REGEN REGISTRY

Methodology to Integrate Algae Wastewater Treatment Technologies to Avoid Emissions from Grey Infrastructure Wastewater Management Systems v1

External R1 Review Round

Reviewer #1

Date: April 1, 2025

CONTENT referenced by reviewer's comment *e.g. Section number + paste exact text*	**REVIEWER'S COMMENT** *Please paste the comment from the reviewer*	**AUTHOR'S RESPONSE** *Please describe how the comment was addressed and include new content in quotations*	**Reviewer's Conclusion** [PASSED/ REJECTED *WITH COMMENTS*]
e.g. 2.1 - "approximately 25%	***e.g. Replace*** *with "adequate"*	*e.g. This was changed to* ***"The majority of the material must have a moisture content of 25% or less, as measured in the field."***	*PASSED*
Monitoring requirements - pg 4: "Project Proponents must measure key parameters such as nutrient concentrations in influent and effluent, direct GHG emissions, and system	Could you elaborate on why this monthly time resolution was chosen? Specifically, how was it determined that this frequency is sufficient to capture operational fluctuations, or	Monthly monitoring was selected as a balance between scientific rigor, operational feasibility, and data reliability. This frequency aligns with established industry norms for environmental monitoring and is	*PASSED*

energy and material usage. Monitoring shall occur at regular intervals, with nutrient and GHG measurements taken monthly and energy and material usage tracked continuously."	potential anomalies in system performance that could affect the accuracy of GHG reduction estimates?	sufficient to capture the seasonal and operational variability typical in wastewater treatment systems. Specifically: · **Temporal Resolution vs. System Dynamics:** Nutrient loads, energy use, and GHG emissions in wastewater treatment facilities tend to vary on seasonal or weekly cycles rather than daily. Monthly sampling provides an adequate resolution to detect meaningful trends, sustained anomalies, or performance degradation over time without being confounded by short-term noise or transient fluctuations. · **GHG Estimation Integrity:** Monthly monitoring ensures that persistent changes such as a drift in N_2O emissions or biosolids generation are captured and incorporated into life cycle-based emissions accounting. Short-lived events (e.g., a brief equipment failure) would not significantly bias annualized emissions estimates, particularly when uncertainty is also explicitly quantified (per Section 3.1.1.7). · **Regulatory and Practical Alignment:** Monthly frequency is consistent with	

		regulatory monitoring requirements for key parameters like nutrient concentrations (e.g., EPA National Pollutant Discharge Elimination System permits), and aligns with operational staffing and lab analysis capabilities, reducing the risk of data gaps or quality control failures. · **Cost-Effectiveness for Long-Term Verification:** The 20-year crediting period necessitates a monitoring approach that is both sustainable and resource-efficient. Monthly monitoring reduces the burden on facility operators while supporting robust trend detection, validation of modeled assumptions, and early identification of performance anomalies. In summary, the monthly interval reflects a pragmatic and scientifically justified monitoring cadence that ensures credible GHG reductions without imposing unnecessary cost or complexity. Project Proponents may choose higher-frequency monitoring if project-specific risk or system dynamics warrant it, and are encouraged to integrate continuous data sources (e.g.,	

		electricity meters, in-situ sensors) where feasible. Changes to methodology: Language has been added to clarify that the monthly sampling frequency is sufficient when paired with formal uncertainty quantification measures (Section 3.1.1.7), ensuring robust GHG estimates without unnecessary monitoring burden. "This monthly frequency reflects a balance between operational feasibility and scientific rigor, and when combined with the uncertainty quantification requirements outlined in Section 3.1.1.7, ensures that potential variability in system performance is adequately captured and accounted for in GHG reduction estimates; however, Project Proponents may adopt higher-frequency monitoring where project-specific dynamics or risk factors warrant increased temporal resolution."	
Section 1.2 Normative References	While the methodology is presented as being globally applicable, the majority of the normative references—such as TRACI v2.1, NREL Cambium,	While the methodology includes U.S.-based normative references such as TRACI v2.1, NREL Cambium, and EPA regulatory frameworks, these are intended as examples	*PASSED*

	and EPA Water Quality Standards—are primarily U.S.-based tools and datasets. Given the regional specificity of these references, particularly in terms of electricity grid emissions, environmental impact categories, and regulatory standards, how do you envision ensuring applicability and consistency for project proponents operating in non-US contexts?	of accepted tools rather than prescriptive requirements. Project Proponents operating outside the U.S. are expected to substitute regionally appropriate equivalents that align with the methodological intent, namely, to ensure rigorous, transparent, and reproducible estimation of environmental impacts. To maintain consistency and credibility across geographies: · **Life Cycle Impact Assessment (LCIA) tools** such as **ReCiPe** or **ILCD** may be used in place of TRACI where more regionally appropriate. · **Electricity grid emissions data** must reflect the host country's actual or projected grid mix, using sources such as **IEA**, **national inventories**, or regional grid operators in place of Cambium. · **Water quality standards** and regulatory benchmarks should be based on national or local regulations, with documentation provided to demonstrate comparability to U.S. EPA standards where relevant.	

		A clarification has been added to the methodology to emphasize that Project Proponents must use geographically relevant datasets and impact assessment methods, while maintaining methodological alignment with ISO 14040/14044 and ensuring full transparency in documentation and justification. Changes to methodology: Added new definitions for ReCiPe, ILCD, IEA to Section 1.2. Added global context to sections 3.1.1.4 and 3.1.16. The existing methodology already references EcoInvent as well which is a global data set.	
Section 3.1: "Baseline Scenario Validation: Identify gray infrastructure and algae-integrated treatment technologies that can deliver comparable performance in meeting the project objectives. Both options must be capable of achieving similar water quality outcomes."	In the baseline scenario validation section, the term "water quality outcomes" is used as a benchmark for comparability between gray infrastructure and algae-integrated systems. Could you clarify how Project Proponents should address situations where multiple pollutants (e.g., nitrogen, phosphorus, BOD, pathogens) are regulated and may require	The methodology requires that algae-integrated systems achieve **comparable or better water quality** than the gray infrastructure baseline. Both systems must be capable of delivering treatment performance that meets the defined project objectives, including regulatory thresholds for pollutants such as nitrogen, phosphorus, BOD, and pathogens. The methodology does not prescribe specific treatment approaches, recognizing that facilities may face varying regulatory and operational	PASSED

	different treatment approaches or performance standards?	contexts. In cases where multiple pollutants must be addressed, it is the responsibility of the Project Proponent to demonstrate that the algae-integrated system provides equivalent or superior water quality performance relative to the gray infrastructure baseline. To reinforce this requirement, language has been added to the methodology to make explicit that similar or better water quality must be achieved, and that differences in treatment approach or system configuration are acceptable so long as performance equivalence is maintained.	
Section 3.1: 4 Perform an LCA: Analyze the GHG emissions associated with the construction, operation, and decommissioning of the selected baseline (gray infrastructure) and the algae-integrated alternative. Both LCAs must adhere to ISO 14040 standards to ensure accuracy and consistency.	In Section 3.1, Step 4, the methodology requires performing an LCA to compare the GHG emissions of the selected gray infrastructure baseline and the algae-integrated alternative, in accordance with ISO 14040 standards. To ensure consistency and comparability across projects, could you please clarify the expected system boundaries for the LCA of the gray infrastructure?	The system boundary for both the gray infrastructure and algae-integrated systems is explicitly defined in Section 3.1.1.2 (Functional Unit and System Boundaries). That section establishes that the boundary must include all relevant processes construction, operation, and end-of-life disposal ensuring a consistent and comprehensive comparison aligned with ISO 14040 standards. As such, we have not reiterated this boundary definition in Section 3.1.1.4, which focuses on the broader LCA assessment phase. We believe this avoids redundancy while maintaining clarity.	PASSED

Section 3.1.1.2 pg. 12: "The functional unit is defined as 1 cubic meter (m3) of treated water."	The current definition of the functional unit as 1 cubic meter of treated water may not ensure a consistent or equitable comparison between algae-based and gray infrastructure systems, particularly in cases where the algae system significantly outperforms the gray system in removing certain pollutants. In such scenarios, a volume-based functional unit could undervalue the environmental benefits of the algae-based approach. To better reflect differences in treatment effectiveness—especially when multiple pollutants are regulated—it may be more appropriate to define the functional unit based on the total mass of pollutants removed (e.g., kg of total nitrogen, phosphorus, or combined load), or to normalize impacts per unit of pollutant removed.	The functional unit of 1 cubic meter (m^3) of treated water is a standard convention in the peer-reviewed literature and LCA practice for evaluating wastewater treatment systems. This volume-based approach enables consistent, scalable comparisons across technologies and aligns with ISO 14040/14044 guidance, which emphasizes clarity and reproducibility in functional unit selection. While we recognize that algae-integrated systems may in some cases outperform gray infrastructure on specific pollutants, the methodology already requires that comparable or better water quality outcomes be achieved (see Section 3.1.1.1). This ensures that emissions reductions are evaluated on a like-for-like basis. Using a mass-of-pollutant-removed functional unit could introduce inconsistencies in scenarios where multiple regulated constituents are present, each with different treatment targets and removal pathways. Therefore, we have retained the volume-based functional unit while requiring comparable pollutant reduction performance, which together	PASSED

		ensure both methodological rigor and environmental relevance.	
Section 3.1.1.3 Phase 1: Life Cycle Inventory "Collecting emissions data from reliable databases such as eGRID or Ecoinvent"	The methodology references the use of eGRID as a source for emissions factors associated with electricity use. However, it's important to note that eGRID only accounts for direct (Scope 1) emissions from electricity generation at the point of combustion, and does not include upstream life cycle emissions associated with fuel extraction, processing, or transport (eGRID Documentation). Since the methodology aims to support life cycle assessments (LCAs) in accordance with ISO 14040, we recommend clarifying this distinction and suggesting the use of life cycle–based data sources (e.g., Ecoinvent, GREET, or region-specific LCI databases) when a full life cycle perspective is required.	We agree that eGRID provides only direct (Scope 1) emissions and does not capture upstream life cycle emissions associated with electricity generation. Given the methodology's alignment with ISO 14040 and its support for comprehensive life cycle assessment, we have revised the relevant section to remove the reference to eGRID and instead recommend life cycle–based data sources. Specifically, the methodology now references EcoInvent, the GREET model and the U.S. Life Cycle Inventory (LCI) Commons database as appropriate sources for electricity-related emission factors, consistent with a full LCA boundary. Changes to the Methodology: Section 3.1.1.3 "Collecting emissions data from reliable databases such as Ecoinvent, US LCI Commons, ANL GREET, or similar databases.	PASSED
Section 6.3 Monitoring Locations and Frequency "Data collection frequency	The methodology requires monthly monitoring of critical parameters such as N_2O, NH_3, and nutrient concentrations, but does	We appreciate this thoughtful comment and agree that the nitrogen composition of algae biomass can be highly variable, influenced by harvest timing,	PASSED

should adhere to regulatory requirements but must occur at least monthly for critical metrics like N2O, NH3, and nutrient concentrations.”	not clearly justify why monthly resolution is appropriate. In algae-based systems, nitrogen uptake can vary significantly from harvest to harvest, and harvesting schedules themselves can differ based on species, climate, and operational strategy. Given this variability, monthly sampling may miss important fluctuations in nutrient removal efficiency and associated GHG dynamics	species, and environmental conditions. However, the proposed methodology does not require tracking nitrogen content in the algae biomass itself. Instead, it focuses on measuring nitrogen concentrations in the effluent discharged from the algae-integrated treatment system, which is the relevant parameter for evaluating nutrient removal performance and environmental compliance for wastewater treatment. This effluent-based approach aligns with regulatory monitoring practices and ensures that nutrient removal is assessed based on the treated water quality delivered to the receiving environment. Monthly sampling of effluent nutrient concentrations is considered sufficient to capture operational trends and long-term treatment performance, while maintaining feasibility for project proponents.	
Pg. 9 Section 2.Project Boundary: “The project boundary for this methodology is defined as the physical and operational scope	There appears to be an inconsistency in the definition of the project boundary. The opening statement frames it as limited to the physical and operational scope of the facility, but later language expands the	Thank you for identifying this important issue. We agree that there was an inconsistency in the definition of the project boundary, and this distinction is critical to the integrity of the methodology. In response, the methodology has been revised to clearly differentiate between the	PASSED

of the wastewater treatment facility where the algae-integrated nutrient removal system is implemented. This includes all processes and infrastructure directly involved in nutrient removal and associated GHG emissions" Pg. 10 : Section 2. "The project boundary includes upstream and downstream activities not directly controlled by the facility, such as the production of materials... or the final disposal of effluent or biosolids..."	boundary to include upstream and downstream life cycle stages (e.g., material production and effluent disposal). Additionally, the final sentence suggests that all measurable reductions occur within the facility, which contradicts the inclusion of external processes. We recommend the methodology clearly distinguish between: The project boundary (used for monitoring and verification within the facility), and The LCA system boundary (used for comparing treatment alternatives via life cycle analysis).	project boundary (used for monitoring, reporting, and crediting within the facility) and the life cycle assessment (LCA) system boundary (used for comparing treatment alternatives). This correction aligns with the intent of the methodology and supports both transparency and methodological rigor. Changes to the Methodology: the text in section 2. Has been updated to clarify and accurately describe the project and system boundary.	

Pg. 7 Section 1.1 Scope: "Avoided GHGs from the production of algae-based products that replace traditional products."	While the methodology acknowledges that avoided GHGs from the production of algae-based products that replace traditional products may be considered, this aspect remains vague and underdeveloped. Co-product treatment is a critical component of accurate life cycle assessment and carbon credit quantification—particularly for algae systems, which can yield a variety of valuable outputs such as biofuels, fertilizers, animal feed, bioplastics, or soil amendments. We recommend that the methodology provide clearer guidance on how to treat these co-products, including: Whether and how avoided emissions from displaced conventional products can be credited; The accounting approach to use (e.g., system expansion, allocation by mass, energy, or economic value);	We appreciate this detailed and important comment. We agree that the treatment of co-products and associated avoided emissions is a critical component of life cycle assessment, particularly in algae-based systems where outputs such as biofuels, fertilizers, or animal feed may displace more carbon-intensive alternatives. To address this, we have revised the methodology to clarify the following: 1. Crediting of Avoided Emissions: Avoided emissions resulting from the displacement of conventional products by algae-derived co-products may be included in the life cycle assessment. However, such claims must be supported by transparent, defensible justification and subject to third-party verification. 2. Accounting Approach: Project Proponents may use system expansion or allocation (by mass, energy, or economic value) consistent with ISO 14044 guidelines. The selected approach must be applied consistently and documented clearly, including sensitivity analysis where relevant. 3. Double Counting: To prevent double counting, credits may not be claimed for the same emissions reductions in more	PASSED

	How to ensure no double counting of emissions reductions if these co-products are credited in other carbon markets or policies (e.g., LCFS, biofuel credits); Treatment of uncertainty and market variability in product displacement assumptions.	than one carbon market or regulatory framework. If a co-product is already receiving credits under another mechanism (e.g., LCFS), those emissions reductions must be excluded from the net GHG benefit claimed under this methodology. 4. Uncertainty and Market Variability: Project Proponents must provide reasonable and evidence-based assumptions for displacement effects, and disclose uncertainty through sensitivity analysis or Monte Carlo simulation as described in Section 3.1.1.7. These clarifications ensure the methodology remains flexible across diverse algae-based applications while maintaining scientific rigor and environmental integrity. Changes to Methodology: A new section "3.1.1.6" has been added to detail how to deal with co-product allocation and additional language has been added to section 3.1.1.8 to support uncertainty with co-products.	

REGEN REGISTRY

Section 3.1.1.1 LCA Goal and Scope Definition: Item 2; “System boundaries must be consistent across both technologies and focus solely on direct impacts (e.g. direct emissions, operational energy use, and material consumption) and not include consequential emissions.	Replace “direct impacts” with “attributional impacts”.	This change has been made. Thank you.	

REGEN
REGISTRY

Reviewer's Blind Review Comments regarding Protocol/Methodology

Kindly enter your comments based on these questions in the table below. Also, if referencing specific text, please include text excerpt or row/page number from the protocol/methodology for ease of reference by the authors. All reviewer comments will remain anonymous unless you choose to be named.

Is the protocol/methodology clearly written with adequate detail for implementation?	Yes, the methodology is well-developed and clearly articulated. The authors have done a great job at providing sufficient technical detail and maintaining generalizability for broader implementation.
Is the underlying foundation of the protocol/methodology clear?	Yes, the authors clearly described the life cycle assessment approach used to compare algae-integrated wastewater treatment systems with conventional gray infrastructure. The methodology provides a solid foundation by detailing system boundaries, life cycle data sources, temporal aspects, and emission sources considered in the analysis.
Is the protocol/methodology feasible?	Yes. The authors have provided a clear and well-structured description of the monitoring, reporting, and carbon credit quantification methods, using established sampling protocols and reputable databases.
Are there any alternative or additional points that should be considered?	No, all my points and concerns have been addressed in the updated methodology document.

Will the proposed guidelines and regulations achieve the results defined in the protocol/methodology?	Yes, the proposed regulations (e.g. stricter nitrogen limits) can help achieve the results defined in the protocol by incentivizing adoption of algae-integrated treatment systems. The methodology outlines a clear framework for implementation including monitoring, life cycle assessment, and verification procedures to ensure that these systems deliver measurable and credible GHG reductions.

Recommendation

Kindly mark with an X

Accept As Is:	
Requires Minor Revision:	X
Requires Moderate Revision:	
Requires Major Revision:	
Reject and Re-submit:	
Rejection: (Please provide reasons)	

General/Additional Comments: