Public Project Description

This document is a project description made available in the Puro Registry to summarize the information available about a certified production facility. The project description is organized as follow:

1 Production Facility and Supplier information

This project description corresponds to the following **Production Facility** and **CO_2 Removal supplier**, acting as registering entity of the facility.

Production Facility	
Production Facility name	Bio-Logical Carbon (Mt Kenya)
Registration date (YYYY-MM-DD)	2023-12
Production Facility ID	14227765
Location of facility	Kabati - Thika
Host Country of removal	Kenya
Has this facility been registered in another registry?	☒No ☐Yes, additional information (registration periods):
This table is filled in by the CO_2 Removal Supplier.	

CO_2 Removal Supplier	
Supplier name	Bio-Logical Carbon Ltd
Supplier address	Kabati – Thika, Kenya
Business ID	14227765
KYC status	Completed
This table is filled in by the CO_2 Removal Supplier.	

The above-mentioned production facility has undergone the following audit, during which the project description, alongside other audit documents were verified.

Facility Audit	
Type of audit	Combined Facility and Output Audit
General Rules version	4.1
Methodology name	Biochar
Methodology edition and version	Edition: 2022 Version: 3
Date of audit completion	2025-07-29
Conclusion of audit	Based on the verification process, EnergyLink Services observed that in general, the organisations had the appropriate processes and procedures in place to quantify the production of CO2 removal and is compliant with the requirements of the Puro General Rules .

	EnergyLink Services have verified that the calculation of CO2 removal achieved through the production of biochar for the period 22 March 2024 to 28 February 2025 has been prepared in accordance with the Puro.earth Biochar Methodology.
Auditing body	Name of audit company
Start date of crediting period	2024-05-22
End date of crediting period	2029-03-22
This table is filled in by the Issuing Body.	

2 Overview of activity, its location, and operators

The information in this section provides an overview of how and where carbon dioxide removal is achieved, and by whom.

2.1 Non-technical description

Instructions	*Please provide a non-technical description of the carbon removal activity taking place at the production facility. Word limit: 100 words.*
Non-technical description	Bio-Logical Carbon Ltd. transforms agricultural waste and invasive species (Prosopis juliflora and macadamia shells) into biochar to support local smallholder farmers vulnerable to climate change. With an annual processing capacity of 15,000 tons of biomass, our facility produces 5,000 tons of high-quality biochar, one of the largest outputs in Africa. This biochar is then converted into granulated bio-fertilizer, blending finely ground biochar with premium compost and microbes to enhance soil structure, water retention, and fertility. Our mission is to sequester 1 million tons of CO_2 by 2030, directly benefiting 1 million smallholder farmers.
This table is filled-in by the supplier and verified by the auditor.	

2.2 Locations

Instructions	*Please provide a list of locations associated with the carbon removal activity. Additional locations or areas can refer to e.g. the location of the storage site, the spatial extent of the area of use of a carbon removal product or sourcing of a specific feedstock.*
Production Facility Location (as registered)	Address: Kabati – Thika, Kenya Coordinates (WSG84, decimal format): Latitude: 0.9496 ° S Longitude: 37.1017 °E
Additional location(s)	*Specify purpose, location, address, coordinates, to the extent possible, for one or multiple additional locations relevant to the removal activity.* NA
This table is filled-in by the supplier and verified by the auditor.	

2.3 Operators

Instructions	*Please provide a full list of operators or organizations that contribute to the removal activity. Add rows as necessary. For each entity, provide the name, a business ID, an address, and the role of the entity.*
CO_2 Removal Supplier	*Entity name: Bio-Logical Carbon Limited* *Entity business ID: PVT-27U5DQY5* *Entity address:* Old Mutual Tower, Upperhill Road, Dagoreti District, Dagoretti, NAIROBI, P.O. Box 43013, Kenya *Role of entity: Project Developer*
Organization 2	*Entity name: Bio-Logical Carbon Ltd* *Entity business ID: 14227765* *Entity address: GROVE FARM NORTHAMPTON ROAD* *WEST HADDON* *NORTHAMPTON* *ENGLAND NN6 7AS* *Role of entity: Shareholder*
Organization 3	*Entity name: NA* *Entity business ID: NA* *Entity address: NA* *Role of entity: NA*
This table is filled-in by the supplier and verified by the auditor.	

3 Technical description of the removal activity

The information in this section provides more technical details about the technologies and processes deployed to achieve carbon dioxide removal.

3.1 Technical description

Instructions	*Please provide a technical description of the carbon removal activity taking place at the production facility. Word limit: 500 words.*
Technical description	**Technical Description** *Technology Used* The Mingyang pyrolysis machinery operates using a batch retort pyrolysis system. This system is designed for the efficient conversion of biomass feedstock into biochar through a controlled, low-oxygen thermal decomposition process. *Reactors Employed* The facility employs batch retort kilns, specifically chosen for their modular operation, allowing individual kilns to be taken offline for maintenance

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without shutting down the entire system. Each kiln consists of internal baskets with piping to facilitate heat distribution and uniform carbonization.

Combustion Chamber and Injection Points

- The combustion chamber is externally heated using volatiles and syngas emitted during pyrolysis.
- Each kiln has injection points for controlled heating, ensuring gradual and uniform temperature increase.
- Excess volatiles are redirected to preheat subsequent kilns, improving energy efficiency and reducing emissions.

Flue Gas Treatment

- The system includes a spray tower and condensers to capture particulates, cool exhaust gases, and reduce emissions.
- The system features a separator for capturing bio-oil and vinegar, enhancing environmental performance and creating additional byproducts.

Feedstocks Used

- The primary feedstocks used include macadamia shells and Prosopis Juliflora, an invasive species, for large-scale biochar production.

Feedstock Processing

- Pre-processing steps involve sieving and drying, ensuring moisture content is optimized for pyrolysis.
- No additional grinding is required as the feedstock is introduced in chunk or shell form.
- Feedstock is loaded into steel baskets, which are then inserted into the kilns.

Main Elements of the Supply Chain

1. Feedstock Sourcing: Biomass is collected from agricultural waste streams (e.g., macadamia shells) and invasive species removal projects (Prosopis Juliflora).
2. Processing and Transportation: The feedstock is transported to the facility, where it undergoes minimal pre-processing before being loaded into the kilns.
3. Biochar Production: Pyrolysis is conducted in batch cycles, optimizing energy use through heat recirculation.
4. Byproduct Recovery: Bio-oil and vinegar are captured for potential resale or reuse.

	5. Biochar Distribution: The final product is packaged and either sold as a standalone material or integrated into bio-fertilizers.
	
	Byproducts and Wastes
	
	• Bio-oil: Certified for use as tarmac (and a fuel)
	• Wood Vinegar (Acetic Acid): Can be used as an organic pesticide or soil amendment.
	• Flue Gas: Treated through a spray tower and condensers to minimize particulate emissions and burnt to fuel pyrolysis.
	• Ash: No ash produced
	
	Annual Input/Output Rates
	
	• Feedstock Input: Each kiln holds 1 tonne of feedstock per batch.
	• Daily Output: A system with four kilns can process up to 12 tonnes of feedstock per day, yielding approximately 4 tonnes of biochar daily.
	• Annual Production:
	  ○ Assuming 6 operating days per week and accounting for maintenance days, the estimated annual output is:
	    ▪ Biochar: 1200 tonnes per year.
	    ▪ Byproducts: Bio-oil: 72,000l & Vinegar 360,000l

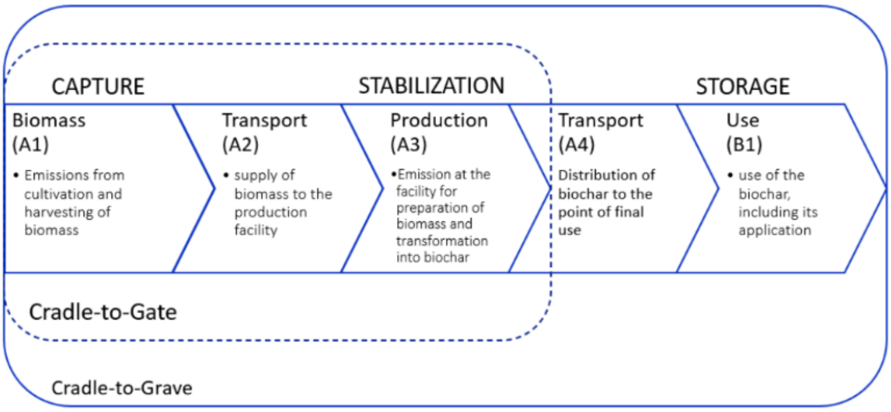
This table is filled-in by the supplier and verified by the auditor.	

3.2 Illustration

Instructions	*Please provide up to three illustrations of the process and technologies described above (e.g. picture of equipment, flowcharts of process).* *Note that you must own the rights to reproduce and publish the illustration and that you also authorize puro.earth to reproduce and publish the illustration in the Puro Registry.*
Authorization to reproduce and publish the illustration	☒ Puro.earth is authorized to reproduce and publish the illustrations below, for use in the Puro Registry.

4 Application of the Puro Standard (boundary, baseline, additionality, quantification)

4.1 Scope and project boundary

Instructions	*Please provide a brief demonstration that the removal activity described above fits within the scope of the methodology and that the system boundaries of the removal activity correspond to the ones defined in the methodology. Word limit: 150 words.*
Scope and system boundary	The system boundary is set cradle-to-grave and includes emissions from harvesting and supply of the biomass, from biomass conversion to biochar through pyrolysis, and from biochar end-use when blended with compost. The Life Cycle Assessment includes disaggregated information on the emissions arising at various stages as illustrated in the diagram below.  where: $E_{biomass}$ = (A1) biomass harvesting + (A2) biomass logistics to processing facility $E_{production}$ = (A3) Biomass preprocessing and thermochemical conversion of biomass to biochar E_{use} = (A4) biochar logistics to its 'grave' + (B1) biochar end-use The composting site is designated as the 'grave' under the Puro.earth biochar methodology, where the final emissions related to biochar crushing and biofertilizer production are accounted for. Since macadamia shells are agricultural waste, no emissions are attributed to their harvest or cultivation. For *Prosopis*, being an invasive species, only the emissions from its harvesting are considered.
This table is filled-in by the supplier and verified by the auditor.	

4.2 Baseline scenario

The information in this section provides a summary of the project-specific ***baseline scenario****.*

Instructions	*Please provide a summary of the project-specific baseline scenario. The summary shall be based on the additionality questionnaire (available separately). Word limit: 150 words.*
Summary of the project-specific baseline scenario	

Macadamia shells are utilized as industrial fuel for boilers and furnaces in factories, while only 0.15% of *Prosopis juliflora*'s total coverage in Kenya is used for charcoal production or timber. There are no net removals in the business-as-usual scenario.
This table is filled-in by the supplier and verified by the auditor.

Further information on the baseline scenario:

Instructions	*If the methodology explicitly defines one or several possible baseline scenarios for the removal activity, please specify which ones was selected:*
Selected baseline scenario	Biomass used as fuel in the baseline scenario
This table is filled-in by the supplier and verified by the auditor.	

4.3 Demonstration of additionality

The information in this section provides a summary of the project-specific ***additionality assessment****.*

Instructions	*Please provide a summary of the project-specific additionality assessment, considering baseline removal, regulatory and financial additionality. The summary shall be based on the additionality questionnaire (available separately). Word limit: 150 words.*
Summary of additionality assessment	
Our projects are additional as they are not mandated by any existing regulations. These projects are voluntarily undertaken to achieve carbon removals that exceed baseline scenarios, which are null. The IRR of the project is –7% without carbon and 27% with carbon. Therefore, the project would not be investable without carbon revenues. The project's Weighted Average Cost of Capital (WACC) is 15% for this project. With revenue from CORCs, the project achieves an Internal Rate of Return (IRR) of 27%. Since this exceeds the calculated WACC, the project is profitable and represents a strong climate finance investment opportunity. A sensitivity analysis shows that without CORC revenue, the project's IRR declines sharply to -7%, underscoring the critical role of climate finance in ensuring the project's financial additionality.	
This table is filled-in by the supplier and verified by the auditor.	

The following files are further made available in the Puro Registry.

Additionality questionnaire (required)	Filename	Puro Additionality v1.9
	Description	Additionality questionnaire signed and audited, used to determine the additionality of the project following the Puro requirements for additionality.
Additional file (optional)	Filename	Bio-Logical Carbon Financial Additionality calculations
	Description	WACC, IRR and Sensitivity Analysis calculations
Additional file (optional)	Filename	Bio-Logical Financial Management Plan V4.2
	Description	Bio-Logical Financial Management Plan

Add rows as necessary, following same template as for additional file. The filename shall be the exact filename as provided in the audit documentation. The description shall be at most a 3-line summary of what the file contains. This table is filled-in by the supplier and verified by the auditor.

4.4 Quantification of net carbon dioxide removal

The information in this section provides a description of how ***quantification of net carbon dioxide removal removals*** *is achieved, including* ***monitoring*** *of the removal activity, and calculation of* ***supply-chain emissions****.*

Quantification implementation

Instructions	*Please describe how the quantification of net carbon dioxide removal, as described in the methodology (see CORC equation), is implemented by the supplier. Word limit: 200 words.*
Description of quantification implementation	
The calculation of CORCs entails determining: • **Biochar's CO_2 Sequestration Potential (E_stored):** Represents the long-term carbon sequestration per ton of biochar applied to soil of soil temperature 20 degrees celcius. The H/C ratio is obtained from regular elemental analysis as certified labs. • **E_biomass:** Accounts for emissions from biomass harvesting and transportation. Transport tracking includes mode, distance, and moisture content, with macadamia traveling 47 km and *Prosopis* 325 km (future facilities will be within 50 km). • **E_production:** Covers emissions from biochar conversion. The facility, powered by Kenya's 92% renewable energy grid, tracks energy use via meters, including diesel preheating. Pyrolysis syngas is recirculated and combusted to optimize efficiency. • **E_use:** Emissions from biochar processing at the composting site are tracked, including energy consumption for crushing biochar and granulation of biofertilizer.	
This table is filled-in by the supplier and verified by the auditor.	

Monitoring and reporting

Instructions	*Please provide a summary of the monitoring procedures and monitoring plan which are in place at the production facility to ensure i) the safety of the removal activity, ii) the eligibility of the removal activity, and iii) the precise quantification of CORCs. The summary shall be project-specific and based on related evidence pieces that were submitted in the audit documentation. Word limit: 500 words.*
Summary of monitoring and reporting plan	
Bio-Logical Carbon has established a comprehensive monitoring plan at its production facility to ensure the safety, eligibility, and precise quantification of CORCs. This monitoring process follows a structured MRV framework that captures data at every stage of biochar production, from feedstock sourcing to final quality control. The monitoring begins with biomass sourcing and logistics, where the procurement team records the origin and transportation distances of all feedstock. To verify biomass weight, the company relies on weighbridge receipts and invoices from suppliers, ensuring accuracy	

in input measurements. Upon delivery, the production team assesses moisture content before loading the biomass into the pyrolysis reactors. During the pyrolysis process, temperature monitoring is conducted to maintain process stability and ensure the completeness of carbonization. Preheating fuel usage and duration are recorded, while kiln temperature is logged every 30 minutes throughout the 8-hour residence time. After pyrolysis, biochar is quenched and offloaded once temperatures reach a safe handling level. The wet mass is immediately measured, and moisture content is determined using a calibrated moisture meter. The dry mass is then calculated and recorded to ensure accurate quantification of CORCs. By following this methodology, Bio-Logical Carbon guarantees the traceability and eligibility of its carbon removal activity. To maintain product integrity, a robust quality assurance system is in place. Daily samples are collected and stored for lab checks, while quarterly samples are sent to independent, accredited laboratories such as Eurofins and Mas Labs in Germany. These external tests analyze biochar carbon content and the hydrogen-to-carbon (H/C) ratio, verifying its stability and environmental quality. The results ensure that the produced biochar meets international biochar standards and remains eligible for carbon credit issuance. In addition to biochar monitoring, Bio-Logical Carbon tracks utility consumption, including electricity and water usage per production unit. This helps optimize resource efficiency while ensuring environmental compliance. Through this monitoring framework, Bio-Logical Carbon ensures that its biochar production remains safe by using well-trained personnel equipped with appropriate PPEs, and meets occupational regulatory criteria.
This table is filled-in by the supplier and verified by the auditor.

Optionally, the following documents may be made available in the Puro Registry once the facility has completed its first Output Audit:

Can the monitoring plan and procedures be made available in the Puro Registry?	
Answer	☐ Yes, entirely. ☐ Yes, in a redacted version. ☒ No. If no, please provide a reason:
Filename(s) to be made public	NA
This table is filled-in by the supplier.	

Supply-chain emissions

The determination of the supply-chain emissions of the removal activity shall be based on a project-specific life cycle assessment, made of a report and calculations. Calculations are updated at least annually, during the Output Audits, with data captured through above-described monitoring.

Instructions	*Please provide a summary or an abstract of the LCA performed. Word limit: 500 words.*
Summary of life cycle assessment	

This Life Cycle Assessment (LCA) evaluates the environmental impact of biochar production in Kenya using macadamia shells and *Prosopis juliflora*. The biochar produced is incorporated into biofertilizer, with pyrolysis gasses sustaining anaerobic combustion in the reactors, while the wood vinegar and tar are sold as a co-product for foliar, and animal feed additive. Trials are ongoing to recycle the wood vinegar and for the tar to be used in road construction.

The LCA adheres to ISO 14040/44 standards and Puro.earth's Biochar methodology, considering cradle-to-grave system boundaries to assess greenhouse gas emissions, carbon removal potential, and CORC (Carbon Removal Certificates) eligibility. The data is sourced from Bio-Logical Carbon's records, ecoinvent's and IPCC emission factors database.

Biochar is produced using a batch reactor set with four kilns (each reactor holds up to 900 kgs of biomass), primarily powered by Kenya's renewable energy grid (92%) to operate its motors, fans and hoist crane. The use of renewable energy greatly reduces the overall environmental footprint of the production process. Total CO_2 emissions per ton of biochar are calculated as 463.99 kgCO_2e for macadamia shells, and 690.35 kgCO_2e for Prosopis. This is expected to decrease significantly as Bio-Logical optimizes its preheating fuel consumption and processes Prosopis biomass sourced within a 50 km radius of its future facility.

The Life Cycle Impact Assessment (LCIA) for one ton macadamia-biochar reveals that transportation emissions from collecting macadamia shells within a 47 km radius of Bio-Logical's production facility amount to 32.37 kgCO_2e. The largest emission source is reactor pre-heating, contributing 293.7 kgCO_2e, while infrastructure and factory building emissions account for 15.60 kgCO_2e and 35.53 kgCO_2e respectively. The smallest emissions come from the end-use application at 2.15 kgCO_2e.

Prosopis sourced from an average distance of 200 km results in transport emissions of 154.80 kgCO2e per ton of biochar produced. The largest emissions contributor, however, comes from preheating fuel, accounting for 211.03 kgCO2e.

The respective E_{stored} (carbon sequestration potential) for each biomass was calculated as: 3214 kgCO_2e (Macadamia shells), and 3073 kgCO_2e (Prosopis). After accounting for system-wide emissions, the net carbon removal is 2750.80 kgCO_2e, and 2382.56 kgCO_2e per ton of biochar blended with compost for each biomass source, respectively.

This table is filled-in by the supplier and verified by the auditor.

Optionally, the following documents may be made available in the Puro Registry once the facility has completed its first Output Audit:

Can the LCA report be made available in the Puro Registry?	
Answer	☒ Yes, entirely. ☐ Yes, in a redacted version. ☐ No. If no, please provide a reason:

Filename(s) to be made public	puro_LCA_Bio_Logical_v2025
This table is filled-in by the supplier.	

5 Social and environmental safeguards

The information in this section provides a summary of the project-specific measures taken to avoid and minimize negative social and environmental effects, as well as maximize positive impacts contributing to the sustainable development goals (SDGs).

5.1 Stakeholder engagement

In line with the Puro General Rules, the CO_2 Removal Supplier must have conducted a stakeholder engagement process and reported its outcome in a written format.

Instructions	*Please reproduce the summary of the stakeholder engagement report. Word limit: 500 words.*
Summary of stakeholder engagement	
Bio-Logical Carbon has undertaken extensive stakeholder engagement as part of the development and operation of its carbon removal facility. This engagement has been structured to ensure transparency, inclusivity, and responsiveness. The primary stakeholders identified include local community residents, business owners, adjacent landowners, and representatives of local authorities (assistant chiefs and police). Key organizations such as Apollo Agriculture, WRI, KALRO, and NEMA have been identified as critical stakeholders due to their involvement in agriculture, research, and environmental management. Vulnerable groups like the Women Farmers Association of Kenya (WoFaAk) are also primary stakeholders, alongside industry experts in agriculture and environmental management. Several consultation activities have been conducted to inform stakeholders and gather feedback. These included site visits, public meetings, and ongoing focus group sessions with smallholder farmers. A significant public meeting, held in September 2023, involved engagement with local community members and area chiefs, facilitated by NEMA's Environmental Impact Assessment (EIA) process. Regular training sessions for farmers, aimed at raising awareness about biochar and sustainable farming practices, have also been a core part of stakeholder interaction. Feedback from stakeholders has generally focused on ensuring local community involvement, particularly regarding job opportunities and supply sourcing. There was strong encouragement to prioritize local hiring and supply procurement, to which Bio-Logical Carbon responded by committing to source feedstock from within a 60 km radius and by offering merit-based local hiring preferences. This aligns with the company's broader commitment to community development and its environmental objectives. Bio-Logical has developed a strategy for continued consultation. This includes compliance with annual licensing requirements from NEMA to ensure ongoing environmental protection. Regular consultations will also be maintained with local stakeholders through continued training sessions	

and collaborations with partners like WRI and KALRO. The company will continue to adhere to local government licensing requirements, ensuring a steady dialogue with relevant authorities. Finally, Bio-Logical Carbon plans to keep stakeholders informed about the outcomes of ongoing trials related to biofertilizer quality and the project's broader environmental impacts.
This table is filled-in by the supplier and verified by the auditor.

In addition, the following documents are made available in the Puro Registry once the facility has completed its first Output Audit:

Stakeholder Engagement Report (required)	Filename	Bio-Logical Carbon Stakeholder Engagement Report
	Description	Stakeholder engagement report completed and audited, following the Puro requirements for stakeholder engagement.
The filename shall be the exact filename as provided in the audit documentation. This table is filled-in by the supplier.		

5.2 Environmental and social safeguards

In line with the Puro General Rules, the CO_2 Removal Supplier must ensure that environmental and social safeguards are in place.

Instructions	*Please summarize the environmental and social impacts relevant to the project, based on the answers provided to the corresponding questionnaire in the audit documentation. Word limit: 500 words.*
Summary of environmental and social safeguards questionnaire	
Environmental and social risks are identified through environmental impact assessments, stakeholder consultations, and continuous monitoring. Mitigation measures include dust control, emission management, safe effluent disposal and responsible water use. Social initiatives focus on job creation, gender equality, and worker safety. Bio-Logical ensures compliance with national laws; DOSH, OSHA, and NEMA. Key compliance documents include business licenses, NEMA air quality and noise permits, OSHA certification, and KEBS/Ecocert certification for biofertilizer. Bio-Logical adheres to Kenya's Employment Act and ILO labor standards, prohibiting forced and child labor. Fair wages, safe working conditions, and non-discriminatory policies are enforced through regular audits and contracts. Identified occupational hazards include air pollution, noise, extreme heat, and manual handling risks, which are mitigated through PPE, training, and ventilation systems. The company promotes gender equality, ensuring equal pay and workplace safety through structured salary scales and grievance mechanisms. The facility meets pollution control standards, with pyrolysis machinery minimizing air pollution, wastewater repurposed as co-products, and solid waste managed by a NEMA-certified contractor. Noise and vibration levels are controlled through secure equipment installation. The company follows biodiversity conservation measures, mitigating habitat disturbances through phased harvesting and land restoration partnerships. Soil erosion risks from *Prosopis* removal are addressed through collaboration with organizations like the Kenya Ecosystem Restoration Alliance.	

The facility does not impact high-value ecosystems, as all biomass harvesting follows Kenya Forestry Service regulations.
This table is filled-in by the supplier and verified by the auditor.

In addition, the following document is made available in the Puro Registry once the facility has completed its first Output Audit:

Environmental and Social Safeguards Questionnaire (required)	Filename	Bio-Logical Carbon Environmental and Social Safeguard
	Description	Questionnaire based on a template provided by Puro, to ensure compliance with the Puro General Rules, regarding social and environmental safeguards.
The filename shall be the exact filename as provided in the audit documentation. This table is filled-in by the supplier.		

5.3 Permits, risk assessments and impact assessments

Depending on the nature and scale of the removal activity, the CO_2 Removal Supplier may have obtained permits or conducted specific environmental assessments (e.g. Environmental and Social Impact Assessment, Environmental Risk Assessment) for compliance with local laws and regulations.

Were the obtention of one or several construction or environmental permits required for the removal activity, for compliance with local laws and regulations?	
Answer	☒Yes, permits were required and successfully obtained. ☐ No, permits were not required.
Permits obtained	1.Name of permit: NEMA EIA LICENSE ID of permit: NEMA/EIA/PSL/30252 Issuer of permit: NEMA Date of issuance: 08/01/2024 Permit file (.pdf): BIO-LOGICAL CARBON NEMA LICENCE 2. NEMA Air Emissions License (final copy yet to be received – draft report attached) 3. WRMA License (final copy yet to be received) 4. DOSH Air quality and Noise License ((final copy yet to be received – draft report attached) Permit URL (if available):
If several permits were obtained, provide the information for each of them. This table is filled-in by the supplier and verified by the auditor.	

Was an environmental and social impact assessment study (EIA) conducted?	
Answer	☒ Yes, an EIA was legally required and thereby conducted. ☐ Yes, an EIA was not legally required but conducted voluntarily. ☐ No, an EIA was not legally required and not conducted.
EIA Report (if conducted)	Title of study: Community Public Participation Filename of report: BIO-LOGICAL CARBON LTD CPR 2023 Can the report be published in the Puro Registry: No

This table is filled-in by the supplier and verified by the auditor.

Was an environmental risk assessment study (ERA) conducted?	
Answer	☐ Yes, an ERA was legally required and thereby conducted. ☐ Yes, an ERA was not legally required but conducted voluntarily. ☒ No, an ERA was not legally required and not conducted.
ERA Report (if conducted)	Title of study: NA Filename of report:NA Can the report be published in the Puro Registry: Yes/No
This table is filled-in by the supplier and verified by the auditor.	

5.4 Positive impacts on SDGs

Depending on the nature of the removal activity, the activity may have positive impacts on the UN Sustainable Development Goals (SDGs).

Instructions	*Please provide a summary of the positive impacts on the SDGs that the removal activity has or plans to has. This summary shall be project-specific and based on related evidence pieces that were submitted in the audit documentation (SDG Reporting files). Word limit: 150 words.*
Summary	Bio-Logical Carbon supports SDG 13 (Climate Action) by converting invasive *Prosopis juliflora* and macadamia shells into biochar, which could otherwise have been used as industrial or residential fuel. The biochar made from that same waste material is able to store carbon (in which the easily mineralized carbon compounds are converted into fused carbon ring structures). When biochar is placed in soil, that carbon can persist for hundreds to thousands of years. Studies, Woolf et al. (2010), suggest that converting gigatonnes of biomass into biochar at a global scale could significantly mitigate climate change by reducing atmospheric greenhouse gas concentrations. Additionally, Bio-Logical advances SDG 2 (Zero Hunger) by producing Asili Bio-Fertilizer, an organic soil amendment enriched with biochar. This enhances soil fertility, increases water retention, and boosts crop yields, directly improving food security for smallholder farmers. Our model leverages carbon finance to support smallholder farmers. We generate carbon credits, selling them to climate-conscious companies, and reinvesting the revenue to subsidize our biochar-based fertilizer. This approach makes climate-smart agriculture accessible, reducing the price of our product from $20 to $12 per 50kg bag. To date, we have supported over 7,204 farmers in 22 out of 47 Kenyan counties, helping them improve soil health, increase yields, and save money while permanently sequestering more than 1500 tonnes of CO2. With our expanded production capacity, we are poised to remove 10,500 tonnes of CO2 annually and support over 100,000 farmers.
This table is filled-in by the supplier and verified by the auditor.	

In addition, the following document is made available in the Puro Registry once the facility has completed its first Output Audit:

SDG Reporting (required)	Filename	NA
	Description	SDG Reporting based on a template provided by Puro, disclosing with SDG indicators are reported and how they are or will be demonstrated.
The filename shall be the exact filename as provided in the audit documentation. This table is filled-in by the supplier.		

6 Other documents available in the Puro Registry

Alongside this project description, several other documents are made available in the Puro Registry for more details.

The documents referenced in this project description are compiled in the following table:

Instructions	To finalize the project description, please list the names of all the public documents to be made available in the Puro Registry, in the order they appear, specifying the number of pages of each document. Add rows as necessary.	
#	**Document names**	**No of pages**
1	Bio-Logical Carbon Stakeholder Engagement Report	6
2	Bio-Logical Carbon Environmental and Social Safeguard	11
3	puro_LCA_Bio_Logical_v2025	23
4		
5		
6		
7		
8		
9		
10		
This table is filled-in by the supplier.		

Besides the documents referenced in this project description, the 3rd-party auditor has reviewed a complete audit package containing numerous documents, performed a site visit, and prepared an audit report and statement.

The facility described here will further be audited annually, in Output Audits, to verify the performance of the removal activity, resulting in the issuance of CORCs. All audits lead to audit reports and statements, which will be available in the Puro Registry, alongside further details on CORC quantification for each monitoring period.

Stakeholder Engagement Report

The purpose of this document is to gather results of the Stakeholder Engagement that has been conducted by the CO_2 Removal Supplier, for its Production Facility, in line with Section 6.4 of the Puro General Rules 4.0 and the Puro Stakeholder Engagement Requirements.

This report is divided in the following sections:

1 Identified stakeholders
2 Consultation activities and outcomes
3 Plans for continued consultation during crediting period
4 Summary

This report will be made **publicly available** in the Puro Registry. It shall not contain information about private individuals (e.g. name, personal address) for privacy reasons. Such information shall be provided separately (e.g. list of participants to consultation activity, as an appendix to the report).

7 Identified stakeholders

Provide an overview of the stakeholders that have been identified as relevant to include in the stakeholder engagement process, following the categories defined below:

Stakeholder categories	Identified stakeholders
Local Stakeholders, i.e. stakeholders in the immediate environment of the facility of the CO2 Removal Supplier, and most prone to experience direct or	Local community residents and the business owners

indirect effects of the respective carbon removal activity.	
Stakeholders with **land-tenure rights** within the vicinity of the project boundary	Landowners within the facility's perimeter and neighbouring manufacturing sites.
Representatives of relevant **local authorities** and relevant **local politicians**	The assistant chiefs, representing the Office of the President at the sub-location level, and Tana River County Government
Local **non-governmental organizations** (NGOs) or international NGOs who are active in the region and relevant to the topic	Apollo Agriculture, World Resource Institute (WRI)
Representatives of relevant **working groups** or **vulnerable** and **marginalized** groups within the vicinity of the project boundary	The Women Farmers Association of Kenya: WoFaAk
Relevant **industry experts**, given there are any in the near environment	• **KALRO**: Kenya Agricultural and Livestock Research Organization • **NEMA**: National Environment Management Authority
Other, please specify:	NA
Answers are to be written in the second column without disclosing private information. For instance, instead of the name of a specific resident, use terminology like "local residents". Likewise, instead of naming specific public employees, prefer to mention the roles and departments. *In case there are no identified stakeholders in a given category, provide a brief justification instead.*	

<u>Activity directly or indirectly impacting indigenous peoples or their livelihoods, ancestral knowledge or cultural heritage</u>:

Question	Answer
Does the list of identified stakeholders include any indigenous peoples or communities?	☐ Yes ☒ No
If answer is "Yes" to the question above, has the free, prior and informed consent (FPIC) been obtained from those indigenous peoples or communities?	☐ Yes. Please provide evidence of the obtention of the FPIC in a separate document.
As per rule 2.1.6 in the <u>Puro Stakeholder Engagement Requirements</u>, note that "FPIC is distinct from stakeholder engagement in that it is derived from indigenous peoples' right to self-determination. While stakeholder engagement involves consultation and collaboration with all parties affected by a project, FPIC goes a step further by requiring the explicit consent of indigenous peoples before proceeding with activities that impact them."	

8 Consultation activities and outcomes

Provide an exhaustive list of all the **stakeholder consultation activities** that have been conducted. Add as many rows as necessary. The activity categories can for instance be one of the followings (but not limited to these ones): public meeting, online webinar, paper questionnaire, electronic questionnaire, interviews, focus group, site visit, door-to-door visits, etc.

Activity categories	Activity name	Activity date (YYYY-MM-DD)
Site Visit	NEMA Facility Construction Environmental Impact Assessment	2023-11-16
Public Meeting	Engagement with the local community and area chiefs through public participation prior to the commencement of facility construction.	2023-09-24
Focus groups	Conducting regular training sessions for smallholder farmers to raise awareness about biochar and promote sustainable farming practices.	Ongoing

Provide a list of all the **stakeholder invitations** that have been sent out, grouping whenever relevant the invitations (e.g., for all local residents as one row). Add as many rows as necessary. The invitation format can be one of the followings (but not limited to these ones): postal letters, email, social media publication, public board information, telephone calls, verbal communication, etc.

Invitation format	Invitation name	Invitation date (YYYY-MM-DD)
Verbal Communication & Public board information	The local area chiefs facilitated public invitations for community participation prior to the commencement of the facility's construction.	2023-09
Phone Call	Bio-Logical's NEMA consultant informed the local area chiefs about the upcoming public participation, emphasizing the importance of inviting a representative cross-section of the community.	2023-09
Email	Bio-Logical's co-founders collaborated with the NEMA consultant to outline and plan the necessary stakeholder engagements.	2023-09

As **supporting evidence** to this report, please provide in a separate subfolder, the following:

- Example of invitations sent out, for different consultation activities (e.g. letters, emails, website announcements).
- Lists of all stakeholders invited to the consultation activities and stakeholders participating in the consultation activities. The lists will not be made public, as they can contain private information.

In case identified relevant stakeholders (section 1) were not invited to the consultation activities, please provide clear **reasons for not inviting** them. Add as many row as necessary. Leave blank if not applicable.

Identified stakeholders	Reasons for not inviting
NA	NA

Provide an extensive summary of i) the **information that was provided to stakeholders** during the consultation activities, ii) the **feedback received** during the consultation activities (with a particular focus on concerns, potential issues and critiques), and iii) the **responses provided to stakeholders** about their feedback.

Summary of the feedback received during the consultation activities
Information provided to stakeholders: Bio-Logical Carbon intends to build a biochar and bio-fertilizer company in Wempa Sublocation, Kabati - Thika Feedback received from stakeholders: Please prioritize hiring from the local community and sourcing supplies locally whenever possible. Responses provided to stakeholders: Feedstock sourcing will prioritize suppliers within a 60 km radius, and hiring will be merit-based with preference given to locals.

In case any relevant stakeholders **could not take part** in the consultation activities due to reasons such as lack of mobile access or physical disability, please describe and summarize how you engaged with them, what their specific feedback was, and how it was answered. Leave blank if not applicable.

Consultation of stakeholders that could not take part in the scheduled consultation activities
NA

As **supporting evidence** to this report, please provide in a separate subfolder, the following:

- Materials presented during the consultation activities (e.g. presentations)
- Documentation of the feedback received (e.g. meeting notes, questionnaire answers)
- Documentation of the responses provided to stakeholders (e.g. consultation reports)

Provide an extensive description of the **changes made to the project** plans to address the concerns and issues raised during the consultation activities.

Description of the changes made to the project for addressing concerns and issues
The Environmental Impact Assessment and the Public participation concluded that the project design is sound and meets all necessary standards.

9 Plans for continued consultation during crediting period

Provide a description of the current plans for maintaining a continued engagement of the stakeholders during the crediting period.

Description of the plans for continued consultation of stakeholders during the crediting period
• Complying with annual licensing from NEMA to ensure environmental protection for all stakeholders. • Ongoing trials with WRI and KALRO to ensure biofertilizer quality assurance. • Adhering to local government licensing requirements and obtaining necessary business permits.

10 Summary

Based on all the information provided above and the evidence provided separately, write an overall summary of the stakeholder engagement. This summary must follow the structure of this report, tackling identified stakeholders, consultation activities and outcome, and plans for continued consultation. This summary is limited to 500 words. This summary must be re-used in the Project Description.

Overall summary (500-word limit)

Bio-Logical Carbon has undertaken extensive stakeholder engagement as part of the development and operation of its carbon removal facility. This engagement has been structured to ensure transparency, inclusivity, and responsiveness.

The primary stakeholders identified include local community residents, business owners, adjacent landowners, and representatives of local authorities (assistant chiefs and police). Key organizations such as Apollo Agriculture, WRI, KALRO, and NEMA have been identified as critical stakeholders due to their involvement in agriculture, research, and environmental management. Vulnerable groups like the Women Farmers Association of Kenya (WoFaAk) are also primary stakeholders, alongside industry experts in agriculture and environmental management.

Several consultation activities have been conducted to inform stakeholders and gather feedback. These included site visits, public meetings, and ongoing focus group sessions with smallholder farmers. A significant public meeting, held in September 2023, involved engagement with local community members and area chiefs, facilitated by NEMA's Environmental Impact Assessment (EIA) process. Regular training sessions for farmers, aimed at raising awareness about biochar and sustainable farming practices, have also been a core part of stakeholder interaction.

Feedback from stakeholders has generally focused on ensuring local community involvement, particularly regarding job opportunities and supply sourcing. There was strong encouragement to prioritize local hiring and supply procurement, to which Bio-Logical Carbon responded by committing to source feedstock from within a 60 km radius and by offering merit-based local hiring preferences. This aligns with the company’s broader commitment to community development and its environmental objectives.

Bio-Logical has developed a strategy for continued consultation. This includes compliance with annual licensing requirements from NEMA to ensure ongoing environmental protection. Regular consultations will also be maintained with local stakeholders through continued training sessions and collaborations with partners like WRI and KALRO. The company will continue to adhere to local government licensing requirements, ensuring a steady dialogue with relevant authorities. Finally, Bio-Logical Carbon plans to keep stakeholders informed about the outcomes of ongoing trials related to biofertilizer quality and the project's broader environmental impacts.

Environmental and Social Safeguards Questionnaire

The purpose of this document is to provide a summary of how the CO_2 Removal Supplier complies with the environmental and social safeguards, as defined in Section 6.4 of the Puro General Rules 4.0. The responses from the supplier are expected to be commensurate with the identified impacts and risks.

This document consists of five sections, noting that the fifth section does not apply to all suppliers:

1. General overview and compliance
2. Labor practices and rights
3. Environmental impact and management
4. Social impact and community relations
5. Biomass sustainability

This document forms part of the evidence needed for the Production Facility Audit. It is corroborated by other documents and evidence provided by the supplier to Puro.earth and the 3rd-party auditors, demonstrating environmental and social safeguards. This questionnaire will be made **publicly available** in the Puro Registry.

11 General overview and compliance

Provide a description of your operations and the context where you are operating in, as relevant for environmental and social safeguards.
Bio-Logical Carbon Ltd. Based in Kabati – Thika, Kenya, transforms agricultural waste and invasive species (Prosopis juliflora and macadamia shells) into biochar and biofertilizer to support local smallholder farmers vulnerable to climate change

Provide an overview of the material environmental and social impacts and risks in your operations, and how they were determined.
Environmental impact assessments (EIA), stakeholder consultations, and ongoing monitoring are used to determine this. Key environmental risks include airborne particulate emissions, which are mitigated through proper dust control measures, and greenhouse gas emissions, which are

addressed by utilizing post combustion emission control on the machinery. Water usage is managed and to reduce on local water resources we use own borehole. Social impacts include providing job opportunities and skills development to local communities, particularly smallholder farmers. Gender equality and labor rights are also a focus, with policies ensuring equal pay and protections against discrimination. Risks related to worker safety, particularly in lifting and high-temperature equipment, are mitigated through strict occupational health and safety protocols and training programs.

Requirement: Abide by national and local laws, objectives, programs, and regulations and, where relevant, international conventions and agreements.	**Rule** 6.4.1.1.i
Do you comply with the requirement?	☒ Yes ☐ No
If not, how and why do you not comply? If yes, how do you know that you comply with the requirement? Please provide details considering the laws and regulations that are most relevant to your operations. Also, include any regulations that are specifically related to your carbon removal activities.	
We ensure compliance through regular audits, permits and adherence to Kenya's DOSH, OSHA regulations and NEMA licencing. We also align with the Kenyan Carbon Markets Regulations Act (2024) and our fertilizer is certified by the Kenya Bureau of Standards (KEBS) and Ecocert.	
Identify any documents or other records that you rely upon to verify compliance.	
• Business Registration and Operation Licences and permits • NEMA (National Environmental Management Authority) Air Emissions Licence • NEMA Noise and Air quality licence • OSHA (Occupational Safety and Health Authority) licence • Ecocert certificate	

Requirement: Respect for **human rights** and avoiding discrimination; abiding by the International Bill of Human Rights and universal instruments ratified by the host country.	**Rule** 6.4.1.1.ii
Do you comply with the requirement? Motivate below.	☒ Yes ☐ No
We honour the Kenyan Constitution and labour laws, ensuring equal opportunities for all employees, regardless of gender, race, or background. We are committed to non-discrimination, fair treatment, and the implementation of policies that protect against any form of exploitation or mistreatment.	

Requirement: Recognize, respect, and promote the protection of the rights of IPs & LCs (**indigenous peoples and local communities**) in line with applicable international human rights law, and the United Nations Declaration on the Rights of Indigenous Peoples and International Labor Organization (ILO) Convention 169 on Indigenous and Tribal Peoples.		**Rule** 6.4.1.1.iii
Do you comply with the requirement? Motivate below.	☒ Yes ☐ No	
For the Mt. Kenya facility operations and set up, we do not have direct interaction with the indigenous people; however, since we source the Prosopis biomass from community land in Tana River County, the local community has been thoroughly informed of our plans. They support our efforts, as the land regeneration initiatives directly enhance their food security and improve livelihoods. This engagement has been led through the local county government and NEMA.		

Note that there is an additional question on free, prior, informed consent below (section 4), and there is a requirement to publish a separate stakeholder engagement report based on a Puro template.

12 Labor practices and rights

Requirement: Labor rights and working conditions, including prohibiting forced labour, child labour or trafficked persons whether in own operations or employed by third parties, fair treatment of employees.		**Rule** 6.4.1.1.iv
Do you comply with the requirement?	☒ Yes ☐ No	
If not, how and why do you not comply? If yes, how do you know that you comply with the requirement?		
Bio-Logical adheres to Kenya's Employment Act. Occupational Safety and Health Act (OSHA). And ILO conventions on labour standards. Regular OSHA Audits, employment contracts, and worker training programs uphold fair wages, safe conditions, and non-discriminatory policies. We prohibit child labour and forced labour, including thorough supplier due diligence. Third-party labour providers must comply with ethical hiring standards, and grievance mechanisms allow employees to report violations confidentially.		
Identify any documents or other records that you rely upon to verify compliance.		
• OSHA permits and certificates		

Requirement: Ensuring a safe working environment and mitigating occupational health and safety hazards.	**Rule** 6.4.1.1.iv
Describe occupational health and safety hazards that you have identified.	
Airborne particulates, high noise levels, extreme heat exposure, musculoskeletal injuries from manual handling, chemical inhalation risks from VOC emissions, and working in confined spaces	

Describe the measures undertaken to mitigate the hazards.
Mitigation measures include PPE (respirators, gloves, fire-resistant gear), ventilation systems, worker training, and emergency response protocols.

Requirement: Providing for equal opportunities in the context of gender; providing equal pay for equal work and protecting against and appropriately responding to violence against women and girls.		**Rule** 6.4.1.1.v
Do you comply with the requirement?	☒ Yes ☐ No	
If not, how and why do you not comply? If yes, how do you know that you comply with the requirement?		
The company enforces equal pay for equal work through structured salary scales and transparent compensation reviews. Recruitment and promotions follow merit-based, non-discriminatory policies, ensuring equal opportunities for all genders. Sexual harassment policies and reporting mechanisms protect employees, with training programs to raise awareness. Regular audits and grievance mechanisms allow for reporting and addressing gender-based violence confidentially.		
Identify any documents or other records that you rely upon to verify compliance.		
• Employment contracts and payroll records • Employee grievance and complaints logs • Workplace safety and well-being reports • Gender equality & anti-harassment policy		

13 Environmental impact and management

Requirement: Pollution prevention, including pollutant emissions to air, water, and soil as well as noise and vibration, and generation of waste and release of hazardous materials, chemical pesticides, and fertilizers.	**Rule** 6.4.1.1.vi
Does the carbon removal activity result in the following impacts? For **each potential impact**, please provide detailed information about its extent and the current measures in place to mitigate these negative impacts.	
• Pollutant discharges to air	
The extent of the emissions are within the NEMA regulations. Oxides of Nitrogen and Sulphur Dioxide emissions were averaged at 25.89 mg/Nm3 and 14.45 mg/Nm3, against the guideline value of 460 mg/Nm3 and 2000 mg/Nm3 respectively. The levels of Hydrocarbons which are reported as methane averaged at 642.47 mg/Nm3, although not subject to Air Quality (2014) Regulation. Please see attached emissions report for reference. Our pyrolysis machinery reduces air pollution through the use of condensers, spray tower and wet scrubbers to clean the pyrolysis gas. To ensure compliance, we continuously monitor flue gas GHG levels, keeping them below jurisdictional limits.	
• Pollutant discharges to water	

There is zero pollution to water since all the co-products (wood vinegar and tar) is captured and safely stored before being sold as co-products to environmentally certified off takers. The off takers are contractually obligated to ensure that these coproducts are not disposed of into water or used for any unintended purposes. They are strictly limited to their designated applications (pesticides, and animal feed additives). As the market for co-products is still in its early stages of development, our offtakers have collected approximately 20,000 litres since the project's inception. Around 30,000 litres are currently stored on-site in IBCs (refer to the attached photo). We are also collaborating with Kanku Kenya Ltd, a wastewater recycling consultant, to explore the potential of recycling wood vinegar through treatment before reuse. The treatability analysis conducted in the laboratory has yielded positive results (please see the attached lab report), and we are now moving forward with scaling up the treatment process. Regarding the tar, we have established a partnership with a bitumen manufacturer, who will utilize it as a component in the production of MC30 and K160 for road construction. Please see attached the lab reports.
● Pollutant discharges to soil
There is no pollutants discharge to soil since our biochar undergoes lab testing to ensure it meets environmental quality standards according to the WBC regulations to determine PCDD/F, PCB and PAH in biochar for soil amendment purposes, while the coproducts are managed with care to prevent any spillage or runoff.
● Noise
Normal facility operations generate minimal noise, ensuring that decibel limits are not exceeded, and noise pollution is effectively controlled. Furthermore, we are located away from any residential areas.
● Vibration
All biochar machinery is stationary, eliminating vibration in the biochar production facility. For fertilizer production, where rotating machinery such as granulators and crushers are used, they are securely mounted to minimize vibration and ensure maximum safety.
● Waste
All solid waste is sorted and regularly disposed of by a NEMA-certified contractor to ensure there is no accumulation on-site and that disposal is conducted safely.
● Release of hazardous materials
There is no release of hazardous materials from our process, as we use materials that comply with national and international standards, and our process relies on sustainably sourced organic inputs with no additives.
● Chemical pesticides and fertilizers
Our fertilizer is fully organic from use of compost manure, biochar and microbes.

Requirement: Biodiversity conservation and sustainable management of natural resources, including avoiding or minimizing negative impacts on terrestrial and marine biodiversity and ecosystems; protecting the habitats of rare, threatened, and endangered species, including areas needed for habitat connectivity.	**Rule** 6.4.1.1.viii

Is the activity taking place in or near environmentally sensitive areas, including protected areas (e.g. nature reserve or national park), or other areas included in a conservation plan? Describe where the nearest such areas are.
No. Our facility is not located near any protected areas, the nearest park is 150 kms away (Aberdares).
Describe impacts and risks that you have identified
The primary risk identified is during the harvesting of *Prosopis* biomass, which could impact avian habitats.
Describe the measures undertaken to minimize and address the impacts and the risks.
The harvesting and regeneration will be phased, the disturbance to bird populations is expected to be temporary and short-lived.

Requirement: Minimizing soil degradation and soil erosion.	**Rule 6.4.1.1.viii**
Describe impacts and risks to soil that you have identified.	
One key risk is soil erosion, as the removal of Prosopis vegetation could reduce ground cover, leading to increased susceptibility to wind and water erosion. Another concern is increased compaction from machinery used in clearing may negatively affect soil permeability and root growth.	
Describe the measures undertaken to minimize and address the impacts and the risks.	
Bio-Logical has partnered with land restoration organisation KERA (Kenya Ecosystem Restoration Alliance) which are tasked to restore the cleared land by planting cover crops i.e. native trees and grassland as soon as the clearing is done.	

Requirement: Minimizing water consumption and stress.	**Rule** 6.4.1.1.viii
Are you located in an area impacted with water stress?	☐ Yes ☒ No
If yes, describe local conditions in terms of water stress and any risk analysis done on the impacts of the CO_2 removal activity on water stress	
NA	
Describe any agreements and/or regulations relating to water sourcing.	
We obtained the WRMA licence (Water Abstraction Permit) for purposes of drilling an onsite borehole	

Describe the measures undertaken to minimize water consumption.
All employees have been sensitized on efficient water usage, no leakages and unmonitored running water is permitted.

Requirement: The CO_2 Removal Supplier shall not convert **natural forests or high conservation value habitats.**		**Rule** 6.4.1.1.viii
Do you comply with the requirement?	☒ Yes ☐ No	
If not, how and why do you not comply? If yes, how do you know that you comply with the requirement?		
All our Prosopis suppliers are required to obtain permits from the Kenya Forestry Service (KFS), which authorizes the harvest of the invasive species under strict guidelines that mandate the restoration of the cleared land with native species and grassland or crop farming.		
Identify any documents or other records that you rely upon to verify compliance.		
• KFS clearing permit • Environmental Impact Assessment study report for the upcoming Tana River facility		

14 Social impact and community relations

Requirement: Avoiding or minimizing adverse impacts **to community health and safety**.	**Rule** 6.4.1.1.vii
Describe potential sources of impact, taking into account all relevant factors in the given context. Consider both routine and non-routine circumstances.	
Routine activities such as biomass harvesting, transportation, and biochar production have no impacts on community health and safety since it is all done according to stipulated environmental regulations. Non-routine activities, such as equipment malfunctions, co-product spills during transportation could lead to accidental exposure to hazardous materials or physical injuries.	
Describe the measures undertaken to minimize and address the impacts and the risks.	
Bio-Logical mitigates these risks through strict safety protocols, routine maintenance, and emergency response plans to ensure minimal disruption.	

Requirement: Preserves and protects **cultural heritage** and cultural and religious sites.	**Rule** 6.4.1.1.ix
Describe the impacts and the risks to cultural heritage and cultural and religious sites that you have identified.	

Our project has no risk of affecting any cultural heritage or religious sites.
Describe the measures undertaken to minimize and address the impacts and the risks.
NA

Requirement: Avoiding **forced physical** and/or **economic displacement**. If avoidance is not feasible, CO_2 Removal Suppliers shall minimize physical and/or economic displacement. This applies also to any access restrictions to lands, territories, or resources, and any customary rights of local right holders.		**Rule** 6.4.1.1.x
Did/does the activity result either in forced physical or economic displacement?	☐ Yes ☒ No	
If yes, describe the impact to local communities and how it was assessed?		
NA		
Provide a comprehensive description of the process that was undertaken, compensation arrangements and measures to mitigate the negative impacts.		
NA		
Also describe in detail how you minimized forced physical or economic displacement.		
NA		

Requirement: When the activity directly or indirectly impacts **indigenous peoples** or their livelihoods, ancestral knowledge or cultural heritage, the CO_2 Removal supplier shall develop the Production Facility with free, prior, informed consent (FPIC).		**Rule** 6.4.2
Is the CO_2 removal activity taking place in an area inhabited by or claimed by indigenous people, or does it influence such an area?	☐ Yes ☒ No	
If yes: does the activity directly or indirectly impact indigenous peoples or their livelihoods, ancestral knowledge or cultural heritage? How was that determined?		
NA		
If there is a direct or indirect impact:		

a. Provide a description of the impact and the measures that were taken to minimize the impact.
NA
b. Describe how and when the indigenous communities were identified and approached for the FPIC process.
NA
c. Describe the mutually agreed process for the negotiations.
NA
d. Describe how the indigenous communities were informed about the potential impacts of the activity on their livelihoods, ancestral knowledge, or cultural heritage.
NA
e. Describe the outcome of the negotiations.
NA
f. Describe how the ongoing consent process is managed to ensure that the indigenous communities continue to agree with the activity as it progresses.
NA
g. Describe grievance mechanisms that are in place for the indigenous communities.
NA
h. Describe how the impacts on the indigenous communities are monitored and addressed during the operation of the Production Facility.
NA

15 Biomass sustainability

Puro methodologies require that whenever biomass feedstock is used in the carbon removal activity, it must be sourced in a sustainable manner.	
Is your carbon removal activity based on using biomass feedstock?	☒ Yes ☐ No
Describe how you ensure that it is sourced sustainably.	
Bio-Logical Carbon sources its biomass by prioritizing feedstock from invasive species, *Prosopis juliflora*, which is cleared from degraded lands in compliance with local environmental restoration efforts and the Kenya Forestry Services regulations. We also ensure that macadamia shells come from local, responsible suppliers such as One Acre Fund, thereby reducing waste and supporting the circular economy. Sourcing is ideally limited to a 60 km radius to minimize transportation emissions. Additionally, Bio-Logical Carbon works closely with local communities and NEMA for the Prosopis sourcing to ensure it does not disrupt land tenure rights or local ecosystems. Regular stakeholder consultations and environmental monitoring ensure that the sourcing process aligns with local regulations, climate goals, and sustainable land management practices.	

Note that additional evidence will be required to demonstrate adequate biomass sourcing as per the Puro Biomass Sourcing Criteria, where applicable.

Life cycle assessment of Bio-Logical Carbon biochar and biofertilizer production and use for CORC calculation

Prepared by: Jeff Kimasere Watitwa
Carbon Operations Manager
Bio-Logical Carbon

Date: 05th March 2025

Abstract

This Life Cycle Assessment (LCA) evaluates the environmental impact of biochar production in Kenya using macadamia shells and *Prosopis juliflora*. The biochar produced is incorporated into biofertilizer, with pyrolysis gasses sustaining anaerobic combustion in the reactors, while the wood vinegar and tar are sold as a co-product for foliar, and animal feed additive. Trials are ongoing to recycle the wood vinegar and for the tar to be used in road construction.

The LCA adheres to ISO 14040/44 standards and Puro.earth's Biochar methodology, considering cradle-to-grave system boundaries to assess greenhouse gas emissions, carbon removal potential, and CORC (Carbon Removal Certificates) eligibility. The data is sourced from Bio-Logical Carbon's records, ecoinvent's and IPCC emission factors database.

Biochar is produced using a batch reactor set with four kilns (each reactor holds up to 900 kgs of biomass), primarily powered by Kenya's renewable energy grid (92%) to operate its motors, fans and hoist crane. The use of renewable energy greatly reduces the overall environmental footprint of the production process. Total CO_2 emissions per ton of biochar are calculated as 463.99 kgCO_2e for macadamia shells, and 690.35 kgCO_2e for Prosopis. This is expected to decrease significantly as Bio-Logical optimizes its preheating fuel consumption and processes Prosopis biomass sourced within a 50 km radius of its future facility.

The Life Cycle Impact Assessment (LCIA) for one ton macadamia-biochar reveals that transportation emissions from collecting macadamia shells within a 47 km radius of BioLogical's production facility amount to 32.37 kgCO_2e. The largest emission source is reactor pre-heating, contributing 293.7 kgCO_2e, while infrastructure and factory building emissions account for 15.60 kgCO_2e and 35.53 kgCO_2e respectively. The smallest emissions come from the end-use application at 2.15 kgCO_2e.

Prosopis sourced from an average distance of 200 km results in transport emissions of 154.80 kgCO2e per ton of biochar produced. The largest emissions contributor, however, comes from preheating fuel, accounting for 211.03 kgCO2e.

The respective E_{stored} (carbon sequestration potential) for each biomass was calculated as: 3214 kgCO_2e (Macadamia shells), and 3073 kgCO_2e (Prosopis). After accounting for systemwide emissions, the net carbon removal is 2750.80 kgCO_2e, and 2382.56 kgCO_2e per ton of biochar blended with compost for each biomass source, respectively.

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Glossary

CORC	Carbon dioxide removal certificates
CDR	Carbon dioxide removal
ISO	International Organization for Standardization
GWP	Global Warming Potential
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LHV	Lower heating value
MJ	Mega Joules
tonkm	ton kilometre, transport unit (1 ton x 1 km)
tonne CO_2e	metric tonne carbon dioxide equivalent

16 Introduction

Bio-Logical Carbon Ltd empowers climate-vulnerable smallholder farmers in Kenya by converting abundant local agricultural waste (macadamia shells) and invasive species (*Prosopis juliflora*) into biochar, a key component of its bio-fertilizer, "Asili".

Asili is a blend of finely ground biochar, chicken manure compost, avocado pulp, mycorrhizal fungi, and beneficial microbes, creating an easy-to-apply biofertilizer that enhances soil structure, water retention, and nutrient delivery. This combination boosts plant growth while promoting long-term carbon sequestration through stable carbon and microbial diversity.

This LCA assesses the environmental impacts of the biochar-based biofertilizer from biomass collection to final application, using cradle-to-grave system boundaries to capture emissions from transportation, biochar production, and end-use.

16.1Goal and scope definition

Goal of the study

This LCA evaluates the environmental impact of producing biochar from agricultural waste and invasive species. The study assesses the environmental impacts across the entire lifecycle of biofertilizer manufacturing, identifying how these impacts are distributed across various stages. It provides detailed insights to address stakeholder inquiries regarding environmental performance and serves as critical background information for the audit process, facilitating registration on the Puro.earth Carbon Dioxide Removal (CDR) marketplace.

The LCA follows ISO 14040/44:2006 standards [1], [2] and Puro.Earth's Biochar Methodology [3].

Scope of the study

Product-systems considered

This LCA includes a Life Cycle Impact Assessment (LCIA), which evaluates environmental implications at all stages, from biomass material supply to biofertilizer granulation.

Biochar Production Process

Biochar is produced through the pyrolysis of macadamia shells, and Prosopis cuttings. The production process involves several stages:

- Macadamia Shells Preparation: Macadamia shells need no pre-processing
- Prosopis juliflora is chopped to desirable sizes (12 cm diameter and 30 cm long) during its harvesting

Pyrolysis Process

The pyrolysis process heats the biomass to 550°C, creating a stable form of organic carbon for longterm soil storage (over 100 years), making it an effective carbon removal approach. Pyrolysis outputs include:

- Biochar: The primary product used as a soil amendment
- Syngas: The pyrolysis gas that sustains the pyrolysis process
- Wood vinegar and tar emulsion: A co-product used in pesticide, foliar spray, and animal feed additive.

Diesel or LPG is used for the initial furnace ignition.

Key project parameters and allocation factors

Bio-Logical's focus is the production of biochar for soil amendment. Therefore, the functional unit is defined as 1 ton of dry biochar stored in soil for a period of 100 years. The other key project parameters based on 11 months of macadamia-biochar production are shown in Table 1 below.

The emissions allocation is calculated based on weight. For every 28 tonnes of biochar produced, 5 tonnes of wood vinegar and tar emulsion are generated. The co-products are sold as a valuable product. Consequently, 100% of the emissions are attributed to biochar.

Key project parameters				**data source**	**comment**
type	**value**	**unit**	**name of parameter**		
p	1	tonnes (dry mass)	Functional unit: biochar produced and used in soil products and used in construction products	NA	
p	11	months	Unit of reporting	NA	
p	544.0	tonnes (dry mass)	Biomass processed over reporting period	From plant records.	
p	212.6	tonnes (dry mass)	Biochar produced over reporting period	From plant records.	
p	38.0	tonnes	Wood-Vinegar, tar sold as co-product (5 tons of co-product produced for every 28 tons of biochar)	From plant records.	
p	100%	%	Allocation factor to biochar, of biomass supply and processing emissions	calculated	
p	36%	tonnes / tonnes, dry	Biochar pyrolysis yield	calculated	

Table 1: Key project parameters

Impact categories and impact assessment methods

The LCA utilizes reference values in line with the Greenhouse Gas (GHG) Protocol, specifically considering Global Warming Potentials (GWPs) over a 100-year time horizon from the IPCC Reports. GWP results are expressed in kilograms of carbon dioxide equivalent ($kgCO_2e$).

System boundaries

Bio-Logical follows a cradle-to-grave system boundary (Figure 1) for the Macadamia shells LCA, starting with biomass collection and delivery to the production facility ("cradle") and ending with biochar composting ("grave"). This includes feedstock collection, transportation, pyrolysis, and the blending of biochar with compost, all taking place in Kenya to ensure geographically relevant Life Cycle Inventory (LCI) data.

Emissions from infrastructure, such as facility construction, are also accounted for. Biogenic emissions from biomass storage are excluded as its negligible contribution to total emissions.

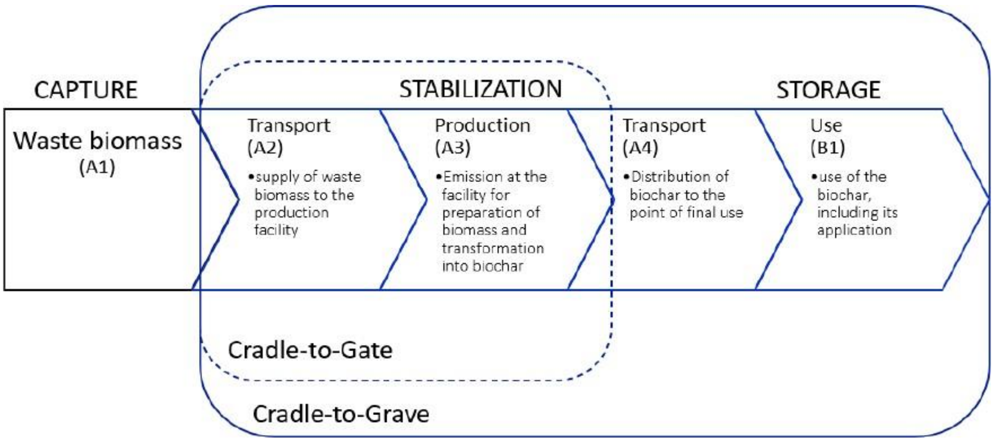

Figure 1: Overall System Boundaries from option B in the Puro Earth Biochar Methodology

The Prosopis juliflora LCA includes biomass harvesting, as depicted in Figure 2, involving the use of chainsaws for cutting down and chopping up the invasive trees.

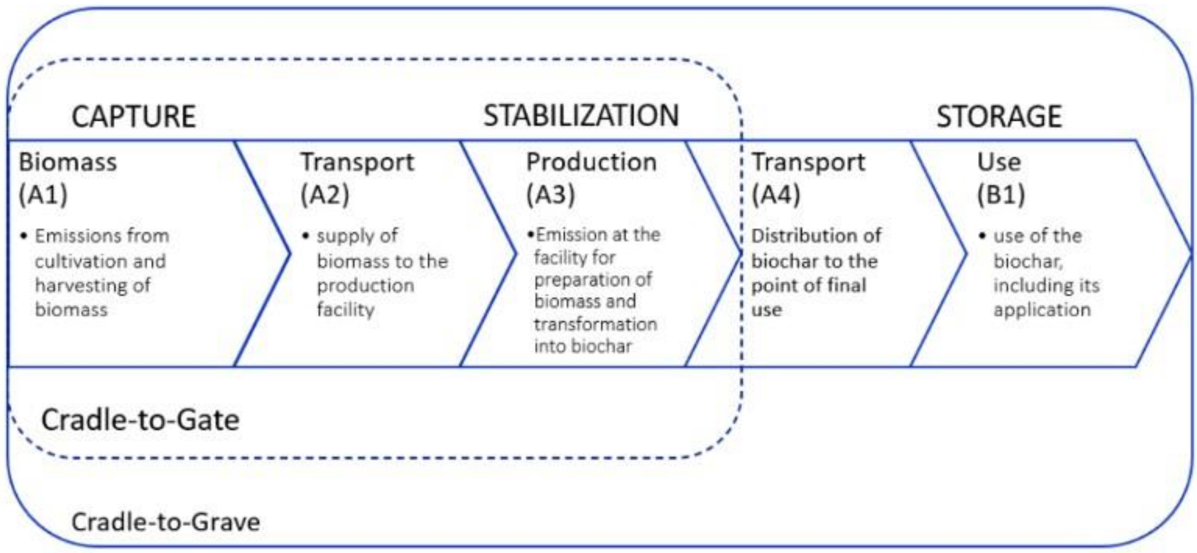

Figure 2: Overall System Boundaries from Option A in the Puro.earth Biochar Methodology

Processes included in the product life cycle are: ● Biomass (Prosopis juliflora) harvesting (A1) ○ The invasive species is cleared from encroached land and loaded on trucks to be transported to Bio-Logical's processing facility.

- Transport (A2) ○ Transportation relies on a 10-ton capacity truck and a fuel efficiency of 6 kilometers per liter when fully loaded.
- Production (A3) ○ Biomass and biochar handling on site, including:
  - Pre-heating of reactors[1], hoist crane, motors, burner and fans operation.
- Transport (A4) ○ The composting site (windrows) is designated as the end-use point for our biochar. Since the biochar is manually transported using wheelbarrows and trolleys, no emissions are considered at this stage.
- Use (B1) ○ Before blending the biochar with compost[23], it is finely crushed to prevent its use as fuel. Once the compost blend matures, it is granulated for easy application by farmers.

Consequently, the emissions from both the crushing and granulating processes are accounted for under E_{use}.

- Biochar transport to customers was excluded as our system boundary ends at the factory composting site ("grave") upon biochar-compost mixing, ensuring the end-use remains on its soil amendment application.
- The biofertilizer is used as a soil additive by small-scale farmers. For this reporting period, it is assumed that application is done manually, as most subsistence farmers depend on laborers rather than machinery. Therefore, no additional emissions are considered.

Assumptions and limitations

Transportation impacts for capital goods were excluded from this LCA as they were deemed to have minimal influence on the overall environmental outcomes. Asili biofertilizer is packaged in 50 kg polypropylene bags, each containing 15 kg of biochar, and many farmers extend the bags' lifespan by reusing them for various agricultural purposes.

Puro.Earth's Biochar methodology calculates CORC values based on biogenic carbon storage and fossil emissions. Biogenic CO2eq emissions are excluded from this study. The life cycle model focuses only on greenhouse gas emissions released into the air, with air pollutants like particulate matter (PM) and total volatile organic compounds (TVOC) omitted, as they do not directly affect climate change, though they are managed to protect air quality.

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[1] Kiln ignition requires 39 litres of diesel for one batch biochar.

[2] Biochar is manually transported on trolleys to the composting site.

[3] Composting is an efficient way to treat biodegradable waste, offering multiple benefits. It reduces waste volume, eliminates pathogens and toxic compounds, and turns organic matter into a valuable, slow-release fertilizer.

Bio-Logical employs the Co-Composted Biochar (COMBI) technique, adding biochar to compostable materials like chicken manure, and avocado pulp. This enhances the final compost's quality and nutrient content while reducing greenhouse gas emissions. Our COMBI compost blends biochar, manure, agricultural waste, along with mycorrhizal fungi and beneficial microbes.

17 Life cycle inventory analysis

17.1 Software, databases, and other data sources

The Life Cycle Inventory (LCI) involves collecting and analyzing the data needed to meet the objectives of the LCA study. The life cycle model was developed using Puro.earth's LCI MS Excel template, which forms the basis for the LCIA that evaluates the environmental impacts of our project.

17.2 Inventory data

The calculation of Carbon Dioxide Removal Certificates (CORCs) associated with our biochar production process adheres to Puro.earth's methodology, summarized below.

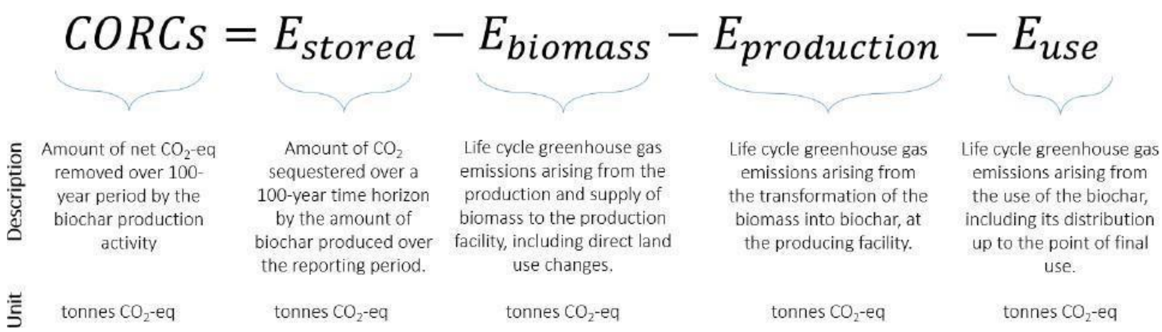

Figure 3: Overall equation for net carbon sequestration over 100 years

Where:

- **Biochar's CO_2 Sequestration Potential (E_{stored})** signifies the estimated amount of carbon dioxide sequestered by the biochar over a 100-year timeframe per ton of biochar used for soil amendment. The calculation methodology is detailed in Section 3.1.

- **$E_{biomass}$** represents the life cycle greenhouse gas emissions associated with harvesting and transporting biomass to the production facility. Emissions from direct land-use changes related to cultivation and harvesting were excluded as we only use agricultural waste and invasive species.

We precisely tracked the transport mode and distance for all raw materials. Road transport using a diesel truck (10 MT capacity, 6 km/litre when loaded) was standard, with no assumed losses. Macadamia biomass travels an average of 47 km to the facility, and we accounted for moisture content in the transported weight, while Prosopis travels an average 200 km (the next site will be built closer to the source within a 50 km radius). Transportation data (ton-kilometers) reflects supplier locations listed in the appendix.

- **$E_{production}$** refers to the life cycle greenhouse gas emissions generated during the conversion of biomass into biochar at our production facility. The facility operates on electricity supplied by the Kenyan grid, which is composed of 92% renewable energy. Energy emissions are calculated based on the facility's installed energy meters (kWh) and the preheating consumption in MJ/L of diesel and MJ/Kg of LPG used.

Ongoing trials are testing the use of *Prosopis juliflora* biomass as a preheating fuel, and if successful, the next LCA will incorporate this adjustment. Initial tests consumed between 3L and 7L of diesel over 30 minutes to ignite 90 kg of *Prosopis* wood in the combustion chamber. This preheated the reactor until self-sustaining pyrolysis was achieved after 2 hours. Preliminary LCIA results indicate an 88.4% reduction in emissions from the preheating stage, with a substantial decrease from 297.39 kgCO2e to 34.44 kgCO2e per ton of biochar produced.

Figure 3 shows the pyrolysis process flow chart, the syngas is recirculated and purified in a system of spray towers and then combusted to fuel the process.

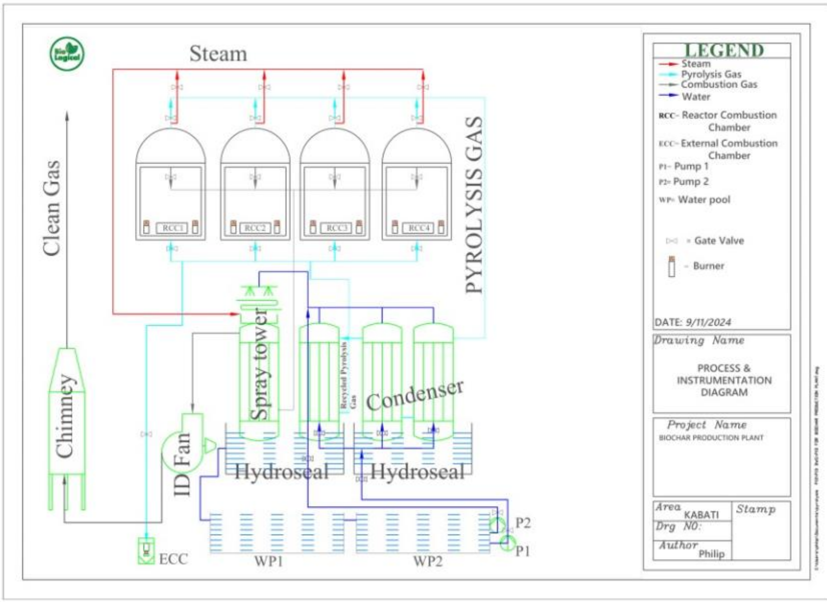

Figure 4: Bio-Logical's pyrolysis reactor flow diagram

It is worth noting that our manufacturer complies with the stringent emissions regulations in China and exports their products worldwide to other global regions where they operate successfully. The product test results are attached in the audit package.

After production, the biochar is immediately quenched to ensure safety and improve its surface area, thereby increasing its porosity. Currently, handling and transportation within the facility are done manually. Each batch of biochar is weighed, and its moisture content recorded to determine the dry weight. Periodic elemental analysis is performed to assess its H/C_{org}.

- **E_{use}**: The composting site serves as the "grave," with emissions accounted for during the processes of biochar crushing and biofertilizer granulation. Based on facility records, these emissions are linked to the energy consumption of 12.8 kWh per ton of biochar dry mass crushed and 1 ton of biofertilizer granulated.

Figure below shows Bio-Logical's rector set rendering.

Figure 5: Bio-Logical's pyrolysis reactor rendering

17.3 On-site water management and usage

To enhance water sustainability, we rely on an on-site borehole, eliminating dependence on grid water. Our system consumes 7 m³ of water per reactor set every two weeks, supporting the spray tower, circulation tanks, and condenser system. This process produces 5 m³ of a mixture comprising water, wood vinegar, and tar.

The condenser captures the condensable portion of the gas, while the spray tower removes pollutants before combustion. Approximately 10% of the pyrolysis gas volume is converted into tar, wood vinegar, and water. This mixture is collected in a tank, with tar and wood vinegar sold as coproducts. 80 liters of water is used to quench each batch at the completion of the pyrolysis process.

17.4 Methods to Ensure Complete Combustion of Pyrolysis Gas and Oil

The pyrolysis process employed by Bio-Logical incorporates a system for managing the combustion of pyrolysis gas and oil, ensuring optimal efficiency and minimal emissions. The system utilizes condensers to separate condensable gases from non-condensable gases produced during pyrolysis. The non-condensable gas, referred to as pyrolysis gas, is directed to the combustion chamber, where it sustains the reactor's operating temperatures, making the process self-sustaining. Meanwhile, condensable gases are collected as byproducts, including tar and wood vinegar, which are sold as coproducts for further processing.

To enhance the quality of combustion, the pyrolysis gas undergoes a thorough cleaning process before combustion. It passes through a spray tower and wet scrubbers that effectively remove particulates and impurities. Any excess pyrolysis gas that is not utilized for heat generation is safely combusted in an external chamber to prevent unintentional atmospheric release.

Ambient air is introduced into the combustion chamber from a single injection point at the bottom, designed to promote turbulent airflow for optimal mixing with pyrolysis gas. The chamber’s geometry facilitates this natural ventilation design, ensuring effective interaction between air and gas.

The peak flue gas temperature during combustion is 590°C, with internal temperatures estimated between 550°C and 700°C. This temperature range is critical for efficient pyrolysis, promoting rapid biomass breakdown and prioritizing biochar production. Insulation within the combustion chambers is achieved using refractory bricks and fiberglass layers, enhancing energy efficiency while ensuring operator safety.

Currently, the system does not employ online sensors or automatic control systems for combustion adjustments; however, a valve system regulates pressure and flow during pyrolysis.

18 Life cycle impact assessment and interpretation

This section presents the findings of our LCIA. Following Puro.Earth's biochar methodology, a 100-year permanence calculation at a soil temperature[4] of 20°C is considered. Further, a break down for emissions across infrastructure, transportation, biochar and biofertilizer production is performed. This analysis determines the total CORC value per ton of biochar produced.

18.1Biochar carbon storage (E_{stored})

E_{stored} represents the estimated amount of carbon sequestered by the biochar over a chosen time horizon (T_H) when applied to soil at a specific temperature (T_S). The calculation follows the methodology outlined by Woolf et al. 2021) [5], given by:

$$E_{stored} = Q_{biochar} \times C_{org} \times F_p^{TH,T_s} \times \frac{44}{12}$$

Where:

- $Q_{biochar}$ is the total amount of dry biochar produced during the reporting period, expressed in metric tonnes.
- C_{org} is the organic carbon content of our biochar, determined through laboratory elemental analysis.
- $F_p^{TH,Ts}$ is the percentage of biochar's organic carbon that remains sequestered after a certain period (TH) in soil with a specific temperature (T_S). This permanence depends on molar H/C_{org} ratio and follows the linear relationship:

$$F_p^{TH,T_s} = c + m \times H/C_{org}$$

The molar H/C_{org} ratio of a biochar sample is derived from the laboratory analysis by dividing the hydrogen mass content by the organic carbon mass content of the biochar, and multiplying this with the ratio of carbon molar mass over hydrogen molar mass i.e.

$$H/C_{org}\,(molar) = \frac{m_H(\%)}{m_C\,(\%)} \times \frac{M_C\,(g\,mol^{-1})}{M_H(g\,mol^{-1})} = \frac{m_H(\%)}{m_C\,(\%)} \times \frac{12}{1.0}$$

The regression coefficients "c" and "m" change based on the chosen time horizon (T_H) and soil temperature (T_S). Table 2 provides the T_S values for a century time horizon. Kenya's average soil temperature is 20°C; therefore, we use "c" as 1.01 and "m" as -0.65 for our calculations.

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Soil temperature T_S	c	m
5°C	1.13	-0.46
10°C	1.10	-0.59
15°C	1.04	-0.64
20°C	1.01	-0.65
25°C	0.98	-0.66
14.9°C	*1.04*	*-0.64*

Table 2: Regression coefficients for estimating biochar stability for a time horizon TH of 100 years at various soil temperatures Ts.

- The factor 44/12 represents the ratio of carbon dioxide's molar mass to carbon's
  molar mass; it converts a given amount of carbon into the equivalent quantity of carbon dioxide (CO_2e)

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Annual mean soil temperature in a specific area or country are obtained from national statistical offices, or alternatively could be derived from global maps of soil temperature e.g. Lembrechts et al. 2021 (https://doi.org/10.1111/gcb.16060) and Langát, Joseph Kimutai. "Soil temperature prediction using measured atmospheric temperature in two high altitude regions of Kenya." *International Journal* 11.3 (2021).

Determining Estored

Our samples of biochar were tested at the Eurofins lab as shown in the appendix.

Therefore, taking:

- Q=1 (one tonne of biochar)
- C_{org}= 95.3% (macadamia shell), and 90.7% (Prosopis).

The Estored (tCO_{2eq}) per respective biomass is calculated as shown in Table 3.

At 20 oC	Macadamia Shells	Prosopis
Q Biochar	1	1
C org	95.30%	90.70%
H:C org	0.14	0.13
$Fp_{TH,Ts}$	92.00%	92.40%

E stored	3.21	3.07

Table 3: E_{stored} at t 20°C

18.2 Determining $E_{biomass}$

A 10-ton truck was used to transport macadamia shell biomass over a distance of 47 km to the production facility, with no expected losses during transit. Transportation data were recorded in tonkilometers (tkm), reflecting both the wet mass of the biomass and the distance traveled.

For Prosopis juliflora harvesting, emissions were calculated based on the time required to clear one ton of biomass using a chainsaw, as recorded by the supplier. It takes approximately two hours to clear and chop one ton. The harvested biomass is then transported over a distance of 200 km to our facility, where it is further preprocessed in nearby sawmills.

18.3 Determining $E_{production}$

$E_{preheat}$

The preheating the pyrolysis reactors uses diesel with an energy density of 38.6 MJ/L or LPG (46MJ/Kg). The fuel consumption is derived from Bio-Logical's records.

$E_{pyrolyis}$

A hoist crane is utilized for loading and unloading the reactors. Additional energy consumers for each reactor set include a water circulation pump, diesel burner and an exhaust line fan. Based on facility records, an average of 25 kWh is required to process one ton of biomass.

System Emissions (E_{system})

The pyrolysis process features a high-efficiency combustion chamber that oxidizes pyrolysis gases, producing mainly CO_2 with minimal CO emissions. Crucially, methane emissions are minimal. Manufacturer tests confirmed no traces of methane in the flue gases, as the system fully utilizes all gases. Please refer to the attached System Emissions sheet and flue gasses emission tests results.

18.4 Determining E_{use}

Emissions from composting ($E_{compost}$)

Emissions produced during composting are considered biogenic, as such, they are part of the natural carbon cycle and not included in the C-sink calculations.

Emissions from crushing and granulation

The biochar is crushed into a fine powder before blending with the compost. The emissions are linked to the energy consumption of 12.8 kWh per ton of biochar dry mass crushed and 1 ton of biofertilizer granulated.

18.5 Infrastructure emissions

We account for infrastructure emissions manufacturing of the pyrolysis reactors and the factory facility, including manufacturing, disposal, maintenance, and resource consumption for materials like steel, refractory, and insulation, over an 8-year lifespan.

18.6 List of emission factors

product	activity	location	unit	source/reference
transport, freight, lorry 7.5-16 metric ton, EURO3	transport, freight, lorry 7.5-16 metric ton, EURO3	RoW	ton kilometer	ecoinvent 3.10-cutoff-5480
electricity, low voltage	market for electricity, low voltage	KE	kilowatt hour	ecoinvent 3.10-cutoff-16746
LPG, burned in stationary burner	LPG, burned in stationary burner	GLO	MJ	2006 IPCC Guidelines
diesel, burned in agricultural machinery	diesel, burned in agricultural machinery	GLO	MJ	ecoinvent 3.10-cutoff-15822
carbon stored in biochar, as CO2	carbon stored in biochar, for 100 years, as CO2	GLO	kilogram	custom
building construction, hall, steel construction	building construction, hall, steel construction	RoW	square meter	ecoinvent 3.10-cutoff-4045
metal working, average for steel product manufactu	metal working, average for steel product manufacturing	RoW	Kg	ecoinvent 3.9.1-cutoff-2343
refractory, fireclay, packed	refractory production, fireclay, packed	RoW	Kg	ecoinvent 3.9.1-cutoff-2443
tap water production	tap water production, underground water without trea	RoW	Kg	ecoinvent 3.10-cutoff-10799
carbon monoxide emissions, as CO	carbon monoxide emission from pyrolysis flue gas (as k	GLO	kilogram	custom
dinitrogen monoxide emissions, as N2O	dinitrogen monoxide emission from pyrolysis flue gas (a	GLO	kilogram	custom
methane emissions, as methane	methane emission from biomass storage (as kg CH4)	GLO	kilogram	custom
methane emissions, as CH4	methane emission from pyrolysis flue gas (as kg CH4)	GLO	kilogram	custom

18.7 Data table

Parameter	Value	Unit	Source/Comment
Macadamia shell transport to site	47	km	Distance from One Acre fund (Sagana) to Bio-logical HQ
Prosopis transport to site	200	km	Average distance from Marigat – Barigo County and Hola – Tana River County to Bio-Logical HQ

Time taken to cut and chop One ton of Prosopis using a Chainsaw	2	Hours	Prosopis supplier records
Saw mill power consumption	23	kWh	Saw mill motor rating
Energy used in Pyrolysis of one ton of biomass	25	kwh	Energy meters install at facility, average taken over production period
Diesel consumed in preheating (calorific value)	38.6	MJ/L	Facility records, fuel consumed is recorded per batch produced
Water consumed per batch for quenching	80	Kg	Water meter records from the facility
Water circulated in system for Scrubbers, Condensers etc	7000	L/set/every 2 weeks	Water meter records from the facility
Wood vinegar, tar emulsion	5000	L/set/every 2 weeks	Facility maintenance records
Energy consumed for one ton DM biochar crushing and one ton fertilizer granulation	12.8	kwh	Energy meters install at facility, average taken over production period

18.8 Data quality analysis

Parameter	Details
Time-related	Data collected over the production period, ensuring up-to-date and relevant measurements.
Geographic coverage	Includes transportation routes from Sagana, Marigat, and Hola to Bio-Logical HQ, and energy consumption in Kenya
Precision	Measurements taken using calibrated meters (energy, water, fuel) and facility records.
Completeness	Comprehensive data covering all major processes: transportation, pyrolysis, and end-use.
Representativeness	Data reflects real-world operations, averaged over consistent production cycles.
Consistency	Parameters consistently measured and recorded using standardized procedures at the facility.
Reproducibility	Results are reproducible with the same equipment and operational conditions.
Sources of the data	Facility records, supplier logs, and energy/water meter readings.
Uncertainty of the information	Low uncertainty due to robust measurement tools and regular calibration

18.9 LCIA results

The results in Tables below quantify the potential Global Warming Potential (GWP) across all life cycle phases, based on the production of one ton of biochar.

Level-1	Level-2	Level-3	*Climate impact in kg CO2-eq*	*kg-CO2 fossil*	*kg CH4 as CO2-eq*	*kg N2O as CO2eq*	*kg oGHG as CO2-eq*

Ebiomass	Supply	RoW / ton kilometer / transport, freight, lorry 7.516 metric ton, EURO3	**32,37**	**19,84**	**0,00**	**0,04**	**12.49**
Eproduction	Pyrolysis operation	GLO / MJ / diesel, burned in agricultural machinery	**293,74**	**290,34**	**0,36**	**3,05**	**0,00**
Eproduction	Pyrolysis operation	GLO / MJ / LPG, burned in stationary burner	**1,13**	**1,13**	**0,00**	**0,00**	**0,00**
Eproduction	Pyrolysis operation	KE / kilowatt hour / market for electricity, low voltage	**10,62**	**10,62**	**0,00**	**0,00**	**0,00**
Eproduction	Pyrolysis operation	RoW / Kg / tap water production, underground water without treatment	**0,07**	**0,07**	**0,00**	**0,00**	**0,00**
Eproduction	Pyrolysis fluegas emissions	GLO / kilogram / methane emission from pyrolysis flue gas (as kg CH4)	**72,46**	**0,00**	**72,46**	**0,00**	**0,00**
Eproduction	Infrastructure requirements	RoW / Kg / metal working, average for steel product manufacturing	**14,31**	**0,00**	**0,00**	**0,00**	**14,31**
Eproduction	Infrastructure requirements	RoW / Kg / refractory production, fireclay, packed	**1,29**	**1,29**	**0,00**	**0,00**	**0,00**
Eproduction	Building for biochar factory and storage	RoW / square meter / building construction, hall, steel construction	**35,84**	**35,84**	**0,00**	**0,00**	**0,00**
Euse	Biochar for compost blend	KE / kilowatt hour / market for electricity, low voltage	**1,83**	**1,83**	**0,00**	**0,00**	**0,00**
Euse	Biochar sold pure 50 km away	KE / kilowatt hour / market for electricity, low voltage	0,01	0,01	0,00	0,00	0,00
Euse	Biochar sold pure 50 km away	RoW / ton kilometer / transport, freight, lorry 7.516 metric ton, EURO3	0,08	0,05	0,00	0,00	0,03
Euse	Biochar sold pure 10 km away	KE / kilowatt hour / market for electricity, low voltage	0,09	0,09	0,00	0,00	0,00
Euse	Biochar sold pure 10 km away	RoW / ton kilometer / transport, freight, lorry 7.516 metric ton, EURO3	0,14	0,09	0,00	0,00	0,05
Estored	Biochar carbon storage use 1	GLO / kilogram / carbon stored in biochar, for 100 years, as CO2	-3214,79	-3214,79	0,00	0,00	0,00

Table 4: Macadamia shells LCIA

Level-1	**Level-2**	**Level-3**	***Climate impact in kg CO2eq***	***kg-CO2 fossil***	***kg CH4 as CO2eq***	***kg N2O as CO2-eq***	***kg oGHG as CO2-eq***
Ebiomass	Supply	RoW / ton kilometer / transport, freight, lorry 7.516 metric ton, EURO3	**154.80**	**94.88**	**0.02**	**0.18**	**59.72**
Ebiomass	harvesting	RoW / hour / power sawing, without catalytic converter	**47.63**	**13.42**	**7.68**	**0.15**	**26.38**
Eproduction	Biomass preprocessing	KE / kilowatt hour / market for electricity, low voltage	**10.98**	**10.98**	**0.00**	**0.00**	**0.00**

Eproduction	Biomass storage	GLO / kilogram / methane emission from biomass storage (as kg CH4)	0.00	0.00	0.00	0.00	0.00
Eproduction	Pyrolysis operation	GLO / MJ / diesel, burned in agricultural machinery	211.03	208.58	0.26	2.19	0.00
Eproduction	Pyrolysis operation	GLO / MJ / LPG, burned in stationary burner	88.38	88.30	0.04	0.04	0.00
Eproduction	Pyrolysis operation	KE / kilowatt hour / market for electricity, low voltage	11.94	11.94	0.00	0.00	0.00
Eproduction	Pyrolysis operation	RoW / Kg / tap water production, underground water without treatment	0.09	0.09	0.00	0.00	0.00
Eproduction	Pyrolysis flue-gas emissions	GLO / kilogram / methane emission from pyrolysis flue gas (as kg CH4)	72.41	0.00	45.19	0.00	0.00
Eproduction	Pyrolysis flue-gas emissions	GLO / kilogram / dinitrogen monoxide emission from pyrolysis flue gas (as kg N2O)	0.00	0.00	0.00	0.00	0.00
Eproduction	Pyrolysis flue-gas emissions	GLO / kilogram / carbon monoxide emission from pyrolysis flue gas (as kg CO)	0.00	0.00	0.00	0.00	0.00
Eproduction	Forklift use	GLO / MJ / forklift, used in industrial production	2.07	1.88	0.00	0.19	0.00
Eproduction	Infrastructure requirements	RoW / Kg / metal working, average for steel product manufacturing	33.56	33.56	0.00	0.00	0.00
Eproduction	Infrastructure requirements	RoW / Kg / refractory production, fireclay, packed	9.09	9.09	0.00	0.00	0.00
Eproduction	Building for biochar factory and storage	RoW / square meter / building construction, hall, steel construction	28.02	28.02	0.00	0.00	0.00
Euse	Biochar for compost blend	KE / kilowatt hour / market for electricity, low voltage	1.96	1.96	0.00	0.00	0.00
Euse	Biochar for compost blend	RoW / ton kilometer / transport, freight, lorry 7.516 metric ton, EURO3	0.78	0.43	0.00	0.00	0.27
Euse	Biochar for compost blend	RoW / Kg / solid manure loading and spreading, by hydraulic loader and spreader	23,62	9.29	0.01	0.10	11.65
Estored	Biochar carbon storage use 1	GLO / kilogram / carbon stored in biochar, for 100 years, as CO2	-3072.92	- 3072.92	0.00	0.00	0.00

Table 5: Prosopis LCIA

Analysis revealed the primary contributor to emissions to be the pyrolysis preheating, significantly higher than other stages in the process. To address this, we're switching to the use of wood and liquefied petroleum gas (LPG) as a potentially cleaner preheating alternatively.

Biomass supply adds to 32.37 kgCO_2e for macadamia shells and 154.8 kgCO_2e for Prosopis. This will significantly decrease once we begin processing Prosopis biomass within a 50 km radius of our proposed second facility in Tana River County.

There are no emissions recorded for biomass storage, disposal of bottom ash, or the production and sourcing of big bags. Blending of biochar with compost has minimal impact at 1.96 kgCO_2e, while the spreading of the compost manure emits 21.05 kgCO_2e.

19 Net Carbon dioxide removal (CORCs)

The 100-year net CORCs are calculated using the following equation:

$$CORCs = Estored - Ebiomass - Eproduction - Euse$$

Macadamia Shells	Climate impact in kg CO2-eq
Estored	3214.79
Ebiomass	-32.37
Eproduction	-429.46
Euse	-2.15
Net (CORC factor)	2750.80

Table 6: Macadamia shells CORCs

Prosopis	Climate impact in kg CO2-eq
Estored	3072.92
Ebiomass	-202.43
Eproduction	-461.57
Euse	-26.36
Net (CORC factor)	2382.56

Table 7: Prosopis CORCs

From the Eurofins laboratory analysis of the biochar's elemental content, the gross sequestration of CO2 is 3214.79 kgCO_2e and 3072.92 kgCO_2e per ton of Macadamia shells, and Prosopis biochar respectively. After deducting the process, supply-chain and end-use emissions, the net CO2 sequestration per metric ton of biochar is 2750.80 kgCO_2e and 2382.56 kgCO_2e respectively.

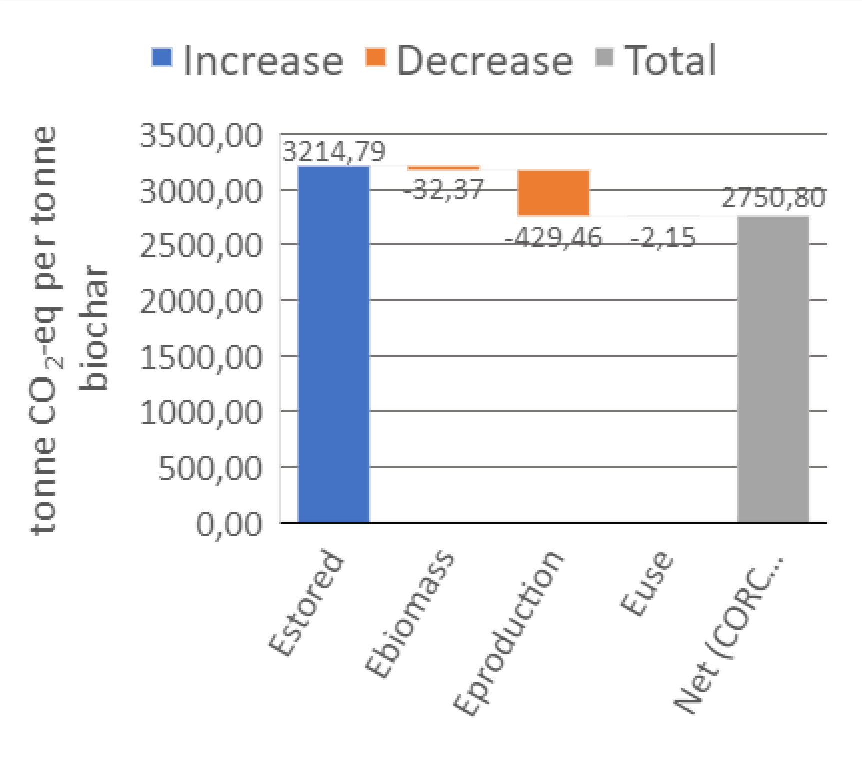

Figure 5: Macadamia shells biochar CORCs

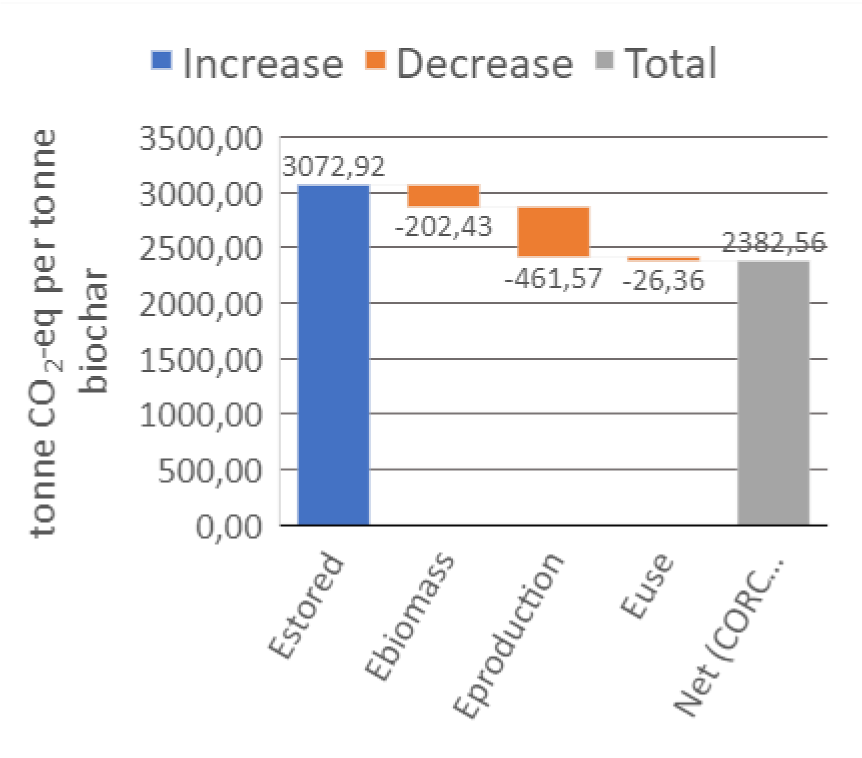

Figure 6: Prosopis biochar CORCs

19.1 Sensitivity analysis

A sensitivity analysis helps assess the reliability of LCA results and the impact of methodological choices. A sensitivity analysis on two key LCIA assumptions for the Macadamia shells biochar production:

- Scenario 1: Increased Transport Distance ○ Change: Biomass sourcing distance increases from 47 km to 100 km.
- Scenario 2: Higher Soil Temperature ○ Change: Biochar applied to soil with a temperature of 25°C instead of 20°C.

Table 8: Sensitivity analysis CORCs calculation

	Estored kgCO2eq	Ebiomass kgCO2eq	Eproduction kgCO2eq	Euse kgCO2eq	CORCs tCO2eq
Baseline (Macadamia shells)	3214.79	32.42	429.46	2.15	2.750
Scenario 1	3214.79	68.89	429.46	2.15	2.713
Scenerio 2	3108.06	32.42	429.46	2.15	2.643

Increasing biomass transport distance from 47 km to 100km resulted in a 1.34% reduction in CORCs (from 2.750 to 2.713 tCO_2e). This highlights the importance of sourcing biomass locally to minimize transportation emissions. While, assuming a soil temperature of 25°C led to a 4.03% decrease in CORCs (from 2.750 to 2.643 tCO_2e). This underscores the influence of end-user region and soil conditions on the carbon storage potential of biochar.

The minimal impact of adjustments confirms the acceptability of our LCA assumptions and calculations.

20 Conclusion

This LCA of Bio-Logical Carbon's biochar and biofertilizer production reveals significant environmental benefits and carbon removal potential associated with the use of local agricultural waste and invasive species. By adhering to ISO 14040/44 standards and Puro.earth's methodology, the assessment provides a comprehensive evaluation of greenhouse gas emissions across the entire lifecycle, from biomass collection to final application. The findings indicate that biochar production from macadamia shells and Prosopis juliflora not only enhances soil health and agricultural productivity but also contributes to substantial carbon sequestration. With calculated net carbon removals of 2750.80 kgCO2e for macadamia shells and 2385.26 kgCO2e for Prosopis per ton of biochar, this project stands as a viable model for sustainable agricultural practices in Kenya. By leveraging renewable energy and optimizing production processes, Bio-Logical Carbon is well-positioned to drive both environmental sustainability and economic resilience in climate-vulnerable communities, ultimately fostering a circular economy that benefits both local farmers and the broader ecosystem.

References

[1] ISO (2006b), ISO 14040:2006, Environmental management – Life cycle assessment – Principles and framework.

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[4] IPCC. (2014). The IPCC's fifth assessment report (AR5). Intergovernmental Panel on Climate Change. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/04/ipcc_ar5_leaflet.pdf

[5] Woolf D, Lehmann J, Ogle S, et al (2021) Greenhouse Gas Inventory Model for Biochar Additions to Soil. Environ Sci Technol. https://doi.org/10.1021/acs.est.1c02425

Appendix

Figure 7: Eurofins Lab Biochar Elemental analysis

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Title :	**Analytical Report for Order 12441033**
EOL Order Code:	**006-10544-73062**
Test report number :	**AR-24-FR-056373-01**
Project name :	**Biochar test 1**
Number of samples :	**2**
Sample type:	**coal**
Date of sample taking :	**2024-09-16**
Sample Taker:	**not specified, sample(s) were delivered to lab**
Sample reception date :	**2024-09-20**
Sample processing time :	**2024-09-20 - 2024-10-15**

The test results solely refer to the analysed test specimen. Unless the sampling was done by our laboratory or in our sub-order the responsibility for the correctness of the sampling is disclaimed. This analytical report is electronically signed and may only be further published completely and unchanged. Extracts or changes require the authorisation of the EUROFINS UMWELT in each individual case.

Our General Terms & Conditions of Sale (GTCS) are applicable, as far as no specific agreements do exist. The GTCS are available on http://www.eurofins.de/umwelt/avb.aspx.

Accredited test laboratory according to DIN EN ISO/IEC 17025:2018 DAkkS notification under the DAkkS German Accreditation System for Testing. The laboratory is according (D-PL-14081-01-00) accredited.

Attachments
XML_Export_AR-24-FR-056373-01.xml

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Report number : AR-24-FR-056373-01

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Parameter	Lab	Accr.	Method	LOQ	Unit	Macadamia Biochar		Prosopis Biochar	
Date and time of sample taking						2024-09-16		2024-09-16	
EOL Sample Code						005-10544-284652		005-10544-284653	
Sample number						124147659		124147660	
						ar	db	ar	db
Biochar properties									
Moisture	FR	F5	DIN 51718: 2002-06	0.1	% (w/w)	13.9	-	26.6	-
Total carbon	FR	F5	DIN 51732: 2014-07	0.2	% (w/w)	82.3	95.6	67.3	91.7
carbon (organic)	FR		Calculation		% (w/w)	82.0	95.3	66.6	90.7
Hydrogen	FR	F5	DIN 51732: 2014-07	0.1	% (w/w)	1.0	1.1	0.7	1.0
Total inorganic carbon (TIC)	FR	F5	DIN 51726: 2004-06	0.1	% (w/w)	-	0.3	-	1.0
carbonate-CO2	FR	F5	DIN 51726: 2004-06	0.4	% (w/w)	1.1	1.2	2.7	3.7

Explanations

LOQ - Limit of quantification

ar - as received

db - dry basis

Lab - Abbreviation of the performing laboratory

Accr. - Abbreviation of the accreditation of the performing laboratory

The parameters identified by FR have been performed by the laboratory Eurofins Umwelt Ost GmbH (Lindenstraße 11, Gewerbegebiet Freiberg Ost, Bobritzsch-Hilbersdorf). The accreditation code F5 identifies the parameters accredited according to DIN EN ISO/IEC 17025:2018 DAkkS D-PL-14081-01-00 .