Criteria for high-quality carbon dioxide removal

CARBON DIRECT

Microsoft

Introduction

The science is clear. In concert with rapid efforts to dramatically reduce greenhouse gas (GHG) emissions, the global community must also pursue carbon dioxide removal (CDR) at an unprecedented scale. The Intergovernmental Panel on Climate Change estimates cumulative removal needs of 100 to 1,000 billion metric tons of carbon dioxide ($GtCO_2$) globally by 2100, with interim annual removal rates that approach 10 $GtCO_2$ by midcentury. The new Intergovernmental Panel on Climate Change Sixth Assessment Report from Working Group Three (AR6 WIII report) reinforces the need for large-scale CDR as an essential pillar to limit warming to no more than 1.5°C and a crucial tool for scenarios that limit warming to no more than 2°C by 2100. This requires rapid scale-up and massive deployment of all viable CDR methods, underscoring the limited state of commercial deployment at present.

Both Microsoft and Carbon Direct are committed to the development of this critical market.

- Carbon Direct Inc. was founded in 2019 with the mission of decarbonizing the global economy. As a science-first organization backed by a team of climate scientists, software engineers, and client managers, we have expertise in all areas of carbon management, from carbon footprinting to offset procurement.
- In January 2020, Microsoft announced its commitment to become carbon negative by 2030 and articulated the need for large-scale CDR, aiming to remove all historical carbon emissions since its founding by 2050.
- In January 2021, Microsoft announced its first portfolio of 1.3 million metric tons of CDR, after executing its first procurement cycle for CDR. (Microsoft ultimately purchased 1.4 million metric tons in its fiscal year 2021.)
- In March 2022, Microsoft announced an additional 1.5 million metric tons added to its CDR portfolio.

Over the past two years, collaborations between Microsoft, Carbon Direct, and the emerging carbon removal industry have shown a common need for clear criteria for high-quality CDR. Both organizations recognize that carbon dioxide removal project developers and purchasers lack a common framework for what constitutes a best-in-class project. Microsoft elaborated on this need in a January 2021 briefing paper, calling out the need for clear accounting of carbon removal and critical guidelines for additionality, durability, and leakage. Microsoft has since published its second-year reflections, in March 2022.

To help address this gap, Carbon Direct's multidisciplinary scientists developed the inaugural Criteria for High-Quality Carbon Dioxide Removal in 2021 to detail both overarching principles and tailored recommendations for a wide range of carbon dioxide removal methods that use natural and/or engineered systems. **The purpose of this document is to provide an update to those criteria, to support and guide candidate suppliers for the Microsoft fiscal year (FY) 2023 Procurement Cycle, and to provide a broadly applicable set of benchmarks to encourage market maturation going**

forward. In publishing this, we hope that a wide audience of stakeholders will use it as the latest guidance on what constitutes high-quality carbon removal.

The principles for CDR and the specific guidance by method that follow are intended to help project developers initiate high-quality projects as well as help buyers in the assessment of high-quality projects. We emphasize that the following information is not a substitute for pre-purchase due diligence to demonstrate scientific efficacy and validation. This document is not intended to replace existing industry standards, which provide important—though in some cases imperfect or underdeveloped—quality assurance. We encourage existing registries to consider how these criteria could influence their protocols going forward.

The science of carbon dioxide removal is evolving, and these criteria will progress with it. This May 2022 edition provides updates across the essential principles as well as each of the carbon removal verticals, highlighted by the inclusion of a new mangrove forestation section. The document also aims to provide more specific guidance regarding harms and benefits stemming from project development, as well as how to incorporate the tenets of environmental justice into carbon removal projects. Carbon Direct continues to work on guidance for additional best-in-class projects across more nascent forms of CDR to complement those included in this document. Promising methods for carbon dioxide removal not included in this document include some forms of blue carbon, macroalgae cultivation, peatland and freshwater wetland restoration, carbon dioxide utilization, and ocean alkalinity enhancement. The absence of guidance in this document on these emerging forms of CDR is not intended to imply a preference for the following methods; however, the methods included in this document reflect most projects that are either operational, planned, or under development.

We look forward to collaborating with CDR project developers and buyers to refine the following principles in the years to come as we work together towards growing the number of high-quality carbon removal projects, which are essential to meeting our climate goals in an evolving policy landscape.

In this document

Essential principles for high-quality carbon dioxide removal

The following common set of shared principles can help characterize high-quality CDR projects. Note that in each case we outline considerations that "must" or "should" be considered; here we use these terms to differentiate between minimum viable project characteristics (*must*) versus ideal project characteristics (*should*).

Additionality and baselines

Removals are **additional** if they would not have occurred without carbon finance. Developers must measure the removals claimed against a **baseline** which should represent a conservative scenario for what would likely have happened without carbon finance (the "counterfactual").

- **Project developers must:**
  - Demonstrate that they require carbon finance to implement their project.
    - When there are multiple finance streams supporting a project, the project developer must convincingly demonstrate that the removals are a result of carbon finance. Even with substantial non-carbon finance support, projects can be additional if investment is required, risk is present, and/or human capital must be developed.
  - Show that the project is not required by existing laws, regulations, or other binding obligations.
  - Show that project activities are not "common practice," leaving aside financial or regulatory incentives.
  - Quantify the most plausible baseline for carbon stocks and flows.
    - Baselines must account for both recent and projected changes in carbon stocks and flows.
    - Baselines should be robust, conservative, and site specific.
- **Project developers should** provide full project financials to demonstrate additionality.

Carbon accounting method

Carbon accounting involves the use of repeatable and verifiable methods to ensure that all greenhouse gases associated with a project are accounted for in a transparent manner, including using cradle-to-grave life cycle assessments (LCAs). This should account for any uncertainties in those estimations in a conservative manner to avoid overestimating the climate benefits of a project.

- **Project developers must:**
  - Cite carbon accounting methods employed.
  - Clearly delineate removed, reduced, and avoided emissions on an annual basis, including breakouts by greenhouse gas type.
  - To avoid double counting, ensure the same carbon removals are not claimed by more than one entity, including abiding by the rules set by Article 6 of the Paris Agreement.
- **Project developers should:**
  - Use a peer-reviewed and scientifically supported accounting methodology for the given removal method and document those sources as appropriate.
  - Conduct a comprehensive LCA, the result of which must conservatively quantify all GHG emissions associated with the full suite of inputs and products from the operation.
  - Use regionally appropriate sampling and data collection methods to quantify emissions and removals associated with a project instead of solely model-based or statistical methods.

Harms and benefits

Minimizing harms involves the avoidance of negative impacts to economic, social, and environmental systems stemming from a CDR project. Because concerns vary by project type and context, the potential harms that follow are not exhaustive but are rather intended to describe some of the more common potential negative impacts across all project types. (Historically, in the context of climate negotiations, this principle has been called "do no harm.")

Beyond simply avoiding harm, ideal projects will be ones that pursue co-benefits by advancing sustainable livelihoods and environmental justice, building climate resilience, supporting water conservation, and protecting ecosystems and biodiversity. Note that issues of sustainable livelihoods and environmental justice are also addressed in the **environmental justice** section following; overlapping elements are repeated within both sections.

- **Project developers must:**
  - Show that projects have a low risk of any materially negative impacts on the surrounding ecosystems (including soil health, biodiversity, water, criteria air pollution) or on local communities.

  - Articulate a strategy for mitigation of impacts to air, water, and land quality.
  - Transparently report any use of toxic and/or persistent environmental pollutants, including agrochemicals.
  - Avoid using pesticides banned in the United States or European Union and avoid using listed persistent organic pollutants.
- **Project developers should:**
  - Advance sustainable livelihoods, build climate resilience, support water conservation, and protect ecosystems and biodiversity.
  - Ensure the benefits of the project are shared among all members of the community by actively including the full range of individuals and groups in planning, execution, and operation regardless of landholder status—especially under-resourced marginalized members of the community.
  - Detail the full life cycle emissions of fossil energy production and consumption and provide a plan to minimize their impacts.
  - Aim to minimize transportation needs for critical operations to limit carbon and criteria pollutant emissions.
  - Plan to adapt feedstocks as industrial processes evolve to reduce carbon footprint and waste production (circular usage).
  - Articulate what percentage of project revenues or profits go to community members and other local partners, and what form those payments take (for example, cash payments, in-kind payments, or funding for community services).

Durability

Durability is defined as the physical longevity and integrity of carbon in storage over time. The durability of stored carbon is limited by both natural and anthropogenic risks of reversal, which can cause carbon to be released prematurely. Until widely accepted methods are developed to equate varied durability terms, longer and more durable storage terms have greater value.

- **Project developers must:**
  - Provide a projected duration (in years) over which removed carbon will be stored.
  - Monitor the stored carbon and demonstrate the ability to reliably detect reversal events.
  - Conservatively estimate a project's risk of reversal using the best available science and accounting for present and future climate change.
  - If not addressed at the protocol level, identify who is liable for remediating the reversal of stored carbon and for what time periods.

- **Project developers should:**
  - Site projects in areas with 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.
  - Use insurance-type products, such as a buffer pool, to address the risk of underperformance, which:
    - Conservatively reflect a scientifically substantiated risk of reversal, taking into account possible increases in risks associated with climate change.
    - Dictate that intentional reversals must be remediated on a 1:1 basis, even in excess of any buffer pool by the project owner.
    - Remove a project's buffer pool contributions at the end of the project's life.

Environmental justice

Environmental justice embodies the idea that all individuals should be equitably protected from environmental risk, and equitably empowered to participate in the environmental decision-making processes that affect them. It begins with acknowledging past and present harms to communities of color, low-income communities, and other communities on the front lines of the climate crisis and racial and economic injustice. In the context of climate justice, it recognizes that those who contribute least to climate change and emissions are affected acutely by the changing climate. Environmental and climate justice work redirects leadership, resources, and decision-making to the communities who are most affected and previously excluded.

Note some of these same principles overlap with the **harms and benefits** section previously.

- **Project developers must:**
  - Show that they engage local communities in an ongoing and transparent manner throughout the project lifetime and adopt best practices for engagement and stocktaking exercises.
  - Address worker compensation in their project proposals and commit to compensating workers with living wages.
  - Avoid development or disturbance of land that has been identified as culturally sensitive or ecologically important by community stakeholders.
  - Prevent community displacement.
  - Show that projects have a low risk of community health impacts (such as via negative impacts to air or water quality, land degradation, sound pollution, and/or other disruptions to local residents), and articulate a strategy for mitigating those risks.
  - Have public carbon reduction targets and clean energy transition commitments.

- **Project developers should:**
    - Actively promote long-term sustainable livelihoods and economic opportunities for local communities, particularly livelihoods that preserve sequestered carbon.
    - Clearly articulate how project benefits are shared with under-resourced and marginalized populations, and how they align with local community priorities.

Leakage

Leakage involves the risk of displacing activities that cause GHG emissions from the project site to another geographic location (including across international boundaries) for economic reasons. Economic leakage occurs when the market demand for an emitting activity is sustained despite the development of a CDR project. *Note:* These concepts are distinct from physical leakage (reversals), which occur when carbon that is stored throughout the course of a carbon offset project is re-released into the atmosphere through either avoidable (for example, a failure to maintain sequestration wells) or unavoidable (for example, extreme weather events) means. Physical leakage is a risk for both engineered and nature-based CDR methods and is discussed in the **durability** section.

- **Project developers must** conclusively demonstrate leakage avoidance, or robustly and conservatively account for the carbon impacts of leakage caused by the project.
- **Project developers should** work to diminish leakage risk in their project design given the difficulties of accurately quantifying leakage.

Monitoring, reporting, and verification (MRV)

Monitoring, reporting, and verification (MRV) involves the development of and adherence to a plan for long-term monitoring of the project for the purposes of quality assurance. This includes adherence to national and subnational regulatory regimes, project development methodologies, and registry protocols where applicable.

- **Project developers should:**
    - Show the modeled performance of proposed projects.
    - Obtain third-party verification of their CDR process and removal volumes.
    - Ideally, directly measure carbon removed throughout the duration of the project rather than rely only on estimates from modeled processes.
    - Adapt MRV practices based on the best available science and industry practices and update as appropriate as methodologies evolve.

Other considerations

Depending on the project type, other considerations may be relevant, including:

- **Feedstock.** Project developers should ensure that a reliable source of sustainable feedstock will be available for the duration of the project, and include all emissions associated with the primary feedstock and any secondary reactants/feedstocks in their overall LCA.
- **Infrastructure.** Project developers should outline all major infrastructure requirements necessary for the project's success, as well as explain how they would interface with existing infrastructure.
- **Product end fate and storage.** Project developers should ensure that any end products from CDR processes will promote product durability, end-use recycling, or long-duration storage (and these products must be included in their LCA).
- **Duration.** Where applicable for CO_2 storage products, project developers should indicate a duration of storage, support this duration with sound and transparent scientific evidence, convey any risk and uncertainty, and outline how, in connection with their MRV plan, they will evaluate and mitigate early reversals.
- **Design for future climate conditions.** Carbon removal projects should design for ecosystem effects under changing climatic conditions to maximize longevity of storage, prevent unintentional reversals (for example, through fire), and ensure sustainability of the project overall (for example, biomass supply).
- **Scalability.** Project developers should describe, if possible, plans or opportunities to scale supply over time and any major impediments to scaling. They should also describe potential adverse environmental impacts from scaling their operations.

Forestation and agroforestry

Forestation, including reforestation and afforestation, is the process of growing trees to establish forests or woodlands. Agroforestry entails the integration of trees into agriculture production systems. Given the large amount of degraded land globally, forestation and agroforestry hold tremendous opportunities to remove carbon from the atmosphere and generate substantial co-benefits for people and nature. Given the complex and place-based social, ecological, and economic dynamics of land use, however, developers should only site projects where socially or environmentally appropriate. Forestation and agroforestry project developers should adhere to the following principles, *which build upon those described previously under* Essential principles for high-quality carbon dioxide removal.

Additionality and baselines

- **Project developers must** determine the natural regeneration baseline using the best available science to predict natural seedling establishment and forest growth in the absence of tree planting.
- **Project developers should:**
    - Demonstrate that forestation or agroforestry activities are a result of carbon finance or could not occur otherwise (for projects with non-carbon finance streams, such as from expected timber sales or conservation funds).
    - Establish control plots to directly measure natural regeneration over the course of the project.
    - Use historical time series of remotely sensed data when claiming a negligible natural regeneration baseline to show that natural recovery of forest is very unlikely to occur.

Carbon accounting method

- **Project developers must:**
    - Use statistically valid sampling methods and best-available models (for example, allometric equations) for quantifying above-ground carbon.

    - Use data from in-situ sampling or conservative root:shoot ratios (that is, use smaller ratios to mitigate uncertainty) to quantify changes in below-ground carbon, where this pool is included.
    - Measure and monitor changes in soil carbon when claiming removals in soils, using the criteria for high-quality soil carbon.
- **Project developers should:**
    - Employ validated and regionally calibrated methods and/or use ground inventories to validate remotely sensed measurements of above-ground biomass changes.
    - Use site-specific data and/or collect data needed to parametrize models used to estimate biomass changes (such as species-specific allometries and wood densities measurements).
    - If soil carbon is not directly measured, establish projects on lands where the net impact of forestation or agroforestry on soil carbon is most likely to be net positive.
    - Quantify any GHG fluxes associated with site preparation including removal of existing vegetation (and if GHG fluxes are determined to be de minimis the project developer should articulate why).
    - Include a life cycle assessment of harvested products for agroforestry and plantation projects.
    - Account for applicable indirect climate impacts. For example, projects occurring in high altitude/latitude areas should account for changes in albedo due to establishment of tree cover.

Harms and benefits

In addition to the Essential principles for high-quality carbon dioxide removal listed earlier:

- **Project developers should** prioritize biodiversity and resilience by growing diverse native species, pursuing ecological restoration or natural regeneration of formerly forested areas where possible, and (where relevant) choosing species and seedling sources which maximize biodiversity and are capable of flourishing under future local climatic conditions.

Durability

- **Project developers must** take active and ongoing measures to mitigate identified risks (for example, forest thinning in fire-prone areas).
- **Project developers should:**
    - When initiating projects that involve harvesting, incorporate harvested biomass into long-lived wood products, either traditional (such as lumber, oriented strand board) or emerging (such as biochar, cross-laminated timber).

  - Plant species adapted to future climate conditions and apply planting patterns that foster resistance to disturbance.
  - Use planting stock that is genetically diverse, in relevant projects.
  - Use the best available information to forecast future risks of disturbance to planted forests and situate projects in areas of lower risk. Salient disturbance risks include but are not limited to direct and indirect impacts of climate change, drought, fire, insects, disease, and social disturbances.

Environmental justice

In addition to the Essential principles for high-quality carbon dioxide removal listed earlier:

- **Project developers must** articulate what percentage of project revenues or profits go to community members and other local partners, and what form those payments take (for example, cash payments, in-kind payments, or funding for community services).
- **Project developers should:**
  - Ensure local communities that may have a stake in project lands, including indigenous groups, are actively and transparently represented in project processes throughout the project lifetime.
  - Where displacement of existing activities occurs, even activities that may be deemed destructive or illicit, ensure alternative livelihoods substitute for the displaced activities.

Leakage

- **Project developers must:**
  - Provide robust and conservative estimates of leakage rates and defend the methods used to determine the reported rate.
  - Ensure leakage deductions are taken and properly accounted for.
  - When claiming low leakage rates, provide evidence that project lands are degraded lands, have low economic value, or that project activities do not significantly displace existing land uses. They must demonstrate this by showing that either:
    - There has been minimal past agriculture use over the preceding decade, they are not operating in an area of active land use change, and the lands are predicted to have low likelihood of future agriculture land use.
    - Tree planting synergizes with ongoing agricultural practices.
- **Project developers should** use remotely sensed land use data to determine leakage estimates, especially when coupled with models of land-use change.

Other considerations

- **Project developers should:**
    - Work with local partners with growing experience to choose areas, species, and operational principles.
    - Where restoration is first of its kind locally, trial restoration in small plots before scaling.
    - Develop seedling planting and monitoring plans to maximize the probability of tree survival during the critical three-year to five-year establishment phase, including physical infrastructure and human capacity considerations.
    - Use cost-effective forestation techniques such as applied nucleation or assisted natural regeneration.
    - Consider the impacts on biodiversity (both benefits and costs) when selecting species for forestation.
    - Work to abide by Kew Gardens' 10 Golden Rules for Reforestation.

Mangrove forestation

Mangrove forests exist along the intertidal zones of most tropical and subtropical coastlines. Mangrove forestation, including reforestation and afforestation, is the process of growing trees to establish mangrove forests. Mangrove forests are very carbon dense and have experienced historically high rates of loss. Mangrove forestation can help remove carbon from the atmosphere and generate substantial co-benefits for people and nature, such as storm surge protection and support of fish nurseries. Given the complex and place-based social, ecological, and economic dynamics of land use, however, developers should only site projects where socially or environmentally appropriate.

Mangrove forestation is often classified as a form of **blue carbon,** a category which also includes tidal marshes, seagrasses, and other forms of coastal and marine carbon sequestration. The unique ecology of mangroves warrants slightly different guidance from the forestation and agroforestry guidelines provided previously. Mangrove forestation project developers should adhere to the following principles, *which build upon those described previously under* Essential principles for high-quality carbon dioxide removal.

Additionality and baselines

- **Project developers must:**
    - Determine the hydrological status of the site and address any impacts to site hydrology that might prevent successful mangrove forestation.
    - Avoid the destruction of non-vegetated coastal ecosystems, such as natural tidal mudflats, which are important and threatened ecosystem types across the globe.
    - Avoid damage, destruction, or harvest of any pre-project mangroves during site preparation activities.
    - Ensure pre-project mangroves are excluded from crediting and their continued existence is monitored throughout the project crediting period.
    - Determine the natural regeneration baseline using the best available science to predict natural seedling establishment and forest growth in the absence of tree planting.

- **Project developers should:**
    - Demonstrate that mangrove forestation activities are a result of carbon finance or could not occur otherwise (for projects with non-carbon finance streams, such as from expected timber sales or conservation funds).
    - Establish control plots to directly measure natural regeneration over the course of the project.
    - Use historical time series of remotely sensed data when claiming a negligible natural regeneration baseline to show that natural recovery of mangrove forest is very unlikely to occur.
    - Include quantification of baseline GHG fluxes and any GHG fluxes associated with site preparation or other change in management strategy.
    - Account for any indirect climate impacts, for example, methane emissions potentially resulting from hydrologic restoration.

Carbon accounting method

- **Project developers must:**
    - Use statistically valid sampling methods and best-available models (for example, allometric equations) for quantifying above-ground carbon, including stratifying by site hydrogeomorphology (for example, fringe versus deltaic settings).
    - Use data from in-situ sampling or conservative root:shoot ratios (that is, use smaller ratios to mitigate uncertainty) to quantify changes in below-ground carbon, where this pool is included.
    - Measure and monitor changes in soil carbon when claiming removals in soils, using the criteria for high-quality soil carbon and again stratifying by site hydrogeomorphology.
    - Develop monitoring plans that integrate all or some of the following approaches to account for changes in carbon stocks due to mangrove forestation: mapping, remote-sensing, long-term field plot measurements, relative sediment elevation table methods, or field-validated modeling.
- **Project developers should:**
    - Employ validated and regionally calibrated methods and/or use ground inventories to validate remotely sensed measurements of above-ground biomass changes.
    - Use site-specific data and/or collect data needed to parametrize models used to estimate biomass changes (such as species-specific allometries and wood densities measurements).
    - If soil carbon is not directly measured, establish projects on lands where the net impact of forestation or agroforestry on soil carbon is most likely to be net positive.

- Quantify any GHG fluxes associated with site preparation including removal of existing vegetation (and if GHG fluxes are determined to be de minimis the project developer should articulate why).
- Include a life cycle assessment of harvested products for local or commercial use.
- Account for applicable indirect climate impacts.

Harms and benefits

None in addition to the Essential principles for high-quality carbon dioxide removal.

Durability

- **Project developers must** take active and ongoing measures (that is, adaptive management plans) to mitigate identified risks to the durability of carbon held in mangrove forests (for example, direct and indirect impacts from sea level rise, storm surge, or watershed management).
- **Project developers should:**
  - Identify potential policy conflicts for long-term management of forests due to unclear demarcations of intertidal zones and overlapping jurisdictions of national or local governments (for example, Ministry of Marine Resources and Ministry of Forests).
  - When initiating projects that involve harvesting, incorporate harvested biomass into long-lived wood products, either traditional (such as lumber, oriented strand board) or emerging (such as biochar, cross-laminated timber).
  - Plant species adapted to future climate conditions and apply planting patterns that foster resistance to disturbance.

Environmental justice

In addition to the Essential principles for high-quality carbon dioxide removal listed earlier:

- **Project developers must:**
  - Avoid project development on lands with unclear or insecure land tenure. Mangroves commonly exist on public lands with customary tenure, raising the risk of tenure disputes and disenfranchisement of local communities.
  - Ensure local communities that may have a stake in project lands, including indigenous groups, are actively and transparently represented in project processes throughout the project lifetime.

- **Project developers should:**
    - Clearly articulate how they will provide benefits to under-resourced and marginalized populations, generate wealth and economic empowerment, and/or foster community involvement with CDR projects.
    - Articulate what percentage of project revenues or profits go to community members and other local partners, and what form those payments take (for example, cash payments, in-kind payments, or funding for community services).

Leakage

- **Project developers must:**
    - Provide robust and conservative estimates of leakage rates and defend the methods used to determine the reported rate.
    - Ensure leakage deductions are taken and properly accounted for.
    - When claiming low leakage rates, provide evidence that project lands have low economic value, or that project activities do not significantly displace existing land uses. They must demonstrate this by showing that there has been minimal past agriculture or aquaculture use over the preceding decade, they are not operating in an area of active land use change, and that the lands are predicted to have low likelihood of future agriculture or aquaculture land use.
- **Project developers should** use remotely sensed land use data to determine leakage estimates, especially when coupled with models of land-use change.

Other considerations

- **Project developers should:**
    - Develop seedling planting and monitoring plans to maximize the probability of tree survival during the critical three-year to five-year establishment phase, including physical infrastructure and human capacity considerations.
    - Use cost-effective and equitable forestation techniques such as Community-Based Ecological Mangrove Restoration, or the engagement of local communities in removing barriers to natural regeneration such that mangrove forests naturally return.
    - Consider the impacts on biodiversity (both benefits and costs) when selecting species for mangrove forestation.
    - Appropriately match species to positions in the intertidal zone and avoid planting solely generalist mangrove species (for example, *Rhizophora* species).

Improved forest management (IFM)

Improved forest management (IFM) involves management changes that increase carbon stocks in forests and in harvested wood products. In practice, realizing and quantifying carbon removal benefits from IFM projects has been difficult. IFM projects have been hampered by uncertainty in project baselines, additionality, and the impacts of market leakage. These uncertainties make accurate quantification of IFM carbon removal challenging and have tended to result in current IFM protocols overestimating rather than underestimating carbon removals. Until further research resolves these challenges, priority should be given to projects with less uncertainty in these factors and those that use conservative assumptions to quantify removals. IFM project developers should adhere to the following principles, *which build upon those described previously under* Essential principles for high-quality carbon dioxide removal.

Additionality and baselines

- **Project developers must** implement conservative baselines that:
    - Reflect initial carbon stocks and trends in carbon stocks over the recent past (at least 10 years, preferably more).
    - Account for recent or projected changes in forest product demand (for example, projects located in regions with decreasing harvesting trends, such as those due to closed mills, can be expected to have increasing baseline stocks).
    - Are specific to the project site rather than only reflecting regional averages.
- **Project developers should:**
    - For projects with multiple charitable and climate-related revenues, demonstrate that IFM activities above the baseline are unequivocally a result of carbon finance.
    - Move towards adopting baselines which allow for quantitative, probabilistic assessments of additionality. Statistical land use models have long been used in planning and academic research to create probabilistic baselines.

Carbon accounting method

- **Project developers must** use the best available tools to measure and verify changes in carbon storage, including:
  - Statistically representative field inventories and/or remote sensing.
  - Allometry based on published regional-specific and species-specific data.
  - Reporting carbon pools with increased storage only where data and measurements can be well substantiated (for example, ignoring increases in soil carbon when uncertainty is high).
  - Reporting all carbon pools with decreased storage resulting from project activities.
- When using remotely sensed data, **project developers should** validate any measurement with field inventories.

Harms and benefits

None in addition to the Essential principles for high-quality carbon dioxide removal.

Durability

- **Project developers should** maximize the durability of carbon storage by:
  - Improving forest health and reducing disturbance hazards (such as wildfire, insects, drought) on project lands, including decreasing the risk of disturbance-induced mortality associated with historical management practices such as fire suppression and adverse species selection.
  - Designing projects that are on lands with a lower natural reversal risk.
  - Incorporating harvested timber or biomass into long-lived wood products, either traditional (for example, lumber, oriented strand board) or emerging (for example, biochar, cross-laminated timber).

Environmental justice

In addition to the Essential principles for high-quality carbon dioxide removal listed earlier:

- **Project developers must** ensure local communities that may have a stake in project lands, including indigenous groups, are actively and transparently represented in project processes throughout the project lifetime.

- **Project developers should:**
    - Clearly articulate how they will provide benefits to under-resourced and marginalized populations, generate wealth and economic empowerment, and/or foster community involvement with CDR projects.
    - Articulate what percentage of project revenues or profits go to community members and other local partners, and what form those payments take (for example, cash payments, in-kind payments, or funding for community services).
    - Work to minimize any economic impacts associated with reduced timber harvesting and actively support long-term economic alternatives.
    - Avoid increasing natural disturbance hazards that may directly or indirectly affect local communities.

Leakage

Market leakage occurs when an IFM project which reduces timber harvesting induces landowners outside the project boundary to increase production. Market leakage can be very difficult to predict and measure. This deep uncertainty presents a problem for accurately assessing leakage risks and assigning appropriate carbon deductions.

- **Project developers must:**
    - For projects that reduce timber harvesting, use conservative leakage assumptions and robustly defend these estimates, taking into account domestic and international leakage.
    - Establish contractual agreements that prevent activity leakage. Activity leakage occurs when a landowner shifts the regulated activity outside of the project boundary.
- **Project developers should:**
    - Ensure market leakage is deducted at the same time that increased stocks are credited, even if existing offset protocols do not require this standard.
    - Be aware that leakage risks for projects are likely highest:
        - In regions where mills are running at capacity due to high demand in wood product markets and timber supply is responsive to price changes.
        - In regions where large amounts of non-participating lands can produce similar timber products.
        - Where the wood products that would otherwise be produced on the project lands are highly substitutable.
    - Work to eliminate or minimize leakage risk by initiating projects that do not reduce long-term timber harvest rates. Project activities that typically do not reduce long-term timber harvest rates include:
        - Forest restoration with little decrease in timber harvesting.

- Reduced impact logging.
- Increased stand productivity through better stand management (such as thinning).
- Increased forest fiber utilization.
- Extended rotation lengths on commercial timberland while employing very conservative leakage rates.

Soil carbon

Since the inception of human agriculture, soils have lost over 500 $GtCO_2e$[1] globally, contributing significantly to climate change and reducing the long-term viability of conventional agricultural management. In response, agricultural producers have begun implementing conservation and/or regenerative practices to restore the carbon previously stored in soils. Soil carbon project developers should adhere to the following principles, *which build upon those described previously under* Essential principles for high-quality carbon dioxide removal.

Additionality and baselines

- **Project developers must:**
    - Document baseline emissions from business-as-usual management using control plots or historical soil carbon data with at least three and ideally five consecutive years and specified sampling dates.
    - Demonstrate that the practice implemented is not already standard management practice on the farm or ranch.
- **Project developers should:**
    - Demonstrate the project activities are not currently common practice in the project region or country using government or peer-reviewed land management data or surveys.
    - Utilize regionally specific baselines to understand whether the site is currently a net source or sink of emissions, and to quantify the improvement associated with beneficial carbon management practices.
    - Ensure that practices aimed at increasing soil organic carbon content do not lead to increases in non-CO_2 greenhouse gases.

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[1] Note that the term CO_2-equivalent (CO_2e) serves to standardize the global warming potential of all greenhouse gas types under a common metric.

    - Not use acreage that has previously hosted carbon projects or has already been managed under conservation practices eligible for carbon project development unless landowners can demonstrate a consistent baseline of conventional management practices over 10+ years prior to implementation of the project.

Carbon accounting method

- **Project developers must:**
    - Account for project removals net of any on-farm emissions that may increase as a result of the project, including but not limited to electricity use, equipment and vehicle emissions, and fertilizer application.
    - Document sampling stratification by practice, soil type, crop, and other relevant environmental factors.
    - Describe the analytical and calculation methods used to assess organic matter and carbon stocks, including the mass/depth basis and any correction applied.
    - Conduct soil sampling as a means to validate ("ground-truth") biogeochemical process models (and associated tools like COMET) that estimate soil organic carbon levels; soil sampling must be viewed as a necessary complement to modeling.
    - Take soil cores at a minimum of 30 cm depth below the organic layer, even if existing offset protocols do not require this, and calculate stocks on an equivalent soil mass basis.
- **Project developers should:**
    - Take soil cores as deep as possible, ideally to 1 meter.
    - Measure organic carbon using accepted methods, such as dry combustion in a carbon and nitrogen (CN) analyzer. Project developers may use novel technological approaches in addition to proven methods for proof of concept; however, they should not use such methods as substitutes for sample collection and analysis.

Harms and benefits

In addition to the Essential principles for high-quality carbon dioxide removal listed earlier:

- **Project developers must** avoid using pesticides and other bioactive agrochemicals banned in the United States or European Union and avoid using listed persistent organic pollutants where a suitable replacement exists.
- **Project developers should:**
    - Advance sustainable livelihoods, build climate resilience, support water conservation, and protect ecosystems and biodiversity.

    - Detail the full life cycle emissions of fossil energy production and consumption, including criteria pollutants, and provide a plan to minimize their impacts.

Durability

- **Project developers must** provide a durability term supported by a detailed monitoring and verification plan that includes documentation of practice continuation following the crediting period and/or additional soil sampling to demonstrate the carbon remains sequestered for the entirety of the contract period.
- **Project developers must** determine the durability on the basis of verification and recourse mechanisms, and all projects should demonstrate especially robust strategies for ensuring carbon remains sequestered (even in instances of ownership changes or extreme weather events). Buffer pools must specify the volume and composition of credits, and should provide a justification for why the safeguard is sufficiently conservative.

Environmental justice

In addition to the Essential principles for high-quality carbon dioxide removal listed earlier:

- **Project developers should:**
    - Actively promote long-term sustainable livelihoods and economic opportunities for local communities.
    - Clearly articulate how they will provide benefits to under-resourced and marginalized populations, generate wealth and economic empowerment, and/or foster community involvement with CDR projects.
    - Articulate what percentage of project revenues or profits go to community members and other local partners, and what form those payments take (for example, cash payments, in-kind payments, or funding for community services).

Leakage

- **Project developers must** detail and quantify leakage risks associated with specific project sites and practices in project design documents, including emissions from livestock or reduced crop yields, and use conservative leakage rates for set-aside type projects on land currently producing agricultural products that are the most susceptible to leakage.

Monitoring, reporting, and verification (MRV)

- **Project developers should:**
  - Use models that have been calibrated and shown to perform well for the particular soil/climate/management combination to estimate interim carbon removal outcomes in order to reduce the cost of on-site soil sampling and laboratory analysis.
  - Use site-specific soil samples as modeling inputs and for model calibration.
  - Use a conservative adjustment on interim carbon removal estimates.
  - For ex post projects, provide full and comprehensive documentation of all soil sample results that have been verified by a designated third party.
  - For ex ante projects, provide the same standard of detailed spatial, temporal, and process specifications for a sampling and measurement regimen as ex post, and commit to share data verified by a third party in future credited years.
  - Specify a monitoring plan to ensure that practices continue for the full duration of the durability period across the entire project area.
  - Propose a specific methodology for long-term measurement, reporting, and verification of soil carbon stocks.
  - Commit to sharing soil data and implementation insights in an open-source platform. To protect the privacy of individual farmers, data may be aggregated and anonymized at the county or regional level by practice and soil type.

Other considerations

Scalability

- **Project developers should** be aware that:
  - While the on-farm implementation of management practices that sequester carbon in soils is well understood, the precise impact on soil carbon stocks is dependent on site-specific considerations such as soil type, crop, and climate.
  - While conservation agriculture practices provide a suite of co-benefits and could reduce reliance on synthetic fertilizers in some contexts, the scalability is ultimately dependent on the willingness of producers to implement these practices persistently and consistently in a verifiable manner.

Biomass-based pathways

Biomass-based pathways for carbon dioxide removal (CDR) describe a range of processes that use biomass to remove CO_2 from the atmosphere (via photosynthesis or chemosynthesis) and sequester that embodied carbon underground or in other long-lived storage applications, such as biochar or innovative wood products. Some pathways may also generate a co-product such as electricity or hydrogen. These biomass carbon dioxide removal and storage (BiCRS) technologies can result in sizable and highly durable CDR. The feedstocks for biomass-based pathways can either come from growing dedicated biomass or using secondary residues and wastes (such as forest or agricultural residues). Biomass CDR project developers should adhere to the following principles, *which build upon those described previously under* Essential principles for high-quality carbon dioxide removal.

Additionality and baselines

- **Project developers must:**
    - Identify the current use, if any, or other fate of biomass resources intended for the project.
    - Identify the most likely counterfactual for biomass resources in question over the time period of the project.
    - Explain the economic viability of the project with or without the requested investment and/or carbon removal procurement, and the role of tax or policy incentives (for example, in the United States 45Q, LCFS) in that viability.

Carbon accounting method

- **Project developers must:**
    - Ensure that carbon removal claims are consistent with a net carbon negative outcome based on a cradle-to-grave life cycle assessment.
    - Include biomass, CO_2, and product transportation.
    - For waste feedstocks, provide detailed accounting and justification of counterfactuals.

- **Project developers should:**
    - Incorporate the considerations of both attributional and consequential life cycle assessments.
    - Include consideration of temporal character of carbon uptake by biomass (growth cycle) and emissions.
    - Clearly outline allocation methods for co-products and sensitivity analysis (how allocation might change results).

Harms and benefits

In addition to the Essential principles for high-quality carbon dioxide removal listed earlier:

- **Project developers must** show that feedstock production, biomass conversion, and carbon disposal operations have a low risk of any materially negative impacts on the surrounding ecosystems (including soil health, biodiversity, water, criteria air pollution) or local communities.
- **Project developers should:**
    - Advance sustainable livelihoods, build climate resilience, support water conservation, and protect ecosystems and biodiversity.
    - Articulate what percentage of project revenues or profits go to community members and other local partners, and what form those payments take (for example, cash payments, in-kind payments, or funding for community services).
    - Detail the full life cycle emissions of fossil energy production and consumption and provide a plan to minimize their impacts.

Durability

- **Project developers using geologic carbon sequestration must** create storage sites that are as safe and as permanent as possible using established permitting processes (for example, Class Ia, Class II, or Class VI for deep injection wells in the United States) or alternatively meet ISO 27914:2017 standard for CO_2 storage.
- **Project developers across all forms of long-lived storage should:**
    - Quantify and report durability over 10-year, 100-year, and, ideally, 1,000-year timeframes.
    - Conduct durability assessments that rely on measurements, not models, whenever possible.
    - Reach relevant agreements during project execution (such as technology, operations and maintenance, feedstock, offtake) to ensure financing of measures that mitigate the risk of reversals throughout and beyond the project operational lifetime.

Environmental justice

These principles apply to all aspects of a biomass-based CDR project: biomass supply, feedstock transportation, conversion, product and CO_2 transport (including proposed pipelines), product (heat, electricity, fuel) end-use, and carbon storage. Each of these links in the BiCRS value chain presents an opportunity for inclusive, equitable development.

In addition to the Essential principles for high-quality carbon dioxide removal listed earlier:

- **Project developers must** show that they engage local communities, from feedstock production to energy conversion to carbon transport and disposal, in an ongoing and transparent manner throughout the project lifetime and adopt best practices for engagement.
- **Project developers should:**
    - Actively promote long-term sustainable livelihoods and economic opportunities for local communities, and build capacity in BiCRS know-how at the local and regional level.
    - Explore how benefits from activities such as forest thinning and product/co-product sales can positively affect under-resourced and marginalized populations, generate wealth and economic empowerment, and/or foster community involvement with CDR projects.

Leakage

- **Project developers must** quantify the likely carbon emissions that result from their project's consumption or displacement of local and regional energy supplies, such as that which might result from the parasitic load for capture and compression of CO_2.
- **Project developers should** consider whether allocating feedstock to carbon removal has potential land-use change impacts or bioeconomy product supply impacts, such as could occur by diverting forestry residuals from engineered wood products (for example OSB) to BECCS.

Other considerations

Feedstock

- **Project developers must** ensure reliable availability of feedstock over the project lifetime.
- **Project developers should:**
    - Minimize the use of fossil energy for transportation of biomass products or CO_2.
    - Prioritize use of wastes and residues over purpose-grown feedstocks. If dedicated crops are used, project developers **must** demonstrate their sustainability advantages.

- When the feedstock is classed as waste, provide evidence that the project represents an optimal use of the feedstock on an overall sustainability basis relative to alternate disposal or reuse pathways.
- Follow a rigorous feedstock sustainability certification process, such as the Roundtable for Sustainable Biofuels Standard.

Product end fate and storage

- **Biochar project developers must** verify that biochar is not used for combustion applications or other applications that would lead to rapid return of carbon to the environment.
- **Biochar project developers should:**
    - Provide biochar elemental analysis to substantiate storage durability.
    - Ensure that biochar is handled and applied according to good practice (such as the guidelines from the International Biochar Initiative).
- **Project developers that produce wood products should** promote:
    - Longevity of product in built environment through repair and reuse.
    - Displacement of fossil-intensive alternatives.
    - End-of-life options that optimize both sustainability and carbon benefit.

Scalability

- **Project developers should:**
    - Propose projects that have a minimum Technology Readiness Level (TRL) of 7 (≥7), corresponding to a "system prototype demonstrated in a plant environment," as defined by the National Academies, 2019. Specifically, technology should have:
        - Demonstration of an actual system prototype in a relevant environment.
        - Final design virtually complete.
        - Demonstration-scale prototype, defined as 5–25 percent of final scale or design, or a 50–250 t/d dry biomass plant.
        - Undergone large pilot-scale testing using dry biomass feedstock at a scale equivalent to approximately 50–250 t/d (excluding projects that have demonstrated full-scale mobile/modular processing units).
    - Have experience with execution and management of projects of similar size and scope to the proposed project.
    - Describe key business model risks, including the structure and stability of subsidies, and technical risks, including a reasonable plan to mitigate those risks.

Carbon mineralization

Most carbon on Earth is naturally bound in minerals where it is thermodynamically stable over geologic timescales. It represents the most durable carbon reservoir on Earth. Carbon mineralization projects mimic the natural processes that bind carbon in rock in both underground (in-situ) and above ground (ex-situ) sites. The latter can include alkaline industrial waste streams or mineral soil amendments in forests and agriculture. Carbon mineralization may also include CO_2 utilization in the built environment. Very few mineralization projects have been commercialized despite their durability and capacity, making development of new projects a priority. Carbon mineralization project developers should adhere to the following principles, *which build upon those described previously under* Essential principles for high-quality carbon dioxide removal.

Additionality and baselines

- **Project developers must:**
    - Provide baseline studies to quantify additionality that include carbon in solid, liquid, and gas form, metals that contribute to mineral carbonate formation, and alkalinity imported into or exported from the project boundaries.
    - Quantify naturally occurring rates of weathering and mineralization.
    - Be aware that some feedstocks will have carbonate mineral content that must be quantified to properly account for a baseline. Low-risk projects will have low-to-zero baseline carbonate mineral content relative to the amount of mineralized material added by the process.

Carbon accounting method

- **Project developers must:**
    - Use the best available measurement methods with built-in redundancy to measure carbon contents and fluxes.

    - Compare upfront carbon emissions associated with project development against carbon uptake annually and over the project lifetime.
    - Evaluate and monitor, where appropriate, the impact of the project on other GHG pathways (such as methanogenesis, N-cycle).
- **Project developers should:**
    - If multiple carbon reservoirs are involved in the mineralization process, ensure that they are clearly identified and, if possible, differentiated through tracer or isotopic studies.
    - For in-situ projects, quantify demonstrable mineralization in subsurface sites.
    - Use cost and life cycle assessments that clearly identify and differentiate continuously produced and stockpiled industrial feedstocks.

Harms and benefits

None in addition to the Essential principles for high-quality carbon dioxide removal.

Durability

- **Project developers should:**
    - List carbon release risk scenarios for solid-bound and liquid-bound carbon, and these risks should be reflected in MRV plans.
    - Present release scenarios that reflect anticipated impacts of climate change and changes in land use or water reservoir development when relevant.

Environmental justice

In addition to the Essential principles for high-quality carbon dioxide removal listed earlier:

- **Project developers must** avoid development or disturbance of land that has been identified as culturally sensitive or ecologically important by community stakeholders. This includes impacts or changes to ecosystems that disadvantage native plants and animals through deployment of soil amendments.
- **Project developers should:**
    - Actively promote long-term sustainable livelihoods and economic opportunities for local communities, including identifying and addressing, where possible, historical negative impacts to local communities.
    - Clearly articulate how they will provide benefits to under-resourced and marginalized populations, generate wealth and economic empowerment, and/or foster community involvement with CDR projects.

  - Where possible redress past community displacements and negative impacts, for example from historical mining operations and related health impacts.

Leakage

- **Project developers should:**
  - Identify alternative uses of waste and demonstrate best use in terms of greenhouse gas impact (this is critical for projects that utilize industrial waste streams).
  - Evaluate and quantify the impact of the project on land use, especially when project infrastructure encroaches on undisturbed land or high-value land use (such as agriculture).

Monitoring, reporting, and verification (MRV)

- **Project developers must:**
  - Supplement modeling with direct measurement of mineralization rates and amounts.
  - Include quantification of carbonate mineral content in feedstock baseline data.
- **Project developers should:**
  - Include cross verification with redundancy (for example, cross-referencing gas/liquid/solid phase fluxes and mass balances).
  - Clearly identify the source of metals (such as calcium, magnesium) contributing to mineral formation, and include in MRV the carbon impact of the metal source.
  - Provide full and comprehensive documentation of MRV protocols and data.
  - Recognize that some feedstocks will have carbonate mineral content and may be heterogeneous, compromising some monitoring methods. Cycling of these materials (dissolution and reprecipitation) can confound other verification tools (for example, radiocarbon).

Other considerations

Infrastructure

- **Project developers should** be aware that additional requirements to baseline infrastructure will depend on how projects interface with existing operations for in-situ (such as geothermal) and ex-situ (such as mining, steel) mineralization.
  - Some ex-situ projects may be greenfield developments, requiring new roads, ports, or facilities.

- Some in-situ projects may require substantial infrastructure to capture or compress air or CO_2.

Scalability

- **Project developers should:**
  - Consider the size and distance to market or area of application for projects in the built-environment or that involve soil amendment applications.
  - Account for changes to rates of mineralization reactions over time due to consumption of highly reactive material and passivation of feedstock.
  - Be aware that ex-situ mineralization will be limited in scale by feedstock supply and in-situ mineralization by the injectivity and capacity of the subsurface reservoir.

Direct air capture

Direct air capture (DAC) uses machines that separate and concentrate CO_2 directly from the atmosphere for the purpose of long-term storage or for use as a feedstock for carbon utilization. DAC machines generally 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). These attributes suggest that DAC could achieve gigaton-scale removal and as such represents both an important pathway to carbon dioxide removal and a potential backstop technology for climate mitigation. However, DAC relies on large amounts of low-carbon energy, both heat and electricity, which may limit deployment speed and scale. DAC project developers should adhere to the following principles, *which build upon those detailed previously under* Essential principles for high-quality carbon dioxide removal.

Additionality and baselines

- **Project developers must:**
    - Clearly demonstrate that increased air capture tonnage would not happen in the absence of the project or carbon income.
    - Include quantification of baseline GHG fluxes and any GHG fluxes associated with energy consumption, site preparation, and carbon storage/utilization.

Carbon accounting method

- **Project developers must:**
    - Clearly document all aspects of the life cycle GHG emissions of the project, including ongoing measurement and reporting of removed and stored CO_2.
    - Include all sources of emissions through the entire project's life cycle, such as emissions due to direct and indirect land-use change from project siting, emissions associated with concrete and steel production and construction, emissions associated with procurement of capture media and chemicals, emissions associated with disposal of waste products, and the full life cycle of emissions from energy use during DAC operation.

- For a project using fossil-fuel energy sources, include full life cycle impacts encompassing both upstream leakage and downstream usage in their carbon accounting considerations (regardless of whether co-capture is involved in the process).

- **Project developers should:**
  - Have a project life cycle of less than 0.3 metric tons of CO_2e emitted per metric ton CO_2 removed from the air.
  - Use energy inputs with low associated emissions.
  - Ensure measurements include emissions throughout the entire value chain of a project (from upstream to operational emissions) across all types of greenhouse gases, including fugitive emissions in compression, transport, and storage of CO_2.

Harms and benefits

In addition to the Essential principles for high-quality carbon dioxide removal listed earlier:

- **Project developers should:**
  - Detail the full life cycle emissions of fossil energy production and consumption and provide a plan to minimize their impacts.
  - Plan to adapt process inputs such as energy, construction materials, sorbents/solvents, and other consumables as industrial processes evolve to reduce carbon footprint and waste production (circular usage).

Durability

- **Project developers must** demonstrate:
  - Sufficient CO_2 storage capacity identified and booked for the full project lifetime, or access to sufficient CO_2 storage elsewhere with credible CO_2 transportation options to that location.
  - Sufficient injectivity at storage site, including well count.
  - Low risk for CO_2 release.

Environmental justice

In addition to the Essential principles for high-quality carbon dioxide removal listed earlier:

- **Project developers must:**
  - Avoid development or disturbance of land that has been identified as culturally sensitive or ecologically important by community stakeholders. This includes land used directly for

DAC facilities, land used for renewable energy installations to power DAC facilities, and land used for CO_2 transport or geological storage.

- Prevent community displacement. In particular, CO_2 or other pipelines constructed partly or entirely in response to DAC development must not inequitably affect historically disadvantaged communities.

- **Project developers should:**
  - Explicitly detail impacts to water, air, and land, and describe a strategy for mitigating community health impacts.
  - Give consideration to potential impacts of sorbent or solvent slip downwind of the facility, even in cases where those levels comply with general health and safety guidelines.
  - Consider the impact that increased water consumption will have on community water prices, and the impacts to local water quality of discharges from capture facilities and sorbent/solvent manufacturing facilities.
  - Have public carbon reduction targets and clean energy transition commitments. Note that any carbon removal from the DAC facility that is sold into the voluntary carbon market cannot also be claimed by the project developer towards meeting these targets.
  - Clearly articulate how they will provide benefits to under-resourced and marginalized populations, generate wealth and economic empowerment, and/or foster community involvement with CDR projects.
  - Detail any associated land-use changes, including any new infrastructure required for project deployment, which could have negative community consequences.

Monitoring, reporting, and verification (MRV)

- **Project developers must** present a valid and viable MRV plan that adheres to key regulatory requirements (for example, Class VI well permits) for either subsurface storage or carbon utilization products.

Other considerations

Feedstock

- **Project developers must** demonstrate that process inputs 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.

- For solvent-based systems, demonstrate the ability to produce, transport, store, and manage solvent and solvent degradation products with low risk to operators and neighboring communities.
- For sorbent-based systems, demonstrate the ability to synthesize sorbent at 1 metric ton per year scale or at a scale consistent with the project timeline.

Infrastructure

- **Project developers must** provide a description of low-carbon energy supply, including land/sea requirements for generation technology, capacity factor, and reliability.
- **Project developers should** describe relevant transmission infrastructure, including new electric power lines and CO_2 pipelines.

Product end fate and storage

- **Project developers must** demonstrate displacement of high carbon-intensity products or processes for projects involving CO_2 reduction in combination with DAC-utilization projects.

Scalability

- **Project developers must:**
    - Present valid cost estimates, ideally verified by third parties, peer review, or demonstrated in prior projects.
    - Test thermal and electrical energy supplies to match theoretical energy requirements.
    - Demonstrate the ability to manufacture or procure proposed design components and systems.
    - Ensure a viable low-carbon energy supply at large scale; ideally projects would have contracted or captive energy supplies.
- **Project developers should:**
    - Have demonstrated prototypes as close as possible to at-scale usage.
    - Ensure that technology vendors provide performance and cost data of the whole system and key components.

Conclusion

Thank you for your interest in partnering with Microsoft on carbon dioxide removal. We welcome feedback on the preceding guidance as this new carbon removal market develops. Please email the Microsoft Carbon Removal team at mscdr@microsoft.com with comments and/or questions.