

Validation Report

For Isometric

CDR Supplier	Planetary
CDR Pathway	Ocean Alkalinity Enhancement (OAE)
Project	Nova Scotia Mineral OAE
Location	Tufts Cove Generating Station 315 Windmill Rd Dartmouth, Nova Scotia 44.674946, -63.595478
Validators	350Solutions Lily Schacht and Tim Hansen
Report Date	March 21, 2025
Crediting Period	February 1, 2024 – January 31, 2029
Version	V1.2

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ISOMETRIC VALIDATION REPORT

Company: Planetary Technologies	Company Contacts: Kelsey Cuddihy Will Burt Mike Kelland	VVB: 350 Solutions Lily Schacht* Tim Hansen, PE
Removal Method: Ocean Alkalinity Enhancement		
Report Date: March 21, 2025		
Document No: 350VR-ISO2403		
Revision: V1.2		

*primary contact/lead author

1. Introduction

350Solutions was contracted to validate Planetary Technologies' Nova Scotia Mineral OAE Project. The validation includes observation of operations during a site visit, collection of files and evidence related to the alkalinity dosing process and ocean monitoring, review of data collection and handling procedures, and evaluation of adherence of the project, as summarized in Planetary Nova Scotia Mineral OAE Project Design Document, for adherence to the relevant Isometric Standards and Protocols.

350Solutions Inc. declares that we are an impartial verifying body, free from any conflicts of interest, capable, and qualified to complete this validation for the current operational period according to the Isometric Standard and applicable protocols and modules utilizing a reasonable level of assurance.

This project validation involved a site visit to the Nova Scotia Mineral OAE Project on September 23, 2024 and a desk review of documents provided by Planetary, including the PDD. 350Solutions affirms that Planetary has the appropriate equipment, procedures, and protocols in place to quantify GHG removal through the addition of alkaline material to a coastal outfall in accordance with the requirements of the following Isometric standards, protocols, and modules:

- Isometric Standard V1.3 [1]
- Ocean Alkalinity Enhancement from Coastal Outfalls V1.0 [2]
- Dissolved Inorganic Carbon Storage in Oceans V1.0 [3]
- Air-Sea CO₂ Uptake V1.0 [4]
- Rock and Mineral Feedstock Characterization V1.0 [5]
- Energy Use Accounting V1.1 [6]
- Transportation Emissions Accounting V1.0 [7]
- Embodied Emissions Accounting V1.0 [8]

A summary of the project and validation is provided below.

Table 1. Validation Summary

GHG Removal Supplier	Planetary
Project Name	Nova Scotia Mineral OAE Project
Project Code	F5X7
Removal Method	Ocean Alkalinity Enhancement from Coastal Outfalls
Validation Report Date	March 21, 2025
Site Visit Date	September 23, 2024

Crediting Period	February 1, 2024 – January 31, 2029
Project Location (Address and GPS Coordinates)	Tufts Cove Generating Station 315 Windmill Rd Dartmouth, Nova Scotia 44.674946, -63.595478
Verification Type	Isometric Standard Validation, including on-site visit and project validation; Isometric Standard V1.3 Ocean Alkalinity Enhancement from Coastal Outfalls V1.0 Dissolved Inorganic Carbon Storage in Oceans V1.0 Air-Sea CO ₂ Uptake V1.0 Rock and Mineral Feedstock Characterization V1.0 Energy Use Accounting V1.1 Transportation Emissions Accounting V1.0 Embodied Emissions Accounting V1.0

2. Technology Description

Planetary Technologies’ doses alkaline waste feedstock into coastal outfalls to increase the local alkalinity of the seawater, called ocean alkalinity enhancement (OAE). This alkalinity neutralizes acidic dissolved carbon dioxide (H₂CO₃) that is present in seawater by converting it into carbonate (CO₃²⁻) and bicarbonate (HCO₃⁻) ions that are already abundant in the ocean. As ocean carbon dioxide (CO₂) is consumed by this process, the ocean absorbs CO₂ from the atmosphere to bring the air and ocean back into chemical equilibrium. Assuming steady state, the mean seawater residence time of alkaline dissolved carbon ions (CO₃²⁻ and HCO₃⁻) charged-balanced by cations other than H⁺ is about 100,000 yrs.

The Nova Scotia Mineral OAE Project takes place in Dartmouth, Nova Scotia, Canada on the site of Nova Scotia Power’s Tufts Cove Generating Station. Planetary’s feedstock for this project is [REDACTED], that is primarily made up of magnesium oxide (MgO) and magnesium carbonate (MgCO₃). The feedstock is shipped from Spain and temporarily stored in a nearby warehouse or in an onsite shipping container.

Feedstock dosing began on July 15, 2024. From July to October 14, 2024, feedstock was then dispensed into a hopper which weighs the feedstock. A screw auger in the hopper transfers the feedstock into the slurry mixing tank, where it is mixed with seawater. Beginning on October 15, pre-weighed feedstock was added directly into the mixing tank, rather than using the hopper. The seawater is pulled from the return line of the power plant’s cooling loop into the mixing tank. The slurry stirs for 30 – 60 minutes, then is mixed with additional seawater and dispensed in the outfall with the remaining cooling loop water.

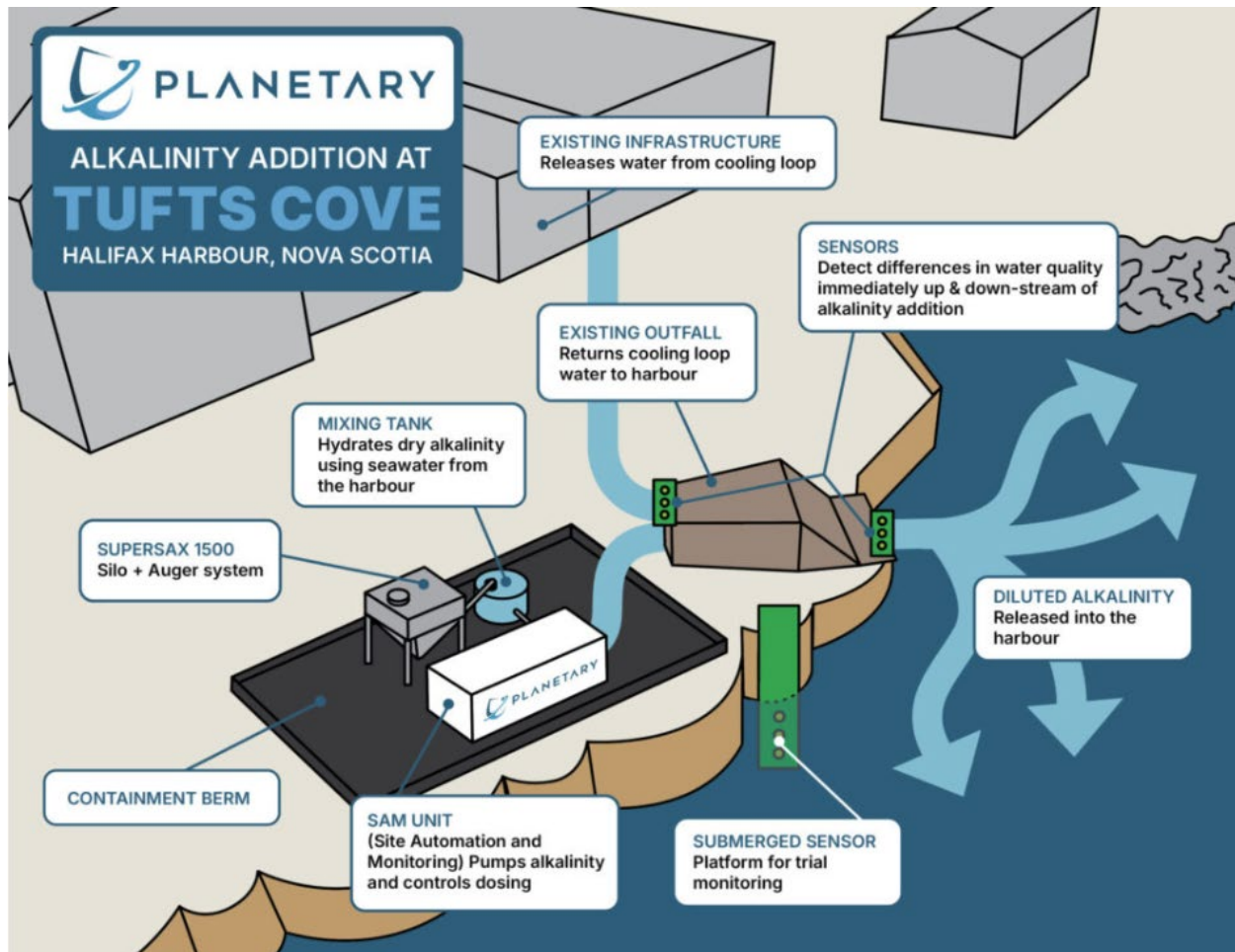


Figure 1. Overview of Planetary Process at Tufts Cove. Beginning on October 15, 2024, feedstock was dispensed directly into the mixing tank, rather than using the Supersax 1500. Credit: Planetary

Gross carbon dioxide removal (CDR) is quantified using near- and far-field modeling using the feedstock dosing record as the input. The feedstock dosing record is used as an input to a coastal 150 m horizontal resolution physical (Regional Ocean Modeling System or ROMS) and biogeochemical model (based on Fennel et al., 2006, 2008) of the Halifax Harbor. A 1D alkalinity release model is used to parameterize alkalinity input with a 2-phase proxy. It is assumed that a fraction of the dosed alkalinity is released in the surface layers and the remainder is released with the sinking and dissolution of a single particle size. Simulations are run with and without alkalinity addition in the ROMS model. Because both TA and TIC are lost at the open boundaries, total CDR is calculated as the net ΔCO_2 air-sea flux between the dosing and baseline simulations.

The unequilibrated alkalinity that leaves the regional domain through the open boundaries is used as input to a global $1/3^\circ$ horizontal resolution data assimilative ocean physical and biogeochemical model (ECCO LLC270 physics with the MITgcm gchem and DIC packages). CDR in ECCO is quantified as the difference in ocean DIC between the dosing and baseline simulations.

The gross CDR is the sum of the CDR calculated in the ROMS and ECCO models. To quantify uncertainty, an ensemble of experiments in the ROMS model with different input parameters and start years, and ECCO model with different start years and are used to provide an estimated uncertainty envelope on simulated CDR. Finally, a calibrated 1-D vertical diffusivity model has been developed and shown to agree closely with the ROMS CDR and is used to broaden the ensemble of sensitivity cases for uncertainty quantification.

Planetary has several monitoring locations to ensure the added alkalinity does not create an unsafe perturbation in the plume. There are two multiparameter sondes that continuously collect pH, total suspended solids (TSS), temperature (T), and salinity (S) before and after the alkalinity is added to the cooling loop water. This is supplemented by weekly bottle samples to measure total alkalinity (TA) and confirm TSS, S, and pH measurements and a mooring next to the outfall with several continuously monitored parameters. See Table 6 for the complete list of monitored parameters.

A diagram of Planetary's OAE process flow and four subprocesses is provided in Figure 1. A complete description of operations related to the four subprocesses can be found in Appendix 3.

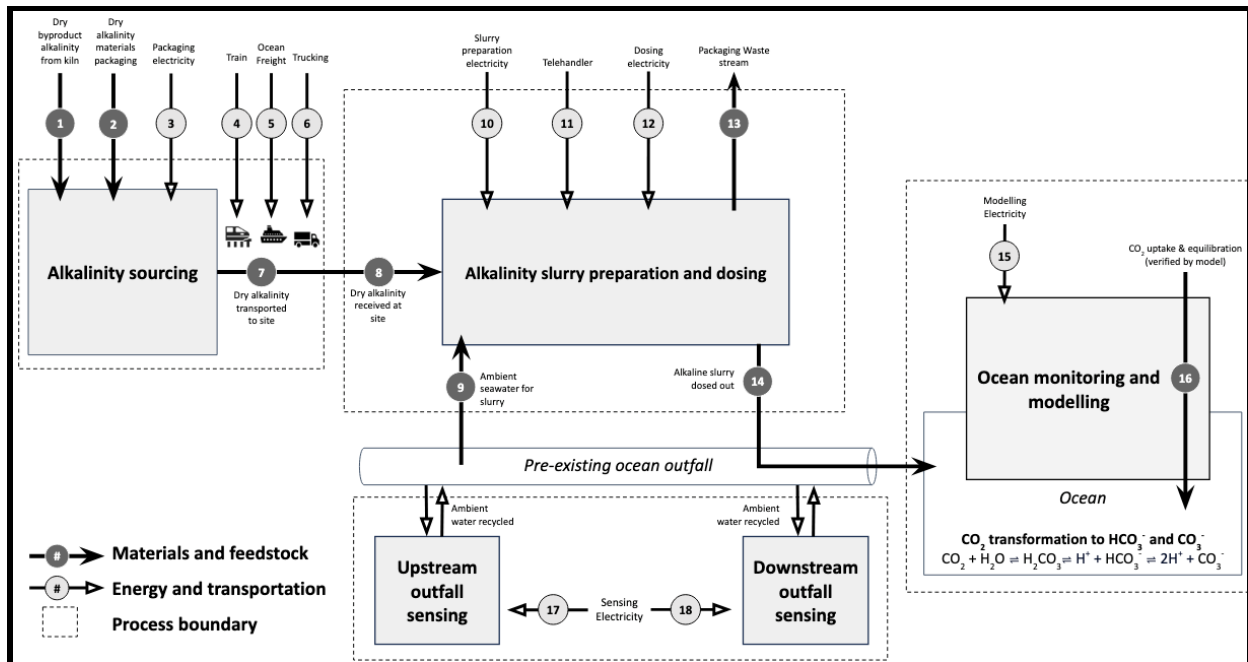


Figure 2. Planetary Technologies OAE Process Flow Diagram. Credit: Planetary

2.1. Inputs & Outputs

A summary of process inputs and outputs including all feedstock, energy sources, consumables, wastes, and stored CO₂ is provided in Table 2.

Table 2. Process Inputs & Outputs

Input / Output	PFD ID No. (Figure 2)	Process(es)	Specification
INPUTS			
Alkalinity Sourcing	1	Alkalinity Sourcing (feedstock material)	Dry feedstock by-product alkalinity from kiln
Transportation: Alkalinity Sourcing	4	Alkalinity Sourcing (train)	Different fuel sources depending on transport modality
	5	Alkalinity Sourcing (ocean freight)	
	6	Alkalinity Sourcing (trucking)	
Energy: Alkalinity sourcing, slurry preparation & dosing, outfall sensing	10	Slurry preparation and dosing (slurry preparation electricity)	Regional grid power
	12	Slurry preparation and dosing (dosing electricity)	
	17, 18	Outfall sensing power (up- and downstream outfall sensing electricity)	
	15	Ocean monitoring power (modeling electricity)	
	3	Sourcing (alkalinity packaging power)	
Slurry preparation & dosing	9	Slurry preparation and dosing (ambient seawater for slurry)	Ambient
Slurry preparation & dosing	8	Dry alkalinity received at site	Feedstock
Alkalinity sourcing	2	Alkalinity sourcing (dry alkalinity packaging)	Material/feedstock
Slurry preparation & dosing	11	Telehandler	Diesel fuel
OUTPUTS			
Slurry preparation & dosing	13	Packaging Waste	Landfilled alkalinity packaging material
Slurry preparation & dosing	16	Dosed Alkalinity	Alkaline slurry dosed out (Average density: 1.2 g/cc)

3. Validation Process

3.1. Objectives and Scope

A planned series of validation activities were conducted by 350Solutions to independently validate the eligibility of the Nova Scotia Mineral OAE Project for registration on the Isometric registry following the guidelines of the Isometric Standard (V1.3.1) and associated modules/protocols. The

intention of the validation is to assess the likelihood that implementation of the project, as described in the PDD, will result in the achievement of the GHG outcomes to be stated by the project proponent, Planetary Technologies.

3.2. Responsibilities

The project proponent, Planetary Technologies, is responsible for the fair presentation of the PDD in accordance with Isometric criteria.

It is the responsibility of 350 Solutions to express an opinion as to whether the PDD and supporting documents support project validation for the relevant Isometric standard, protocol, and modules.

3.3. Validation Body Details

350Solutions is an accredited inspection & verification body by ANAB under ISO 17020 for completion of ISO 14034 Technology Verifications and was the first accredited entity in North America for ISO 14034. 350Solutions is based out of Raleigh, North Carolina, USA. The Technical Lead for the Nova Scotia Mineral OAE project validation is Lily Schacht. Veronica Tamsitt from Submarine Scientific was subcontracted by 350Solutions to assist in model validation using the Air-Sea CO₂ Exchange module and validation of alkalinity loss claims. Quality assurance was provided by Tim Hansen. Complete verifier qualifications are included in Appendix 4.

3.4. Protocols and Modules Applied

The validation was conducted following the specifications of the following standards, protocols, and modules:

- Isometric Standard V1.3 [1]
- Ocean Alkalinity Enhancement from Coastal Outfalls V1.0 [2]
- Dissolved Inorganic Carbon Storage in Oceans V1.0 [3]
- Air-Sea CO₂ Uptake V1.0 [4]
- Rock and Mineral Feedstock Characterization V1.0 [5]
- Energy Use Accounting V1.1 [6]
- Transportation Emissions Accounting V1.0 [7]
- Embodied Emissions Accounting V1.0 [8]

3.5. Approach

The validation process activities are described in Table 3. Appendix 1 contains checklists used to validate the project against the relevant Isometric standard, protocol, and modules. The files that were reviewed are listed in Appendix 2. Photographs of the facility, equipment, and operations are provided in Appendix 3.

Table 3. Validation Activities

Date(s)	Activity	Tasks
Sept 10-20, 2024	PDD Review	- Assess PDD against relevant protocol and modules - Compile list of evidence required for validation
Sept 23, 2024	Site Visit	- Observe on site operations including: - o feedstock loading - o Slurry production - o Slurry sampling and analysis - o Pump and flow meter configuration - o Data and automation infrastructure - o Up- and downstream sampling skids - o Collection of bottle samples - o Mooring sensor rig - Observe methods used at the Dalhousie lab for bottle sample analysis - Tour of alkalinity storage warehouse - Discussion of: - o feedstock sourcing and production - o Life cycle analysis approach and assumptions - o Community engagement - o Relationship with Nova Scotia Power - o Additionality - o Modeling approach
Sept 24 – Nov 14, 2024	Additional Document Review	- Review supporting documentation provided by Planetary
Nov 14-19, 2024	Report writing	- Draft report other than modeling section
Nov 19, 2024 – Feb 5, 2025	Model Validation Review and Report Writing	- Review data supporting near- and farfield models for CDR quantification
Feb 5 – March 17, 2025	Quality assurance and revisions	- Review by internal QA - Edits to address concerns raised by internal QA
March 17 – 21, 2025	External review and revisions	- Review by Isometric and Planetary - Edits to address comments from reviewers

4. Validation Summary

4.1. Validation Opinion

350Solutions has reviewed the documentation of the technology, the instrumentation, the procedures, and performance and has found that the data presented in the Nova Scotia Mineral OAE Project PDD, supporting validation information, and the site visit:

☒ **Meets the requirements of the Isometric Standard V1.3 and Ocean Alkalinity Enhancement from Coastal Outfalls V1.0 for Validation**

☐ **Meets the requirements of the Isometric Standard V1.3 and Ocean Alkalinity Enhancement from Coastal Outfalls V1.0 for Validation with minor modifications**

☐ **Does Not Meet the requirements of the Isometric Standard V1.3 and Ocean Alkalinity Enhancement from Coastal Outfalls V1.0 for Validation**

Our opinion is provided with a reasonable level of assurance for Planetary's activities at Tufts Cove Generating Station and associated activities (alkalinity sourcing, ocean monitoring, ocean modeling).

Notice: 350Solutions, Inc. declares that we are an impartial auditor, free from any conflicts of interest, capable, and qualified to complete this audit according to the Isometric Standard and related Validation and Verification Body Requirements. Verifications and audits conducted by 350Solutions are based on an evaluation of technology performance and CO₂ removal claims via site visit observations and review of data submitted by the audited company. Audits are completed in accordance with rules and methodologies specified by Isometric and utilizing the appropriate quality assurance procedures established under the 350Solutions accredited ISO 17020/14034 Quality Management Program, noting that this verification is not a fully compliant ISO 14034 verification. 350Solutions makes no expressed or implied warranties as to the performance of the technology and does not certify that a technology will always operate at the levels verified, nor that it meets all state, local, or federal legal requirements.

By adhering to the requirements of the Isometric standards, protocols and modules, Planetary's Nova Scotia Mineral OAE Project has been validated as eligible for crediting in accordance with the criteria listed in Section 3.4 with a reasonable level of assurance.

Validator Information		
VVB	Lead Validator	Validation ID No.
350Solutions, Inc.	Lily Schacht	ISO2403

Lily
Schacht

*Digitally signed by Lily Schacht
Date: 2025.03.21 10:29:11 -04'00'*

Signed: Lily Schacht (Lead Verifier)

Timothy
A. Hansen

*Digitally signed by
Timothy A. Hansen
Date: 2025.03.21
10:38:53 -04'00'*

Tim Hansen (Quality Assurance)



7.4.2	<i>Alkalinity losses</i>	Acceptable – Strict adherence to pH and alkalinity limits ensures very low risk of secondary precipitation and biotic calcification in line with latest research. Risk of change in counterfactual alkalinity release to be managed through additional sediment sampling and lab experiments
8.0	<i>CO₂ storage</i>	Acceptable – Reversal risk for the applicable protocol is very low, corresponding to a buffer pool of 2%.
10.0	<i>Monitoring plan</i>	Acceptable – All required parameters are modeled at appropriate frequencies during periods with and without dosing. Instrumentation and analytical methods are standard for the field and meet Isometric requirements.
10.4	<i>Feedstock characterization</i>	Acceptable – All required physical and chemical properties of the feedstock have been measured on multiple samples. Toxicity assessment indicated LC50 > 10,000 mg
OVERALL ELIGIBILITY		ELIGIBLE
Eligible Period		February 1, 2024 – January 31, 2029

4.3. Validation Limitations

While Planetary has provided evidence of compliance with the relevant Isometric standard, protocol, and modules, meeting project validation requirements, this validation does not constitute a full verification of total removals as certain items related to verification cannot be completed until gross carbon removal has been calculated and a GHG statement generated. These forward action requests (FARs) will be reviewed and assessed during verification once a GHG statement is available.

Table 5. Validation Forward Action Requests

ID	Finding / Issue	Audit Evidence	Protocol Reference	Required Action	Resolution
1	The PDD provides full LCA calculation description and monitoring plan, providing adequate documentation of approach for LCA and data use, but a full LCA including uncertainty was not provided due to status of project development.	2024 XXXX x TC Inventory Planetary; Planetary PDD 2024 Complete	7.4	Provide LCA including gross carbon removal from OAE in accordance with protocol	To be confirmed at Verification
2	The PDD provides a description of the planned uncertainty analysis and sensitivity analysis with adequate documentation of the approach, but full analyses not provided due to status of project development.	Planetary PDD 2024 Complete	5.5	Provide uncertainty and sensitivity analysis for GHG Statement	To be confirmed at Verification
3	The PDD provides a description of the planned modeling approach, but all model files and code needed to repeat the simulation, 2D maps of the air-sea CO ₂ flux, 3D output of DIC, and results from model sensitivity tests and	Planetary PDD 2024 Complete	Air-sea CO ₂ Uptake Module 3.1.4, 5.0	Provide all model code, configuration, and required model outputs for air-sea CO ₂ uptake module	To be confirmed at Verification

	assessment of uncertainty not provided due to status of project development.				
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4.4. Evidence Required for Verifications

In addition to the Forward Action Requests, the items in Table 6 are required for all verifications.

Table 6. Data and evidence required for verification

Input / Output Stream	Sub-Process	Required Data (Measurement or estimate)	Units	Protocol Reference	Net CDR Calculation Parameter
Alkalinity	Alkalinity sourcing	EQOH* per unit feedstock	Tonnes EQOH/tonne feedstock	7.4.1	$\Delta\text{CO}_2\text{e}_{\text{AirSeaFlux, RP}}$
		Packaging emissions	kgCO ₂ e/tonne feedstock	7.4.4	CO ₂ eEmissions, RP
		Transportation emissions	kgCO ₂ e/tonne feedstock	7.4.4	CO ₂ eEmissions, RP
Alkalinity	Alkaline slurry mixing and dosing	Feedstock dosed	Tonnes feedstock/day	7.4.1	$\Delta\text{CO}_2\text{e}_{\text{AirSeaFlux, RP}}$
Fuel		Telehandler diesel consumption	L	7.4.4	CO ₂ eEmissions, RP
Electricity		Mixing and dosing power use	kWh		
Waste stream		Material packaging waste mass	kg	7.4.4	CO ₂ eEmissions, RP
Ocean outfall	Up- and downstream outfall sensing	Sensing Electricity	kWh	7.4.4	CO ₂ eEmissions, RP
		Upstream seawater alkalinity, pH, TSS, salinity, trace metals	μmol/kg, pH units, mg/L, PSU, mg/L	10.2. Monitoring Requirements	N/A
		Upstream seawater pH	pH units		
		Upstream seawater TSS	mg/L		
		Upstream seawater temperature	°C		
		Upstream seawater salinity	PSU		
		Downstream seawater alkalinity, pH, TSS, salinity, trace metals	μmol/kg, pH units, mg/L, PSU, mg/L		
		Downstream seawater pH	pH units		
		Downstream seawater TSS	mg/L		
		Downstream seawater temperature	°C		

		Downstream seawater salinity	PSU		
Bulk Ocean	Ocean monitoring - Moored Sensors	Ocean and air pCO ₂	ppm		
		Ocean pH	pH units		
		Ocean temperature	°C		
		Ocean TSS	mg/L		
		Ocean salinity	ppt		
		Ocean total alkalinity	μmol/kg		
		Ocean chlorophyll <i>a</i> fluorescence	mg/L		
Bulk Ocean	Ocean monitoring - Boat sampling	Vertical profiles - Ocean pH, TSS, dissolved oxygen, temperature, salinity	pH units, mg/L, % saturation, °C, PSU, μmol/m ² /s		
		Bottle samples - Ocean alkalinity, pH, TSS, salinity, trace metals	μmol/kg, pH units, mg/L, PSU, mg/L		
		Sediment grabs - Sediment metals content	mg/kg		
Modeling	Modeling	Electricity	kWh	7.4.4	CO ₂ e _{Emissions} , RP
		Model output files	ΔCO ₂ e _{AirSeaFlux} , RP	7.4.1	ΔCO ₂ e _{AirSeaFlux} , RP

* EQOH = Equivalent hydroxide content

5. Revision History

Table 7. Revision History

Version	Date Issued	Noted Changes
Draft Version 1.0 (v1.0)	November 19, 2024	N/A
Draft Version 1.0.1 (v1.0.1)	February 5, 2025	Updated to include model validation
Draft Version 1.0.2 (v1.0.2)	February 10, 2025	Grammatical and typographical revisions; addition of appendices
Draft Version 1.1 (v1.1)	March 17, 2025	Revisions following internal review
Final (v1.2)	March 21, 2025	Revisions following review by Planetary and Isometric

6. References

- [1] Isometric, “Isometric Standard v1.3.1.” Accessed: Nov. 20, 2024. [Online]. Available: <https://registry.isometric.com/standard/1.3.1>
- [2] Isometric, “Ocean Alkalinity Enhancement from Coastal Outfalls.” Accessed: Nov. 20, 2024. [Online]. Available: <https://registry.isometric.com/protocol/ocean-alkalinity-enhancement/1.0>

- [3] Isometric, “Dissolved Inorganic Carbon Storage in Oceans v1.0.” Accessed: Nov. 20, 2024. [Online]. Available: <https://registry.isometric.com/protocol/dic-storage-in-oceans/1.0>
- [4] Isometric, “Air-Sea CO₂ Uptake - v1.0.” Accessed: Nov. 20, 2024. [Online]. Available: <https://registry.isometric.com/protocol/air-sea-gas-exchange/1.0>
- [5] Isometric, “Rock and Mineral Feedstock Characterization V1.0.” Accessed: Jan. 06, 2025. [Online]. Available: <https://registry.isometric.com/protocol/rock-and-mineral-feedstock-characterization/1.0>
- [6] Isometric, “Energy Use Accounting v1.1.” Accessed: Nov. 20, 2024. [Online]. Available: <https://registry.isometric.com/protocol/energy-use-accounting/1.1>
- [7] Isometric, “Transportation Emissions Accounting v1.0.” Accessed: Nov. 20, 2024. [Online]. Available: <https://registry.isometric.com/protocol/transportation/1.0>
- [8] Isometric, “Embodied Emissions Accounting v1.0.3.” Accessed: Nov. 20, 2024. [Online]. Available: <https://registry.isometric.com/protocol/embodied-emissions/1.0>

Appendix 1: Validation Checklists

Appendix 2: Files Reviewed

Appendix 3. Description of Operations

Appendix 4: Verifier Qualifications

350Solutions, Inc. Corporate Experience

350Solutions serves as an independent expert in cleantech, low carbon, and environmental technologies. We provide an unbiased assessment of innovative technologies. 350Solutions is accredited through ANAB under ISO 17020 as an independent inspection body to provide independent technology evaluation services using the ISO 14034 ETV process. In addition, 350Solutions staff include a Certified Measurement and Verification Professional (CMVP for IPMVP) and a North Carolina Registered Professional Engineer (P.E.).

Lily Schacht
Carbon Removal Verification Engineer, 350Solutions

EDUCATION:

MS, Environmental Engineering, University of Wisconsin – Madison, 2019

BS, Chemical, Energy, and Environmental Engineering, Washington University in St. Louis, 2017

EXPERIENCE SUMMARY:

Lily Schacht is an Environmental and Chemical Engineer with experience in process engineering, environmental chemistry, analytical methods, and life cycle analysis (LCA). At 350Solutions, Lily works on verifying carbon dioxide removal (CDR) technologies, with a focus on mineralization-based pathways, including enhanced weathering, direct air capture, and ocean alkalinity enhancement. Previously, Lily led agronomic research at an enhanced weathering CDR supplier where she organized field trials across multiple states to quantify carbon removal and crop yield changes after rock application. Before that, Lily developed rapid prototyping instrumentation to optimize a biomineralization process in concrete production and aided in scaling up the process to pilot-scale. Lily also built environmental impact models for process variable sensitivity analysis of demo-scale manufacturing processes. These models were used to drive the direction of research and development to minimize product life cycle impacts. Throughout her career, Lily has developed analytical chemistry methodologies for both liquid- and solid-phase analyses.

RESEARCH AND PROFESSIONAL EXPERIENCE:

March 2024 – Present: Carbon Removal Verification Engineer, 350Solutions

Verify CDR technologies on behalf of registries and the XPRIZE Carbon Removal challenge.

Specializes in mineralization pathways, including mineralization kinetics, measurement methods, and open-system modeling.

Nov 2022 – Feb 2024: Researcher, Lithos Carbon

Quantified carbon removal rates and agronomic impacts of enhanced weathering on cropland across six US states; Evaluated chemical analysis methods for precision relative to cost.

Nov 2023 – Jan 2024: Independent Consultant, Keel Labs

Built an environmental impact model to evaluate potential material and process changes; Recommended areas for reducing material usage up to 80%

Dec 2020 – Oct 2022: Research Scientist II, Biomason

Guided experimentation and data analysis throughout all R&D teams to inform techno-economic analysis (TEA) and LCA; built and led the carbonate biomineralization prototyping workstream for rapid iteration; developed real-time measurement techniques for critical process parameters in solid state

SELECTED PUBLICATIONS & PRESENTATIONS:

- **Schacht, L.**, Baum, M., Liu, H., & Yap, M. (2023) Scaling Enhanced Rock Weathering: Agronomic Impacts at Field-Scale [[Abstract](#)]. ASA, CSSA, SSSA International Annual Meeting, St. Louis, MO.
- **Schacht, L.** and Ginder-Vogel, M. Arsenite Depletion by Manganese Oxides: A Case Study on the Limitations of Observed First Order Rate Constants. *Soil Syst.* 2018, 2(3), 39. <https://doi.org/10.3390/soilsystems2030039>

Tim Hansen, P.E.
Founder and CEO, 350Solutions

EDUCATION:

B.S., Chemical Engineering, University of Virginia, 1993

M.S., Engineering Science, Thayer School of Engineering, Dartmouth College, 1995

EXPERIENCE SUMMARY:

Mr. Hansen has 28 years of experience in management of energy and environmental technology development and demonstration projects and programs, as well as multimedia environmental engineering efforts. The majority of his recent work has focused on the evaluation of carbon removal (CDR) technologies, including validation of projects and verification of credits for multiple CDR pathways. Mr. Hansen's primary technical focus has been the management and technical performance of large technology evaluation programs in the advanced energy, transportation, and climate change areas, with a specific focus on verification of innovative low-carbon and carbon removal technologies.

RESEARCH AND PROFESSIONAL EXPERIENCE:

2019-Present Founder – CEO, 350Solutions, Inc.

Owns and operates a small cleantech engineering consulting business focused on the independent evaluation of new cleantech and low-carbon innovations and their impacts, with a current focus on carbon removal technologies. Provides independent technology verification, carbon removal credit verification, engineering consulting, testing and evaluation, techno-economic assessment, and other support to companies developing, using, or investing in new low-carbon technology innovations.

2012-2019: Director - Energy and Environment, Southern Research

Managed scientific and technical staff performing research, development, and evaluation of innovative clean energy technologies. Projects range from \$25,000 to \$6 million in size. Technical focus areas included biofuels and biochemicals, carbon capture and utilization, and renewable energy.

PROJECT EXPERIENCE:

Mr. Hansen has executed several independent technology performance verifications of emerging climate tech and carbon tech innovations, as CEO of 350Solutions, Director of Energy & Environment at Southern Research, and Director of the U.S. EPA's Greenhouse Gas Technology Center. Mr. Hansen has recently focused on carbon removal technologies, completing verifications of carbon removal credit projects (biochar, carbonated materials, biomass injection) for registries, due diligence audits of enhanced weathering, DAC, direct ocean capture, and CO₂ to polymer technologies for credit offtake buyers, and leading development of independent methodologies for bio-oil sequestration for a novel CDR registry. Mr. Hansen has completed clean technology evaluations for various commercial and government clients, involving evaluation of commercial feasibility, economic and environmental impacts, and technology performance. Mr. Hansen has evaluated and verified technologies for the XPRIZE Carbon Removal in 2022 and 2024 and served as the contracted Measurement and Verification Program Lead for the NRG COSIA Carbon XPrize. Mr. Hansen served as U.S. Technical Expert for the development and implementation of ISO 14034 – Environmental Technology Verification.

RECENT PUBLICATIONS:

- Hansen, et al. Pilot Scale Demonstration & Independent Verification of Carbon Utilization Technologies for the NRG COSIA Carbon XPRIZE. TechConnect Briefs 2019. June 17, 2019.
- Tim Hansen, Kevin McCabe, Bill Chatterton, Michael Leitch, Integrating the ISO 14034 standard as a platform for carbon capture and utilization technology performance evaluation, *Clean Energy*, Volume 5, Issue 4, December 2021, Pages 600–610, <https://doi.org/10.1093/ce/zkab033>

VERONICA TAMSITT

EDUCATION

Ph.D. Oceanography, Scripps Institution of Oceanography, UC San Diego, 2018

Thesis: Aspects of the three-dimensionality of the Southern Ocean Overturning Circulation

B.Sc. Oceanography with Honors, University of Washington, 2012

Thesis: Nitrous Oxide in the eastern tropical North Pacific

EXPERIENCE

Submarine PBC – Remote

2023 –

Co-founder and Head of Oceanography

University of South Florida – St Petersburg Florida/Remote

2021 – 2023

Research Scientist

University of New South Wales and Centre for Southern Hemisphere Oceans Research CSIRO Oceans and

Atmosphere – Australia / Remote

2018 – 2021

Postdoctoral Research Associate

Scripps Institution of Oceanography, UCSD – San Diego, CA

2012 – 2018

Graduate Student Researcher

Stable Isotope lab, University of Washington,

Department of Oceanography – Seattle, Washington

2010 – 2012

Undergraduate Student Researcher

SELECTED PUBLICATIONS

Dawson, H. R., England, M. H., Morrison, A. K., **Tamsitt, V.**, & Fraser, C. I. (2024). Floating debris and organisms can raft to Antarctic coasts from all major Southern Hemisphere landmasses. *Global change biology*, 30(8), e17467.

Bach, L. T., **Tamsitt, V.**, Baldry, K., McGee, J., Laurenceau-Cornec, E. C., Strzepek, R. F., ... & Boyd, P. W.

(2023). Identifying the Most (Cost-) Efficient Regions for CO₂ Removal With Iron Fertilization in the Southern Ocean. *Global Biogeochemical Cycles*, 37(11).

Tamsitt, V. (2023). New insights into air-sea fluxes and their role in Subantarctic Mode Water formation.

Philosophical Transactions of the Royal Society A, 381(2249).

Xie, Y., **Tamsitt, V.**, & Bach, L. T. (2022). Localizing the southern ocean biogeochemical divide. *Geophysical Research Letters*, 49(8), e2022GL098260.

Bach, L., **V. Tamsitt**, J. Gower, C. L. Hurd, J. A. Raven, P. W. Boyd (2021). Testing climate intervention with ocean afforestation using the Great Atlantic Sargassum Belt. *Nature Communications*, 12(1), 1-10.

V. Tamsitt (2018). Moving Windows to the Deep Ocean. *Nature Climate Change*, 8(11), 941-942

Tamsitt, V., H. Drake, A. K. Morrison, L. D. Talley, C. O. Dufour, A. R. Gray, S. M. Griffies, M. R. Mazloff, J. L.

Sarmiento, J. Wang, And W. Weijer, (2017). Spiraling Pathways Of Global Deep Waters To The Surface Of The Southern Ocean. *Nature Communications*, 8, 172.

SELECTED CONFERENCE & WORKSHOP PRESENTATIONS

V. Tamsitt, 2022. *Invited panelist on marine Carbon Dioxide Removal permanence*, Ocean Carbon and Biogeochemistry Marine Carbon Dioxide Removal Measurement Reporting and Verification (mCDR MRV) Workshop, University of Rhode Island, USA

V. Tamsitt, 2022. *New understanding of air-sea fluxes and their role in water mass formation*, Invited oral presentation, Royal Society Discussion Meeting on Southern Ocean heat and carbon uptake, London, UK

GRANTS AND FUNDING

Collaborative Research: Diagnosing the role of ocean eddies in carbon cycling from a high resolution data-assimilating ocean biogeochemical model

NSF Office of Polar Programs, co-Investigator changed to Principal Investigator

Amount: \$288,000 | Duration: 2022 - 2025

The Role of Cyclonic Upwelling Eddies in Southern Ocean CO₂ Flux

NSF Office of Polar Programs, co-Investigator

Amount: \$1.1M | Duration: 2021 - 2024

Biogeochemical Argo synthesis products of oxygen, nitrate, and pH for increased community utilization of autonomous profiling observations

NOAA Climate Program Office, co-Investigator

Amount: \$130k | Duration: 2021- 2024