QATUAN
Biopiscinas & Ecopaisagismo

To:
From: Jamie Conway

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A Decentralized Hybrid Energy System:

MODULAR INTEGRATION OF RENEWABLE NODES FOR CIRCULAR YIELD AND LOCALISED CO-BENEFITS

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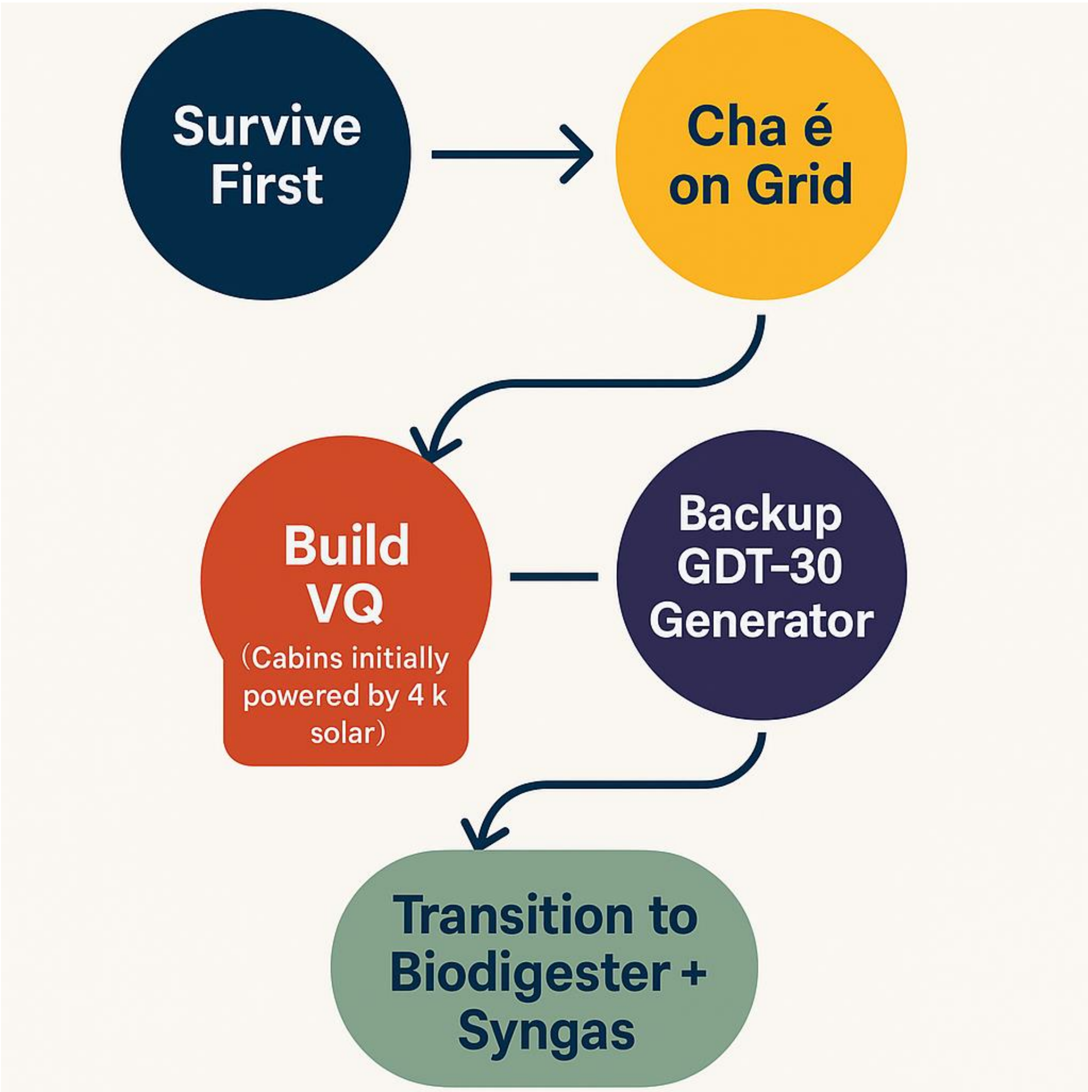

Figure 1. *Figure: Phased Energy Rollout Plan for VQ and Cha é*

Title: A Decentralised Hybrid Energy System: Modular Integration of Renewable Nodes for Circular Yield and Localised Co-Benefits

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1. Introduction

This section introduces the philosophical and structural framing of the decentralised hybrid energy system. It outlines how geographically distributed nodes are unified through design logic and logistics coordination, and why this approach is both technically efficient and socially meaningful.

This document presents a formal academic overview of a decentralised energy project designed as an integrated, multi-nodal renewable system. Though distributed geographically across several functional sites, the system is unified in design logic, resource flow, and operational coordination. It functions as a combined-cycle, hybrid energy infrastructure embedded within a larger regenerative development model.

2. Site Overview and Functional Allocation

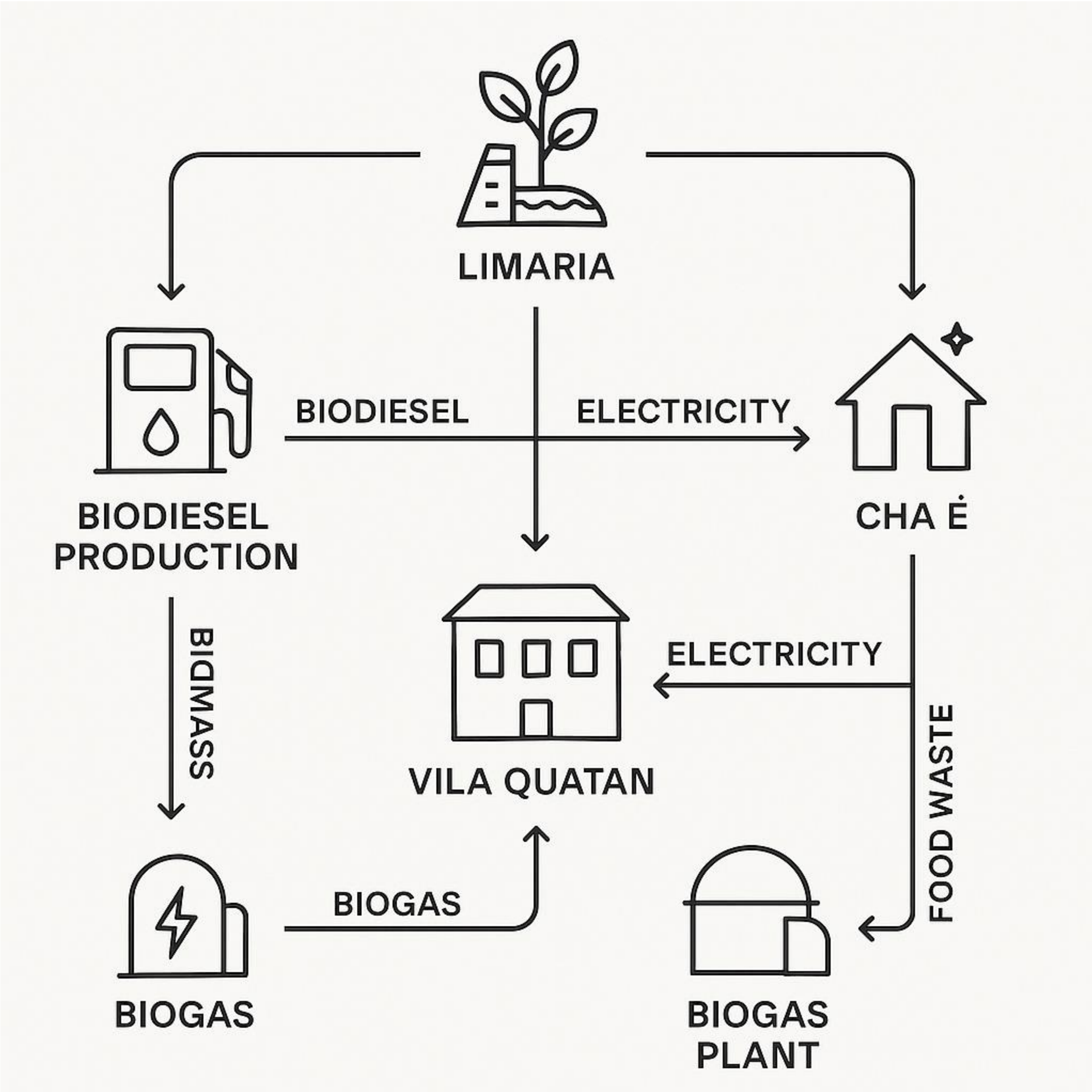

Figure: Distributed Energy Integration Flow Diagram
A simplified system schematic illustrating the circular flow of biodiesel, biomass, biogas, and electricity across the four-node network: Limaria, Cha é, Vila Qatuan, and Bogies. Each element contributes to a decentralised energy microgrid where waste becomes fuel, and distributed generation reinforces local resilience.

This section maps out the specific sites that form the decentralised network—VQ, Limaria, Cha é, and Bogies. Each node serves a distinct role in the broader system and is designed to scale independently while remaining interconnected through energy, waste, and data flows.

2.1 Vila Qatuan (VQ)

- Primary Node & Demonstration Centre
- Energy strategy begins with **survival-first realism**, evolving towards regenerative demonstration
- Each cabin powered by initial 4kW PV systems with standalone battery banks (modular scaling)
- Diesel generator (e.g., GDT 30 – 33kVA/26kW rated) provides backup for build phase and peak loads
- Cooking and hot water via LPG (upgradable to biogas)
- Plans to integrate syngas-fuelled engines and biodigestors as site expands
- Microgrid planned for future node interconnection and battery pooling

2.2 Limaria

- Agroforestry & Biodiesel Hub (~50 km from VQ)
- Biodiesel fabrication equipment includes:
    - Oil extraction unit (cold press or expeller)
    - Transesterification reactor (100–200L batch system)
    - Methanol and catalyst handling station
    - Drying and settling tanks
    - Safety & spill containment measures
- Mini-hydro turbine along riverbank (~10% total grid contribution)
- Biomass boiler-turbine unit for residue conversion
- Primary biodiesel production node for logistics and energy blending
- Independent operation with overproduction potential

2.3 Cha é

- Community Energy & Education Node
- Initially grid-connected with LPG cooking and GDT 30 generator backup
- Solar bank planned as near-term upgrade
- Food waste collected and transported to Bogies
- Participatory workshops, citizen science dashboards, and data stations

2.4 Bogies (The Pig Farm)

- Nutrient Recovery & Methane Production Zone
- Methane capture from animal and food waste
- Direct grid-overproduction potential
- Circular animal-assisted education centre
- Waste processed into compost and/or redirected back to VQ

3. Shared Logistics and Inter-Site Dependencies

Here we describe the coordinated exchange between nodes—how materials, energy, and waste are cycled across the system to maximize efficiency and interdependence. This reflects the project's circular bioeconomic logic and operational sustainability.

- Cha é's food waste transported to Bogies for biodigestion
- Limaria supplies biodiesel for logistics across nodes
- Syngas or pig manure transported from Bogies to VQ
- VQ returns biodigested residue to Bogies or processes locally
- QAIB backend unites data reporting, analytics, and training schedules

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4. Core Energy System Metrics & Outputs

This section presents projected performance indicators across energy production, waste conversion, material outputs, and emissions reductions. These metrics support system benchmarking, monitoring, and potential carbon offset reporting.

Updated Node Output Chart

	Node	Daily Energy Demand (kWh)	Primary Energy Source	GHG Offset Potential (tCO2eq/year)	Surplus Production to Grid (kWh/day)
1	Vila Qatuan	180	PV + Diesel + Biogas	25	0
2	Limaria	50	Biomass + Hydro + Biodiesel	40	15
3	Cha é	180	Grid + PV	5	5
4	Bogies	60	Biogas + Compost	60	30

4.1 Combined Energy Yield Projections

- Total projected annual output: XX MWh/year (to be modelled)
- Holistic Mix:
  - 10% Hydro (Limaria)
  - 20% Solar (PV + Thermal across VQ and Cha é)
  - 30% Biogas (Primarily from Bogies, digestors at VQ)
  - 40% Biomass (Boiler systems at Limaria, secondary nodes)

4.2 Yield-to-Waste Conversion Metrics

- Food waste from Cha é to methane at Bogies
- Pig waste to biodigestors at VQ
- Biomass-to-kWh conversion
- Fertiliser yield from digestate streams

4.3 Circular Co-Products

- Biofertiliser (from digestors and compost loops)
- Biochar bricks and construction materials
- Compost from Bogies

4.4 GHG Reduction & Carbon Metrics

- Emissions offset via avoided methane release
- Permanent carbon sink via biochar application
- Preliminary carbon credit potential: XXXX tCO2eq/year

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5. Educational & Social Integration

This section explains how energy systems are embedded in public education, citizen science, and training pathways. Beyond infrastructure, the system builds capacity and regenerative literacy.

- Live digital dashboards at each node (potentially Aeva-powered)
- Citizen Science stations logging methane output, solar data
- School workshops, apprenticeships, and vocational training embedded
- Community-led microgrids built for resilience and literacy

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6. Replicability & Modularity

This section outlines how each site is designed as a replicable module, with low-cost infrastructure and open-source principles for transferability across diverse rural and peri-urban landscapes.

- Each node designed as a standalone replicable unit
- Can be scaled independently or in cluster arrangements
- Mobile systems (e.g., demo carts, pop-up labs) allow rural deployment
- Infrastructure built for educational, technical, and environmental training

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7. Conclusion

A synthesis of the document's key messages—highlighting how a survival-first energy strategy can evolve into a regenerative and pedagogical infrastructure, simultaneously serving local needs and global narratives.

This decentralised energy system is both technically efficient and socially embedded. It uses logistics-aware design to distribute power generation while forming a holistic network of circular yield. The result is not just energy independence, but regenerative literacy, youth engagement, ecological repair, and infrastructural dignity across diverse rural contexts.

Appendix: Technical Layout Overview

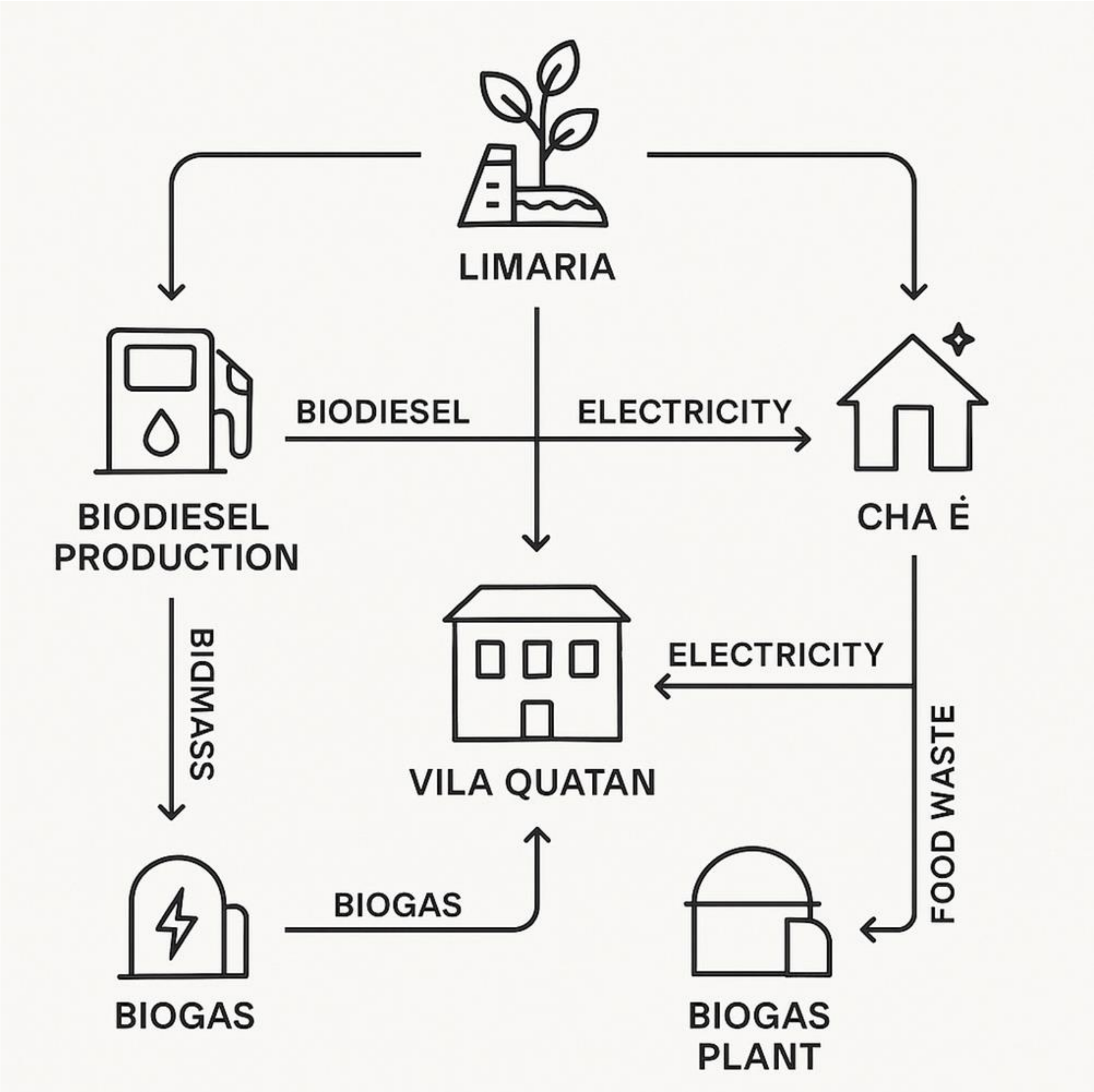

Figure: Distributed Bioenergy System Flow

A schematic showing how Limaria, biodiesel production, biogas systems, and node-specific energy needs (Cha é, VQ) are interconnected via electricity, biomass, and food waste cycles. Each unit contributes to decentralised resilience and reinforces the circular economy logic.

The technical system layout includes modular energy nodes operating semi-autonomously and connected via logistical and digital feedback loops. Each node incorporates its own primary generation method (e.g., PV at VQ, biodiesel at Limaria, biogas at Bogies), with battery buffering and/or backup gensets.

Future versions of this document will include formal system schematics illustrating:

- Battery and diesel integration
- Load-sharing priorities across microgrid phases
- Solar and thermal interconnectivity

Appendix: Costing and Financial Outlook (Preliminary)

Example: Single-Cabin Setup (VQ Phase 1)

- 4kW PV system: R$20,000–25,000
- Battery storage (~10kWh): R$12,000–15,000
- Diesel genset (GDT-30 shared): R$6,000/cabin allocated
- Installation, wiring, base construction: R$10,000

Total per cabin: R$45,000–56,000 (~USD $9,000–11,000)

Phased development with rental income supports gradual expansion without needing full upfront investment. Larger site infrastructure costings (e.g., biodigester, syngas plant, piping) to be detailed per node in follow-up.

Appendix: Planning and Regulatory Alignment

This proposal anticipates engagement with the following procedures in Brazil:

- Environmental impact assessment (for Limaria and Bogies)
- ANEEL off-grid compliance (for standalone microgeneration)
- INMETRO certification of all electrical systems
- Use of open licensing for educational infrastructure

Initial phases (PV + diesel + LPG) comply with municipal codes and local environmental ordinances.

Appendix: Risk Identification and Mitigation Strategy

Risks:

- **Fuel logistics (diesel/biodiesel):** mitigated by Limaria's internal production and shared storage
- **PV degradation or theft:** mitigated through modular placement, fencing, insurance
- **Battery lifecycle/heat stress:** managed via $LiFePO_4$ chemistry and periodic load balancing
- **Noise pollution (gensets):** addressed via housing insulation and phase-out plans to syngas
- **Training gaps for advanced systems:** solved via embedded QAIB educational programs at each node

System design allows fallback to basic functionality under partial failure, ensuring resilience and recoverability.

Appendix: Gravity Battery Feasibility Note

An early-stage exploration into gravity-based mechanical energy storage at VQ assessed the use of a 1-tonne mass lifted 6 metres to store electricity. The calculated yield was approximately 0.01635 kWh, revealing the physical limitations of small-scale gravitational storage. While not feasible for substantial backup needs, the system retains significant value as an educational demonstration of energy density, mechanical potential, and human-energy relationships. Future iterations may involve public-facing models or counterweight-flywheel hybrids as interpretive infrastructure. Currently, diesel engines—particularly those running on locally produced biodiesel or syngas—remain the most effective storage-and-release tools for VQ-scale loads.

Appendix: Gravity Storage – Field Reality vs. Theoretical Promise

A practical review of a gravity-based energy storage test revealed a critical mismatch between intuitive expectations and physical reality. A field estimate proposed that a 200W pump could raise 20,000 litres of water to a height of 10m. In theory, this would store roughly 0.545 kWh of potential energy. However, when the actual energy required to lift that volume is calculated, it becomes clear that a 200W pump would be insufficient to perform that task.

The power needed to lift 20,000 litres (20,000 kg) to 10 meters is approximately 545W (at 100% efficiency), meaning the original estimate underrepresents the energy demand by nearly 2.7x. In turn, the notion that 800W could be recovered from this cycle is revealed to be energetically impossible. The conclusion underscores the impracticality of gravity-based storage for anything other than micro-demonstration purposes.

The exercise has been retained here not only for its conceptual insight but also to highlight the necessity of rigorous calculation and field-adjusted planning when attempting innovative infrastructure.

Appendix: Battery Storage Strategy for VQ

To support VQ's daily energy load of approximately 180–200 kWh, a battery bank is required to balance generation (diesel/syngas and PV) with silent, overnight or load-smoothing operation.

Preferred Options (Ranked by Practicality & Cost):

1. Second-Life Lithium-Ion Battery Bank
    - Capacity Target: 200 kWh usable
    - Cost: $100–200/kWh ($20k–$40k)
    - Source: Repurposed EV batteries (e.g., Tesla or Nissan Leaf modules)
    - Advantages: Cost-effective, modular, educational value
2. New $LiFePO_4$ (Lithium Iron Phosphate) System
    - Capacity Target: 100–150 kWh (expandable)
    - Cost: $350–400/kWh
    - Advantages: High safety, long cycle life, good thermal tolerance

3. Lead-Acid (Tubular OPzS/OPzV Industrial Cells)
    - Capacity Target: 100 kWh
    - Cost: $150–200/kWh
    - Disadvantages: Heavy, low DoD, high maintenance, heat-sensitive

Strategic Notes:

- Water-based pumped storage (e.g., 20,000 litres at 10 m head) was also explored, yielding less than 1 kWh, and deemed infeasible for meaningful storage.
- Chemical battery systems remain the most appropriate tool for balancing generation at this stage.
- Diesel generators (syngas or biodiesel-powered) remain the backbone of night or heavy load power, with batteries acting as the buffer and silent continuity system.

This tiered storage design ensures that VQ balances high performance, community engagement, and cost-efficiency while retaining adaptability for future upgrades.

Appendix: Financial Projections and IRR Modelling Summary

This section provides a preliminary financial snapshot for each node within the decentralised energy network. It includes estimates of initial capital investments, operational expenses, projected savings or revenue, and expected returns.

Node-Level Financial Overview

Node	Initial Investment (USD)	Annual Operating Cost (USD)	Annual Revenue/Savings (USD)	Breakeven Period (Years)	IRR Estimate (%)
Vila Qatuan	60,000	8,000	15,000	6	14
Limaria	45,000	5,000	10,000	5	16
Cha é	35,000	6,000	9,000	6	12
Bogies	40,000	7,000	14,000	4	18

Comprehensive Node Development Cost Estimates

Node	Description	Estimated Cost (USD)
Vila Qatuan	Full build incl. cabins, battery upgrade, syngas, biogas, water	$150,000–180,000
Limaria	Biodiesel processor, biomass boiler, hydro turbine setup	$110,000–130,000
Cha é	Grid-tie, solar bank upgrade, backup genset, workshop infra	$75,000–95,000
Bogies	Large biodigester, compost handling, education, biogas grid	$85,000–105,000

These expanded figures reflect the projected full realisation of each node as a regenerative infrastructure site. Initial survival-phase investments are scaled here to include circular co-product streams, community training systems, durable grid-ready assets, and QAIB-linked learning pathways.

Assumptions & Notes:

- Figures are first-pass estimates informed by current equipment costs, rural labour rates, and known infrastructure components.
- Revenue includes fuel savings, rental income, compost/fertiliser value, and reduced grid dependency.
- Breakeven calculated via simple cost-recovery model.
- IRR values assume consistent operation over a 10-year period without major subsidy.
- Future iterations may include net present value (NPV), variable diesel pricing, and downtime risk.

Appendix: Carbon Accounting Methodology

This section provides a high-level approach to estimating carbon impacts, offsets, and accounting mechanisms within the decentralised energy system. It aligns with voluntary carbon market protocols and UNFCCC-recognised methodologies for emissions reporting.

1. Accounting Principles

- Scope 1: Direct GHG reductions from fuel switching (e.g., diesel to biogas/syngas)
- Scope 2: Reduced emissions from grid decoupling (e.g., PV at VQ and Cha é)
- Scope 3: Lifecycle impacts of compost, digestate, and fertiliser displacement

2. Offset Sources & Quantification

- Methane capture from pig manure and food waste (Bogies, VQ)
- Biochar integration into soil (permanent carbon sink)
- Compost usage replacing synthetic fertilisers
- Diesel displacement through biodiesel and syngas

3. Preliminary Emissions Avoided (Estimates)

- Methane offset (Bogies): ~22–28 tCO_2eq/year
- Diesel displacement (Limaria to VQ): ~15–18 tCO_2eq/year
- Compost vs synthetic NPK: ~3–5 tCO_2eq/year
- Biochar sink: ~5–10 tCO_2eq/year (depending on application rate)

4. Monitoring & Verification Strategy

- Methane flow meters at digesters (Bogies and VQ)
- Weight-based tracking of biochar and compost use
- QAIB dashboard logging fuel consumption and grid displacement

5. Certification Pathway (Future-Ready)

- Alignment with Gold Standard for the Global Goals or Verra VCS
- Pre-registration for micro-scale methodologies (≤10,000 tCO_2eq/year)
- Potential integration with national carbon registry (Brazil)

This appendix serves as a placeholder for a full lifecycle analysis (LCA) and carbon reporting system to be developed in Phase 2 of implementation.

Appendix: Education Module Overview

The decentralised energy project doubles as a pedagogical infrastructure, embedding sustainability literacy into every node of the system. The educational integration is designed to support citizen science, technical training, regenerative practices, and international curriculum alignment.

1. Target Learners

- Local apprentices and technicians
- School-age youth (primary to secondary)
- Citizen scientists and community members
- National and international sustainability researchers

2. Core Educational Channels

- Live digital dashboards and visualisations powered by QAIB/Aeva
- Field labs for energy generation (biogas, PV, hydro, biochar)
- On-site workshops on composting, water cycles, carbon offsetting
- Modular curriculum aligned with Brazilian standards and GLOBE Protocols

3. Certification Pathways

- QAIB badge system for regenerative competencies
- Alignment with SENAI, PRONATEC, or partner vocational systems
- Potential micro credential co-certification with NASA Open Science & HarvardX frameworks

4. Learning Outcomes

- Systems thinking and regenerative design
- Technical maintenance of off-grid infrastructure
- Open science methodologies and citizen data handling
- Community-driven innovation and resilience building

5. Knowledge Sharing Strategy

- Aeva ThinkMachine integration for multilingual knowledge base

- Inter-node communication via citizen dashboards
- Open-source documentation for replication across Latin America

Education is not a side-effect but a core deliverable. Every generator, every biodigester, and every dashboard is a living classroom.

Appendix: Energy Phasing Strategy – From Survival to Demonstration

Appendix: Course Reading List and Reference Materials

This project has been informed by a wide array of foundational and advanced materials, spanning energy systems, sustainability theory, circular economy design, and off-grid engineering practices. The reading list reflects both formal coursework and independent study that contributed to system thinking, infrastructure planning, and regenerative development modelling.

Formal Bibliography

- Ruddick, W. (n.d.). *Grassroots Economics: Reflection and Practice*. Nairobi: Grassroots Economics Foundation.
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- HarvardX. (2024). *Fundamentals of Neuroscience Parts 1–3*. Harvard University.
- European Commission. (2020). *Smart Cities and Communities – European Innovation Partnership*. Brussels.
- RDG (2025). *Smart Cities: Energy Systems and Sustainability Integration*. Research Design Group.
- QAIB Internal Archives (2024–2025). *Quantum Design Series & Cognitive Membrane Dynamics*. ThinkMachine Frameworks.
- QAIB Engineering Unit (2023–2025). *Syngas Microgrid Integration Notes and FT Process Applications*. Field Technical Reports.

Core References & Learning Modules:

- *Design and Management of Energy Projects* – Master's Course Materials
- *Project Development* and *Project and Its Organization* – Energy Degree Modules
- *NASA Open Science 101*, especially modules on open infrastructure and sustainable research
- *HarvardX Neuroscience Course* – on systems complexity and decision-making
- *Grassroots Economics: Reflection and Practice* – Will Ruddick (Translation & Commentary by QAIB)
- *Smart Cities: Energy Systems and Sustainability Integration* – RDG Framework
- *Circular Bioeconomy and Regenerative Design* – Internal ThinkMachine frameworks
- *Fischer-Tropsch Process, Biogas Digestate Applications, and Syngas Microgrid Engineering* – Technical references from QAIB development archives

Supplementary Papers & Notes:

- Cognitive Membrane Dynamics and Quantum Design Series (QAIB)
- Open-source systems documentation from successful off-grid demonstration projects
- Field-tested feasibility studies from the Qatuan Site (since 2018)

"What we've actually managed to do today, is truly assess a movement away from fossil fuels for our own benefits. In doing so, we've recognised how much we consume, how difficult it is to 'store' energy, and what it takes to 'provide' for it. The inevitable realization is that energy at the moment, surrounded by caveman thinking processes, leads to a necessity for a system of perpetual generation without storage — which immediately leads to an economic situation perpetually in search of sustainable growth — which, is exactly where we now find ourselves as a civilisation-scale dilemma."