The Three-Tier Validation Pipeline

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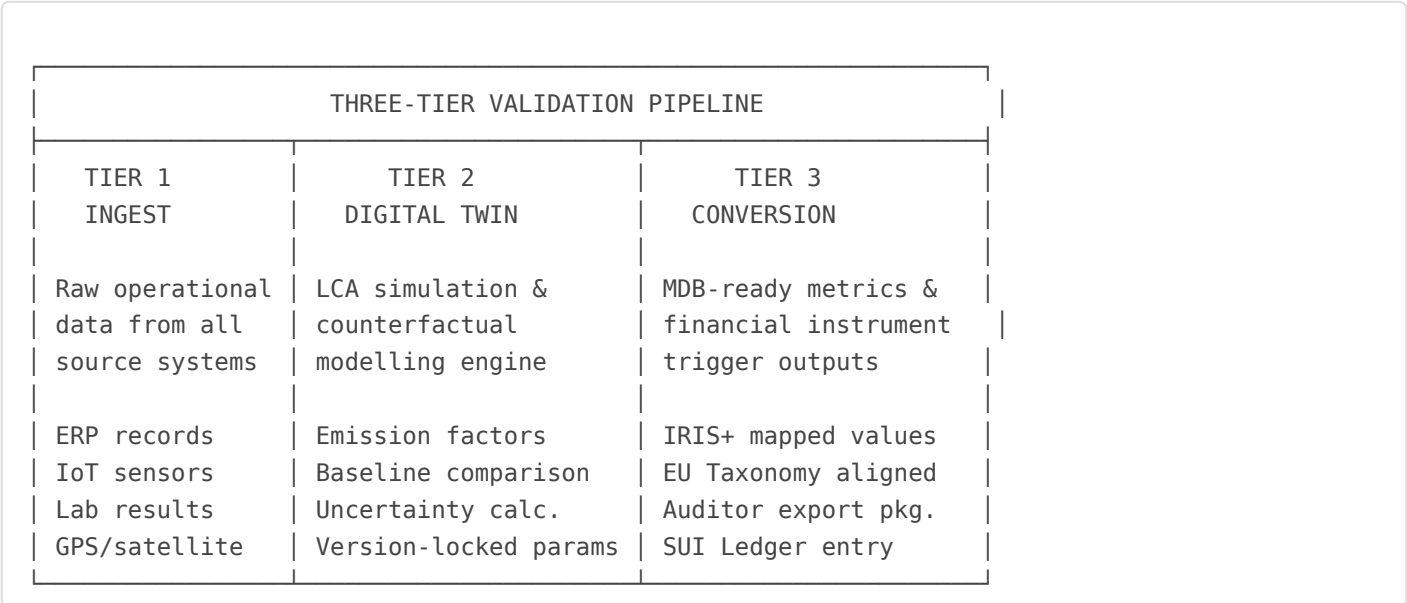
The Three-Tier Validation Pipeline is the data architecture that converts raw operational records into verified SUI events. It is named for its three sequential layers: Ingest, Digital Twin, and Conversion. Each tier has a defined responsibility, a defined data format, and a defined handoff protocol to the next tier.

Pipeline Overview



Tier 1: Ingest

Purpose

Capture all raw evidence of product application events in structured, timestamped form. The Ingest tier is the intake valve of the SSOT — every piece of data relevant to a SUI claim must enter through it.

Data Sources by Sector

Sector	Typical Ingest Sources
AgTech / Bio-inputs	Batch production records (ERP), field application GPS logs, customer delivery confirmations, soil lab analysis PDFs
Clean Energy / EV	IoT charging session data (kWh, duration, vehicle ID), grid connection records, utility meter readings
Water Treatment	Flow meter readings, water quality sensors (turbidity, pH, pathogen count), treatment plant operational logs
Circular Economy	Material inflow/outflow manifests, weight measurements, recycler receipts, chain-of-custody certificates
Built Environment	BMS (Building Management System) data, energy audit reports, occupancy sensors, utility bills

Ingest Requirements

- **Timestamp:** Every record carries a machine-generated UTC timestamp, not a manually entered date
- **Source ID:** Every record carries the identifier of the system or device that generated it
- **Immutability flag:** Once ingested, records are locked; corrections create new records with a "supersedes" link to the original
- **Schema validation:** Records are validated against a defined schema on ingest; malformed records are quarantined, not silently dropped

Tier 2: Digital Twin

Purpose

Apply the SUI calculation logic to the ingested records — comparing observed outcomes to the counterfactual baseline, applying emission factors, calculating uncertainty, and producing a per-application SUI magnitude.

What "Digital Twin" Means Here

In this context, "Digital Twin" refers to a computational model of the enterprise's impact mechanism — not a real-time operational simulation. The Digital Twin encodes:

- The Life Cycle Assessment (LCA) model for the product's impact pathway
- The baseline values (counterfactual scenario) and their uncertainty ranges
- The emission factors or conversion coefficients (e.g., IPCC AR6 values for N?O emission from synthetic nitrogen)
- The aggregation rules (how individual application events are summed to period totals)

Version Control for Model Parameters

Every change to the Digital Twin model — a new emission factor, an updated baseline, a revised LCA boundary — must be version-controlled. Each SUI event in the ledger is tagged with the model version that produced it. This allows historical SUI calculations to be reproduced exactly, even after model updates.

Digital Twin Outputs

For each ingested application event, the Digital Twin produces:

- SUI magnitude (central estimate)
- Uncertainty range (±N%, at 95% confidence)
- Model version tag
- Calculation audit log (step-by-step computation)
- Data quality flag (complete data vs. estimated vs. proxy)

Tier 3: Conversion

Purpose

Transform the Digital Twin outputs into the formats required by different stakeholders — investors, MDBs, auditors, regulators, and the SUI Ledger itself.

Output Formats

Output	Format	Audience
SUI Ledger Entry	Structured JSON record in the SSOT	SSOT system, auditors
IRIS+ Report	Indicator values mapped to IRIS+ codes	Impact investors, GIIN reporting
EU Taxonomy Contribution Statement	% revenue / capex / opex aligned	European institutional investors
MDB Project Brief	AIMM-compatible impact narrative + data table	IFC, IDB Invest, ADB co-investors
Auditor Export Package	CSV + methodology PDF + raw data links	Third-party verifiers (ISAE 3000)
Investor Dashboard	Aggregated charts + drill-down to unit level	Board, VCs, DFI monitors

Conversion Layer Controls

The Conversion tier must enforce several data integrity controls:

- **No manual overrides:** Conversion outputs are computed, not manually adjusted. Any "rounding" or "presentation formatting" must be documented and must not change material values.
- **Uncertainty propagation:** Uncertainty from the Digital Twin is carried through to all Conversion outputs, not dropped at the reporting layer.

- **Audit trail linkage:** Every Conversion output includes a reference back to the Tier 2 records that produced it, and through those, to the Tier 1 raw inputs.

The Pipeline in Practice: Becaps Example

1. **Ingest:** Becaps ERP records batch #BC-2024-0441: 500 kg product shipped to cooperative Finca Verde, La Calera, Colombia. GPS delivery confirmed. Cooperative confirms application to 500 ha (1 kg/ha). Soil lab reports uploaded: pre/post nitrogen content for 12 sample plots.
2. **Digital Twin:** Model applies: Baseline = 220 kg N/ha (DANE 2023 Colombian synthetic fertiliser use). Observed = 85 kg N/ha (lab-confirmed). Net displacement = 135 kg N/ha. IPCC AR6 conversion: 135 kg N × 0.758 CO?e/kg N = 102.3 kg CO?e/ha. Uncertainty: ±12.3 kg CO?e (±12%). Model version: DT-Becaps-v2.1.
3. **Conversion:** 500 SUI events recorded in ledger (one per hectare). IRIS+ PI5765 report: 51,150 kg CO ?e avoided this batch. Auditor export package generated. MDB project brief updated with cumulative totals.

Next: The Digital Twin for Impact Verification — building and validating the computational model.

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