

Health & ecosystem impact assessment for abiotic marine carbon dioxide removal

Fall 2024

Context

Frontier aims to support promising carbon removal projects that can be done responsibly and maximize benefits to communities and ecosystems while minimizing potential harms. As a part of purchasing diligence, we assess the project's approach to legal and regulatory compliance, ecosystem safety and distribution of community benefits.

We have built mechanisms into Frontier's purchasing diligence and contracting to (1) minimize the potential known risks of projects; and (2) establish processes for adaptive management over time to ensure that projects stop if negative impacts are identified.

In some cases, existing regulations (OSHA, MSHA, EPA Controls, etc.) will be sufficient to manage project risks. For the specific safety risks where applicable regulatory regimes do not exist or do not fully retire the risks, Frontier uses the rubric below to inform whether to purchase from the project. This analysis also helps Frontier identify additional controls that should be added into the project contract to ensure safe, responsible deployment.

This assessment rubric

This rubric was developed by environmental, safety and health sciences firm <u>Ramboll</u> to help reviewers for Frontier's offtake purchasing program assess whether a project removing CO2 through abiotic marine carbon dioxide removal (mCDR) with a specific focus on alkalinity enhancement (electrochemical or mineral addition in oceans or rivers) (1) is set up for safe deployment and (2) has a best-in-class approach to monitor and mitigate any potential ecosystem and health and safety risks.

We do this by selecting for projects with low substantive risk and strong procedural controls across key risk categories:

- Low substantive risk Risks are inherently lower because of the nature of the approach and the way the company has designed a deployment. For example, a project that uses a particularly well-characterized biomass feedstock.
- <u>Strong procedural controls</u> A project has appropriate instrumentation and processes in place to monitor ecosystem interactions along with governance controls that trigger deployment shifts if any negative impacts are observed. For example, a project has a comprehensive plan to monitor local ecosystem impact parameters and a process to halt the intervention if variation is observed.

Pre-Deployment assessment rubric

	Assessment Category		nt Accordant Description	Delen Dele		Assessment Rubric		
As	ssessment Category	Туре	Assessment Description	Relevant Pathway	High pass	Low pass	Needs improvement	Guidelines for advanced monitoring & mitigation
1 -	Overall Project Gove	rnance						
а	Regulatory compliance	Procedural	Project complies with local, state, and federal regulations	All projects	Proponent has a regulatory compliance expert and has a plan for compliance. Client has a mechanism for tracking compliance. Planning prioritizes hazard elimination where practical	plan for compliance and		In the U.S., potentially applicable regulations include: • Local, State and federal permitting for CO2 transport and disposal (incling injection wells if applicable). • Local, State and federal environmental regulations associated with water and waste. • OSHA worker exposure, safety data sheet requirements • Federal or state permitting for potential releases to water (plant wastewater discharge, storm runoff if applicable) or waste disposal (depending on wastes generated and materials used for alkalization)
b	Compliance with ongoing, transparent environmental health & safety monitoring and reporting	Procedural	Project has established requirements for project reporting and auditing	All projects	Proponent will receive regular, independent audits of environmental and safety outcomes for this project Proponent plans to transparently report audit findings and safety data to relevant project stakeholders, including communities	Proponent will receive regular, independent audits of environmental and safety outcomes for this project	No plans for third party review or transparent reporting	Require monitoring and reporting on environmental health and safety metrics within purchase contract and project measurement & monitoring Protocol
c	project-specific	Substantive and procedural	Project activity will result in atmospheric carbon reoval (establish CDR efficacy) Project has a clear plan for third party verification of project's carbon removal data and claims, and intends intends to report outcomes transparently	Primarily electrochemical alkalinity enhancement	Proponent robustly demonstrates estimated carbon dioxide removal (CDR) benefit compared to counterfactual scenario. Proponent sources electricity sourced entirely from renewable sources and processes optimized for energy efficiency	Proponent robustly demonstrates estimated carbon dioxide removal (CDR) benefit compared to counterfactual scenario. Proponent sources electricity from a combination of renewable energy and fossil fuels, but ensures energy sourcing emissions are fully accounted for within the project lifecycle assessment, including accounting for instances in which clean energy used would otherwise reduce fossil emissions. When using fossil fuels, electrochemical processes are primarily performed during times of the day where the demands on the electrical grids are the lowest.	Proponent does not accurately assess additionality or determine impact. Electricity sourcing not optimized based on environmental/social impacts, or environmental tradeoffs have not been adequately assessed and accounted for in measurement protocol	2. Source electricity from renewable sources; locate facilities where renewable energy structures are in place or

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2 - Local Ecological Impacts								
а	Appropriate pH for aquatic life	Substantive	Project establishes appropriate pH range for alkalized water to balance ocean/river alkalization benefits against local impacts at the discharge site. For mineral weathering, material dissolution does not icrease total suspended solid concernations or increase turbidity in	All projects	requirements. Plan to publish findings is encouraged for High Pass rating.		Safe pH range of treated water is assumed without basis, no verification or monitoring planned	 Establish pre-alkalization and turbidity baseline for water pH Prior to implementation of project, assemble data on range of pH observed and turbidity in treated water. Plan to monitor before, during, and after alkalization (robust MRV/surveillance plan) to confirm that the alkalized water pH and total suspended solids (TSS) are within a safe range for aquatic life.
b	Impingement/ entrainment of marine life	Substantive	Project has safe water intake practices to minimize impingement/entrainment of marine and has mitigation infrastructure planned or in place.	All projects cycling water	See "Guidelines for advanced monitoring & mitigation" for requirements. Plan to publish findings is encouraged for High Pass rating.		Negative impacts on impingement/entrainment not adequately evaluated, no expert engaged.	 Conduct site screening and site selection, preferrably using existing intake pipes, pumps, and other infrastructure Conduct site characterization and identify vulnerable species and populations near intake pipes Ensure infrastructure is in place to mitigate impinged/entrained marine life. This may inlcude rotating screens within intake pipes that release impinged marine life back into the ocean. Plan to monitor before, during, and after electrochemical process (robust MRV/surveillance plan) to confirm that the intake pipes and pumps are adequately constructed and mitigation practices are effective. Monitor and record impinged marine life, documenting their species, vulnerability, and mortality status.
с	Environmentally safe handling/ treatment of process chemicals, byproducts and wastes	Substantive	Project characterizes wastewater outputs & treatment needs, risk mitigation methods for potential spills, and circular economy opportunities to minimize waste production	Projects generating wastewater or solid, liquid or gaseous wastes, or integrating into waste water operations	requirements. Plan to publish findings is encouraged for		No plan to address process chemicals, byproducts, and wastes	 Fully understand types and quantities of byproducts generated and have a plan for measuring and monitoring byproducts. Hazardous wastes must be managed in accordance with Federal, State, and federal, state and local regulations. Establish wastewater treatment needs, performance standards, and wastewater treatment design. Establish spill prevention, control, and countermeasures (SPCC) plan. Optimize for circular economy opportunities to minimize waste production.
d	Biodiversity impacts of facility siting	Substantive	Project assesses and understands competing uses (both social and environmental) for land or water resources, as applicable, at the location of the elctrochemical alkalization plant	All projects	The electrochemical alkalization plant or mineral dissolution infrastructure is located on existing developed land and there are no biodiversity impacts associated with the construction of the plant or mineral deployment	location for the construction of the electrochemical or mineral alkalization facility is not currently supporting communities or providing high-quality natural habitat	Construction impacts have not been assessed or justified, land-use conflicts have been identified, no plan to protect biodiversity	 Conduct field studies to determine potentially suitable electrochemical alkalization sites Assess conflicts associated with increased land or water resource demand or land-use change and other environmental/social goals Include biodiversity enhancement plans and ecosystem benefits within construction plans Use green energy for the operatons
e	Metal contamination risk	Substantive	Project effectively characterizes trace metal concentrations of potential mineral feeedstock sources, selects for safe feedstocks, and if necessary, identifies an alkalinity introduction rate that protects aquatic ecosystems from metal toxicity	Alkalinity enhancement via mineral addition	See "Guidelines for advanced	monitoring & mitigation" for re	Ni concentration in EW material is	 Conduct trace metal analysis of specific akaline material Determine whether material introduction and dissolution rate must be limited to protect aquatic ecosystems, and if necessary, identify such a limit Monitor this parameter post-alkalinity addition.

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					High pass	Low pass	Needs improvement	Guidelines for advanced monitoring & mitigation
3 - Off-Site Ecological Impacts		npacts						
a	CO2 transport-induced impacts	Substantive	Project assesses environmental, social, and health impacts of CO2 transportation (as well as transportation of other wastes/ byproducts if applicable)	Projects removing CO2 from seawater	requirements. Plan to publis	d monitoring & mitigation" for sh findings is encouraged for ss rating.	Negative CO2 transportation impacts not adequately evaluated, no expert engaged.	 Assess availability of pre-existing pipelines for CO2 transportation. If no pipelines or transportation means are accessible, develop transportation plan. Biodiversity impacts can be reduced by using trenchless underground piping
b	Geologic carbon sequestration (GCS) injection well-induced impacts	Substantive	Project demonstrates understanding of safe injection well practices and has controls in place to minimize potential for GCS-induced seismicity, leakage, or caprock fracturing, and to minimize freshwater/land-use impacts	Projects geologically injecting CO2 removed from seawater	"Guidelines for advanced mo	o follow the requirements in onitoring & mitigation." Plan to raged for High Pass rating.	Negative GCS impacts not adequately evaluated, no expert engaged.	 Conduct site screening and site selection, ensure that identified well(s) have desired storage capacity and appropriate supportive geology. Projects where CO2 generation (from seawater) and storage are in relatively close proximity have potential for lower environmental, safety and health impacts. Conduct site characterization (including social characterization) Establish pre-injection baselines and assemble data for permitting (EPA Class VI or V Permit and locally applicable permits). Plan to monitor before, during, and after injection (robust MRV/surveillance plan) to confirm that the well is adequately constructed and prevents subsurface fluids from leaking into drinkable groundwater, and that subsurface pressure is actively managed to avoid seismicity
с	Alkaline material sourcing	Substantive	Assess carbon emissions, other enviro • Whether selected EW material is a b • Whether grinding is required to achi- • Distance from source to application	enhancement via	EW material is sourced as a by-product of existing mineral extraction with minimal additional grinding and limited transportation distance	If mining, grinding, and/or long-distance transport are required, project has conducted environmental impact assessment and assess acceptability of environmental and socioeconomic tradeoffs	Alkaline material sourcing not optimized based on environmental impacts, or environmental tradeoffs have been assessed and are not acceptable	Apply life cycle analysis concepts to compare candidate sources of alkaline material and deployment application sites.
4 - 1	Worker Wellbeing							
а	Worker health & safety	Procedural	Plan to protect workers from hazards such as: • Acids and bases • Hazardous gases • Electrical hazards	All projects	for hazardous material ha	sessment and a plan prepared ndling, storage & disposal, zard communication	No health & safety plan	 Conduct health & safety risk assessment and prepare site-specific health and safety plan Supply personal protective equipment if applicable Develop Emergency Action Plan Develop Spill Response Plan Develop Lock-Out/Tag-Out plan for electrical safety. Safety training

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5 - Community Wellbeing								
а	Community engagement	Procedural	Plan for and begin early implementation of engagement with the community surrounding the deployment site(s)	All projects	Obtains buy-in and community support for deployment through education, partnership with local leaders, etc.	Keeps community informed on deployment strategy through one-way communications	Community is not informed	 Deeply engage community during project exploration and factor community input into project design. Inform community of project policies that will be implemented to avoid accidental release of captured CO2, mitigate ecosystem impacts, and/or minimize disruptions Accurately evaluate and convey economic and social impacts to community Exemplary projects commit to and display trustworthiness and partnership from project inception through deployment and beyond. Project updates are communicated in a timely and transparent manner
6	6- Benefits							
а	Local alleviation of river or ocean acidification	Substantive	Assess local river or ocean acidification alleviation potential	All projects	Local alleviation of river or ocean acidification and associated biological benefits will be monitored and findings will be published	alkalization assumed rather	Not applicable (no projects rejected based on this issue)	

If a project passes the assessment and is selected for a purchase through Frontier, any of the 'guidelines for advanced monitoring and mitigation' that are not already sufficiently addressed in existing regulation are incorporated into the project's measurement protocol and included in the purchase contract.

Frontier only accepts and makes payment for carbon removal deliveries if a project (1) demonstrates ongoing regulatory compliance, (2) provides third party verification that the activities comply with the protocol, and (3) transparently and publicly reports ecosystem impact data.