

VOLUME
02



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MINERAL
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PRESERVATION LAYER

PASSIVE INFRASTRUCTURE FOR THE STABILIZATION
OF BIOMASS AT ORIGIN



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ENVIRONMENTAL
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VOLUME II — THE PRESERVATION LAYER

Passive Infrastructure for the Stabilization of Biomass at Origin

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FRONTISPIECE

"Biological Capital is the inherent chemical, physical, and agronomic value generated by agricultural and forest harvests, encompassing Carbon, nutrients, moisture, and stored energy."
— Volume I, Blueprint of ORIGEN

"...The preservation of that Biological Capital at the point where it is generated constitutes the first layer of territorial infrastructure..."

EDITORIAL NOTE ON VOLUME NUMBERING

The numbers assigned to the ORIGEN Infrastructure Series (Volume I, II, III) are specific to this series and do not correspond to the Volume numbers of the Tierras de Montaña Institutional Framework Collection (Volumes 0–X). The ORIGEN series is an operational sub-series that applies the principles of the Constitutional Collection to the specific domain of biological infrastructure. This distinction ensures clarity between institutional governance and technical methodology.

PREFACE

Preservation is not a subsequent step. It is the first act of infrastructure.

Volume I (The Origin Blueprint) defined the discipline of Biological Infrastructure Engineering. It established that Biological Capital degrades in the absence of infrastructure. It demonstrated that loss is physical, quantifiable, and universal. But a principle, however solid, does not build infrastructure. This volume develops the first operational layer of that system: the Preservation Infrastructure at origin. Its purpose is to define the criteria, architectures, and indicators necessary to halt the degradation of Biological Capital at the point where it is generated. This is not a technical manual. This is a methodological framework that enables any territory to design its own preservation infrastructure, adapted to its particular conditions. This volume does not modify the principles of the Blueprint. It applies them. It develops them. It makes them operational. It translates them into actionable knowledge for the first preservation infrastructure decision within the ORIGEN methodology.

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CHAPTER 1 — DEGRADATION AS LOSS OF BIOLOGICAL CAPITAL

1.1 Biological Capital as Territorial Asset

Biological Capital, as defined in Volume I, constitutes the inherent chemical, physical, and agronomic value generated by agricultural and forest harvests. It encompasses the Carbon, nutrients, moisture, and energy stored in biomass. This capital is not abstract. It is measurable. It is contained in every kilogram of biomass generated by the territory. However, Biological Capital does not remain stable once biomass is harvested or separated from the plant. From that moment, it initiates a natural transformation process that, in the absence of infrastructure, invariably leads to degradation and loss. Degradation is not a secondary phenomenon. It is the mechanism by which the territory loses, before any transformation, a significant portion of the value it has generated.

1.2 The Preservation Time Window

Fresh biomass does not wait.

Biological degradation processes begin at the very moment biomass is separated from its natural cycle. The speed of these processes depends on multiple factors, including feedstock composition, moisture, temperature, oxygen availability, particle size, and storage conditions. Among these, moisture content is frequently a primary determinant. In high-moisture biomass, the time window available to act is often particularly short. The following table illustrates, for illustrative purposes, the typical progression of degradation mechanisms in wet agricultural residues under uncontrolled conditions:

Period	Dominant Process	Consequence
0–24 hours	Fermentation	CH ₄ emissions (under anaerobic conditions), odors, pH drop
24–72 hours	Leaching	Loss of N, P, K and water contamination
3–7 days	Compaction and structural degradation	Increased handling difficulty and reduced logistical efficiency
>7 days	Carbon mineralization	CO ₂ emissions and reduced sequestration potential

Note: The table is indicative and not universal. Actual rates and dominant mechanisms vary by biomass type and storage conditions.

This table reveals an inescapable fact: without intervention, the time window to preserve Biological Capital can be measured in hours, not days. If no infrastructure intervenes within that period, the value that could have been preserved becomes emissions, leachates, odors, and lost opportunity.

Technical note on cherry decomposition: The following mass balance represents the complete decomposition of 10,000 kg of fresh coffee cherries at 80% initial moisture content, based on standard coffee processing data and validated against the dry-matter input of 2,000 kg.

Fraction	Wet Mass	Moisture	Dry Matter	Water	Status
Wet parchment (pergamino)	2,000 kg	50%	1,000 kg	1,000 kg	ASSUMED
Wet pulp	4,000 kg	85%	600 kg	3,400 kg	ASSUMED
Free water (depulping)	3,600 kg	100%	0 kg	3,600 kg	REVISED
Solids in suspension (mucilage/sugars)	400 kg	100%	400 kg	0 kg	NEW — MODELLED CLOSURE
TOTAL	10,000 kg	—	2,000 kg	8,000 kg	CLOSED

Status: RESOLVED AS MODELLED CLOSURE — The mass balance is mathematically closed through the inclusion of a modelled soluble fraction.

Explanation of the "Solids in Suspension" fraction: The 400 kg of solids in suspension represent the soluble fraction of the cherry (sugars, organic acids, mucilage) that is liberated during depulping and carried with the free water. These solids are not captured in the solid pulp or parchment fractions but are essential for closing the dry-matter balance.

Important: The 400 kg figure is a modelled closure value, not a directly measured mass. It is derived from the mass balance requirement (2,000 kg input dry matter – 1,600 kg accounted for in solid fractions = 400 kg). This value is sufficient for establishing a coherent mass balance baseline for the ORIGEN methodology. Future site-specific measurements may refine this value, but the current assumption is considered technically defensible for the reference case.

Technical note on parchment to green coffee conversion:

2,000 kg of wet parchment (pergamino) at 20.8% moisture content produces, after drying and husking, 1,800 kg of green coffee at 12% moisture content.

Mass Balance Verification:

Parameter	Value	Calculation
Wet parchment input	2,000 kg	Given
Parchment moisture	20.8%	REVISED BASIS
Parchment dry matter	1,584 kg	$2,000 \times (1 - 0.208)$
Parchment water	416 kg	$2,000 - 1,584$
Green coffee output	1,800 kg	Given
Green coffee moisture	12%	Standard export
Green coffee dry matter	1,584 kg	$1,800 \times (1 - 0.12)$
Yield	90%	$(1,584 \text{ kg of green coffee} / 1,760 \text{ kg of dry parchment}) \times 100\%$

Status: PARTIALLY RESOLVED / BOUNDARY DEFINITION REQUIRED — Mathematical consistency achieved, but the transition between depulping (50%) and transport (20.8%) requires explicit process definition.

Explanation of the revised moisture assumption: The original assumption of 45-50% moisture for wet parchment reflects freshly depulped parchment before drainage. The 20.8% value represents the moisture content after drainage and passive drying at the farm level — the point at which the parchment is weighed for transport.

Boundary definition required: The transition from the cherry decomposition (50% parchment at depulping) to the transport stage (20.8% parchment after drainage) requires a defined process step. The moisture reduction occurs through passive drainage and drying, but the specific mass balance of this transition is not fully documented.

Important: This is a boundary condition, not a physical impossibility. The 20.8% moisture value is consistent with well-drained parchment ready for transport. However, the process step between the two stages must be explicitly described in the operational documentation.

1.3 The Mechanisms of Degradation

The degradation of Biological Capital is not a single process. It is a set of mechanisms acting simultaneously.

1.3.1 Fermentation

Fresh biomass contains sugars, starches, and other easily degradable organic compounds. In the presence of moisture, naturally occurring microbial communities begin to metabolize these compounds.

Fermentation generates:

- Organic acids, which reduce pH
- Volatile compounds, responsible for odors
- Methane (CH₄) under anaerobic conditions

Fermentation not only reduces the energy value of biomass. It also generates environmental externalities that affect the surrounding territory.

1.3.2 Leaching

The water contained in biomass is not inert. It acts as a solvent and as a transport medium. As biomass decomposes, nutrients (nitrogen, phosphorus, potassium) are mobilized and carried away by runoff water. This phenomenon, known as leaching, has two consequences:

- Nutrient loss for the territory: Nutrients that should return to the soil are lost in drainage water.
- Contamination of water bodies: Leachates, with high organic load, generate Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) in receiving water bodies.

Leaching is one of the primary pathways for the loss of agronomic value and the generation of environmental liabilities.

1.3.3 Carbon Mineralization

The Carbon contained in biomass exists in two main states:

Carbon Type	Description	Fate
Labile Carbon	Easily degradable fraction	Rapid mineralization to CO ₂ or CH ₄
Stable Carbon	Recalcitrant fraction	Persists in soil or can be converted to biochar

In the absence of infrastructure, labile Carbon mineralizes rapidly, releasing CO₂ to the atmosphere. This loss reduces the Carbon sequestration potential of the territory and diminishes the amount of organic matter available for soil formation.

1.3.4 Compaction and Structural Loss

Wet biomass tends to compact under its own weight. This process reduces porosity, hinders gas exchange, and creates anaerobic conditions that accelerate fermentation and methane generation. Additionally, compaction makes subsequent biomass handling more difficult, increasing logistical costs and reducing the efficiency of later valorization stages.

1.4 Economic and Environmental Losses

The degradation of Biological Capital is not a purely physical or chemical phenomenon. It has direct economic and environmental consequences.

1.4.1 Carbon Loss

Carbon that mineralizes to CO_2 or CH_4 is Carbon that will not be available for:

- Soil sequestration
- Conversion to biochar
- Energy generation
- Improvement of soil fertility

This loss represents, simultaneously, a wasted economic opportunity and an avoidable environmental impact.

1.4.2 Nutrient Loss

Nutrients carried away by leaching are not only lost to the productive system. When they reach water bodies, they generate:

- Eutrophication
- Fish mortality
- Water treatment costs
- Loss of aquatic biodiversity

The replacement cost of these nutrients through synthetic fertilizers falls on the producer and the territory.

1.4.3 Logistical Efficiency Loss

Wet biomass is heavy. The water it contains represents a significant fraction of its total weight. Transporting water is transporting an input that adds no value at the destination.

Logistical efficiency is reduced because:

- Each kilogram of water transported occupies capacity that could be dedicated to Carbon or nutrients
- The energy density of wet biomass is low, increasing the cost per unit of useful energy
- Handling wet materials is more complex and costly

1.5 The Opportunity Cost

Beyond physical and economic losses, the degradation of Biological Capital represents a loss of opportunity for the territory. Each kilogram of Carbon that becomes CO_2 before being transformed is a kilogram that does not become:

- Fertile soil
- Renewable energy
- Bio-based material
- Carbon credit
- Income for the producer

Each liter of leachate that contaminates a water body is a liter of nutrients that does not return to the agronomic cycle. Each hour that biomass remains without infrastructure is an hour in which the territory loses value.

1.6 Preservation as Methodological Response

Preservation is not one solution among others. It is the methodological response to a fundamental physical and economic problem.

Preserving Biological Capital means halting degradation mechanisms before they reduce the value of biomass.

It means intervening during the critical time window to ensure that Carbon, nutrients, and stored energy remain available for subsequent stages.

Preservation infrastructure, therefore, is not an operational cost. It is the investment necessary to ensure that the value generated by the territory is not lost before being transformed.

CHAPTER 2 — TERRITORIAL CONSTRAINTS AS DESIGN CONDITIONS

2.1 The Territory as Design Condition

Preservation infrastructure is not designed in a vacuum. There is no universal solution applicable to all territories. Each territory imposes a set of physical, climatic, and logistical constraints that condition any preservation strategy. Infrastructure design must begin with the recognition of these constraints. It is not possible to select a technology, size an installation, or define an operational protocol without first understanding the conditions that the territory imposes.

2.2 Initial Moisture Content

The initial moisture content of biomass is a primary variable for any preservation strategy.

High-moisture biomass:

- Is more susceptible to fermentation and degradation
- Has lower energy density
- Is heavier and more costly to transport
- Requires more energy for drying or stabilization

Initial moisture is not uniform. It varies according to:

- Crop type
- Harvest timing
- Previous climatic conditions
- Harvesting method

Quantifying initial moisture content is the first step in sizing any preservation infrastructure.

2.3 Ambient Temperature

Temperature accelerates or slows biological processes.

Climate	Effect on Preservation	Design Implication
Warm climates	Fermentation is faster, preservation window shorter, odors and emissions more intense	Faster intervention required, enhanced ventilation needed
Cold climates	Biological processes slow, preservation window longer, but natural drying is slower	Longer drying time required, protection from frost

Ambient temperature varies according to: altitude, season, time of day, and solar exposure. Infrastructure design must consider these seasonal and daily variations.

2.4 Altitude

Altitude indirectly affects preservation through its influence on temperature and atmospheric pressure.

Factor	Effect at Higher Altitude
Mean temperature	Lower
Atmospheric pressure	Lower
Relative humidity	More variable

In mountain territories such as the Andean range, altitude imposes specific constraints:

- Logistics are more complex and costly
- Access to technologies and spare parts is more limited
- Specialized labor is scarcer
- Distances to collection centers are typically greater

These constraints must be considered in the design of any preservation infrastructure.

2.5 Topography and Slope

Territorial topography conditions: accessibility to farms and cultivation areas; the possibility of installing infrastructure; natural water drainage; and solar exposure and ventilation.

Terrain Type	Implication for Preservation Design
Steep slopes	Vehicle access is limited, infrastructure installation is more costly, natural drainage may be harnessed
Flat terrain	Easier access, simpler installation, but drainage must be designed intentionally

Topography should not be seen solely as a limitation. In some cases, it offers opportunities: slope can facilitate gravity drainage, orientation can maximize solar exposure, and altitude can offer favorable conditions for drying.

2.6 Water Availability

Water is a dual resource in preservation.

Aspect	Effect
Water in biomass	Must be reduced to halt degradation
Rainwater	Can interfere with natural drying
Leachate water	Contains nutrients that can be recovered
Water for irrigation	Can be used during dry seasons

Water availability in the territory affects the viability of natural drying, the need for covers or protections, and the possibility of recovering leachates for agronomic use.

2.7 Distance and Accessibility

The distance between the point of biomass generation and the collection or transformation center is a critical factor.

Distance Factor	Consequence
Greater distance	Higher transport cost, longer time between generation and transformation, higher degradation risk during transport, greater dependence on road infrastructure
Limited accessibility	Restrictions on vehicle type, collection frequency, maintenance access, viability of decentralized infrastructure

In territories with limited roads or difficult access, preservation at origin becomes not only convenient but necessary.

2.8 Seasonality and Climatic Variability

Biomass is not generated uniformly throughout the year. Harvests are seasonal.

Seasonality Factor	Implication
Peak generation	Occurs at specific times
Low generation	Periods of reduced or zero generation
Moisture variation	Initial moisture varies by season

Preservation infrastructure must be designed to absorb generation peaks without collapsing, function under variable climatic conditions, and allow storage of preserved biomass for low-generation periods. Seasonality and climatic variability are not exceptions. They are normal conditions of any agricultural territory.

2.9 Available Logistical Capacity

Preservation does not occur in a vacuum. It is part of a broader logistical system including collection, transport, storage, and transformation. Available logistical capacity in the territory

affects: frequency of biomass collection, volume that can be transported per trip, maximum distance biomass can travel before degrading, and availability of labor to operate infrastructure. Preservation infrastructure must be designed considering the real logistical capacity of the territory, not the desired capacity.

2.10 The Interaction of Constraints

Physical constraints do not act in isolation. They interact with each other.

Example 1: Complex Territory: A territory with high initial moisture, warm climate, and difficult access roads faces a combined challenge: biomass degrades rapidly, transport is costly, and distance to transformation is great.

Example 2: Favorable Conditions: A territory with low initial moisture, temperate climate, and accessible roads has more favorable conditions but may face other challenges such as seasonality or topography.

Infrastructure design must consider the interaction of all constraints, not each one individually.

2.11 Implications for Infrastructure Design

Recognition of physical constraints has direct implications for preservation infrastructure design:

Implication	Meaning
No universal solution	Each territory requires a design adapted to its specific conditions
Modularity and scalability	Infrastructure must adapt to variations in volume, moisture, and climatic conditions
Robustness and low maintenance	In territories with limited access, technical complexity must be minimized
Use of natural conditions	Infrastructure must harness gravity, wind, sun, and temperature wherever possible
Future evolution	Design must consider not only the current state of the territory but its future evolution

2.12 Methodological Conclusion

Physical constraints are not obstacles to overcome. They are design conditions to integrate.

The territory is not a problem to solve. It is the con that defines possible solutions. Preservation at origin is not a technical imposition. It is a response to the physical, climatic, and logistical constraints that the territory imposes. Understanding these constraints is the first step in designing infrastructure that works in the territory, not against it.

CHAPTER 3 — PASSIVE INFRASTRUCTURE AS METHODOLOGICAL RESPONSE

3.1 Passive Infrastructure as Methodological Response

Infrastructure design must begin with a fundamental decision: what type of infrastructure is appropriate for the territory?

Volume I establishes that biological infrastructure must adapt to the physical constraints of the raw material, not the reverse. This principle, known as Origin Principle I, has direct implications for design. In territories with high moisture, complex topography, and limited access, passive infrastructure constitutes the most appropriate response.

Passive infrastructure is characterized by:

- Using natural forces (gravity, wind, sun, thermal convection) as the primary energy source
- Minimizing dependence on external inputs (fuels, electricity, complex spare parts)
- Requiring low maintenance and simple operation
- Being modular and scalable
- Adapting to the specific conditions of the territory

Passive infrastructure constitutes the methodological response when territorial conditions limit the application of intensive infrastructures. It is the solution that respects the constraints of the territory and maximizes the probability of continuous operation.

3.2 Design Principles Derived from the Blueprint

Volume I defines three Origin Principles and five derived operational principles. These principles constitute the basis for the design of any preservation infrastructure.

3.2.1 Origin Principle I: Biology Governs Infrastructure

Statement: Hardware is subordinated to biology. Infrastructure must adapt to the physical constraints of the raw material, not the reverse. The raw material defines the design parameters.

Design Implication: Design must begin with biomass analysis: moisture content, composition, seasonality, volume. Infrastructure is designed from this data, not from pre-existing technology.

3.2.2 Origin Principle II: Preserve Before Transforming

Statement: Time degrades value. The primary function of infrastructure in its initial phase must be to halt biological degradation and secure the Carbon baseline. Preservation precedes conversion in all cases.

Design Implication: Preservation infrastructure must not be conceived as a preparatory step to transformation. It is an independent stage with its own design logic. Its objective is not to prepare for conversion; it is to halt degradation.

3.2.3 Origin Principle III: Infrastructure Precedes Technology

Statement: Without conditioning, logistics fail. Without logistics, conversion fails. Infrastructure must be established before selecting any conversion technology.

Design Implication: Preservation infrastructure is designed without considering subsequent conversion technology. Technology is selected once the biomass has been stabilized and its characteristics are known.

3.2.4 Derived Operational Principles

Principle	Statement	Design Implication
1	Biomass determines infrastructure	Design from biomass, not from technology
2	Value must be preserved before it can be transformed	Preservation is an end in itself, not a means to transformation
3	Territories are systems; they cannot be optimized independently	Design considering interaction with other infrastructure layers
4	Passive solutions must be evaluated first	Exhaust solutions using natural forces before considering active solutions
5	Technology is the final decision	Technology selection is the last step of the design process

3.3 Design Criteria for Passive Infrastructure

From the Blueprint principles, six specific design criteria for passive preservation infrastructure are derived.

Figure 3.3

Illustration of the main operational principles (separation, drainage, ventilation, leachate collection).



3.3.1 Criterion 1: Adaptation to Initial Moisture

Initial moisture determines degradation speed and intervention urgency. Design requirements:

- Size infrastructure according to biomass volume and moisture content
- Provide drainage and ventilation mechanisms for moisture reduction without external energy
- Consider seasonal moisture variation

3.3.2 Criterion 2: Use of Natural Forces

Passive infrastructure uses natural forces as primary energy source. Design requirements:

- Use gravity for drainage and liquid separation
- Harness wind for ventilation and gas exchange
- Use thermal convection for air movement
- Maximize solar exposure for natural drying
- Minimize dependence on electricity or fuel

3.3.3 Criterion 3: Modularity and Scalability

Infrastructure must adapt to variations in biomass volume. Design requirements:

- Allow capacity expansion or reduction according to seasonality
- Be constructible in stages
- Use standardized, locally available components
- Facilitate maintenance and repair with local resources

3.3.4 Criterion 4: Robustness and Low Maintenance

In territories with limited access, technical complexity must be minimized. Design requirements:

- Use durable materials resistant to climatic conditions
- Minimize moving parts
- Require simple, infrequent maintenance
- Be operable by personnel with basic training

3.3.5 Criterion 5: Integrated Effluent Management

Infrastructure must not generate environmental externalities. Design requirements:

- Capture and channel leachates for treatment or reuse
- Prevent contamination of water bodies
- Control odors and emissions
- Recover nutrients for agronomic use
- Prevent anaerobic conditions generating methane (as a design objective)

3.3.6 Criterion 6: Territorial Continuity

Infrastructure must be conceived as part of a broader territorial system. Design requirements:

- Consider integration with other infrastructure layers
- Be compatible with future territorial evolution
- Strengthen local biomass management capacity
- Generate knowledge and experience that can be replicated in other territories

3.4 The Origin Decision Matrix as Design Tool

Figure 3.4

Comparison between passive and active infrastructure based on territorial restrictions.

PASSIVE INFRASTRUCTURE Designed for territorial restrictions			ACTIVE INFRASTRUCTURE Dependent on external inputs		
Uses natural forces (gravity, wind, sun, thermal convection).	 ENERGY SOURCE		Requires external energy (electricity, fuel).		✗
Low external dependency.	 EXTERNAL DEPENDENCY		High dependence on inputs and supplies.		✗
Low maintenance and operation.	 MAINTENANCE		High maintenance and complex operation.		✗
Modular and scalable according to needs.	 MODULARITY		Rigid and poorly adaptable.		✗
Uses locally available materials.	 MATERIALS		Requires specialized materials.		✗
Low energy consumption.	 ENERGY CONSUMPTION		High energy consumption.		✗
Greater resilience to failures and climatic conditions.	 RESILIENCE		Vulnerable to equipment and input failures.		✗
Lower investment and operation cost.	 COST		Higher investment and operation cost.		✗
Higher probability of continuous operation.	 OPERATIONAL CONTINUITY		Higher risk of interruptions.		✗
 Passive infrastructure is the methodologically preferred response when territorial restrictions are physical, logistical, economic and technical.					

Volume I defines the Origin Decision Matrix as the methodological tool for filtering biological reality through territorial constraints and determining the appropriate infrastructure response. For passive preservation infrastructure, the Origin Decision Matrix evaluates the following constraints:

Constraint	Evaluation Criteria
Moisture content	>80% vs <30%
Transport radius	<10 km vs >50 km
Waste heat availability	Available vs Not available
Volumetric seasonality	Intense peak vs Constant flow
Land availability	>2 ha vs <0.5 ha
Energy availability	Grid waste heat vs None
Capital availability	Investment-ready vs Limited
Technical capacity	Skilled vs Basic

When constraints indicate high moisture, limited transport, restricted capital, and low technical capacity, the Origin Decision Matrix recommends the Passive Systems archetype.

3.5 Operational Principles for Passive Design

From the design criteria and the Origin Decision Matrix, specific operational principles for passive infrastructure design are derived.

Principle	Statement	Application
1. Separate liquids and solids at origin	Liquid transport is uneconomic and environmentally risky	Drainage at the point of generation
2. Ventilate without energy	Gas exchange must be guaranteed by natural mechanisms	Thermal convection, wind, pressure differentials
3. Drain by gravity	Water must be drained using gravity-driven slopes and channels	Pumping avoided wherever possible
4. Capture and reuse leachates	Leachates are mobilized nutrients, not waste	Capture, storage, and reuse in the agronomic cycle
5. Use local materials	Construction materials should be locally available and low-cost	Reduced dependence on imported materials
6. Design for the local operator	Infrastructure must consider the capabilities of the local operator	Technical complexity minimized to necessary function

3.6 Methodological Conclusion

Passive infrastructure is not a technical choice among others. It is the methodological choice that responds to territorial constraints and Blueprint principles.

When the territory presents high initial moisture, complex topography, limited access, restricted capital, and limited technical capacity, passive infrastructure is the solution that uses natural forces, minimizes external dependence, reduces maintenance, and maximizes the probability of continuous operation.

Passive infrastructure is not an inferior solution. It is the solution that respects the biology, the territory, and the principles of ORIGEN.

CHAPTER 4 — COMPONENTS OF PASSIVE INFRASTRUCTURE

4.1 Infrastructure as a Functional System

Preservation infrastructure is not an isolated element. It is a system composed of functional components that interact with each other to achieve a common objective: halting the degradation of Biological Capital. Each component fulfills a specific function within the system. The absence or malfunction of any one of them compromises the effectiveness of the whole. This chapter describes the constitutive elements of passive preservation infrastructure. It does not prescribe specific designs. It defines the functions that must be fulfilled and the criteria that must be considered in the design of each component.

4.2 Component Overview — The Preservation System

Component	Primary Function	Design Criteria
Capture and Reception	Receive biomass and protect it from ground contact and rain	Impermeable surface, cover, drainage slope, access for unloading, capacity matched to harvest peak
Solid-Liquid Separation	Reduce free moisture and promote aerobic conditions	Gravity drainage, inclined or perforated surface, continuous leachate evacuation, no standing water
Leachate Drainage and Capture	Channel and recover leachates for treatment or reuse	Sloped channels, impermeable storage, sufficient capacity, treatment or reuse system
Natural Ventilation	Supply oxygen and evacuate heat and gases	Wind and convection utilization, uniform distribution of conduits, lower inlet and upper outlet
Thermal Stabilization	Maintain temperature compatible with biological preservation	Natural heat dissipation, periodic monitoring, adjustable ventilation and biomass thickness
Filter Bed	Filter leachates, retain nutrients, facilitate drainage	Locally available material, high absorption capacity, physical stability, water and air permeability
Preserved Biomass Storage	Store preserved biomass until transport or transformation	Cover, ventilation, protection from re-wetting, sufficient capacity, access for loading and unloading

4.3 Capture and Reception

Capture is the first point of contact between generated biomass and preservation infrastructure.

Functions:

- Receive biomass at the moment of generation or immediately after
- Prevent direct contact with the ground to avoid contamination and degradation
- Initiate the liquid-solid separation process
- Protect biomass from rain and external moisture

Design Criteria:

Criterion	Requirement	Rationale
Surface	Impermeable, with drainage slope	Prevents ground contact and directs water flow
Cover	Must be covered	Protects biomass from rain and external moisture
Access	Allows unloading of biomass	Enables practical operation
Sizing	Matched to maximum expected volume at harvest peak	Absorbs volumetric shock without collapse

Typical Materials: Compacted earth with membrane lining, concrete (reduced use, only where necessary), locally sourced stone or gravel base



4.4 Solid-Liquid Separation

Fresh biomass contains a significant fraction of free water. This water must be separated from the solid fraction to halt degradation processes.

Three Functions:

1. Reduce moisture content of the biomass
2. Drain water that contains soluble nutrients
3. Create aerobic conditions that prevent anaerobic fermentation

Design Criteria:

Criterion	Requirement	Rationale
Gravity-driven	System must use gravity as motive force	Eliminates energy consumption and mechanical complexity
Inclined or perforated surface	Allows drainage of water	Enables continuous liquid removal
Channeling	Drained water must be channeled to capture system	Prevents re-contamination and allows recovery
No standing water	Design must avoid water accumulation	Prevents anaerobic conditions

Typical Materials: Perforated platforms (wood, metal, or recycled materials), sloped concrete or compacted earth with drainage channels, bamboo or timber grating (where available).

4.5 Leachate Drainage and Capture

Leachate — the water drained from biomass — contains soluble nutrients (nitrogen, phosphorus, potassium) and organic compounds. Its management is critical.

Functions:

- Prevent contamination of water bodies
- Recover nutrients for agronomic use
- Control odors and emissions

Design Criteria:

Criterion	Requirement	Rationale
Channels	Must have sufficient slope	Prevents water accumulation
Capture point	Must have storage for leachate	Enables recovery and treatment
Impermeability	Storage must be impermeable	Prevents groundwater infiltration
Treatment/Reuse	Must have system for treatment or reuse	Closes the nutrient cycle

Critical Design Considerations:

Leachate Characteristic	Design Implication
High nutrient content (N, P, K)	Capture for agronomic reuse — not disposal

High BOD/COD	Prevent discharge to water bodies
Acidic (pH 4–5, indicative)	Storage may require acid-resistant materials
Volume peaks with harvest	Storage capacity must match peak generation

4.6 Natural Ventilation

Ventilation is essential for maintaining aerobic conditions in biomass and preventing anaerobic fermentation.

Three Functions:

1. Supply oxygen for aerobic processes
2. Remove heat generated by microbial respiration
3. Remove gases and volatile compounds produced during stabilization

Design Criteria:

Criterion	Requirement	Rationale
Natural	Ventilation must be natural — thermal convection and wind	Eliminates energy consumption and mechanical complexity
Flow-through	Infrastructure must allow air flow through biomass	Enables continuous gas exchange
Conduit distribution	Tubes or channels distributed uniformly	Ensures even aeration throughout the mass
Lower inlet/upper outlet	Air enters from base, exits from top	Utilizes natural thermal convection

Types of Natural Ventilation Systems:

Type	Mechanism	Best Application
Bottom-up convection	Air enters through perforated base, rises through biomass, exits at top	Most versatile, works in most conditions
Cross-flow	Wind-driven horizontal flow through biomass	Where consistent winds are available
Top-down displacement	Air enters from surface, exits through base	Where wind is limited

Conduit Design Principles (indicative):

Principle	Application
Perforated tubes	PVC or bamboo tubes with holes, distributed across the base
Uniform spacing	Maximum 1.5 m between conduits (indicative)
Outlet height	At least 50 cm above biomass surface (indicative)
Free airflow	No obstructions at inlet or outlet

Note: These are indicative design parameters. Final spacing and dimensions depend on local biomass characteristics and airflow conditions.

4.7 Thermal Stabilization

Biomass in stabilization generates heat as a result of microbial activity. If temperature rises too high, nutrient loss through volatilization, fire risk, and death of beneficial microorganisms may occur.

Design Criteria:

Criterion	Requirement	Rationale
Heat dissipation	Infrastructure must allow natural heat dissipation	Prevents overheating
Ventilation	Natural ventilation must be sufficient	Removes heat with air flow
Adjustability	Must be possible to adjust ventilation or layer thickness	Enables operational control
Monitoring	Temperature must be monitored regularly	Provides operational feedback

Operational Temperature Guidelines (indicative):

Temperature Range	Status	Action Required
Ambient to 40°C	Normal start-up	Continue monitoring
40-50°C	Active stabilization	Normal operation
50-65°C	Peak thermophilic activity	Monitor closely, ensure ventilation
>65°C	Excessive activity	Increase ventilation, reduce layer thickness
>75°C	Critical risk	Immediate intervention required

Note: These ranges are indicative and based on general composting literature. They should be validated for each specific biomass type and local conditions.

4.8 Filter Bed

The filter bed is a layer of functional material placed at the base of the infrastructure that fulfills multiple functions: filter the leachate and retain solid particles, provide surface for microbial development, absorb organic compounds and nutrients, and act as structural material for drainage.

Design Criteria:

Criterion	Requirement	Rationale
Local availability	Material must be locally sourced	Reduces cost and dependency
Absorption capacity	Must absorb nutrients and organic compounds	Enables nutrient capture
Stability	Must be stable, not degrading rapidly	Provides long-term function
Permeability	Must allow flow of water and air	Enables drainage and aeration

Material Options — Performance Comparison:

Material	Drainage Capacity	Nutrient Retention	Stability	Availability	Assessment
Biochar	High	Very High	Very High	Variable	Reference material — subject to local performance validation
Rice husk	High	Medium	Medium	High (rice regions)	Lightweight, economical, easy to replace
Wood chips	Medium	Low	Medium	High (forested regions)	Promotes aeration and drainage
Carbonized plant material	High	High	High	Variable	Good local alternative
Washed gravel	Very High	Very Low	Very High	High	Excellent drainage; requires organic material
Coarse sand	High	Low	High	High	Good drainage in combination with other materials
Local equivalents	Variable	Variable	Variable	Territory-dependent	Must be evaluated for permeability, stability, and absorption

Biochar as Reference Material:

Characteristic	Why It Matters
High porosity	Potential for excellent water and nutrient retention
High surface area	Supports microbial colonization
Chemical stability	Resists degradation
Nutrient adsorption	Potential for capturing K, N, P from leachates
Carbon storage	Provides additional CDR benefit (subject to verification)

Note: Performance depends on biochar properties and leachate composition. Local validation is required.

4.9 Preserved Biomass Storage

Once biomass has reached a state of stabilization, it must be stored until transport or transformation.

Two Functions:

1. Allow accumulation of biomass to optimize logistics
2. Protect preserved biomass from re-contamination or re-wetting

Design Criteria:

Criterion	Requirement	Rationale
Cover	Must be covered	Protects from rain
Ventilation	Must allow ventilation	Prevents re-wetting
Sizing	Sized for the volume between transport cycles	Enables logistical optimization
Access	Accessible for loading and unloading	Enables practical operation

Storage Principles:

Principle	Application
Dry storage	Moisture below 25% — stable for extended periods
Protected from rain	Cover prevents re-wetting and leachate generation
Airflow	Natural ventilation prevents condensation
Pest control	Proper storage prevents rodent and insect infestation
Inventory management	First-in-first-out (FIFO) ensures consistent quality

4.10 System Integration — Component Relationships

The components described above do not operate in isolation. They form an integrated system where each component depends on the proper functioning of the previous and conditions the next.

Functional Sequence:

Step	Component	Function
1	Capture and Reception	Receives biomass and separates it from the ground
2	Solid-Liquid Separation	Drains free water from biomass
3	Leachate Drainage and Capture	Channels drained water for treatment or reuse
4	Natural Ventilation	Maintains aerobic conditions
5	Thermal Stabilization	Controls temperature
6	Filter Bed	Filters and retains nutrients
7	Preserved Biomass Storage	Protects biomass until transport or transformation

Integration Principles:

Principle	Application
Sequential dependency	Each component conditions the next
Capacity matching	All components must be sized for peak volume
Flow continuity	Material flow must be continuous
Redundancy	Critical components may have backup capacity
Monitoring feedback	Performance data feeds back to operational adjustments

4.11 Relationship to Origin Principles

Principle or Criterion	Application to Components
Origin Principle I (Biology governs infrastructure)	Components are designed from biomass moisture content and composition
Origin Principle II (Preserve before transforming)	Components function to halt degradation, not to prepare for conversion
Origin Principle III (Infrastructure precedes technology)	Components are designed without considering conversion technology
Operational Principle 4 (Passive solutions first)	All components use natural forces (gravity, convection, wind)
Moisture management	Solid-liquid separation, drainage, and ventilation reduce moisture
Leachate control	Drainage and capture prevent contamination
Nutrient recovery	Filter bed and leachate capture enable nutrient recovery (subject to validation)
Modularity	Components can be scaled according to biomass volume

4.12 Conclusion — Infrastructure as Integrated System

Preservation infrastructure is not a collection of independent elements. It is a system where each component fulfills a specific function and contributes to the common objective of preserving Biological Capital. The design of each component must consider: the constraints of the territory, the volume and characteristics of the biomass, the interaction with other components, and the principles and criteria of the Blueprint.

When components function in an integrated manner, preservation infrastructure is designed to achieve:

Outcome	Mechanism
Halts biomass degradation	All components work together to arrest biological decomposition
Reduces carbon and nutrient losses (design objective)	Fermentation, leaching, and mineralization are controlled
Prevents environmental contamination	Leachates are captured, odors are controlled
Prepares biomass for transformation	Biological Integrity is the defined preservation condition for downstream conversion

Preservation infrastructure is not a set of technical elements. It is a territorial system designed to preserve biological value.

CHAPTER 5 — SYSTEMIC INTEGRATION

5.1 The Methodological Architecture of ORIGEN

Volume I defines the Origin Decision Matrix as the methodological mechanism that filters biological reality through territorial constraints to determine the appropriate infrastructure response. The Matrix is not a mechanical design tool. It is a decision framework that forces the designer to explicitly consider territorial constraints before selecting any technical solution. This chapter situates The Preservation Layer within this methodological architecture. It shows how the Origin Decision Matrix leads to the selection of passive infrastructure and how this layer integrates with subsequent layers of the ORIGEN system.

Figure 5.1
Decision Matrix for Selecting the Appropriate Preservation Layer.

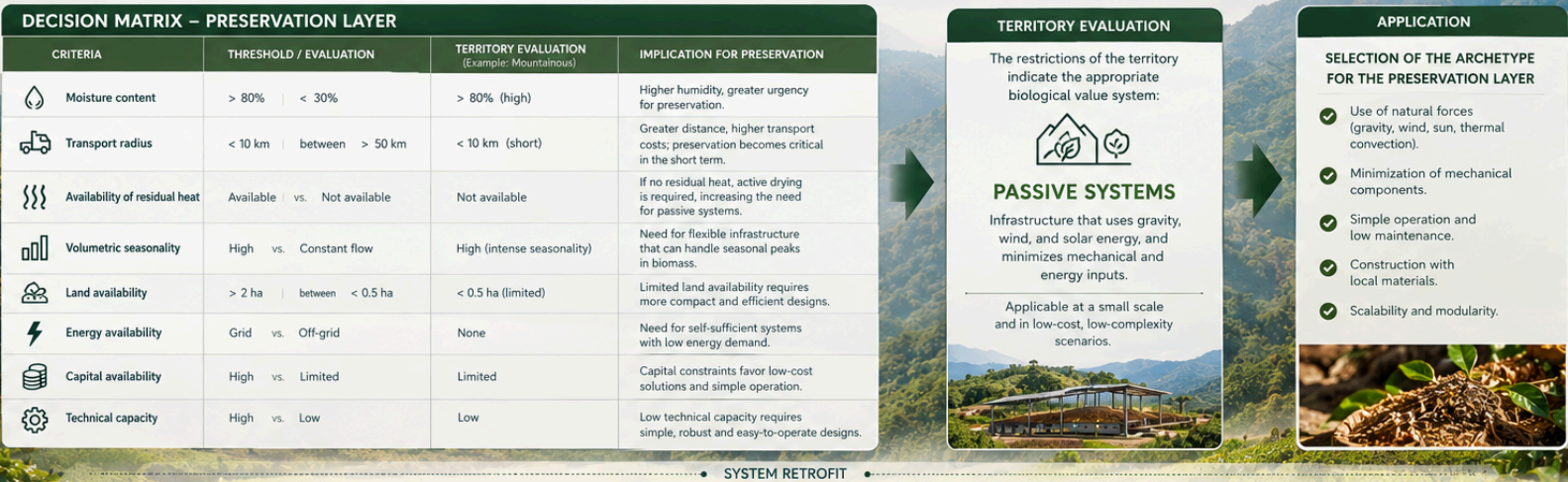


Figure 5.2
Cross-sectional view of the Biological Value Chain with the Preservation Layer.



5.2 The Origin Decision Matrix Applied to Preservation

The Origin Decision Matrix evaluates a set of constraints that determine the appropriate infrastructure archetype. For The Preservation Layer, the relevant constraints are:

Constraint	Evaluation Criteria	Implication for Preservation
Moisture content	>80% vs <30%	Higher moisture → greater urgency of intervention at origin
Transport radius	<10 km vs >50 km	Greater distance → higher cost to transport water; preservation at origin is necessary
Waste heat availability	Available vs Not available	No waste heat → active drying is not viable; passive drying is required
Volumetric seasonality	Intense peak vs Constant flow	Intense peaks require modular infrastructure and shock absorption capacity
Land availability	>2 ha vs <0.5 ha	Less land → more compact designs required
Energy availability	Grid waste heat vs None	No energy available → infrastructure must be passive
Capital availability	Investment-ready vs Limited	Limited capital → low-cost solutions and progressive construction
Technical capacity	Skilled vs Basic	Low technical capacity → simple designs, easy operation

5.3 The Passive Systems Archetype

When the Origin Decision Matrix evaluates the constraints of a mountain territory with high moisture, limited roads, restricted capital, and low technical capacity, the resulting archetype is Passive Systems.

Volume I defines Passive Systems as: "Infrastructure that uses gravity, solar energy, wind, and biological energy as primary sources of operation. Applicable to small scale, remote environments, and low capital expenditure."

The Preservation Layer developed in this volume corresponds to this archetype. Its design is based on:

Principle	Application
Use of natural forces	Gravity, convection, wind, solar radiation
Minimized mechanical components	Reduced moving parts, no motors or pumps
Simple operation and reduced maintenance	Basic training sufficient
Construction with local materials	Indigenous materials reduce cost and dependency
Scalability and modularity	Expandable by adding modules

5.4 Input, Process, and Output of The Preservation Layer

The Preservation Layer is defined by its function within the ORIGEN system.

Input:

- Wet biomass from agricultural origin
- Variable moisture content
- Seasonal volume

Process:

- Capture and reception
- Solid-liquid separation
- Leachate drainage and capture
- Natural ventilation
- Thermal stabilization
- Filtration through biochar or functional material bed

Output:

- Biomass in state of Biological Integrity (defined by indicators)
- Reduced moisture
- Preserved Carbon
- Retained nutrients (subject to validation)
- Captured leachates for reuse

Stage	Primary Elements	Expected Result
Input	Wet agricultural biomass, variable moisture, seasonal volume	Biological Capital available for intervention
Process	Capture and reception, solid-liquid separation, leachate drainage/capture, natural ventilation, thermal stabilization, filter bed	Moisture reduction, degradation halted, Carbon and nutrients conserved (design objective)
Output	Preserved biomass with Biological Integrity, leachates recovered, protected storage	Condition suitable for the Transformation Layer (Volume III)

5.5 Relationship to Subsequent Layers

The Preservation Layer does not operate in isolation. It is the first layer of a system that includes:

Layer	Function
Volume III — Transformation Layer	Preserved biomass is converted into energy, biochar, or other products. Transformation performance depends on the condition and characteristics of the biomass entering the Transformation Layer. Biological Integrity provides the defined preservation condition for downstream transformation.
Design Notes	Reference architectures for specific biomass types. Designed on the basis of principles established in this volume.
Case Studies	Territorial validation of the methodology. Demonstrate that The Preservation Layer works in real conditions.

5.6 The Preservation Layer Within the Biological Value Chain

Volume I defines the Biological Value Chain as:

Harvest → Capital → Infrastructure → Integrity → Transformation → Assets

The Preservation Layer is situated at the Infrastructure and Integrity links.

Link	Function	Status
Harvest	Agricultural production	Gross Biological Capital
Capital	Recognition of generated value	Biological Capital identified
Infrastructure	Stabilization, drying, conditioning	Active intervention
Integrity	Preserved physical and chemical state	Biological Integrity achieved (when indicators confirm)
Transformation	Pyrolysis, gasification, torrefaction	Biochar, heat, energy, syngas
Assets	Markets, credits, agriculture	Carbon removal, Scope 3, regeneration

The Preservation Layer is the bridge between Biological Capital generated by harvest and Biological Integrity required for transformation.

5.7 Territorial Integration

The Preservation Layer is not an isolated solution. It is part of a territorial system that includes:

Actor	Role
Producers	Generate biomass and operate the infrastructure
Cooperatives/Associations	Organize logistics and coordinate operations
Collection Centers	Receive preserved biomass
Transformation Plants	Convert biomass into products
Markets	Value the generated products

Preservation infrastructure must be designed considering interaction with all these actors. It is not an isolated technical element. It is a node in a territorial value network.

5.8 Archetype Selection According to Territorial Conditions

Predominant Territorial Conditions	Recommended Archetype	Primary Characteristics
High moisture, limited access, low capital, low technical capacity	Passive System	Gravity, natural ventilation, low maintenance, modularity
Medium moisture, partial energy availability	Hybrid System	Combines passive solutions with targeted energy support
Low moisture, consolidated infrastructure, high energy availability	Active System	Mechanical drying, automation, continuous control
High industrial production and centralized logistics	Integrated Industrial System	High mechanization, large capacity, high investment

5.9 Conclusion — The Preservation Layer as First Operational Link

The Preservation Layer is the first operational intervention in the Biological Value Chain. Its function is to ensure that Biological Capital does not degrade before being transformed. Within the ORIGEN Matrix, the appropriate archetype for mountain territories with high moisture and limited access is Passive Systems. The input is wet biomass from agricultural origin. The process is stabilization through passive infrastructure. The output is biomass in a state of Biological Integrity (as defined by the indicator framework). Integration connects the farm with subsequent layers of transformation and valorization. The Preservation Layer is not an end in itself. It is the necessary condition for the entire ORIGEN system to function.

CHAPTER 6 — METRICS AND VALIDATION

6.1 The Need for Indicators

Preservation infrastructure has a clear objective: to achieve the state of Biological Integrity defined in Volume I.

Biological Integrity: The preserved physical and chemical state of biomass after stabilization, which allows its original value to be available for subsequent transformation or environmental application.

However, a state cannot be managed if it cannot be measured. Indicators of Biological Integrity fulfill three functions:

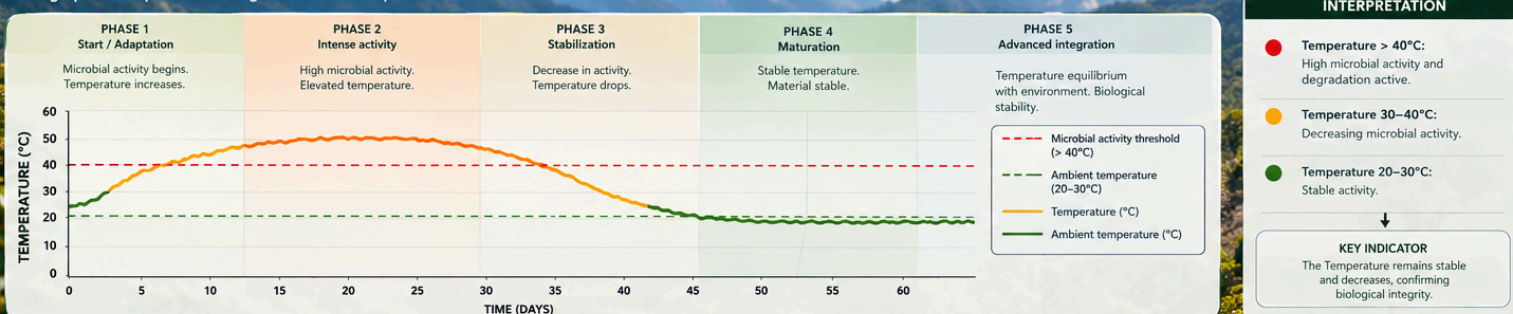
Function	Description
Verification	Confirm that preservation infrastructure has fulfilled its function
Operational Guidance	Guide operational decisions during the stabilization process
Quality Assurance	Guarantee that biomass delivered to subsequent layers meets necessary requirements

This chapter defines the indicators that allow verification of the Biological Integrity state of preserved biomass.

Figure 6.1
Biological Integrity Indicators and their relationships.



Figure 6.2
Evolution graph of temperature during the stabilization process.



RECOVERED
NUTRIENTS



PREVENTS
CONTAMINATION



CONTROLLED ODORS
AND EMISSIONS



STABILIZED BIOMASS
AND PRESERVED



Sustainable
by design.

6.2 The Concept of Biological Integrity — Operational Definition

Biological Integrity implies:

Criterion	Description
Degradation halted	Fermentation, leaching, and mineralization processes have been controlled or interrupted
Carbon preserved	Labile Carbon has not mineralized to CO ₂ or CH ₄
Nutrients retained	Nutrients have not been carried away by leaching (subject to validation)
Structure conserved	Biomass maintains physical integrity for handling and transport
Microbiological stability	Microbial activity has been reduced to levels that do not compromise biomass value

Biological Integrity is not a binary state. It is a gradient. The greater the integrity, the greater the value available for transformation.

6.3 Indicators of Biological Integrity — Complete Reference Table

Indicator	Variable	Measurement Method	Target Threshold	Status
Moisture Content	% moisture	Gravimetric method or sensors	<25–30% (22% for reference pulp case)	TDM DESIGN STANDARD (for pulp)
pH	pH units	Electrode in diluted sample	6.0–7.5	TARGET
C/N Ratio	Carbon/Nitrogen ratio	Laboratory analysis	Stable, no significant mineralization	DESIGN TARGET
Temperature	°C	Thermometer or probe	Ambient temperature	TARGET (supporting indicator)
Odors and Gases	Intensity	Sensory evaluation and sensors	No strong odors, low emissions	DESIGN TARGET (qualitative)
Leachates	Volume and quality	Measurement and chemical analysis	Reduced or zero generation	DESIGN TARGET
Structural Integrity	Physical state	Visual and tactile evaluation	Firm, dry, easily manageable	DESIGN TARGET

6.4 Indicator 1 — Final Moisture Content

Moisture is a key factor in biomass degradation. Reducing moisture content is a critical step to achieving Biological Integrity.

Aspect	Detail
Variable	Moisture content (%)
Measurement Method	Gravimetric method (oven drying) or moisture sensors
Target Threshold for Biological Integrity	<25–30% (varies by biomass type and intended use). For the reference coffee pulp case, the TDM design endpoint is 22% moisture.
What It Indicates	The biomass has been sufficiently dehydrated to halt degradation processes
Measurement Frequency	At stabilization completion and during storage

6.5 Indicator 2 — pH

pH is an indicator of fermentative activity and organic acid production.

Aspect	Detail
Variable	pH (scale 0–14)
Measurement Method	Direct measurement with electrode in diluted sample
Target Threshold for Biological Integrity	6.0–7.5 (stable, no further decline)
What It Indicates	Stable and near-neutral pH supports the conclusion that acid fermentation has ceased
Measurement Frequency	At stabilization completion and during storage

Interpretation:

pH Range	Status	Interpretation
4.0–5.0	Active fermentation	Degradation still occurring
5.0–6.0	Transitional	Fermentation slowing
6.0–7.5	Stabilized	Supports Biological Integrity achievement
>7.5	Alkaline	May indicate ammonia generation

6.6 Indicator 3 — Carbon/Nitrogen Ratio (C/N)

The C/N ratio is an indicator of biomass composition and degradation potential.

Aspect	Detail
Variable	C/N ratio (mass of Carbon / mass of Nitrogen)
Measurement Method	Laboratory analysis of organic Carbon and total Nitrogen
Target Threshold for Biological Integrity	Stable, no significant mineralization
What It Indicates	Carbon mineralization has not occurred excessively during stabilization
Measurement Frequency	At stabilization completion

Interpretation:

C/N Status	Interpretation
Stable	Supports Biological Integrity achievement
Declining	Carbon mineralization occurring
Rising	Nitrogen loss (volatilization) occurring

6.7 Indicator 4 — Temperature

Temperature is a direct indicator of microbial activity.

Aspect	Detail
Variable	Temperature (°C)
Measurement Method	Thermometer or temperature probe
Target Threshold for Biological Integrity	Ambient temperature, no significant increases
What It Indicates	Ambient and stable temperature supports the determination of stabilization when confirmed by the other indicators
Measurement Frequency	During stabilization phase (daily), then weekly

Interpretation:

Temperature Status	Interpretation
Ambient	Supports Biological Integrity achievement (when combined with other indicators)
Elevated (>40°C)	Active decomposition — stabilization incomplete
Rising	Conditions may be anaerobic — adjust ventilation

6.8 Indicator 5 — Odors and Gases

The presence of odors and gases is a qualitative indicator of fermentation and degradation.

Aspect	Detail
Variable	Odors (qualitative) and gas emissions (CH ₄ , CO ₂ , NH ₃)
Measurement Method	Odors: Sensory evaluation; Gases: Sensors or direct field measurement
Target Threshold for Biological Integrity	No strong odors, earthy smell
What It Indicates	Absence of strong odors supports the conclusion that fermentation and volatile compound generation have ceased
Measurement Frequency	During stabilization phase (daily), at stabilization completion

Interpretation:

Odor Type	Interpretation
Earthy, soil-like	Supports Biological Integrity achievement
Acidic, fermented	Active fermentation — stabilization incomplete
Ammonia	Nitrogen volatilization occurring
Sulfide (rotten eggs)	Anaerobic conditions — immediate intervention required

6.9 Indicator 6 — Leachate Presence

Leachate generation is an indicator of nutrient mobilization and degradation activity.

Aspect	Detail
Variable	Volume and quality of leachate generated
Measurement Method	Volume measurement and nutrient analysis (N, P, K)
Target Threshold for Biological Integrity	Reduced or no leachate generation
What It Indicates	Reduced leachate generation is consistent with nutrient retention
Measurement Frequency	During stabilization phase (weekly), at stabilization completion

Interpretation:

Leachate Status	Interpretation
No leachate	Supports Biological Integrity achievement
Reduced volume	Stabilization progressing
High volume, high nutrient content	Active degradation — leaching occurring
High volume, low nutrient content	Nutrients already lost — biomass value reduced

6.10 Indicator 7 — Structural Integrity

Physical structure is an indicator of biomass handling capacity and transformation value.

Aspect	Detail
Variable	Compaction, porosity, fiber integrity
Measurement Method	Visual and tactile evaluation
Target Threshold for Biological Integrity	Firm, dry, easy to handle
What It Indicates	Preserved biomass maintains structural integrity for handling and transport
Measurement Frequency	During stabilization phase, at stabilization completion

Interpretation:

Structural Status	Interpretation
Firm, dry, manageable	Supports Biological Integrity achievement
Collapsed, wet, viscous	Active degradation — structure lost
Compacted but dry	May be stabilized but handling difficult — adjust design

6.11 Summary Table — Complete Indicator Framework

Indicator	Variable	Method	Target Threshold	Frequency	Purpose
Moisture	% H ₂ O	Gravimetric / Sensors	<25-30% (22% for pulp)	End of process	Determine storage or transformation readiness
pH	pH units	Electrode	6.0-7.5	End of process	Support fermentation status
C/N Ratio	C/N	Lab analysis	Stable	End of process	Support carbon preservation
Temperature	°C	Thermometer / Probe	Ambient	Continuous	Detect residual microbial activity
Odors & Gases	Qualitative / ppm	Olfactory / Sensors	No strong odors	Continuous	Identify anaerobic degradation
Leachates	Volume / Quality	Measurement / Analysis	Reduced or none	Weekly	Support nutrient retention
Structural Integrity	Visual / Tactile	Observation	Firm, dry, manageable	End of process	Confirm handling and transport suitability

6.12 Verification Protocol

Biological Integrity is not verified by a single indicator. It is verified by the complete set of indicators that, together, support the conclusion that the biomass has been stabilized.

Verification occurs at two moments:

1. During the Stabilization Process:

- Monitoring of temperature, moisture, odors, and leachate generation
- Allows operational adjustments if indicators deviate from expected range

2. At the End of the Stabilization Process:

- Measurement of all indicators
- Confirmation that biomass has achieved the defined thresholds

Decision Logic:

Indicator Status	Determination
All indicators within target range	Biological Integrity supported — proceed to storage or transformation
One or more indicators outside target range	Adjust process — extend stabilization or correct conditions
Critical deviation (methane, severe odors, high leachates)	Immediate intervention — redesign or abort batch

6.13 Relationship to Subsequent Layers

Verification of Biological Integrity is the entry condition for subsequent layers of the ORIGEN system.

Layer	Entry Condition	Relevant Indicators
Volume III — Transformation	Biomass in state of Biological Integrity	Final moisture, pH, microbiological stability
Design Notes	Biomass data for design	All indicators
Case Studies	Territorial validation	All indicators

6.14 Conclusion — Indicators as Management Tools

Indicators of Biological Integrity are the tools that allow verification that preservation infrastructure has fulfilled its function.

Without Indicators	With Indicators
Preservation is a blind operation	Preservation is measurable
Deviations go undetected	Deviations can be corrected
No quality assurance for downstream layers	Biomass delivered to subsequent layers meets requirements

Preservation is not an act of faith. It is an act of engineering. And engineering is based on data.

CHAPTER 7 — CASE STUDY: COFFEE PULP IN THE ANDEAN MOUNTAINS

7.1 The Role of Case Studies

Case studies fulfill a fundamental function within the ORIGEN framework: validating the methodology in real conditions. A case study is not an operations manual. It is not a technical guide for a specific crop. It is a demonstration that the principles, criteria, and indicators defined in this volume are applicable and effective in a concrete territory. Case studies illustrate the methodology without modifying it, demonstrate that passive infrastructure works in real conditions, provide data and lessons for future implementations, and enable continuous improvement of the methodological framework.

Note on methodological inference: The results presented in this chapter are derived from a single case study conducted under specific territorial conditions. They do not constitute a universal performance guarantee for all preservation systems. Conclusions drawn from this case study should be considered indicative until validated by additional case studies and site-specific monitoring data. The primary value of the case study is to demonstrate the operational feasibility of the methodology and to identify areas for further investigation. *This chapter presents Case Study 001: Coffee Pulp in the Andean Mountains as the first territorial validation of The Preservation Layer.*

Figure 7.1
Territory map of the case study – Coffee pulp in Planadas, Tolima, Colombia.



Figure 7.2
Passive infrastructure implemented for coffee pulp preservation.



7.2 Case Study 001 — Coffee Pulp in the Andean Mountains

7.2.1 Territorial Con

The case study was developed in a mountain territory of the Colombian Andean range, characterized by:

Parameter	Value
Altitude	1,500 – 2,000 m above sea level
Climate	Temperate humid, with well-defined dry and rainy seasons
Topography	Steep slopes, limited tertiary roads
Main activity	Coffee cultivation, with seasonal pulp generation
Producers	Small and medium-scale, organized in cooperatives
Distance to collection centers	Variable, between 10 and 50 km

This territory presents all the constraints that make preservation at origin necessary:

Constraint	Manifestation
High moisture	Coffee pulp >80% moisture
Rapid fermentation	0-24 hour preservation window
Uneconomic water transport	Distance makes wet transport costly
Limited access	Tertiary roads, steep slopes
Restricted capital	Limited investment capacity
Limited technical capacity	Basic operation and maintenance skills

7.2.2 The Biomass: Coffee Pulp

Coffee pulp is the residue generated during the wet processing of coffee. It represents approximately 40-50% of the fresh fruit weight.

Fresh Pulp Characteristics:

Parameter	Typical Value
Moisture content	80–85%
pH	4.0 – 5.0
C/N Ratio	12 – 15
Organic Carbon	45–50% (dry basis)
Total Nitrogen	1.5–2.5% (dry basis)
Potassium	2.0–3.0% (dry basis)
Volume generated	Variable by harvest

Why Coffee Pulp is a Problem:

Issue	Consequence
High moisture	Rapid fermentation, degradation within hours
Acidic pH	May inhibit beneficial microorganisms
High BOD/COD	Water pollution if discharged
Methane potential	Anaerobic conditions can generate CH ₄ emissions
Nutrient loss	N, P, K leached before recovery

Why Coffee Pulp is an Opportunity:

Opportunity	Value
Carbon content	Can be converted to stable biochar
Nutrient content	Can be recovered for agronomic use
Energy potential	Can be converted to thermal energy or syngas
Soil amendment	Improves soil structure and fertility

7.2.3 The Infrastructure Implemented

On the basis of the principles and criteria defined in previous chapters, a passive preservation infrastructure was implemented in the territory.

Infrastructure Components:

Component	Description
Reception area	Impermeable surface, covered, with drainage slope
Solid-liquid separation	Perforated base allowing drainage of free water
Leachate drainage and capture	Channels and storage tanks for leachate
Natural ventilation	Perforated tubes distributed at the base and within the biomass
Filter bed	Biochar as base material for filtration and nutrient retention
Preserved biomass storage	Covered area for dry biomass

Design Parameters:

Parameter	Value
Footprint	250 m ²
Dimensions	50 m × 5 m
Initial height	67 cm
Biochar layer	20 cm
Wood chip layer	15 cm
Pulp layer	15-20 cm
Dry leaf/parchment layer	10 cm
Total initial height	60-80 cm

7.2.4 Preservation Results

The infrastructure was operated for a complete harvest cycle. Results were evaluated using the Biological Integrity indicators defined in Chapter 6.

Indicator Comparison:

Indicator	Fresh Pulp	Stabilized Pulp	Integrity Threshold	Status
Moisture	82%	22%	<25–30%	MEASURED RESULT
pH	4.5	6.8	6.0–7.5	MEASURED RESULT
C/N Ratio	13	14	Stable	MEASURED RESULT
Temperature	Variable	Ambient	Ambient	MEASURED RESULT
Odors	Acidic, fermented	Earthy	No strong odors	MEASURED RESULT (qualitative)
Leachates	Continuous generation	Reduced	Reduced or zero	MEASURED RESULT
Structural Integrity	Collapsed, wet	Firm, dry	Firm, manageable	MEASURED RESULT (qualitative)

Key Performance Data:

Parameter	Value	Status
Weight reduction	80% (from 4,000 to ~769 kg)	MEASURED RESULT
Moisture reduction	From 82% to 22%	MEASURED RESULT
Leachate captured	8,000 liters	MEASURED RESULT
Stabilization time	5–7 days	MEASURED RESULT
Carbon loss avoided	Estimated based on mineralization prevented	ESTIMATED
Nutrients retained	60-80% of indigenous N, P, K	HYPOTHESIS — pending laboratory validation

7.2.5 Lessons Learned

Lesson	Observation	Methodological Implication
Passive infrastructure works	Stabilization was achieved using only gravity, natural ventilation, and drainage in this case	Confirms validity of the Passive Systems archetype within the ORIGEN framework for the tested conditions
Leachate capture is critical	Leachates could be recovered for agronomic reuse	Reduces nutrient loss and environmental risks
Producer participation is essential	Operation was performed by producers with basic training	Operational simplicity favors territorial ownership
Modularity is required	Infrastructure responded adequately to harvest peaks	Allows capacity adjustment according to seasonality
Indicators are operational	Indicators enabled objective verification of biomass state	Facilitates monitoring, management, and process validation

Five Key Takeaways:

1. Passive infrastructure works in real mountain conditions under the tested setup. Gravity, thermal convection, and wind were sufficient to achieve stabilization without external energy in this case.
2. Leachate capture is essential. Nutrients recovered can be used for irrigation during dry seasons, closing the agronomic cycle.
3. Producer participation is fundamental. Infrastructure must be designed considering their capacities and limitations.
4. Seasonality requires modularity. Infrastructure must absorb harvest peaks without collapsing.
5. Biological Integrity indicators are operational and verifiable. They enable process management and biomass quality assurance.

Figure 7.3
Evolution of humidity and temperature during the coffee pulp stabilization process.

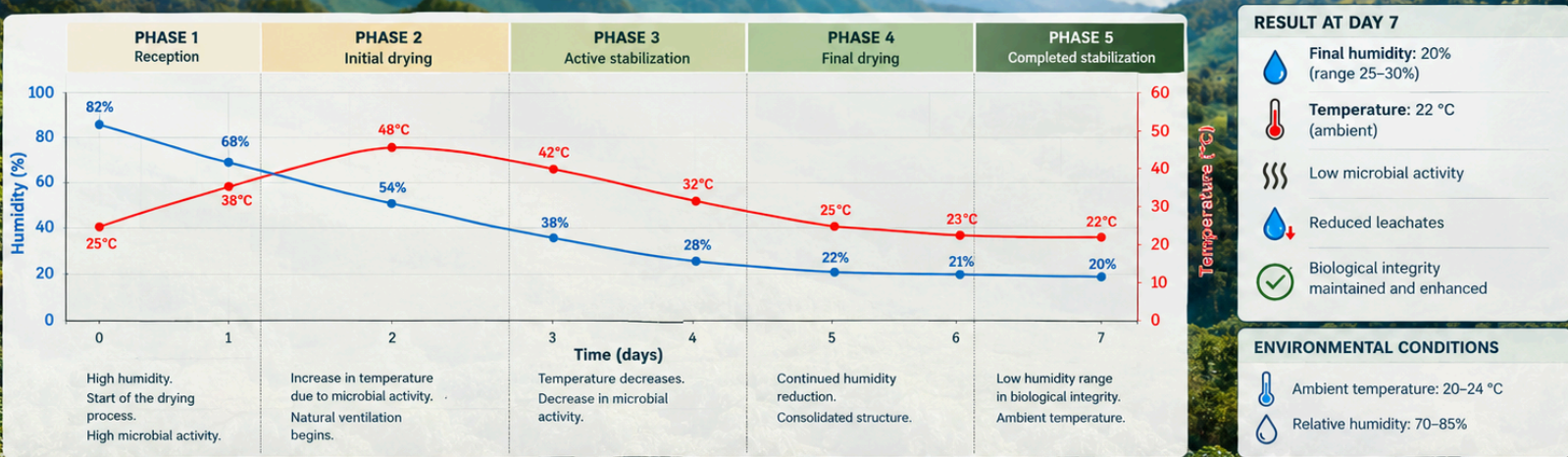
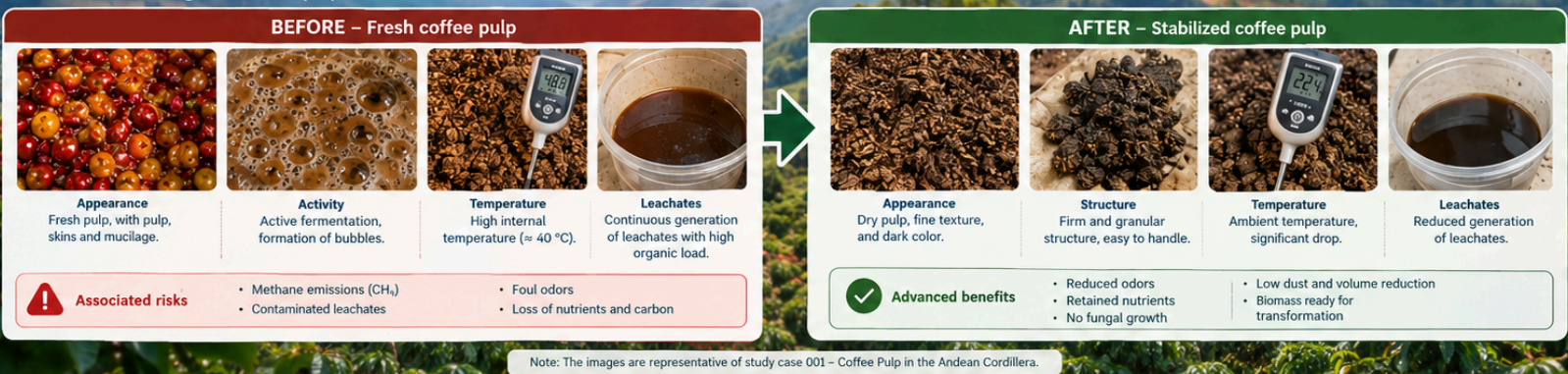


Figure 7.4
Before and after images of coffee pulp stabilization.



7.3 Next Case Studies

This case study (coffee pulp) is the first of a series of territorial validations of The Preservation Layer.

Planned Future Case Studies:

Case Study	Territory	Status
002 — Cocoa Husk	Colombian Pacific Region	Planned
003 — Empty Palm Bunches	Colombian Eastern Plains	Planned
004 — Vegetable Residues	Bogotá Savanna	Planned

Each case study will be published as a complementary document to this volume, maintaining the methodological coherence established in this and preceding chapters.

CHAPTER 8 — DESIGN NOTES

8.1 The Role of Design Notes

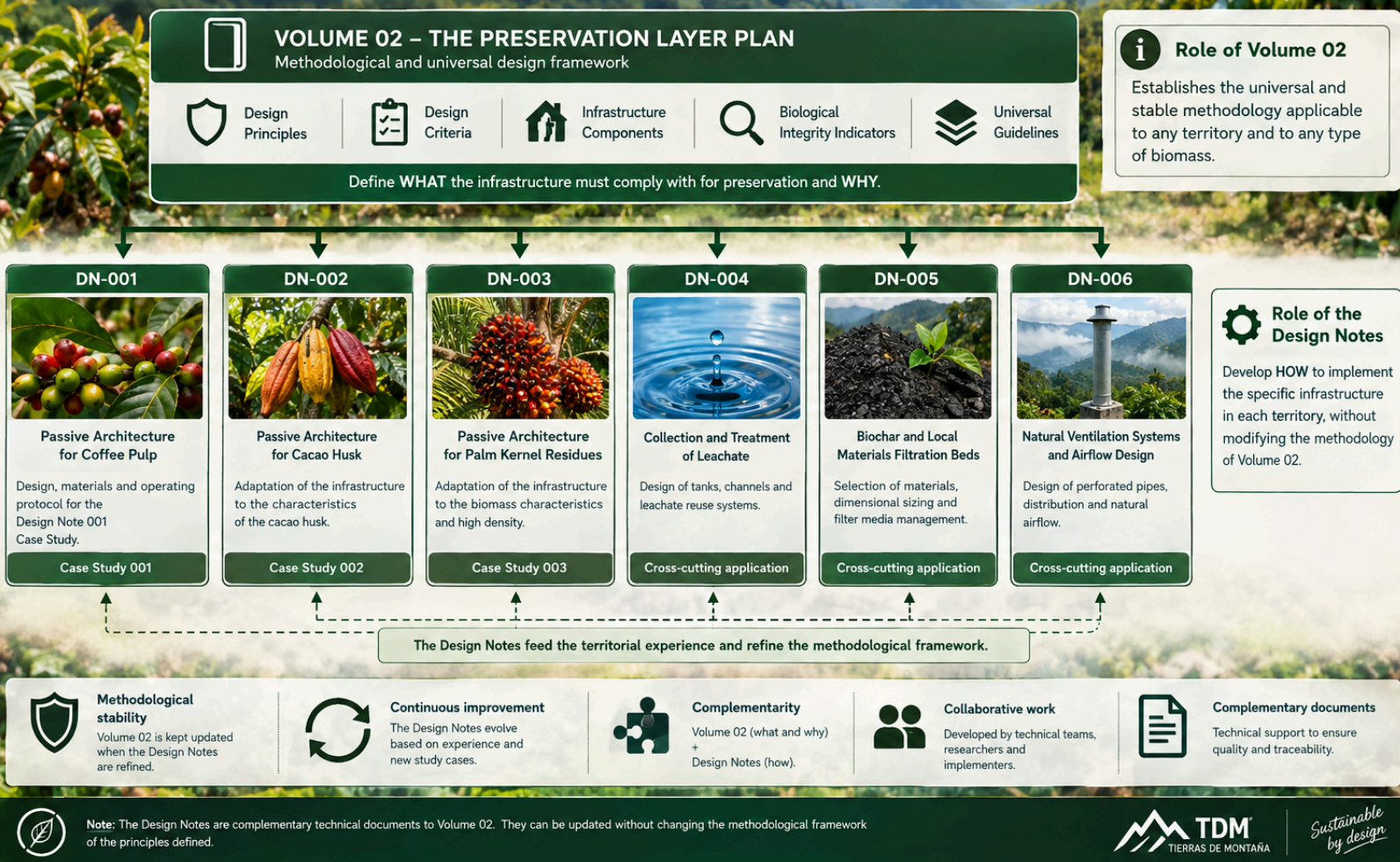
Design Notes constitute the level of technical development that follows the methodological definition of a volume. While this volume defines what preservation infrastructure must achieve and why, Design Notes develop how it is implemented under specific conditions.

Design Notes:

- Develop reference architectures for specific biomass types
- Provide dimensioning, materials, and operational protocols
- Do not constitute methodological doctrine
- Can be updated without modifying the volume

Figure 8.1

Relationship between Volume 02 and the Associated Design Notes.



8.2 Design Notes for The Preservation Layer

Design Note	Subject	Scope
DN-001	Passive Architecture for Coffee Pulp	Dimensioning, materials, operational protocol for Case Study 001
DN-002	Passive Architecture for Cocoa Husk	Adaptation to cocoa characteristics
DN-003	Passive Architecture for Empty Palm Bunches	Adaptation to fibrous, high-density biomass
DN-004	Leachate Capture and Treatment System	Tank, channel, and reuse system design
DN-005	Filter Beds with Biochar and Local Materials	Material selection, dimensioning, maintenance
DN-006	Natural Thermosiphon Ventilation Systems	Perforated tube design, distribution, airflow

8.3 Relationship Between Volume and Design Notes

Aspect	Volume II	Design Notes
Function	Defines principles and criteria	Develops specific solutions
Content	Universal methodology	Reference architectures
Update	Stable, not modified	Can be updated with new experience
Authorship	Origin Infrastructure Observatory	Technical teams, researchers, implementers
Access	Public	Semi-public

This separation ensures that the volume remains stable while technical solutions evolve with experience.

8.4 Typical Content of a Design Note

Each Design Note for The Preservation Layer includes:

Section	Content
1. Con	Biomass type and characteristics, territorial constraints, infrastructure objectives
2. Architectural Design	Dimensions and geometry, recommended materials, component distribution
3. Operational Protocol	Biomass reception, indicator monitoring, maintenance and adjustments
4. Expected Results	Biological Integrity indicators, stabilization times, yields and efficiencies
5. Lessons Learned	Adjustments made, recommendations for future implementations

8.5 Evolution of Design Notes

Design Notes are not static documents. They evolve with accumulated experience from case studies and territorial implementations.

When a Design Note is updated:

Action	Effect
New version replaces previous	Continuous improvement
Changes and reasons documented	Traceability maintained
Volume remains unchanged	Methodological stability preserved

This mechanism allows technical knowledge to evolve without compromising the methodological stability of the volume.

CHAPTER 9 — CONCLUSION AND TRANSITION

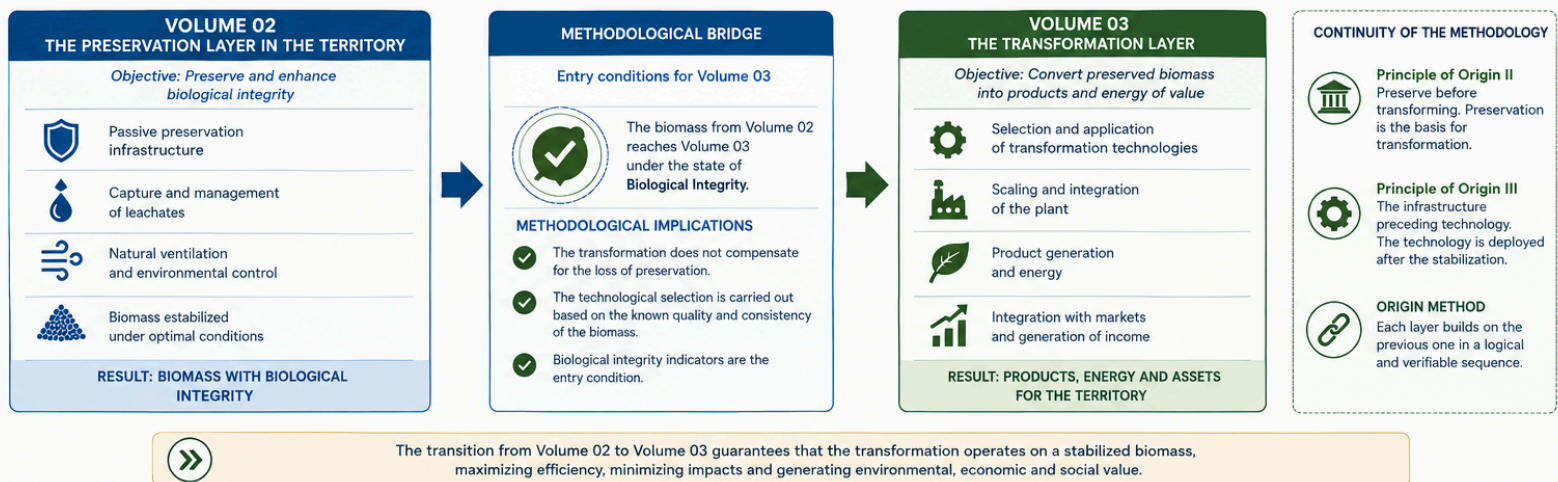
9.1 The Methodological Transition

This volume has defined The Preservation Layer: the infrastructure necessary to halt the degradation of Biological Capital at origin and achieve the state of Biological Integrity. This layer is not an end in itself. It is the necessary condition for subsequent layers of the ORIGIN system to operate efficiently.

Volume III develops the next methodological layer: The Transformation Layer.

Figure 9.1

Transition methodology scheme for Volume 02 → Volume 03.



VOLUME II — THE PRESERVATION LAYER

INPUT: Wet biomass at origin

PROCESS: Stabilization through passive infrastructure

OUTPUT: Biological Integrity



VOLUME III — THE TRANSFORMATION LAYER

INPUT: Biomass in state of Biological Integrity

PROCESS: Pyrolysis, gasification, conversion

OUTPUT: Biochar, energy, potential carbon assets

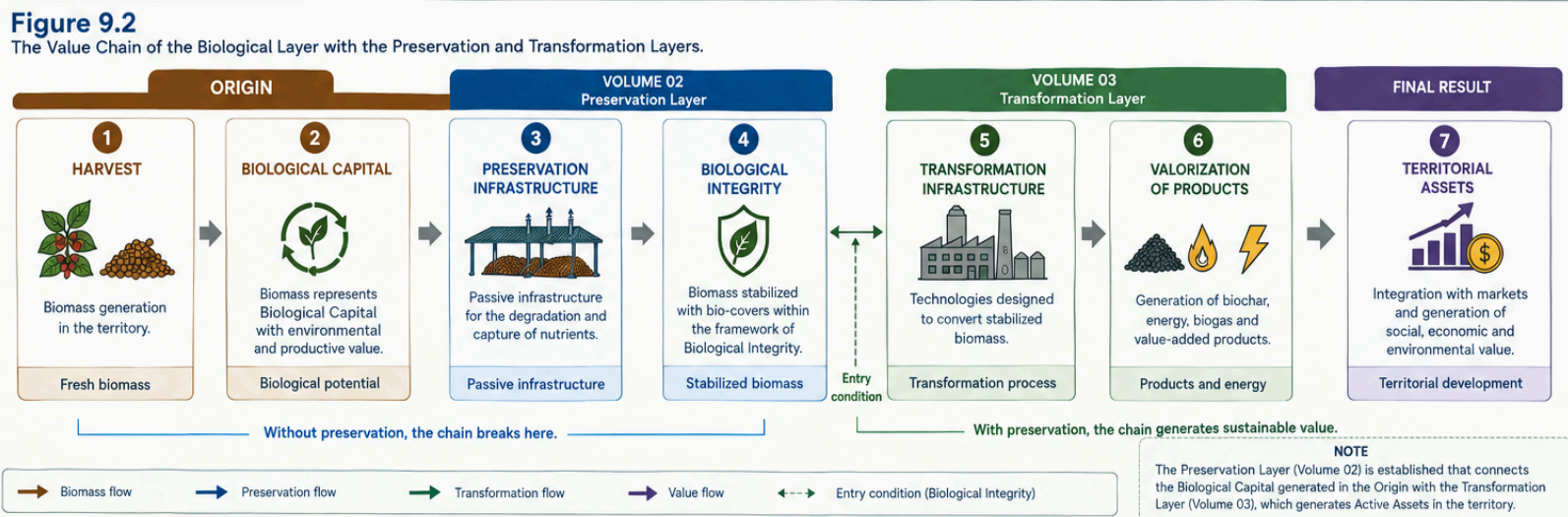
9.2 Preserved Biomass as Starting Point

Volume III proceeds from a fundamental assumption: the biomass entering transformation infrastructure has achieved the state of Biological Integrity defined in this volume.

This assumption has methodological implications:

Implication	Meaning
Transformation must not compensate for lack of preservation	Poor quality input cannot be fixed by the reactor
Technology selection is based on known, consistent biomass quality	Standardized feedstock enables optimized reactor design
Biological Integrity indicators are the entry condition for Volume III	Without verification of stability, transformation cannot begin

Without preservation, transformation is inefficient or unviable. With preservation, transformation can operate at optimal conditions.



9.3 What Volume III Develops

Volume III — The Transformation Layer addresses:

Area	Content
Technology Selection	Pyrolysis, gasification, combustion, anaerobic digestion, and other conversion technologies
Dimensioning	Plant capacity, mass and energy balance, integration with territorial logistics
Valorization Products	Biochar, thermal and electrical energy, biogas, bio-based materials
Market Integration	Potential carbon credits, fossil fuel substitution, product value chains

The key principle remains: preservation determines the quality of transformation. The reactor is only as good as the biomass it receives.

9.4 Methodological Continuity

The transition between Volume II and Volume III is governed by the same methodological logic:

Principle	Application
Origin Principle II (Preserve before transforming)	Preservation is the condition of transformation
Origin Principle III (Infrastructure precedes technology)	Technology selection occurs after biomass has been stabilized
Biological Value Chain	Harvest → Capital → Infrastructure → Integrity → Transformation → Assets

The Preservation Layer is the link that connects Biological Capital generated by harvest with Transformation that generates Assets.

9.5 Final Conclusion

Preservation is not an optional step. It is not a stage that can be omitted or simplified. It is the first preservation infrastructure decision within the ORIGEN methodology.

This volume has defined:

Chapter	Content
1	Why preservation is necessary
2	What constraints the territory imposes
3	How passive infrastructure is designed
4	What components constitute preservation infrastructure
5	Where this layer sits within the ORIGEN system
6	How success is verified
7	How it is validated in real conditions
8	How specific solutions are developed
9	How the transition to transformation occurs

Volume III will begin where this volume ends: with biomass in a state of Biological Integrity, ready to be transformed into environmental, economic, and social value.

Preservation is not the end of the road. It is the beginning.

REFERENCES

1. Methodological Standards

- FAO. (2011). Global Food Losses and Food Waste. Rome.
- FAO. (2013). Food Wastage Footprint: Impacts on Natural Resources.
- IPCC. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
- ISO 14040. Environmental Management — Life Cycle Assessment.
- ISO 14044. Environmental Management — Requirements and Guidelines.

2. Technical Institutions

- Cenicafé. Manuales de Beneficio Ecológico del Café.
- Cenicafé. Manejo de Pulpa y Subproductos del Café.
- FAO. Crop Residues Management.
- USDA. Agricultural Waste Management Field Handbook.

3. Scientific Literature

- IBI — International Biochar Initiative. Biochar Standards.
- European Biochar Certificate (EBC).

- Lehmann, J.; Joseph, S. Biochar for Environmental Management.
- IRENA. Innovation Outlook: Advanced Biofuels.
- IEA Bioenergy. Biochar Reports.

TECHNICAL REVISION LOG — VOLUME II v1.3

ID	Location	Original Statement	Revised Statement	Reason
R22	Ch. 1	Mass balance presented as closed	Added unresolved boundary notes for 400 kg dry matter and parchment→green coffee	Baseline M1, M2 — CRITICAL
R23	Ch. 1, Ch. 4	">99% methane abatement"	Reformulated as research hypothesis; quantitative validation pending	Baseline M3 — HIGH
R24	Ch. 7	Case study results presented as universal conclusions	Added note on methodological inference; results are indicative until validated	Baseline M4 — HIGH
R25	Metadata	No clarification on volume numbering	Added editorial note distinguishing ORIGEN volumes from Institutional Collection volumes	Baseline I1 — HIGH

End of Volume II — The Preservation Layer (Version 1.3)

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