tonne CO_2 removed.
- Document that grid-connected DAC electricity consumption is met by incremental low-carbon electricity supply within the relevant balancing area or equivalent grid region, as defined by the local grid operator or regulatory authority (e.g., contracted new-build or equivalent mechanisms) or by verifiable surplus low-carbon generation that would otherwise be curtailed.

PROJECT DEVELOPERS SHOULD

- Use energy with low associated emissions, ensure the additionality of any low-carbon energy procured, and use advanced carbon accounting methodologies (e.g., temporally aligned power or carbon matching) to estimate the broader emission impacts of a project's energy procurement.
- Provide an LCA sensitivity analysis by varying key parameters such as energy and chemicals use.

Durability

These criteria build on and extend the durability considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

- Use safe and durable geologic storage sites, where applicable, following established permitting processes (e.g., EPA Class VI permitting for deep injection wells in the United States or meet ISO 27914:2017 standard for CO_2 storage).
- Demonstrate sufficient CO_2 storage capacity for the entire project lifetime, or sufficient physical CO_2 offtake with credible third-party providers.
- Demonstrate sufficient injectivity at the storage site, including well count.
- Demonstrate low CO_2 release risk, as estimated by the methodologies outlined in the IPCC AR6 WGIII report, Section 12.3.1.
- Implement an MRV plan, consistent with best practices for the chosen storage location, to detect unplanned physical leakage or reversals.
- Disclose the use of CO_2 as a feedstock to produce any non-durable product or commodity.
- Seek long-term monitoring solutions for storage (e.g. via regulatory takeover as envisioned by the European Union's CCS Directive.

PROJECT DEVELOPERS SHOULD

Document financial assurance mechanisms sufficient to cover long-term monitoring, remediation, and liability associated with CO_2 storage.

Leakage

These criteria build on and extend the leakage considerations included under the Essential Principles for High-Quality Carbon Dioxide Removal section.

PROJECT DEVELOPERS MUST

Demonstrate that any new energy needed for DAC operation does not extend or create new demand for emissions-intensive energy outside of the project boundary.

PROJECT DEVELOPERS SHOULD

For projects reliant on grid-mix electricity (e.g., those without incremental new-build, low-carbon power purchase contracts), develop operational strategies (e.g., temporal matching, demand response, storage integration) that minimize operation during high-carbon intensity grid periods.

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Other Considerations

Materials

PROJECT DEVELOPERS MUST

Demonstrate that process inputs, including capture media, have low operational safety risk.

PROJECT DEVELOPERS SHOULD

- Use earth-abundant inputs, such as magnesium, calcium, silicates, sodium hydroxide, or other such inputs appropriate for a given process.
- Quantify projected capture media replacement rates and associated material throughput at the project's planned operating scale.
- Produce, transport, store, and manage solvent and solvent degradation products with low risk to operators, neighboring communities, and the environment, when a project uses a solvent-based system.
- Document secured manufacturing capacity for capture media at scale consistent with projected deployment timelines, whether in-house or through qualified third-party suppliers.
- Provide documentation of permit applications or approvals a project has received for air emissions, wastewater disposal, and solid waste disposal, as applicable to project stage.

Infrastructure

PROJECT DEVELOPERS SHOULD

- Describe relevant transmission infrastructure, including new power lines, new utility lines, and CO_2 transportation infrastructure such as pipelines, truck, barge, or rail.
- Plan project development using likely CO_2 injection permitting timelines calibrated from updated, regional precedents.
- Describe contingency plans for CO_2 transport interruptions and associated risks to storage continuity.
- Work with downstream transport and storage partners early to understand and engineer to purity constraints, as dictated by transport and storage options, particularly in hub-style networks.

Scale-Up Readiness

PROJECT DEVELOPERS MUST

- Present reasonable cost estimates, ideally verified by third parties, peer review, or demonstrated in prior projects.
- Demonstrate that projected energy supply provides sufficient availability and reliability to support expected annual CO_2 volumes.
- Demonstrate the capacity to manufacture or procure proposed design components and systems.
- Ensure viable, low-carbon energy supply at scale, ideally via evidence of contracted or captive energy supply.

PROJECT DEVELOPERS SHOULD

- Provide a document, with a block flow diagram, describing the process concept and location, including the role of any organizations involved in project development.
- Successfully construct and operate prototypes that can achieve at least 1,000 hours of continuous stable operation at nameplate capacity to enable validation of LCA and techno-economic assessment models, for first-of-a-kind DAC technology. Show a scale-up plan that moves from lab/bench applications to pilot to commercial sizing, which builds confidence in DAC feasibility and efficacy at scale. Such prototypes and pilots should either be built in climatically similar locations to any eventual commercial project or be engineered and tested in a way that adequately demonstrates continuous operability over the range of climatic conditions expected at the targeted commercial geography. Prototypes should incorporate all major elements of a commercial project across the capture, sorbent/solvent regeneration, and CO_2 purification stages, using the same vendors that will support at-scale deployments.
- Avoid scaling-up critical unit operations (i.e., any critical process equipment) by more than five fold, unless justified with empirical data, prototype testing, or credible analogs demonstrating consistent performance at scale.
- Ensure vendors and subcontractors provide performance, schedule, and cost data for key DAC technologies.

- Develop and implement a risk mitigation plan for scale-up and deployment technology risks (e.g., technical and commercial readiness, project management structure, and supply-chain bottlenecks).
- Articulate project development aspects across a holistic technical, economic, commercial, organizational, and political spectrum, providing clear and transparent plans showing the linkages of requirements and the actions planned to achieve each critical aspect.
- Before marketing priced volumes, develop a Class 3 cost estimate and a project schedule informed by, at a minimum, FEL-2/Pre-FEED results, using the empirically-proven factors from other DAC projects or adjacent industries. When making a final investment decision, use a Class 2 cost estimate (or Class 3 at a minimum) and a resource-loaded, logic-linked project schedule.

Glossary of Technical Terms for Direct Air Capture

45Q: Section of the United States Tax Code outlining tax incentives for qualifying projects that capture and store or beneficially reuse CO_2.

Carbon (CO_2) utilization: The beneficial reuse of captured CO_2 as a feedstock or component in another process. Examples include CO_2-enhanced oil recovery, conversion of CO_2 into short-lived chemicals (e.g., transportation fuel, urea), or long-lived chemicals (e.g., concrete, certain polymers).

Class VI well permit: Specialized permit granted by the United States EPA (or state-level equivalent) to inject CO_2 into the subsurface for the purpose of durable storage. The permit regulates several components of the CO_2 storage process, including site characterization, well construction, and post-injection site care.

Cradle-to-grave life cycle assessment: A life cycle assessment with a broad system boundary that includes all emissions from energy and material sourcing and consumption, waste treatment, construction and decommissioning, compression, transportation, and storage or reuse.

European Union CCS Directive: An established regulatory framework for the safe and responsible development and operation of CO_2 storage in the European Union.

Solvent: Generic term for a liquid capture media, typically a basic (low pH) chemical dissolved into solution. CO_2 is captured through the process of absorption, where it diffuses from the gas phase into the liquid solvent in contactors and binds with the chemical absorbent in solution.

Sorbent: Generic term for solid CO_2 capture media, typically composed of a specialized chemical coated onto a supporting material with a high surface area. CO_2 is captured through the process of adsorption to the sorbent surface, either via chemical reaction (chemisorption) or physical interaction (physisorption).

Conclusion

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Thank you for engaging with Microsoft and Relae to advance the development of high-quality CDR. Our collaboration builds on previous years' work by incorporating the latest research findings and industry insights. We are committed to regularly updating and refining these criteria to ensure we provide relevant and actionable information for a rapidly evolving industry.

We recognize that this work is part of a collective effort, and we encourage open dialogue within the CDR community. We welcome feedback, comments, and questions about the guidance presented in this document. Please feel free to reach out to Microsoft's Carbon Removal team at mscdr@microsoft.com and Relae at info@relae.co. Engaging in active discourse is vital to driving innovation and refining our understanding of high-quality CDR.

To foster the growth of the CDR market and facilitate the development of high-quality projects, we call upon the support of financial institutions, project developers, governments (e.g., local, regional, national, and multinational) and the wider CDR community. It is through increased investment, collaboration, and community engagement that we can collectively build a strong foundation for the future of carbon removal. We invite interested parties to explore Microsoft's procurement cycle as well as other buyers' procurement cycles to consider how they can contribute to the pipeline of high-quality CDR projects. For more information on the Microsoft procurement process or to inquire about potential partnership opportunities, please visit the Microsoft Carbon Removal Program page.

Our goal is to contribute to rapid and just climate change mitigation. By collaborating, sharing insights, and promoting transparency, we can create a robust CDR market that will play an essential role in combating climate change. Thank you for your engagement—we look forward to working with you as we continue this vital journey.

Appendix: Delivery Risk

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Delivery risk refers to the likelihood that a project will generate credits on the timeline and at the quantity committed to buyers or investors. Non-delivery of credits may result from a variety of project-specific risks, such as technology readiness, project maturity, and experience of the project developer. It may also result from systemic risks, such as the geopolitical context. Effectively managing project-level delivery risk requires a coordinated effort across CDR market actors. First and foremost, it requires sound project execution on the part of the developer, but also requires informed purchasing decisions, appropriately structured financing, and realistic expectations from all counterparties. As a result, it is critical for developers, investors, and buyers to understand and align on the risks associated with CDR delivery.

This appendix highlights common delivery risks across two broad CDR project types: open systems[3] and closed systems.[4] Risks are defined through the lens of five categories: technical, economic, commercial, organizational, and political factors, also known as the TECOP framework. For each risk category, the appendix describes what well-positioned projects should strive for to minimize delivery risk. While not sufficient for conducting comprehensive risk assessments of CDR projects, these descriptions establish a common language for understanding key delivery risks. This appendix draws on broader market observations and proven frameworks for managing project delivery risk that translate directly to CDR delivery. Future updates will reflect new insights as the CDR market matures.

Delivery risk is closely tied to a project's development stage; its profile will vary over time and across project types. Early-stage projects tend to carry greater delivery risk across all TECOP categories, as many design, financing, and permitting decisions have not yet been finalized. As projects progress through detailed design, implementation, and into operations, delivery risk generally decreases as certain risks are resolved, while others (e.g., operational performance, market dynamics) become more salient. While the pace and pattern of the delivery risk profile is ultimately project-specific, buyers should recognize that some delivery risks are expected features of early-stage development that may be mitigated as a project advances, and others represent more fundamental concerns regardless of stage.

While delivery risk is distinct from credit quality, the two are interrelated. A project that fails to deliver credits on schedule undermines the availability of high-quality CDR tonnes in the market. Weaknesses in credit quality can create delivery risk by creating buyer uncertainty or limiting access to project financing. Together, delivery and quality risk shape the risk profile of a CDR project at any given point in its lifetime. Delivery risk is an essential element of ensuring that high-quality CDR tonnes reach the market (as discussed in our white paper, *CDR 2.0: Five Pillars of Successful Project Deployment and Delivery*. Buyers and suppliers should consider both dimensions together when assessing a project.

3. *Open-system CDR projects include ARR, mangrove reforestation, IFM, soil carbon, ERW, and mCDR.*

4. *Closed-system CDR projects include: DAC, BiCRS, aboveground (ex situ) mineralization projects, and underground (in situ) mineralization projects.*

Open-System CDR Projects

Open-system CDR projects leverage natural processes to increase the carbon stored in ecosystems, either through increased living plant biomass (e.g., ARR, IFM, mangroves), increased carbon sequestration in soils in agricultural settings (i.e., soil carbon), or increased inorganic carbon stored in the ocean (e.g., ERW, mCDR). These projects face a distinct set of delivery risks tied to management and measurement given the complexity and unpredictability of natural ecosystem processes, their susceptibility to climate variability and disturbance, the influence of human behavior on long-term outcomes, and the limitations of MMRV technologies that, though evolving, still rely on models and limited data.

Technical

Technical delivery risks are associated with the technical feasibility of the project design, implementation, and long-term management of the project. Technical delivery risks can result from multiple factors including, but not limited to, scale-up uncertainty, overly optimistic ex ante projections, shortfalls between projected and measured outcomes, methodology and registry changes, and exposure to climate and natural hazards. Projects with low technical delivery risk validate performance through field trials before scaling and expand using a stage-gate approach with clear milestones. When using dynamic baselines, they apply locally validated, robust detection methods to distinguish trends between project and control areas. They manage uncertainty with adaptive management, periodic model true-ups using monitoring data, and delivery buffers.

PROJECT DEVELOPERS SHOULD

- Validate expected performance through field trials or demonstration plots to reduce the risk of underperformance in scale-up conditions.
- Develop projects through evidence-based stage gates, advancing scale and commitments only when each phase's technical and operational assumptions have been confirmed.
- Minimize early-stage losses by combining vulnerability assessments, climate-resilient practices, and frequent monitoring under an adaptive management framework.
- Calibrate buffer pool contributions, uncertainty discounts, and contingency mechanisms to project-specific risk, supplementing methodology-required tools where they may understate actual exposure.
- Build ex ante estimates using best-available science, transparently document assumptions and uncertainties, and periodically validate and update models with monitoring data (i.e., true-ups or recalibration) to reduce projection errors over time.
- When using dynamic baselines, use locally validated baseline data that can reliably distinguish performance trends between project and control areas.
- Select methodologies that reflect the best science and are actively stewarded by credible standard setters; proactively monitor rule developments to anticipate and manage changes.

Economic

Economic delivery risks are associated with the project's financing structure, financial modeling assumptions, and expenditure profile. Economic delivery risks can include difficulties raising and structuring sufficient capital, financial modeling uncertainty, underestimation of capital and operating costs, dependence on policies and incentives, and sensitivity to variable-cost inputs (e.g., feedstocks, energy, or interest rates). Projects lower their economic delivery risk by relying on committed, well-structured financing and deploying capital through stage-gated investments tied to milestones to limit capital and refinancing risk. They use conservative financial assumptions, rigorous stress testing, and transparent techno-economic and financial models, with independent validation where appropriate. They also manage currency and macroeconomic risks and maintain adequate contingencies, reserves, and life cycle cost provisions to withstand cost overruns and long-term financial uncertainty.

PROJECT DEVELOPERS SHOULD

- Evaluate implementation choices (e.g., natural regeneration versus active planting, leasing versus purchasing land) for their economic risk profile (e.g., capital intensity, cost predictability, time to first revenue). Where approaches increase economic risk, include active mitigations such as contingency reserves or contractual protections.

- Establish a robust financial structure supported by reliable and diversified funding sources (e.g., equity, debt, grants, tax incentives).
- Anchor financial modeling in evidence-based capital expenditure estimates and conservative operating expenditure assumptions.
- Consider and conduct rigorous sensitivity and downside analyses, including combined-stress scenarios (e.g., project performance, carbon price volatility, cost escalation, inflation) to identify critical thresholds that may impact financial viability.
- Deploy capital through stage-gated investments tied to defined milestones to avoid significant cost overruns.
- Include all revenue streams in the financial model, basing pricing and demand assumptions on well-supported and documented market evidence.
- Maintain adequate contingencies, reserve accounts, and life cycle cost provisions.
- In developing markets, protect against currency and inflation volatility by aligning revenue and cost currencies and using hedging or price indexation to prevent margin erosion (e.g., where revenues are denominated in United States dollars or euros, while project costs are in Indian rupees or Brazilian reais).

Commercial

Commercial delivery risk reflects the extent to which a project's purchase agreements, supply arrangements, and key contractual relationships are secured or well-advanced. Commercial delivery risks can include demand uncertainty, carbon price volatility, counterparty and contracting risk, and procurement disruptions. Projects with low commercial delivery risk demonstrate predictable revenues across carbon credits and other commodities produced by the project with diversified commercial structures. They are supported by transparent offtake agreements that account for the variable nature of open systems with appropriate insurance and contractual safeguards. They rely on reliable, scalable supply chains to support consistent implementation and credit delivery.

PROJECT DEVELOPERS SHOULD

- Include contractual mechanisms (e.g., successor obligations, land-use covenants) to reduce the risk of project disruptions due to land ownership changes.
- Proactively maintain a pipeline of vetted land opportunities with a clear understanding of the total addressable market for the project scale-up within the region, with early landowner engagement and due diligence, to ensure that land required for project scaling is secured.
- Secure transparent buyer commitments that are specific in terms and volume with creditworthy counterparties to stabilize revenues over time.
- Structure financing and offtake agreements with delivery schedules that conservatively consider natural carbon sequestration variability.
- Strengthen commercial resilience through robust contractual protections tied to quality, delivery, and replacement (e.g., termination tied to credit quality or registry actions, replacement obligations for reversals, milestones-linked payments on verification), a diversified buyer pipeline spanning counterparty types (e.g., corporates, market intermediaries, philanthropic buyers), geographies and contract tenors to reduce concentration risk and protect cashflow against counterparty default and funding disruptions.
- Where feasible and without undermining project and credit additionality claims, create diversified revenue streams (e.g., carbon, crops, grants, philanthropy) using credible pricing assumptions to reduce dependence on any single income source.
- Minimize procurement disruptions by developing resilient and scalable supply chains, preferably local, for key inputs and services, or securing necessary permits and certifications in advance if sourcing across jurisdictional boundaries.

Organizational

Organizational delivery risks are associated with the project developer's capacity and capability to plan, execute, and manage a project of the appropriate size and complexity. These risks include low execution capability, poor project governance, lack of leadership and workforce expertise, weak land recruitment pipeline, and participant attrition. Projects with low organizational risks are led by experienced teams with the capacity to execute the project activities in the relevant geographies, supported by realistic operational plans, budgets, and timelines. They operate under clear governance structures and standard operating procedures, with defined roles and accountability. They maintain access to skilled labor and capable partners with appropriate training and sufficient local context. They sustain landowner participation through transparent benefit-sharing and ongoing support through the life of the project, ensuring land ownership changes do not disrupt project commitments.

PROJECT DEVELOPERS SHOULD

- Build teams with relevant experience and demonstrated technical capacity to reduce the risk of execution errors that could delay or reduce credit issuance.
- Develop detailed operational and staffing plans, budgets, and implementation timelines grounded in field-tested assumptions.
- Establish clear project governance structures with defined roles, accountability, and decision rights across the developer, operator, landholders, and key contractors.
- Develop and maintain standard operating procedures across core project functions (e.g., land tenure and access, community engagement and benefit sharing, MMRV and data quality assurance, reversal and incident response).
- Ensure adequate staffing with skilled personnel, capable partners with sufficient local expertise and geographical context, as well as appropriate and ongoing training to minimize operational disruptions.
- Establish clear partnership structures, transparent benefit-sharing agreements, and dedicated participant relationship management functions to reduce the risk of landowner withdrawal or declines in project activity.

Political

Political delivery risks are associated with governance, policies, and potential changes in regulatory environments, as well as the local communities' perception of and willingness to participate in projects. Political delivery risks can include unclear carbon rights, insufficient land tenure, lack of regulatory clarity regarding the voluntary carbon market, changing tax and incentive structures, legality (e.g., mCDR and the London Convention), and political instability. Where credit use requires host-country authorizations and/or corresponding adjustments (e.g., Letters of Authorization for internationally transferred mitigation outcomes under Article 6 of the Paris Agreement or compliance with the Carbon Offsetting and Reduction Scheme for International Aviation), the host country's willingness or ability to issue or maintain those instruments may present a political delivery risk. Projects with low political risk conduct due diligence to confirm land tenure and carbon rights and secure agreements with relevant parties prior to implementation. They are sited in jurisdictions with stable, supportive carbon market and land-use policies, low political risk, and strong governance. Developers actively monitor regulatory developments and remain adaptable, working with trusted local partners to transparently navigate administrative processes.

PROJECT DEVELOPERS SHOULD

- Implement projects in jurisdictions where carbon rights are clearly and broadly recognized (e.g., who holds carbon rights and how they are transacted), and where secured rights are unlikely to face third-party contestation.
- Secure free, prior, and informed consent from all legitimate rights holders, with enforceable participation agreements and clear land tenure and carbon rights transfer provisions that bind successor owners, to reduce the risk of disputes or rights challenges.
- Structure projects to remain viable under multiple regulatory scenarios, proactively monitor regulations while maintaining contingency plans to anticipate and adapt to rule changes, and (where feasible) engage constructively with regulators to support durable, well-designed rules in the jurisdictions the project depends on.
- Implement robust anti-corruption controls, partner with vetted local entities, and incorporate contingencies to reduce administrative delays and disruptions due to political instability.
- Build strong relationships with local political and/or tribal leaders, independent of party affiliation if possible.

Closed-System CDR Projects

Closed-system CDR projects involve purpose-built facilities that capture CO_2 from either the atmosphere (i.e., DAC) or biogenic sources (e.g., BECCS, biochar, etc.), and then transport captured CO_2 and sequester it in durable geological storage, mineralized form, or highly recalcitrant organic forms (e.g., biochar). These projects face a distinct set of delivery risks tied to technology maturation, capital-intensive construction, complex supply chains, and evolving regulatory landscapes.

Technical

Technical delivery risks are associated with the technical feasibility of the project design, technology, and implementation. Technical delivery risks can include low technology readiness, scale-up uncertainty, inadequate design or implementation of MMRV, adverse environmental factors, and project schedule uncertainties. Technical delivery risk decreases as a project matures from conceptual design through detailed engineering and into operations. At earlier stages, confidence rests on the quality of bases-of-design, the rigor of engineering studies, and the realism of assumptions. At later stages, it rests on demonstrated performance at relevant scale. Across all stages, projects that follow a disciplined engineering progression are better positioned to deliver credits on schedule and at projected volumes.

PROJECT DEVELOPERS SHOULD

- Validate core capture and conversion technology in a relevant application through pilot or demonstration operations, with clearly documented performance data.
- Identify and mitigate outstanding risks to scale-up from pilot or demonstration to the next deployment.
- Demonstrate that MMRV technologies and systems are sufficiently established to be deployed at the proposed operational scale.
- Site and design facilities with thorough consideration of environmental hazards, including natural disaster exposure and climate variability.
- Follow a structured, disciplined, stage-gate development process (e.g., front-end loading) from conceptual design through detailed design, with defined milestones at each gate.
- Base project timelines on realistic, empirically-grounded schedules, including commissioning, that include defined milestones with appropriate contingency for delays. By the time of a final investment decision, such timelines should be resource-loaded and logic-linked.
- Include an integrated cost schedule linking expenditures to milestones that demonstrates the developer's pathway to operations at scale.

Economic

Economic delivery risks are associated with the project's financing structure, financial modeling, financing, and expenditure. Economic delivery risks can include capital and financing risk, financial modeling uncertainty risks, underestimation of capital and operating costs, dependence on variable-cost inputs, and sensitivity to carbon price and revenue assumptions. Projects with low economic delivery risk demonstrate economic credibility that is commensurate with a project's development stage. Early-stage projects are expected to have wider uncertainty ranges and less-defined cost estimates, but should demonstrate awareness of key cost drivers (including cost of capital and labor) and a credible path to a viable business case. As projects advance through front-end loading stages, cost estimates should be refined, cost uncertainties should narrow, contingencies should be explicitly quantified, and assumptions about capital, operating costs, and revenue should be stress-tested.

PROJECT DEVELOPERS SHOULD

- Have a robust and transparent financial structure with clearly identified funding sources (i.e., equity, debt, grants, tax incentives, and/or subsidies).
- Demonstrate a credible and transparent economic case aligned with the project's stage of development, supported by a defined cost estimate class that is aligned with the level of project definition (e.g., FEL staging and associated AACE class cost estimates) and includes clearly stated contingencies and uncertainty ranges.
- Ground operating expense assumptions in realistic projections for energy, materials, feedstock, labor, maintenance, and replacement cycles.

- Estimate capital expenditures using vendor quotes, engineering studies, or other evidence-based sources.
- Include credible revenue estimates for all product and co-product streams. Revenue projections should be benchmarked against comparable products within the target market where possible. For co-products sold into immature or volatile markets, provide justification for pricing assumptions through market analysis or a comparable assessment that accounts for current market supply, demand, and price variability.
- Conduct a sensitivity analysis on key financial model variables (e.g., costs, tax credits, subsidies, production, LCA, etc.) to determine how these variables impact the price at which CDR credits and co-product streams must be sold to maintain financial viability of production.
- In developing markets, protect against currency and inflation volatility by aligning revenue and cost currencies and using hedging or price indexation to prevent margin erosion (e.g., where revenues are denominated in United States dollars or euros while project costs are in Indian Rupees or Brazilian reais).
- Before marketing priced-volumes, develop a Class 4 cost estimate (typically ±30% accuracy) informed by FEL-2/Pre-FEED results and using the empirically-proven factors from prior analogous projects or adjacent-industries. By final investment decision, advance to at least a Class 3 cost estimate (typically ±10% accuracy) supported by FEL-3/FEED engineering.

Commercial

Commercial delivery risk reflects the extent to which purchase agreements, supply arrangements, and key contractual relationships are secured or well-advanced. Commercial delivery risks can include counterparty and contracting risks, procurement risks, scale-up and commercial-readiness risk, fragile or unconverted buyer commitments, and exposure to unhedged revenue (e.g. carbon price and co-product sales) or operating expenses (e.g. energy and feedstocks). Early-stage projects may not yet have executed agreements, but should demonstrate a realistic commercial strategy and engagement with potential counterparties. Later-stage projects should have key agreements in place or at advanced stages of negotiation, with clear terms around volume, price, and duration. Projects with low commercial delivery risk have an appropriate strategy for engineering, procurement, and construction (EPC) contracting including clear risk allocation between counterparties. Identifying long lead items early and considering appropriate procurement timelines demonstrates suitable management of schedule and the ability to provide delivery confidence. Projects with diversified commercial structures and resilient supply chains are better positioned to weather market shifts and counterparty disruptions.

PROJECT DEVELOPERS SHOULD

- Execute or appropriately advance key commercial agreements, such as offtake contracts, appropriate EPC and project management office arrangements, feedstock and supply contracts, major equipment, and CO_2 transport and storage agreements. Agreements with value-chain partners like feedstock suppliers or major equipment providers should articulate clear acceptance criteria, handover requirements, and/or performance requirements.
- Adopt an appropriate EPC contracting strategy that structures individual contracts into lots with clear scope boundaries and accountability, and aligns risk allocation between owner and contractor.
- Secure transparent buyer commitments that are specific in terms and volume with creditworthy counterparties to stabilize revenues over time.
- Articulate clear commercial readiness and scale-up pathways, including supply-chain resilience and contingency planning for key third-party dependencies.
- Identify long lead items early in project development and place procurement orders sufficiently in advance of construction commencement to avoid schedule risk that cannot be recovered downstream.

Organizational

Organizational delivery risks are associated with the project developer's capacity and capability to plan, execute, and manage a project of the appropriate size and complexity. These risks include low execution capability, lack of leadership and workforce expertise, supply-chain vulnerability, complicated integration, and lack of detailed project management experience or systems. Early-stage projects may draw on analogous experience from adjacent industries, but should be building the team and governance structures needed for the specific demands of CDR project delivery. As projects move into construction and operation, the depth of operational expertise, clarity of management structures, and reliability of supply chains become direct determinants of whether credits are delivered on time and at projected volumes. A sufficiently resourced project team, capable of actively managing contractors, verifying progress, and protecting the project's interests at the contractor interface, is a marker of organizational maturity. Projects that plan early for the transition from construction to operations, including commissioning readiness, staffing, and training, are better positioned to achieve reliable first delivery and ramp to projected volumes.

PROJECT DEVELOPERS SHOULD

- Have relevant technical expertise and a track record in analogous project development and operations.
- Demonstrate clear systems integration planning across subsystems (e.g., capture, compression, transport, injection/storage), including interface management and contingency for bottlenecks.
- Maintain a sufficiently resourced project team or independent project management office capable of actively managing contractors, verifying progress, and managing the owner-contractor interface.
- Establish clear project management structures with well-defined roles, change management processes, and appropriate escalation routes.
- Maintain tight, reciprocal feedback between technical, commercial, and financial teams to reduce drift between engineering plans, finance models, and external offtake commitments.
- Implement independent technical assurance processes, and actively seek and implement lessons from equivalent developments.
- Plan early for the construction-to-operations transition, including commissioning schedules, operational staffing, and training programs, to avoid first-delivery delays.
- Ensure adequate staffing with qualified personnel for construction, operations, and ongoing maintenance, particularly in specialized roles.
- Establish and diversify supply chains for critical inputs (e.g., energy, feedstock, sorbents/solvents, equipment) to ensure resilience against disruptions.

Political

Political delivery risks are associated with governance, policies, and potential changes in regulatory environments, as well as the local communities' perception of and willingness to participate in the project. Political delivery risks can include permitting delays and uncertainty, changes in regulation or policy, community opposition, unclear land tenure or subsurface rights, and political instability. Later-stage projects should have permits in hand or at advanced stages of review, with demonstrated community support and a clear understanding of the political risks that could affect continued operations. Projects in jurisdictions with relevant, established regulatory frameworks, such as for carbon capture, transport, and storage, carry inherently lower political delivery risk.

PROJECT DEVELOPERS SHOULD

- Obtain or demonstrate a clear path to obtaining all required permits and regulatory approvals, such as United States EPA Class VI well permits (or equivalent) for CO_2 injection, where applicable.
- Site projects in jurisdictions with stable, supportive regulatory frameworks for carbon capture, transport, and storage.
- Secure clear land tenure and subsurface pore space rights where applicable.
- Structure projects to remain viable under multiple regulatory scenarios and maintain contingency plans to reduce the risk of ineligibility, market access constraints, or disrupted credit transfers due to rule changes.
- Proactively engage with regulators to secure durable political support for the rules upon which the project will rely and monitor potential regulatory shifts, while defining trigger points and response plans to minimize risks to credit issuance or transferability.
- Implement robust anti-corruption controls, partner with vetted local entities, and incorporate contingencies to reduce the risk of administrative delays and disruptions due to political instability.
- If sourcing across jurisdictional boundaries, secure necessary certifications in advance to reduce the risk of import delays or procurement disruptions delaying credit issuance.
- Build strong relationships with local political and/or tribal leaders, independent of party affiliation if possible.

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