ReCircuit Research Whitepaper

Building the Intelligence Layer for the Circular Economy

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Research publication. ReCircuit is founder-led and early-stage; prototype work is in development.

Executive Summary

What problem exists?

The circular electronics system is data-poor at the moment decisions matter most. Devices enter collection streams with weak identity, incomplete condition records, uncertain residual value, limited chain-of-custody evidence, and inconsistent carbon accounting. Valuable assets are often treated as generic waste because the decision infrastructure around them is fragmented.

Why now?

The pressure is rising from three directions: e-waste generation is growing faster than documented recycling, critical minerals are strategically important, and product-level sustainability data is becoming more important under policy regimes such as the EU Ecodesign for Sustainable Products Regulation and Digital Product Passport framework [1], [2], [4].

Why AI?

AI can help interpret unstructured evidence at scale: images, serial labels, component photos, repair notes, route constraints, market signals, and emissions factors. Its role is not to replace certified processors or auditors; its role is to produce better decision support, confidence scoring, exception handling, and traceable records.

Why ReCircuit?

ReCircuit is focused on the missing intelligence layer between collection and recovery. The proposed platform treats every device as a decision object with identity, condition, material, carbon, compliance, and routing context. The goal is not another recycling directory; the goal is infrastructure for smarter circular decisions.

What is the vision?

ReCircuit aims to become a material intelligence platform that helps consumers, businesses, recyclers, and governments choose higher-value circular pathways: repair, reuse, resale, component harvesting, certified recycling, or secure destruction. The current work is research and prototype development, not a deployed enterprise network.

Abstract

Electronic waste is no longer only a disposal problem. It is a fragmented intelligence problem across product identity, material value, reverse logistics, climate accounting, repairability, and compliance evidence.

ReCircuit proposes an AI platform for material intelligence across the circular economy. The platform vision combines structured device intake, computer vision, forecasting, pricing logic, carbon estimation, ESG evidence, and API-accessible records so that recovery decisions can be made with more context and less ambiguity.

This publication separates current status from future capability. ReCircuit has a public website, research foundation, architecture direction, and prototype work in development. It does not claim customers, revenue, funding, deployments, investors, employees, partnerships, awards, or validated performance metrics.

Original Diagrams

The website package includes original SVG diagrams. The PDF below reproduces each diagram as publication-safe vector tables.

System Architecture

Frontend	**API Layer**	**Backend Services**	**Data Pipeline**
AI Layer	**Evidence Store**	**Reporting Exports**	

Data Flow

Intake	**Validation**	**Model Review**	**Decision**
Human Override Log	**ESG Evidence Packet**		

Circular Economy Loop

Electronics	**Collection**	**Triage**	**Reuse + Repair**
Component Recovery	**Recycling**	**New Materials**	

AI Pipeline

Images	**Metadata**	**Computer Vision**	**Forecasting**
Recommendation	**Carbon + ESG Methods**	**Confidence Review**	

Enterprise Workflow

Consumers	**Businesses**	**Recyclers**	**Asset Intelligence Graph**
ESG Reports	**Government Views**		

Global Context

Electronic waste, critical minerals, circularity, reverse logistics, and product data are converging.

Global e-waste reached 62 billion kg in 2022, with only 22.3 percent documented as formally collected and recycled in an environmentally sound manner. The same monitor projects 82 billion kg of e-waste by 2030 under current trajectories [1]. These figures describe more than a waste stream; they describe a global information failure around products, materials, accountability, and recovery choices.

Critical minerals make the recovery problem strategically important. The International Energy Agency identifies copper, lithium, nickel, cobalt, graphite, and rare earth elements as central to clean energy supply chains and notes that market transparency, supply concentration, and ESG risk are policy priorities [2]. Recycling and urban mining cannot remove the need for primary mining, but they can create secondary supply, reduce waste, and improve resilience [3].

Circular economy theory emphasizes keeping products and materials in circulation at their highest value through maintenance, reuse, refurbishment, remanufacture, and recycling [9]. Electronics recovery is difficult because product condition, component value, hazardous material risk, repairability, data security, and market demand must be evaluated quickly and consistently.

Policy is also moving toward product-level data. The European Commission describes the Digital Product Passport as a digital identity card for products, components, and materials, intended to support sustainability, circularity, and legal compliance [4]. ReCircuit's research direction aligns with that shift: recovery systems need structured records that can move with products and materials.

Problem Statement

Existing systems are fragmented across visibility, traceability, decision making, and compliance.

The end-of-life electronics ecosystem is not one system. It is a chain of partial systems: consumer drop-off, corporate asset disposition, local collection, informal aggregation, repair shops, refurbishers, data sanitization providers, logistics vendors, recyclers, smelters, compliance teams, and auditors. Each node may know something important, but the evidence often fails to travel.

Visibility is weak because device identity and condition are not consistently captured at intake. Traceability is weak because the record of movement, custody, and processing is often separated from the physical asset. Decision making is weak because repair, resale, parts harvesting, recycling, and destruction are evaluated through local heuristics rather than a shared intelligence layer.

Compliance is becoming harder because sustainability claims require evidence. The GHG Protocol Scope 3 Standard provides a global methodology for value chain emissions accounting and identifies upstream and downstream categories beyond a company's direct operations [5]. ISO 14064-1 specifies principles and requirements for organizational GHG quantification and reporting [6]. Recovery platforms must therefore separate measured facts from estimates, confidence from proof, and operational convenience from audit evidence.

Current Status

- ReCircuit has a research position, public website, architecture direction, and prototype in development.
- No customer deployments, certified processor integrations, audited emissions claims, or measured recovery performance are claimed.

Proposed Future Capabilities

- Structured device intake with evidence capture.
- Recovery recommendation engine with uncertainty and override logging.
- ESG evidence packets aligned with chain-of-custody and emissions accounting needs.

Platform Vision

ReCircuit as an AI platform for material intelligence across the circular economy.

The ReCircuit platform vision is organized around a simple object: the recoverable asset. A recoverable asset may be a phone, laptop, PCB, battery pack, accessory, server component, or mixed electronic item. The platform does not treat the asset as anonymous waste. It builds a structured record around identity, photos, condition, component signals, safety flags, ownership context, location, market pathway, estimated emissions effect, and compliance evidence.

The intelligence layer then compares possible circular pathways: repair, reuse, resale, refurbishment, component harvesting, certified recycling, or secure destruction. Each pathway has a different economic, carbon, safety, data security, and compliance profile. ReCircuit's proposed contribution is to make that comparison explicit.

The long-term platform is not a black-box sustainability score. It is a decision system with inputs, outputs, assumptions, confidence levels, evidence requirements, and human review.

Artificial Intelligence

AI should improve decisions while exposing uncertainty.

Computer vision can classify device category, visible condition, corrosion, cracked glass, missing components, battery swelling risk indicators, and component candidates. Forecasting can estimate route demand, collection density, seasonal inflows, and market movement for recovered parts. Recommendation systems can compare circular pathways using rules, model outputs, price signals, and processor constraints.

Large language models can assist with document understanding, policy search, user guidance, record summarization, and ESG narrative drafting, but they must not become the source of truth for measured facts. In ReCircuit's design, LLM outputs are advisory and cite the underlying asset record, policy source, or user-provided evidence.

Carbon estimation is treated as a model-backed estimate, not a proof claim. It can use device category, weight, transport route, recovery pathway, emissions factors, and confidence intervals to help compare options. Any public or customer-facing claim would require methodology review, factor provenance, and audit-ready documentation.

Current Status

- AI methods are architecture and prototype-stage concepts.
- No trained production computer vision model, audited emissions engine, or deployed recommendation system is claimed.

Proposed Future Capabilities

- Image-based condition triage.
- Decision recommendations with confidence and human override.
- Carbon and ESG evidence generation with methodology notes.

Enterprise Platform

Different stakeholders need different workflows over the same asset intelligence graph.

Consumers need simple intake, pickup guidance, device preparation instructions, and trust signals about where a device is going. Businesses need bulk upload, asset traceability, data security evidence, reporting exports, and workflow approvals. Recyclers need operational triage, batch planning, contamination and safety flags, route prioritization, and downstream records. Governments need anonymized program visibility, policy metrics, compliance views, and infrastructure planning.

ReCircuit's proposed enterprise platform is therefore multi-sided but not unfocused. The shared primitive is the recoverable asset record. Each stakeholder sees a different surface over that record: intake, operations, compliance, public program performance, or research analytics.

The platform should be designed for conservative claims. Dashboards must distinguish measured data, modeled estimates, pending evidence, human overrides, and unavailable data. This is especially important for ESG reporting, where weak evidence can create reputational and regulatory risk.

Business Model

Revenue mechanisms should follow real workflow value, not speculative projection.

A realistic ReCircuit business model could combine software subscriptions, per-asset processing fees, API usage, compliance report generation, analytics modules, and implementation services for organizations with high electronics turnover. Government or campus programs could use procurement or grant-supported pilots where the objective is infrastructure learning rather than immediate enterprise sales.

The model should avoid dependency on unverified carbon credit revenue or inflated materials arbitrage. Early revenue, if pursued, should be tied to measurable utility: intake automation, operational prioritization, evidence generation, reporting time reduction, and improved recovery routing.

Current Status

- No revenue is claimed.
- No pricing has been validated with customers.

Proposed Future Capabilities

- Prototype-led discovery with recyclers, campus labs, businesses, and municipal programs.
- Pilot pricing based on workload, asset volume, and reporting complexity.

Risks

A credible circular AI platform must identify its own failure modes.

Technical risk includes poor image quality, dataset bias, device diversity, safety-critical misclassification, weak materials estimation, and model drift. Financial risk includes long enterprise sales cycles, low willingness to pay in waste operations, and high integration costs. Regulatory risk includes changing definitions of sustainability claims, waste handling rules, product passport requirements, and cross-border movement controls.

Execution risk is significant because ReCircuit is founder-led and early-stage. The platform vision spans AI, logistics, compliance, climate accounting, and enterprise workflow design. That scope must be sequenced carefully. Security risk includes sensitive asset information, serial numbers, location data, business inventory, and potentially personal data on devices. AI limitation risk includes hallucinated policy summaries, overconfident recommendations, and false precision in emissions estimates.

The mitigation strategy is staged development: narrow prototype, transparent assumptions, human review, source-linked records, conservative claims, security-by-design, and independent validation before any public performance claim.

About the Founder

Founder biography, factual and non-resume style.

Mohnish M is the founder of ReCircuit and House of Mohny. He is a Computer Science Engineering student building at the intersection of AI systems, product engineering, climate technology, and circular economy infrastructure.

ReCircuit reflects a research-led founder thesis: the circular economy needs better intelligence infrastructure before recovery systems can scale with trust. The current work focuses on public research, product architecture, prototype development, and clear communication of what has and has not been built.

System Architecture

Each subsystem is described by purpose, inputs, outputs, current status, and future work so capability claims remain bounded.

Subsystem	Purpose	Current status	Future work
Frontend	User-facing portal for intake, dashboards, reports, research, and public communication.	Public website live. Research portal generated in v2.0. Product UI remains prototype-stage.	Role-based dashboard, upload experience, report preview, accessibility hardening, offline collection mode.
Backend	Application services for asset records, workflow state, authorization, audit logging, and integrations.	Architecture defined. No production backend deployment claimed.	Event-driven services, tenant model, RBAC, immutable audit trail, integration adapters.
AI Layer	Decision-support layer for classification, condition analysis, forecasting, recommendation, and text assistance.	Concept and prototype direction. No production model metrics claimed.	Dataset design, baseline models, human review loop, evaluation harness, model cards.
Computer Vision	Analyze device photos and component images for visible condition and category signals.	Research and prototype design.	Image capture protocol, labeled dataset, active learning, false-negative review for safety-critical classes.
Forecasting	Forecast collection volume, route demand, downstream capacity, and market movement.	Proposed future capability.	Synthetic planning model, pilot data capture, calibration against real operations.
Pricing Engine	Compare economic pathways for resale, repair, parts harvesting, recycling, or destruction.	Architecture concept only.	Market source governance, price confidence bands, override logs, regional constraints.
Carbon Intelligence	Estimate emissions implications of alternative recovery pathways with visible assumptions.	Research-stage methodology.	Factor registry, methodology review, uncertainty scoring, audit export.
ESG Engine	Prepare evidence packets for Scope 3, diversion, chain-of-custody, and recovery reporting.	Report architecture defined. No audited reports claimed.	Report templates aligned to customer needs, assurance workflow, API export.
API Layer	Allow organizations and processors to exchange asset, workflow, and report data.	Future capability.	REST/GraphQL schema, webhooks, OAuth, rate limits, audit logging.
Cloud Infrastructure	Secure, scalable runtime for data storage, models, file handling, and observability.	Not deployed as production infrastructure.	IaC, secrets management, encrypted storage, monitoring, cost controls.
Data Pipeline	Move asset evidence from intake through model processing, decisioning, reporting, and analytics.	Architecture complete at concept level.	Schema registry, validation rules, event bus, lineage tracking, data retention policy.

Enterprise Workflows

Stakeholder	Workflow	Value
Consumers	Upload device details, receive preparation guidance, schedule or locate recovery path, track handoff status.	Lower friction, clearer trust, better preparation before collection.
Businesses	Bulk asset intake, policy-based routing, data security evidence, Scope 3 and diversion exports.	Better reporting workflow and defensible evidence for electronics disposition.
Recyclers	Triage incoming items, flag safety issues, prioritize higher-value recovery, confirm processing events.	Operational visibility and more consistent handling decisions.
Governments	View anonymized program metrics, infrastructure gaps, collection trends, and compliance evidence.	Better planning for circular economy programs and public recovery infrastructure.

Roadmap

Period	Stage	Milestone
Q3 2026	Research	Publish Whitepaper v2.0, finalize prototype architecture, define dataset and evidence schema.
Q4 2026	Prototype	Build interactive intake flow, synthetic decision engine, diagrammed report generation, and model evaluation plan.
Q1 2027	MVP	Release controlled MVP with asset record creation, manual review, carbon estimate placeholder, and downloadable evidence packet.
Q2 2027	Pilot	Invite campus labs, local recyclers, and collection operators for narrow pilots with explicit success criteria.
2028	Enterprise	Expand integrations, role-based dashboards, compliance workflows, and processor-facing API surfaces.
2030	Global platform	Long-term vision: connect material traceability, recovery decisions, product data, and climate intelligence at scale.

Risk Register

Category	Risk	Mitigation
Technical	Model errors, device diversity, image quality, sparse data, and unsafe routing recommendations.	Human review, confidence thresholds, narrow pilot scope, model cards, and safety-critical escalation rules.
Financial	Circular operations may have limited software budgets and long buying cycles.	Focus on measurable workflow value and low-friction pilot design.
Regulatory	Waste handling, product passport, data protection, and ESG claim rules may change.	Source-linked policy monitoring and conservative claims.
Security	Asset data, serials, locations, and business inventories can be sensitive.	RBAC, encryption, audit logs, least-privilege APIs, and retention controls.
Market adoption	Stakeholders may resist new workflows if benefits are unclear.	Design around existing operations and prove value in narrow workflows.
AI limitations	Overconfident or hallucinated outputs can weaken trust.	Treat AI as decision support, require source evidence, and expose uncertainty.

Appendix A: Glossary

Recoverable asset

A device, component, material stream, or batch that may be repaired, reused, harvested, recycled, or securely destroyed.

Material intelligence

Structured knowledge about product identity, condition, components, value, carbon impact, custody, and recovery pathway.

Digital Product Passport

A digital identity record for products, components, and materials intended to support sustainability, circularity, and compliance.

Decision intelligence

A system that turns data, rules, predictions, constraints, and human judgment into explainable operational decisions.

ESG evidence packet

A structured export containing facts, estimates, custody events, methodology notes, and data gaps behind a sustainability report.

Appendix B: Future Research

- How can image capture protocols improve reliability for device and component classification?
- Which evidence fields are necessary for credible electronics Scope 3 and diversion reporting?
- How should confidence intervals be represented in recovery recommendations?

- What minimum data model can support product passport, processor, and corporate reporting use cases without overburdening operators?
- How can circular routing optimize for value, emissions, safety, and local infrastructure constraints simultaneously?

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