Biochar Projects on Malama: Full Protocol & Technical Architecture Report

Protocol Compliance: Isometric Biochar Production and Storage v1.2

Blockchain Infrastructure: Cardano (Native Tokens & DIDs)

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1. Executive Summary: The "Proof of Truth" Architecture

Malama Labs utilizes a decentralized verification stack to ensure that every carbon credit is backed by immutable, auditable proof.

This system relies on three core pillars:

1. **Identity (DID) Layer:**
    - **Project Company:** Validated via KYB (Know Your Business). Issued a **Project DID**.
    - **Authorized Staff:** Validated via KYC. Issued **Staff DIDs** linked to the Project DID.
    - **Sensors (Machine Identity):** Critical hardware (scales, CEMS) issued **Device DIDs** with embedded private keys for signing data at the source.
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2. **Project Wallet:** A dedicated Cardano wallet that holds the project's assets.
    - **Liquid Carbon Tokens (LCT):** Minted upfront upon Project Validation (Phase 1). Represents **60%** of projected removal potential over 10 years.
    - **Verified Carbon Tokens (VCT):** Minted ex-post (Phase 4). Represents **100%** of verified sequestration. *Note: LCTs are burned as VCTs are minted.*
3. **Source of Truth:** Every data point originates from either a **Validated Sensor** (Hardware Sign) or an **Authorized Human** (DID Sign).

Phase 1: Project Setup & Baseline (Pre-Operations)

Goal: Establish legality, safety, and the "zero state" before carbon removal begins.

Token Action: Upon Phase 1 Verification, the Protocol mints a % of Projected Carbon Tokens to the Project Wallet. The final % is determined by a Risk Score that is AI driven based on the Project Design Document taking into account the level of project completeness, a finding that the project is economically feasible, the risk associated with the project developers level of experience and reputation in the network, the type of carbon sequestration the project is undertaking.

1.1 Required Documents (Immutable Records)

All documents are hashed to IPFS; the Content ID (CID) is signed by the uploader's DID.

Document / Item	Source (Origin)	Metadata Requirements (JSON)	Verification Method
Project Design Document (PDD)	**DID:** Project Lead	doc_type: "PDD", version: "1.2", protocol: "Isometric-Biochar-v1.2", total_projected_cdr: "1000 tCO2e"	**DID Signature:** Project Lead signs IPFS Hash.
Biomass Sourcing Agreement	**DID:** Legal Team	supplier_did: [DID], feedstock_type: "Bamboo", term_years: "5"	**Smart Contract:** On-chain agreement reference.
Affidavit of Waste	**DID:** Supplier	material_type: "Residue", economic_value: "0.00", exclusion_clause: "Biomass_Module_v1.3"	**DID Signature:** Supplier DID counter-signs.
Land Use / Right of Use	**DID:** Landowner	parcel_id: [ID], rights_assigned_to: [Project DID], duration: "10_Years"	**DID Signature:** Landowner DID counter-signs.
Social Risk Assessment	**DID:** 3rd Party Auditor	auditor_did: [DID], risk_score: "Low", mitigation_plan: "Dust_Control_v1"	**Multi-Sig:** Project Lead + Auditor.

Stakeholder Meeting Minutes	**DID:** Project Lead	meeting_date: [Unix], attendee_count: "15", outcome: "Approved"	**DID Signature:** Signed by Project Lead.
Environmental Risk Assessment	**DID:** Env. Consultant	soil_risk: "None", water_risk: "Low", heavy_metal_baseline: "Pass"	**DID Signature:** Consultant DID.

1.2 Sensor Deployments & Baseline Data

Sensor / Data Point	Source (Origin)	Metadata Requirements (JSON)	Verification Method
Farm Soil Baseline	**Lab API (Oracle)**	soil_carbon_baseline: "1.2%", pH: "6.5", heavy_metals: "Safe", lab_accreditation: "ISO 17025"	**Oracle Feed:** Direct data push from Lab LIMS.
Satellite Baseline	**API (Sentinel-2)**	ndvi_score: "0.45", capture_date: [Unix], resolution: "10m"	**Oracle Feed:** Automated API pull.

1.3 Events

- **Community Consultation Meeting:** Town hall recorded via signed minutes.
- **Site Selection & Boundary Mapping:** GPS Polygon of facility/fields established on-chain.

1.5 Adaptive Pre-Issuance Logic: The AI Risk Engine

- **Overview**

In traditional carbon markets, project developers often face a "capital gap"—waiting 12–24 months for verification before receiving any tradable assets. Malama Labs bridges this gap by issuing **Liquid Carbon Tokens (LCT)** upon the successful validation of the Project Design Document (Phase 1).

However, issuing 100% of projected credits upfront introduces significant delivery risk. To balance **Capital Efficiency** for developers with **Risk Protection** for buyers, the Protocol does not use a flat issuance rate. Instead, it utilizes a proprietary **AI Risk Engine** to calculate a dynamic **Minting Ratio**.

● The Risk Scoring Algorithm

The AI Risk Engine analyzes the Project Design Document (PDD) and on-chain identity data to generate a **Confidence Score (0–100)**. This score determines the percentage of the total projected carbon removal that is safe to mint as LCTs.

The Algorithm evaluates four weighted vectors:

- **Project Completeness & Technical Maturity (30%)**
    - **Analysis:** The AI scans the PDD for operational readiness.
    - **Key Indicators:**
        - Are all critical contracts (Land Use, Feedstock Sourcing) smart-contract-signed or just uploaded as PDFs?
        - Are sensor DIDs (Device IDs) already registered and active on the network?
        - Is the engineering design fully compliant with the specific Isometric Protocol version?
    - **Scoring:** A project with active sensors and signed smart contracts scores higher than one with pending permits.
- **Economic Feasibility & Unit Economics (20%)**
    - **Analysis:** The AI evaluates the financial resilience of the project to ensure it won't run out of cash before delivery.
    - **Key Indicators:**
        - **LCA Margin:** Does the Life Cycle Assessment show a healthy net-carbon margin, or is it razor-thin?
        - **Offtake Agreements:** Are there pre-existing buyers for the physical biochar (e.g., agricultural sales)?
        - **Cost of Goods Sold (COGS):** Is the projected cost per tonne realistic compared to regional benchmarks?
    - **Developer Reputation (Trust Score) (25%)**
        - **Analysis:** The Protocol queries the on-chain history of the Project Proponent’s DID.
        - **Key Indicators:**
            - **Historical Delivery:** What percentage of previous LCTs were successfully converted to Verified Carbon Tokens (VCTs)?
            - **KYB/KYC Depth:** Level of identity verification (e.g., Biometric vs. Document-only).
            - **Network Age:** How long has this developer entity been active in the Malama ecosystem?
        - **Methodology & Sequestration Risk (25%)**

- **Analysis:** Inherent risk associated with the specific carbon pathway chosen.
- **Key Indicators:**
    - **Biochar (High Stability):** Lower risk due to the permanence of inertinite carbon (centennial stability).
    - **Enhanced Weathering (Medium Stability):** Moderate risk due to measurement complexity and weathering rate variability.
    - **Reforestation (Higher Risk):** Higher risk due to biological threats (fire, disease, reversal).

The Minting Formula

The final percentage of projected tokens minted is derived from a base liquidity rate, adjusted by the AI Confidence Score.

Minted = Base Rate + Confidence Score x Volatility Factor

- **Base Rate:** Typically **30%** (The minimum liquidity provided to valid projects).
- **Max Cap:** Typically **80%** (To ensure a safety buffer is always retained).

Scenario Examples:

Project Type	Completeness	Economics	Developer History	Methodology	AI Risk Score	Minting %
"Maui 505"	High (Contracts Signed)	High (Waste Feedstock)	Verified (Previous Success)	Biochar (Stable)	**92/100**	**75%**
New Entrant	Med (Pending Permits)	Med (Tight Margins)	New DID (No History)	Weathering (Complex)	**45/100**	**40%**

2.4 Governance & Safety

- **Human-in-the-Loop:** If the AI Risk Score falls below a specific threshold (e.g., 40), the issuance is paused for manual review by a Malama Auditor.
- **Dynamic Adjustment:** If real-time sensor data (Phase 2) shows deviations from the PDD (e.g., reactor temperature fluctuations), the Smart Contract can freeze unspent LCTs in the Project Wallet to prevent further risk exposure.

Phase 2: Feedstock Sourcing & Production (The "Action")

Goal: Convert biomass to biochar safely and account for all emissions.

2.1 Required Documents

Document / Item	Source (Origin)	Metadata Requirements (JSON)	Verification Method
Feedstock Weight Ticket	**Sensor:** Weighbridge	device_id: "Scale-001", weight_kg: "3720", load_id: "Load-884"	**Hardware Sign:** Private key in sensor signs data.
Moisture Content Log	**DID:** Ops Staff	moisture_percent: "15", method: "Oven Dry", batch_id: "Batch-001"	**DID Signature:** Staff DID signs entry.
Reactor Engineering Diagrams	**DID:** Engineer	reactor_type: "Auger", pressure_rating: "1.5 Bar", diagram_hash: [IPFS CID]	**DID Signature:** Certified Engineer DID.
Reactor Maintenance Log	**DID:** Ops Staff	maintenance_type: "Seal Check", technician_did: [DID], status: "Pass"	**DID Signature:** Staff DID.

ISO 17025 Lab Report (Pollutants)	**Lab API (Oracle)**	pah_level: "<0.5mg/kg", heavy_metals: "Pass", safety_check: "True"	**Oracle Feed:** Lab API.
ASTM D5291 Lab Report (Carbon)	**Lab API (Oracle)**	c_org: "89%", h_c_ratio: "0.3", durability_factor: "0.92"	**Oracle Feed:** Lab API.

2.2 Sensor Deployments & Tracking

Sensor / Data Point	Source (Origin)	Metadata Requirements (JSON)	Verification Method
CEMS (Emissions Monitor)	**Sensor:** Gas Analyzer	ch4_flow: "0.001 kg/hr", n2o_flow: "0.000 kg/hr", timestamp: [Unix]	**Hardware Sign:** Signed data packet (1-min interval).
Reactor Temperature	**Sensor:** Thermocouple	avg_temp_c: "550", min_temp_c: "540", duration: "240 min"	**Hardware Sign:** Signed data packet (continuous).
Reactor Pressure	**Sensor:** Pressure Gauge	pressure_bar: "1.2", leak_detected: "False"	**Hardware Sign:** Signed data packet.
Weighbridge / Load Cells	**Sensor:** Scale	mass_in: "3720 kg", mass_out: "615 kg", yield_percent: "16.5%"	**Hardware Sign:** Signed data packet.

2.3 Events

- **Feedstock Delivery:** GPS tracked transport from source to reactor.

- **Pyrolysis Run:** Start/Stop time logged by machine DID.
- **Sampling Event (Method A):** Composite sample taken; Chain of Custody initiated.

Phase 3: Transport & Storage (The "Removal")

Goal: Move the biochar to its permanent home and prove it stays there.

3.1 Required Documents

Document / Item	Source (Origin)	Metadata Requirements (JSON)	Verification Method
Biochar Weight Ticket (Final)	**Sensor:** NIST Scale	net_weight_kg: "615", cert_id: "NIST-2025-X", batch_id: "Batch-001"	**Hardware Sign:** Private key signature.
Bill of Lading / Receipt	**DID:** Logistics	carrier_did: [DID], pickup_time: [Unix], delivery_time: [Unix]	**Multi-Sig:** Carrier + Receiver.
Application Affidavit	**DID:** Farm Operator	application_method: "Broadcast", loss_rate: "0.1%", field_id: "Waihee-01"	**DID Signature:** Farm Operator DID.

3.2 Sensor Deployments & Tracking

Sensor / Data Point	Source (Origin)	Metadata Requirements (JSON)	Verification Method
GPS Logistics Tracker	**Sensor:** Truck IoT	route_hash: [Hash], distance_km: "6.4", fuel_used_l: "2.1"	**Geo-Fence:** Smart contract verifies destination matches Farm Polygon.

Spreader GPS	**Sensor:** Tractor IoT	coverage_area: "12.5 acres", application_rate: "50 kg/acre"	**Spatial Verification:** GPS tracks overlay on Field Boundary.

3.3 Events

- **Load Out:** Biochar custody transfer (Reactor -> Truck).
- **Delivery:** Biochar arrival at farm (Truck -> Storage).
- **Application:** Final spreading event (Storage -> Soil).

Phase 4: Quantification & Verification (The "Credit")

Goal: Calculate the net impact and mint the asset.

Token Action: Smart Contract Burns LCTs and Mints VCTs based on Final Net Calculation.

4.1 Required Documents

Document / Item	Source (Origin)	Metadata Requirements (JSON)	Verification Method
LCA Report	**DID:** System Auto-Gen	total_emissions: "0.8 tCO2e", feedstock_emissions: "0", transport_emissions: "0.3"	**Algorithmic:** Calculated from aggregated sensor data.
Net CDR Calculation Sheet	**DID:** System Auto-Gen	gross_removal: "2.0 tCO2e", net_removal: "1.96 tCO2e", buffer_pool: "2%"	**Algorithmic:** Isometric Formula (Eq 1).
Verification Report	**DID:** VVB (Verifier)	verification_standard: "Isometric v1.2", audit_result: "Pass", verifier_did: [DID]	**DID Signature:** VVB signs final report.

Credit Issuance Statement	**Registry**	token_id: [Asset ID], serial_numbers: [Range], mint_date: [Unix]	**On-Chain:** Transaction Hash.

4.2 Events

- **Data Aggregation:** System compiles all signed proofs into a Verification Pack.
- **Third-Party Audit:** VVB reviews proofs and physically visits site.
- **Credit Issuance:** Registry executes minting policy.

Master Timeline Visualization

Phase	Timeframe	Key Milestone
1. Setup	Months 1-2	**Validation:** PDD Approval, Risk Assessments. **Token:** Mint LCT (60%).
2. Production	Day 0	**Activity:** Feedstock Delivery, Pyrolysis Run (CEMS/Temp active).
3. Quality	Day 1-5	**Analysis:** Lab results (PAHs, C-org) received via Oracle.
4. Storage	Day 6-7	**Activity:** Transport, Spreading, GPS Verification.
5. Credit	Day 30+	**Verification:** Audit complete. **Token:** Burn LCT / Mint VCT (100%).