

An IoT-Enhanced Life Cycle Assessment Framework for Continuous Environmental Impact Monitoring in Solar Energy Systems

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CORE MESSAGE: Dynamic LCA becomes operational and trustworthy when real-time IoT monitoring transforms static environmental assessment into continuous intelligence.

INTRODUCTION & AIM

The ESG Trust Gap & The Problem

- Static LCA Limitations: Current environmental assessments rely on retrospective, aggregated datasets.
- Contextual Blindspots: Fail to capture operational variability.

The Transition Challenge

- Expanding solar energy requires trust among public institutions, developers, and communities.

Aim of the Study

- Propose an IoT-enhanced dynamic Life Cycle Assessment (dLCA)

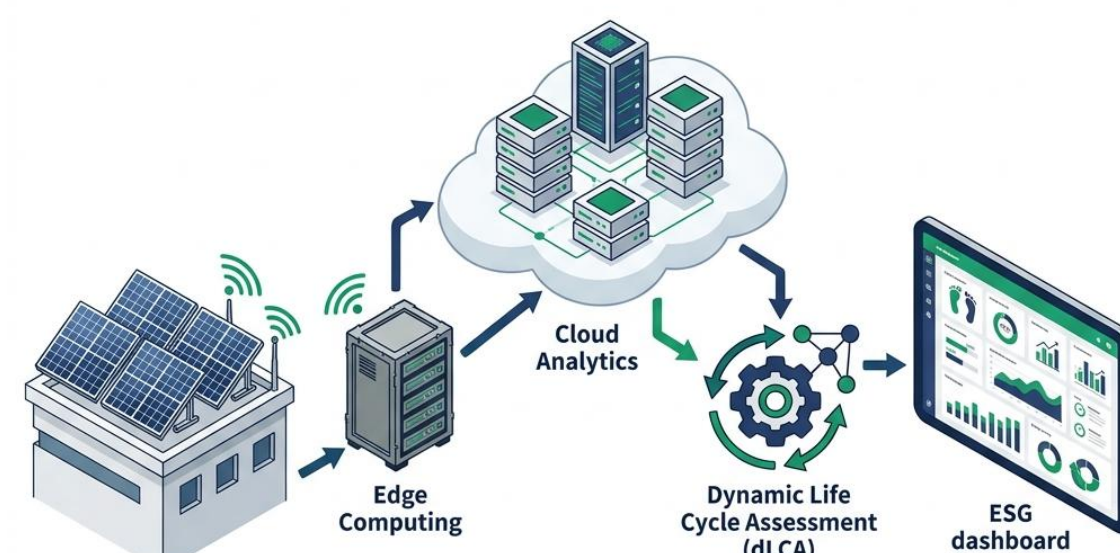
METHOD

Edge/Cloud IoT Architecture

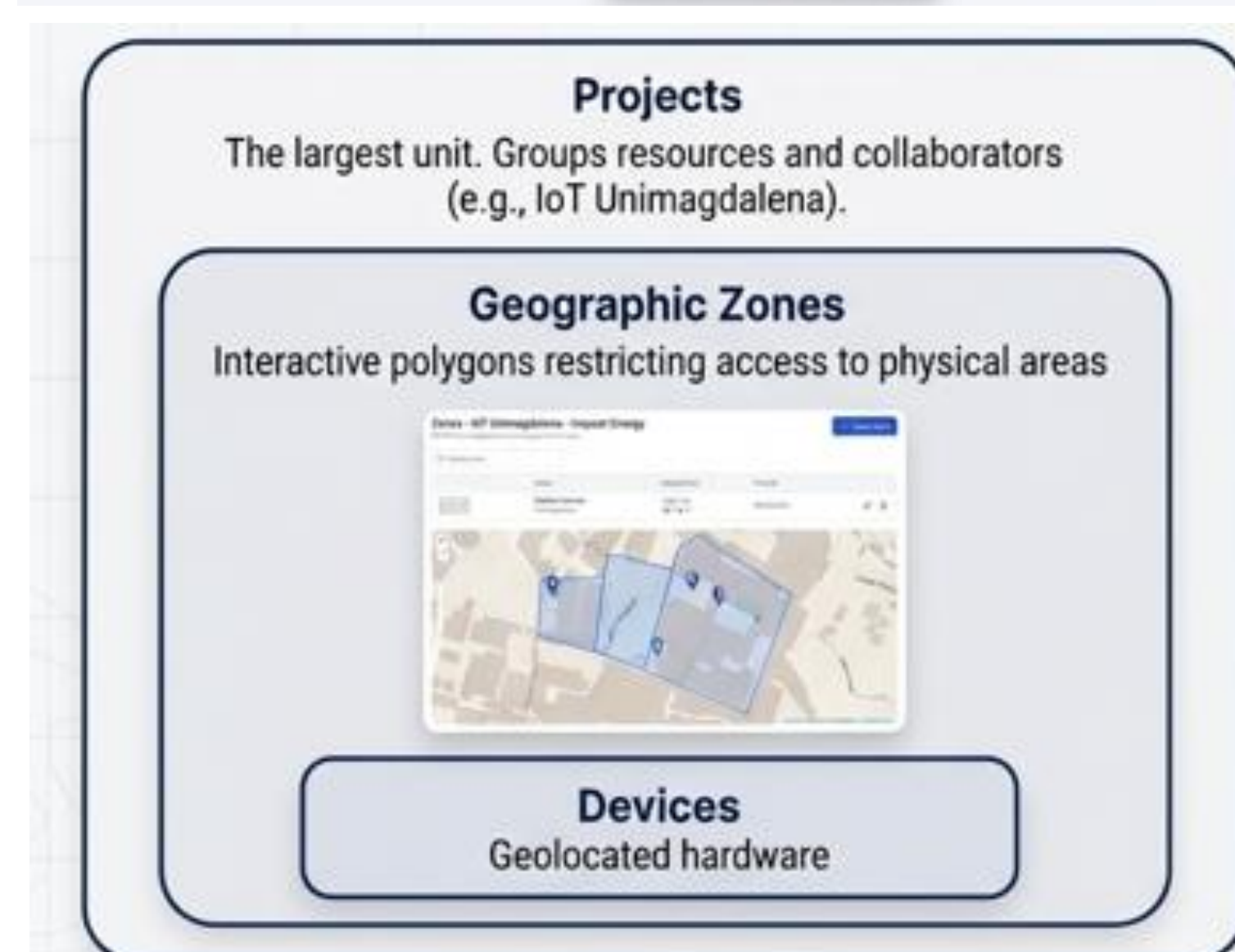
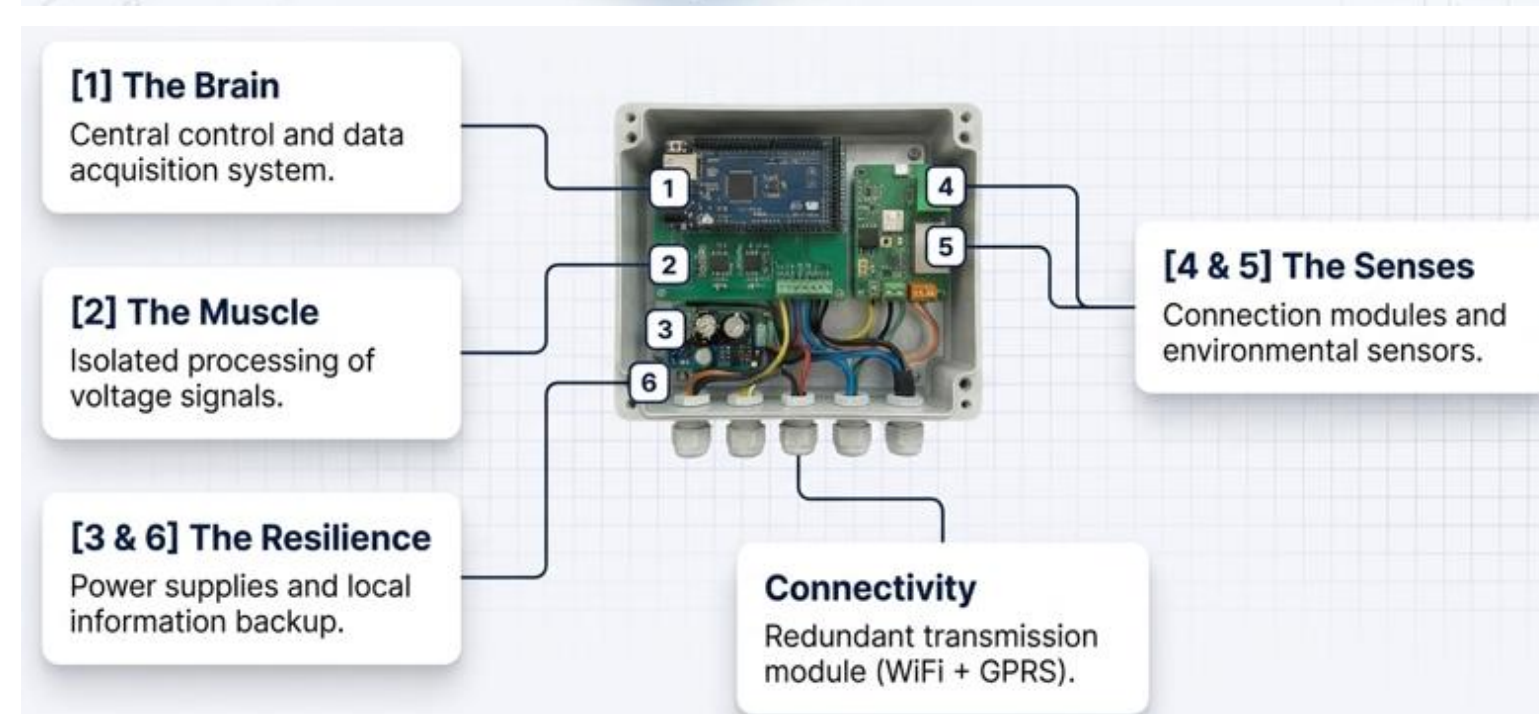
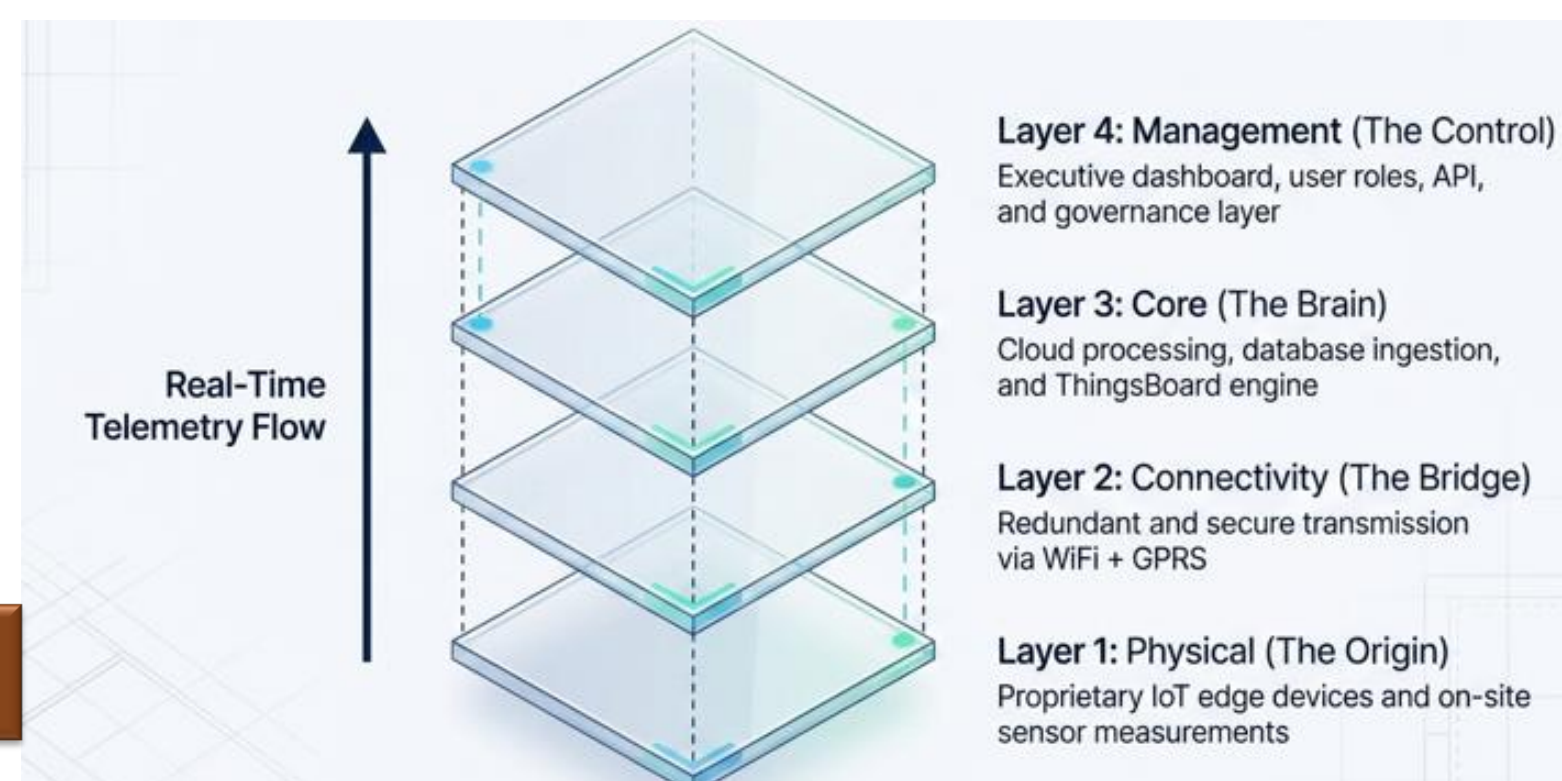
- Edge Devices: Capture and pre-process local environmental and operational data in real-time.
- Cloud Services: Aggregate, harmonize, and feed processed telemetry into the dynamic assessment workflow.

Dynamic LCA (dLCA) Integration

- Replaces static snapshots with dynamic updates of inventory parameters.
- Ensures strict data provenance, temporal consistency, and interoperability.



Static LCA		IoT-Enhanced dLCA	
Temporal Resolution	Retrospective, aggregated, time-invariant datasets.	Temporal Resolution	Dynamic updates of inventory parameters throughout key project phases.
Contextual Accuracy	Blindspots regarding operational variability.	Contextual Accuracy	Captures real-time, context-specific dynamics.
Data Provenance & Trust	Quality challenges in emerging economies.	Data Provenance & Trust	Auditable transparency for public institutions, developers, and communities.



RESULTS & DISCUSSION

Platform Operationalization & Dashboards

- Fully operationalized within the IMPACT Energy.CO digital platform.
- Enables robust tracking of environmental performance over time.

Governance & Colombian Case Study

- Tested in a real-world Latin American context.
- Key Outcome: Overcomes limits of temporal resolution and dramatically increases stakeholder trust and data transparency.

CONCLUSION

- Evolution of Practice: Advances LCA from retrospective analysis to dynamic monitoring.
- Traceability: Improves data quality control and transparency.
- Decision-Making: Provides a transferable methodological foundation for governance.

FUTURE WORK

- Scaling platform for fully quantitative dLCA assessments.
- Enterprise integration and journal publication.

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