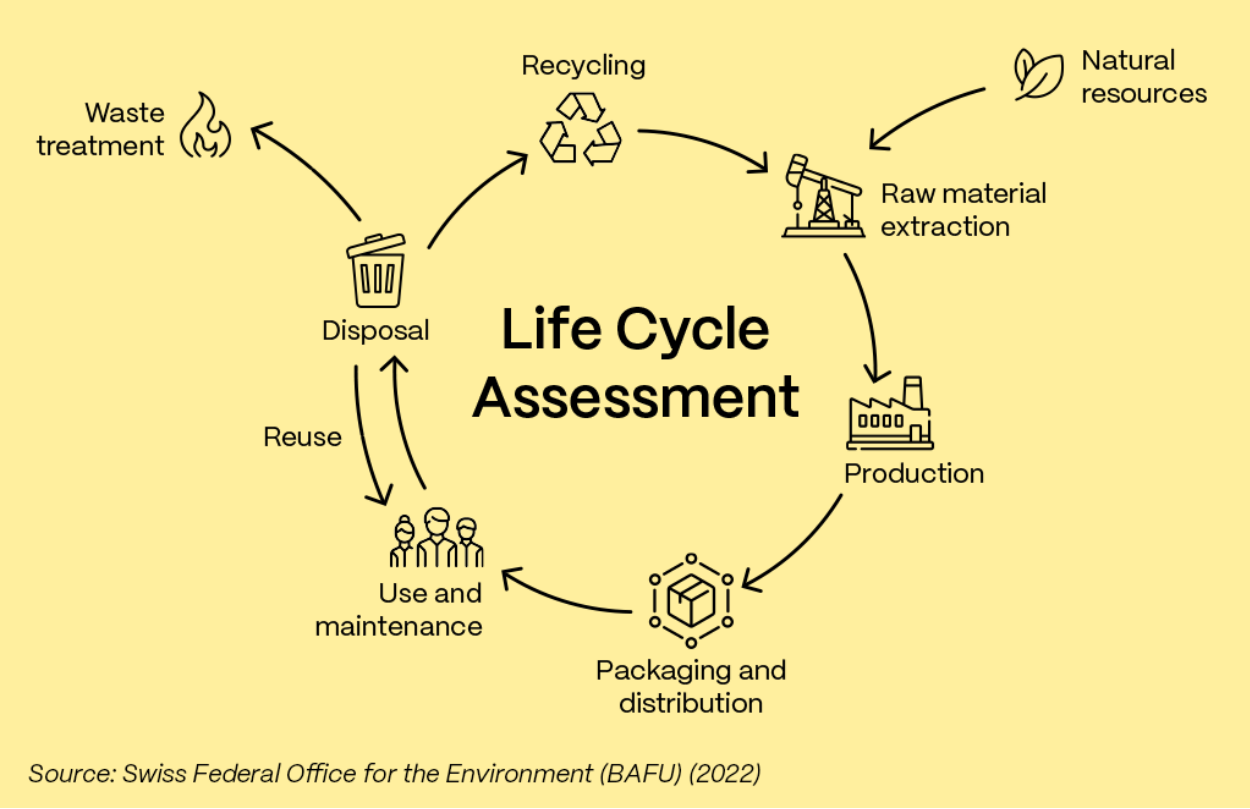
From LCA Database to AI-Enabled LCA Infrastructure

Xiaohui Lu
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https://www.tiangong.earth

碳足迹产业技术创新联盟
Carbon Footprint Alliance

TianGong

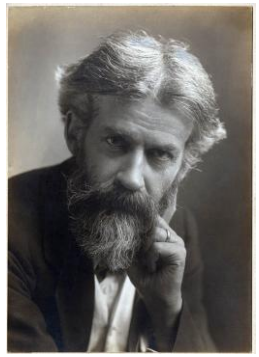
2 Life Cycle Assessment (LCA)



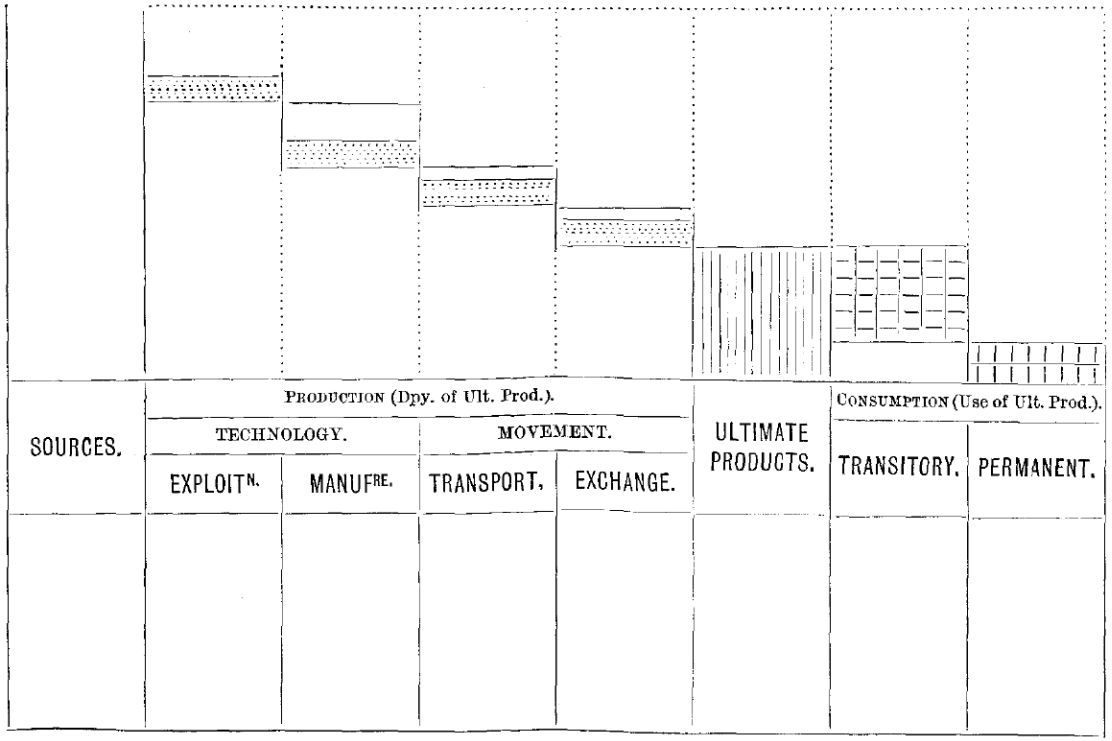
LCA evaluates the environmental impacts of a product system from its whole life cycle

This talk will be about how AI is used to develop an LCA database

3 Beginning of LCA



The **first LCA-like study** was done by **Patrick Geddes**, a Scottish biologist and urban planner, to record the energy and material flows caused by the extraction, processing, transport, trade and use of coal (Geddes 1884).



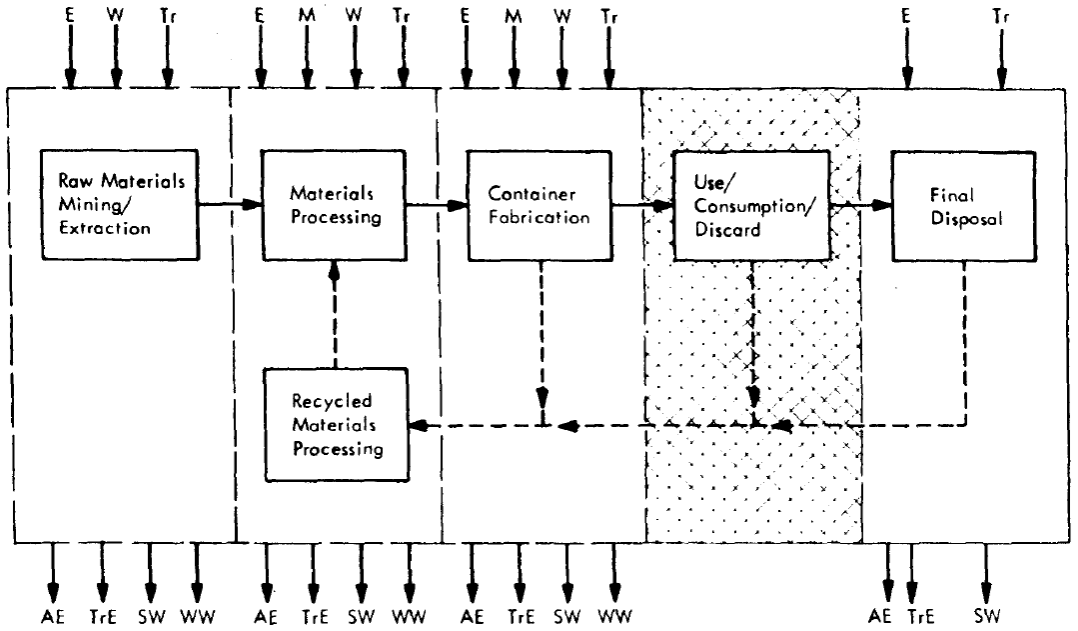
The early modern LCA studies can be dated back to 1960s. In the US there was a 1969 study commissioned by **Coca Cola** comparing **life cycle environmental impacts of packaging** (Hunt and Franklin, 1974; 1996).



Harry Teasley (Coca Cola)

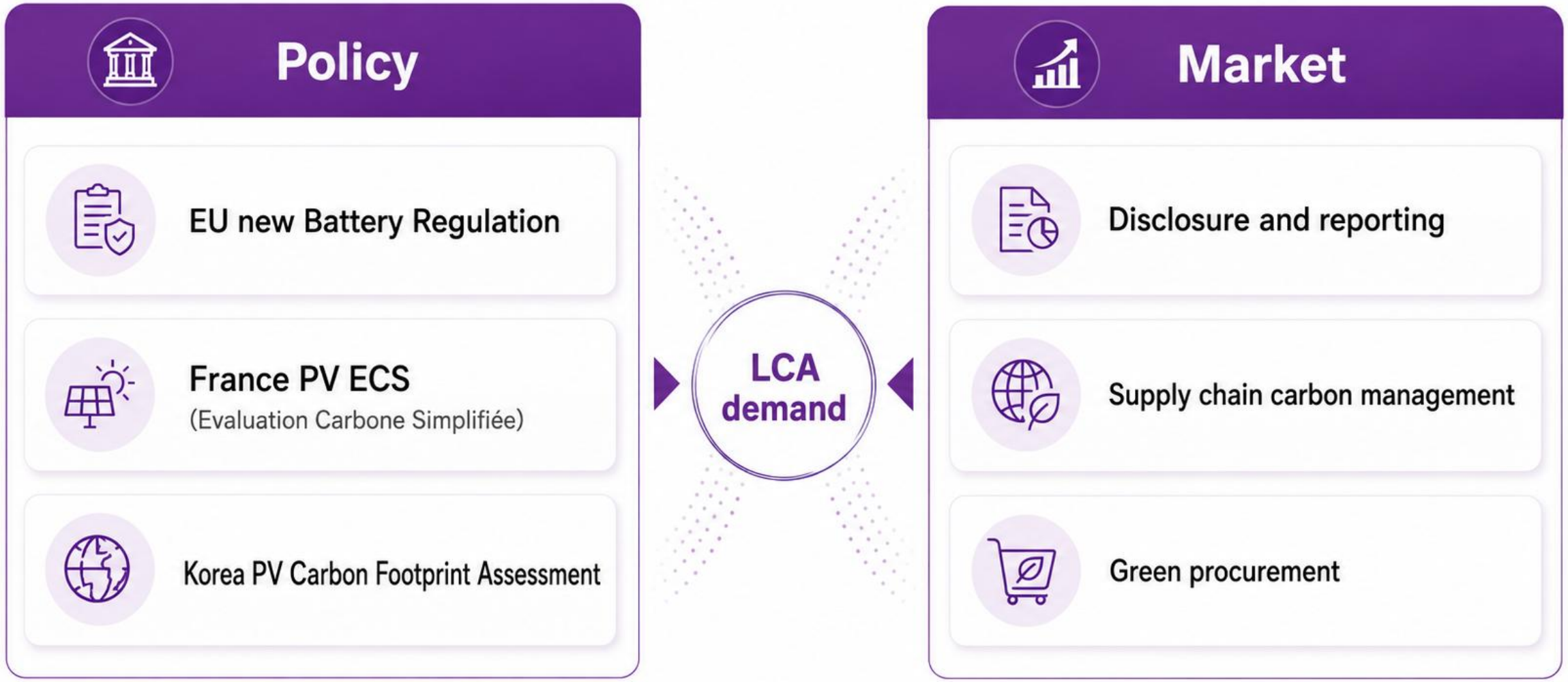


Arsen Darnay (Midwest Research Institute)

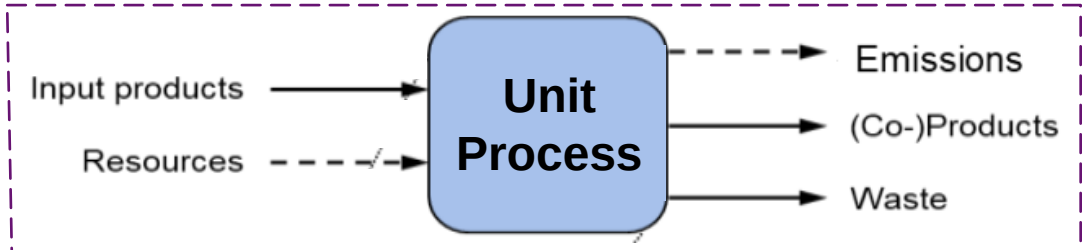


4 How is LCA relevant today?

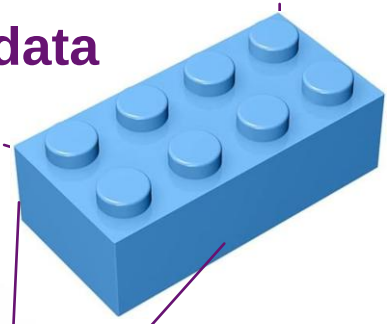
Policy and market forces are jointly driving LCA demand



5 How to do an LCA?

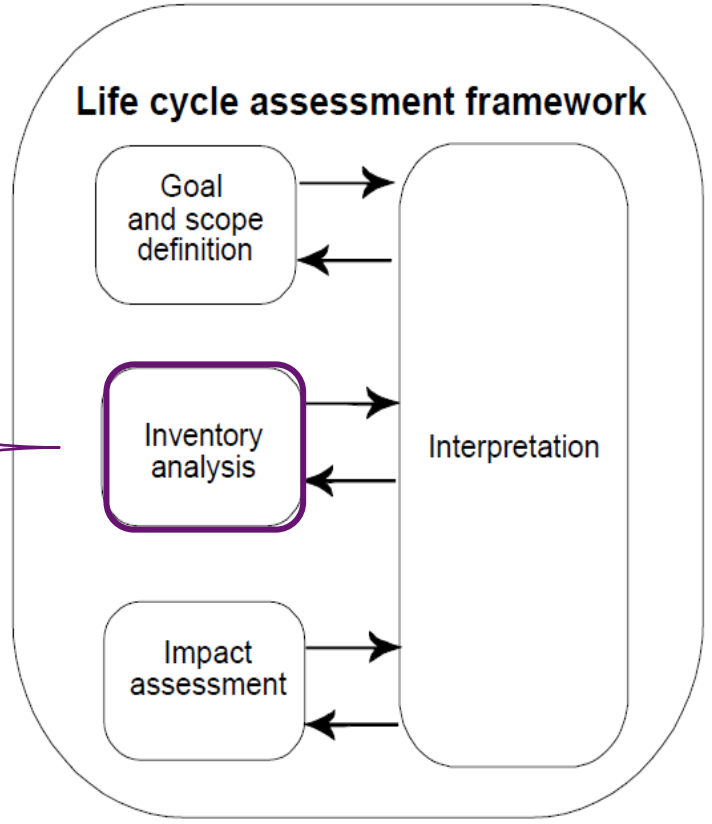


② data



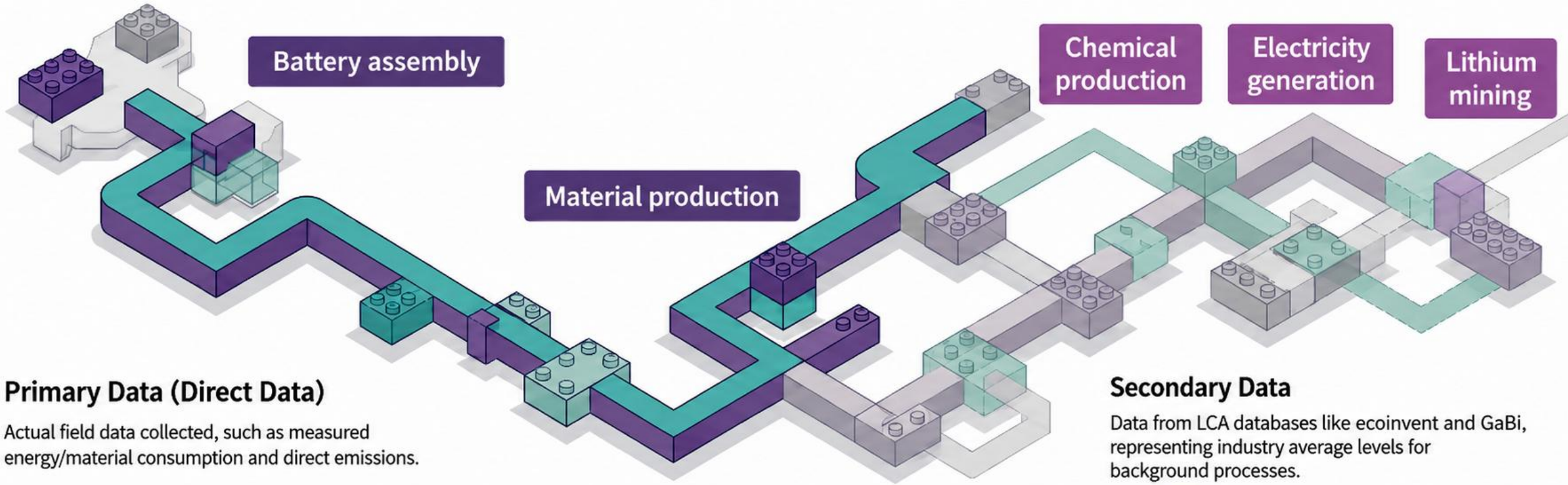
① life cycle inventory modeling





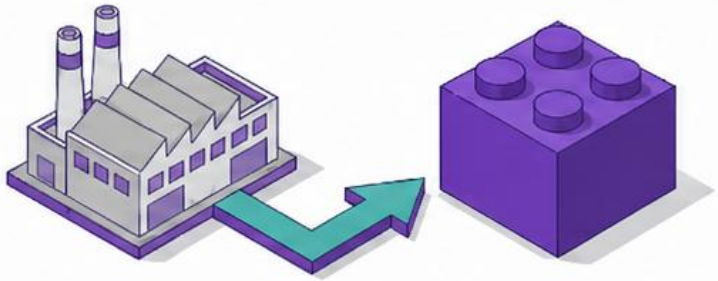
ISO 14040

6 Where are the data from?



Primary Data (Direct Data)

Actual field data collected, such as measured energy/material consumption and direct emissions.

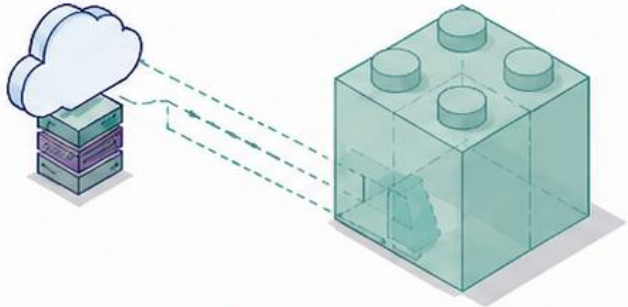


On-site collection → Core manufacturing, direct suppliers

When primary data is missing, databases fill gaps in background processes, making full LCA calculation possible.

Secondary Data

Data from LCA databases like ecoinvent and GaBi, representing industry average levels for background processes.



LCA Databases → Energy background, generic raw materials, upstream supply chain

7 What does an LCA database look like?

Product (steel, aluminum, cement, …)

	P1	P2	P3	P4	…	Pn
P1						
P2						
P3						
P4						
…						
Pn						
F1						
…						
Fm						
E1						
…						
Ek						

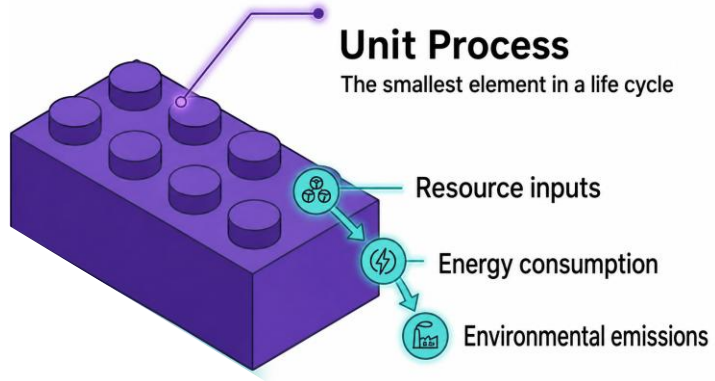
Product

Resource (water, oil, …)

Emissions (CO_2, SO_2, ….)

Digital typology of the technology system

Each column is a unit process



Technology Matrix

$$\mathbf{h} = \mathbf{b}\mathbf{A}^{-1}\mathbf{f}$$

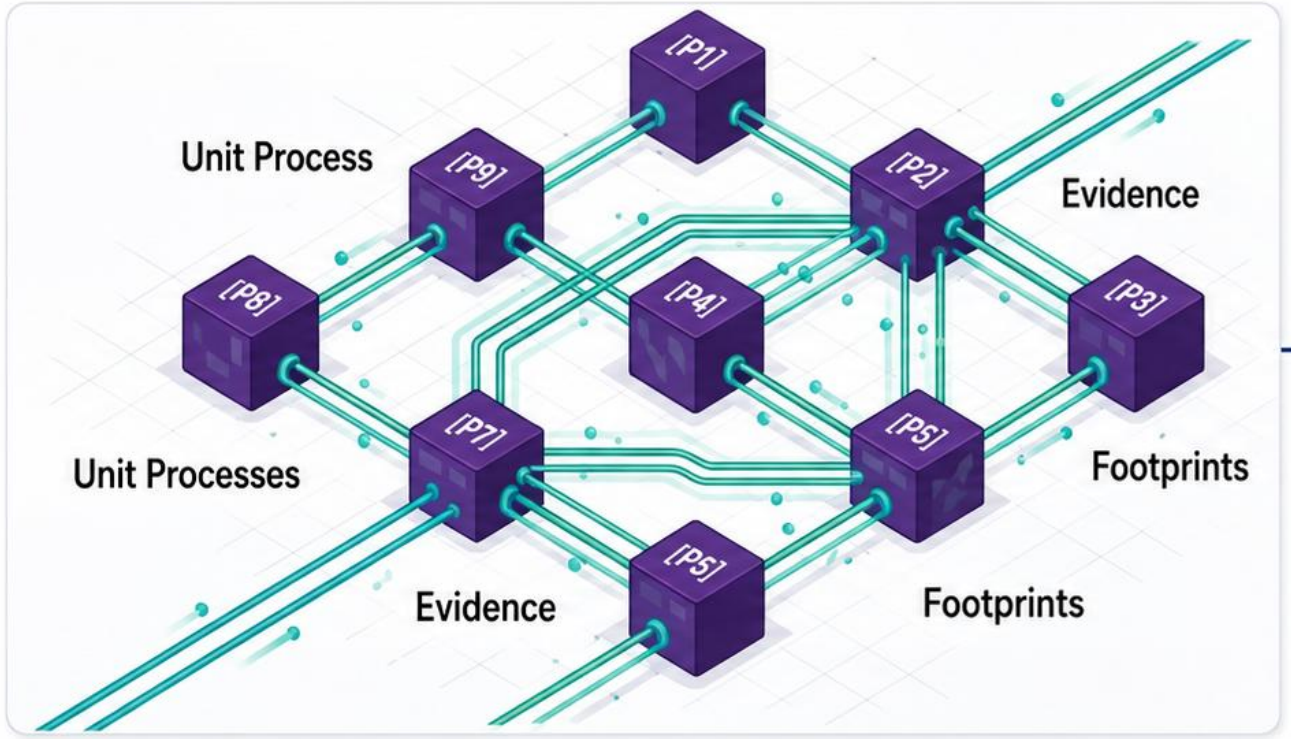
Environmental footprint per unit product

Resource/emission intensities

Functional unit vector

8 LCA data are not just data

but a result supported by a series of pre-conditions with evidence



Top Layer: Core Data

LCA calculation direct invocation layer.

Components: Reference flows, Inputs/Outputs matrix

Middle Layer: Metadata

Ensures data interpretability, comparability and organization.

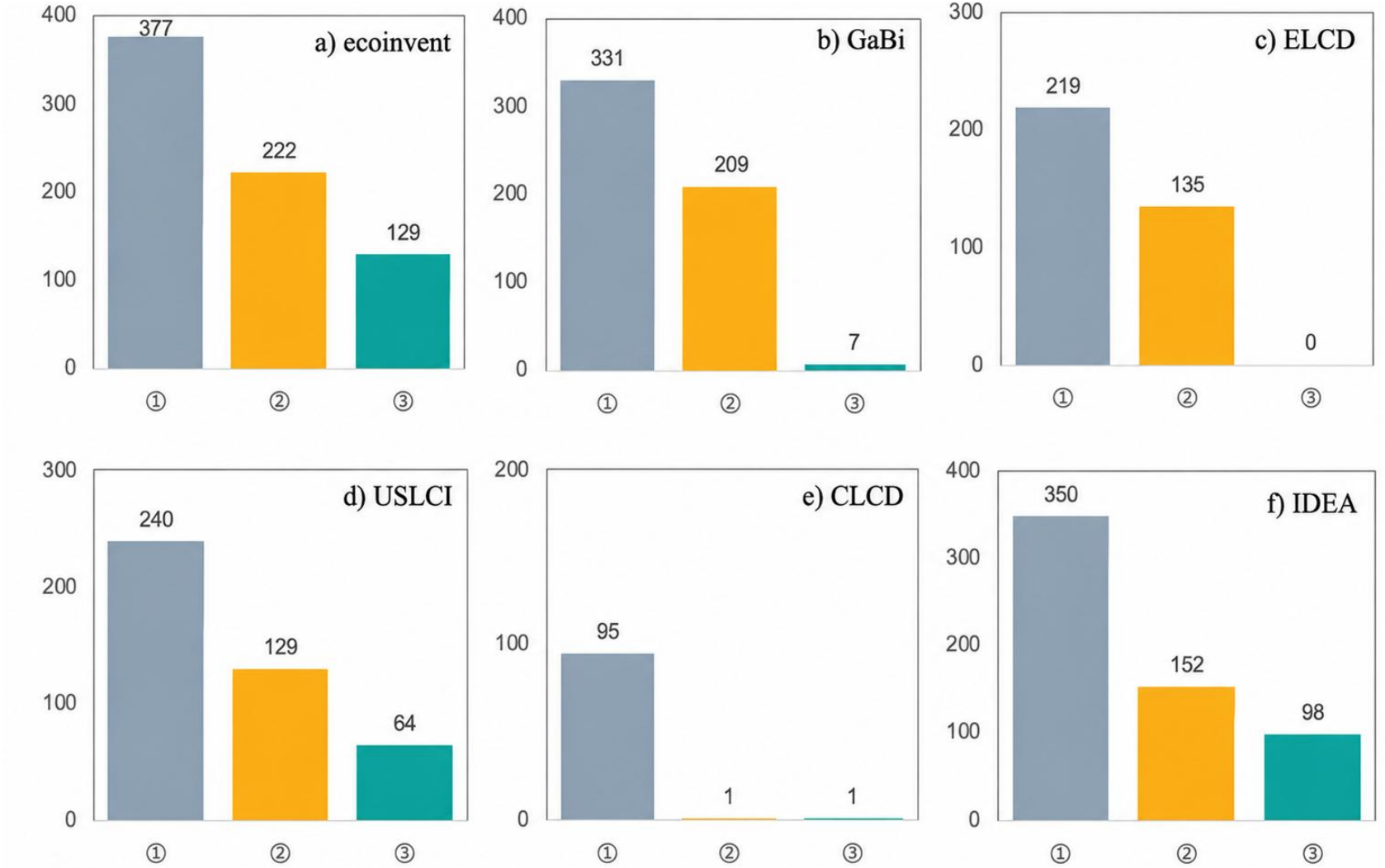
Components: Geography, Time, Technology parameters, Uncertainty, Representativeness, Identifiers, Units, Classifications

Base Layer: Evidence Documents

Immutable trust anchors, directly tracing origins.

Components: Statistical yearbooks, Methodology notes, Review records, Original literature

9 Challenges in LCA databases: poor transparency



Data choice becomes a "brand" game.

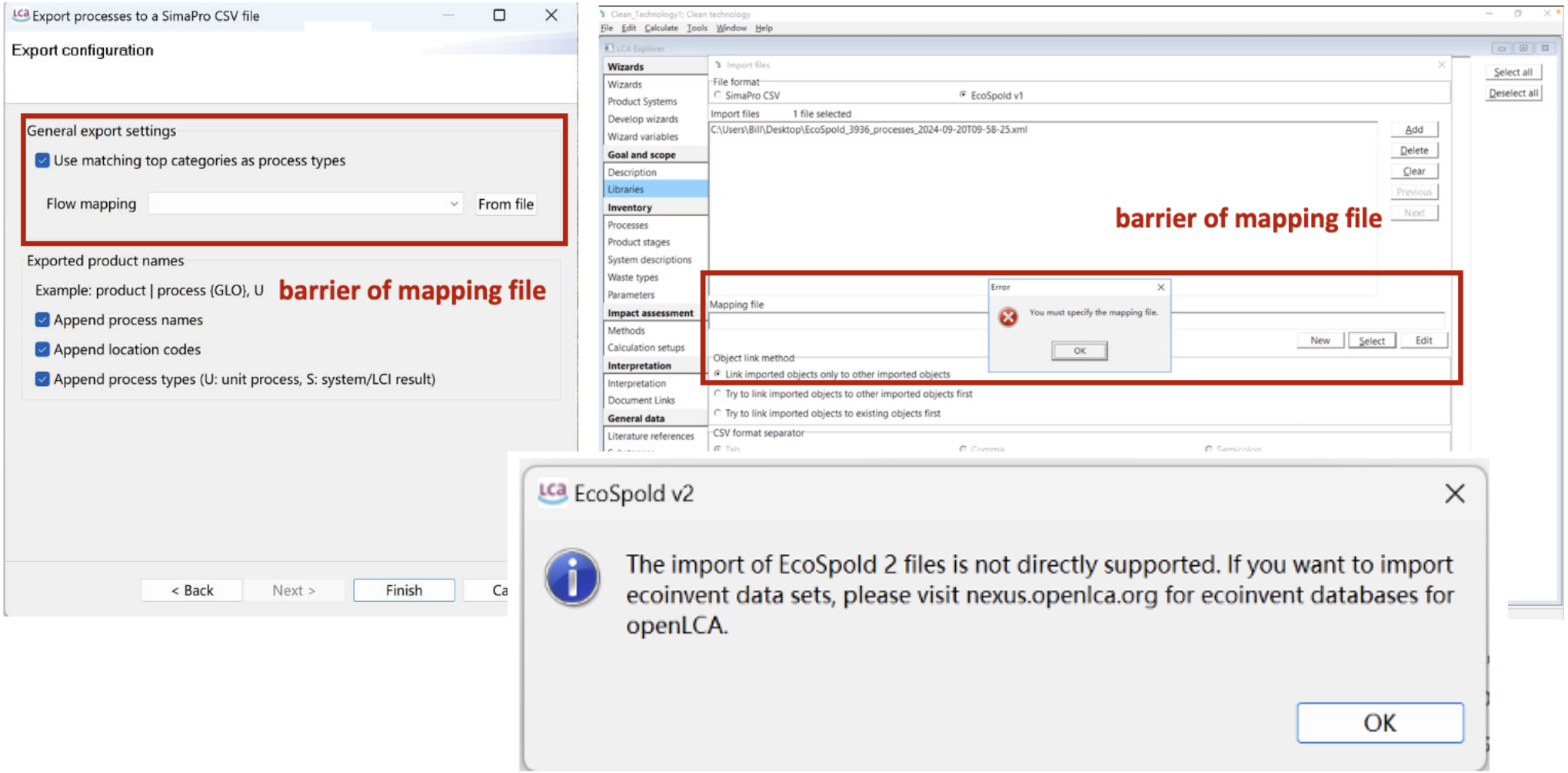
- *"… in this study we used xxx database which is widely used in LCA studies with global reputation …"*

Guo et al. (2025)

10 Challenges in LCA databases: poor interoperability

Business interests lead to intentionally messy LCA database ecosystem

Inconsistent naming Different data format Difficult data exchanging



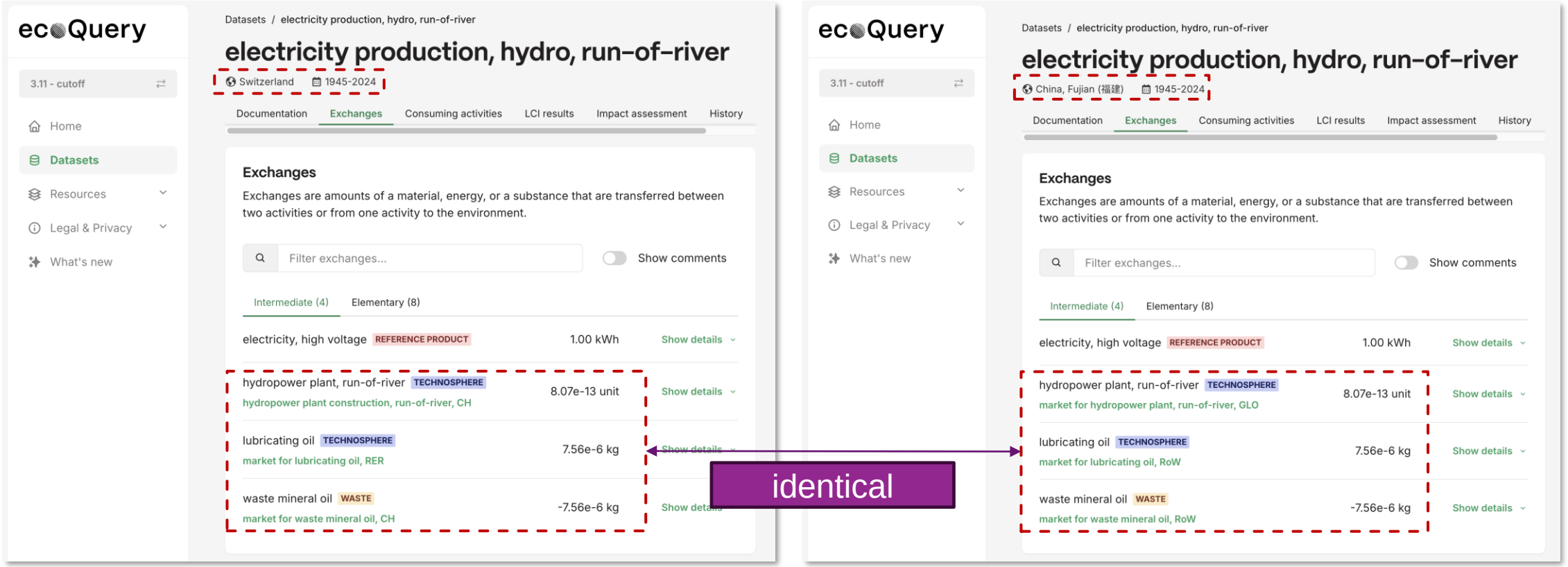
11 Challenges in LCA databases: poor representation

Data are Europe-centric, lacking regional representation, especially for China.

- Data for hydropower electricity of Fujian is exactly the same as that of Switzerland
- Data for Chinese PV are global average
- … …

Switzerland hydropower process data

China, Fujian hydropower process data



12 LCA in China

Largely in academia until 2023

Since November 2023

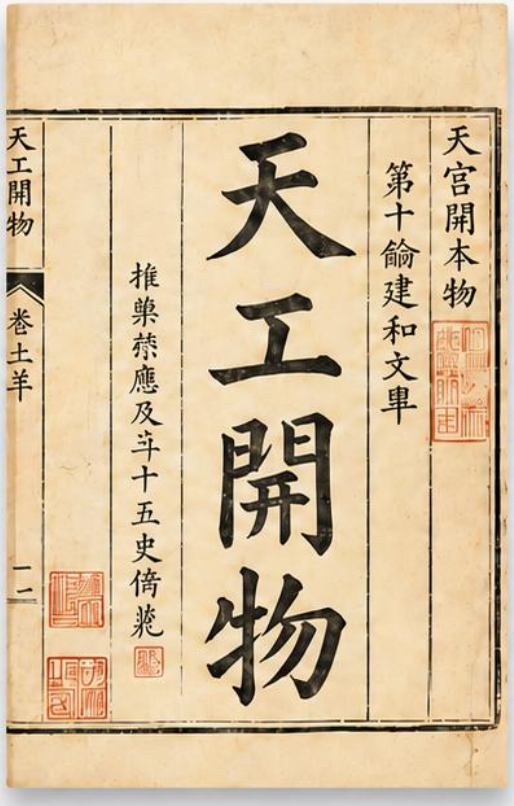
Establishing a product carbon footprint management system in China

Nov 24, 2023	**National Reform and Development Commission**
Jun 4, 2024	Ministry of Ecology and Environment
June 29, 2024	State Council
July 21, 2024	Central Committee of CPC
July 31, 2024	Central Committee of CPC and State Council
Mar 5, 2025	National Congress
Mar 13, 2026	**Outline of the 15th Five Year Plan (2026–2030)**

The Challenge:
Lack of a good China-specific LCA database

The TianGong Initiative:

building an LCA database for China from the ground up





Inspired by Tiangong Kaiwu

Named after the 1637 Chinese encyclopedia of technology and craft.

Grounded in real LCA needs

Designed to address practical challenges in building LCA data systems.

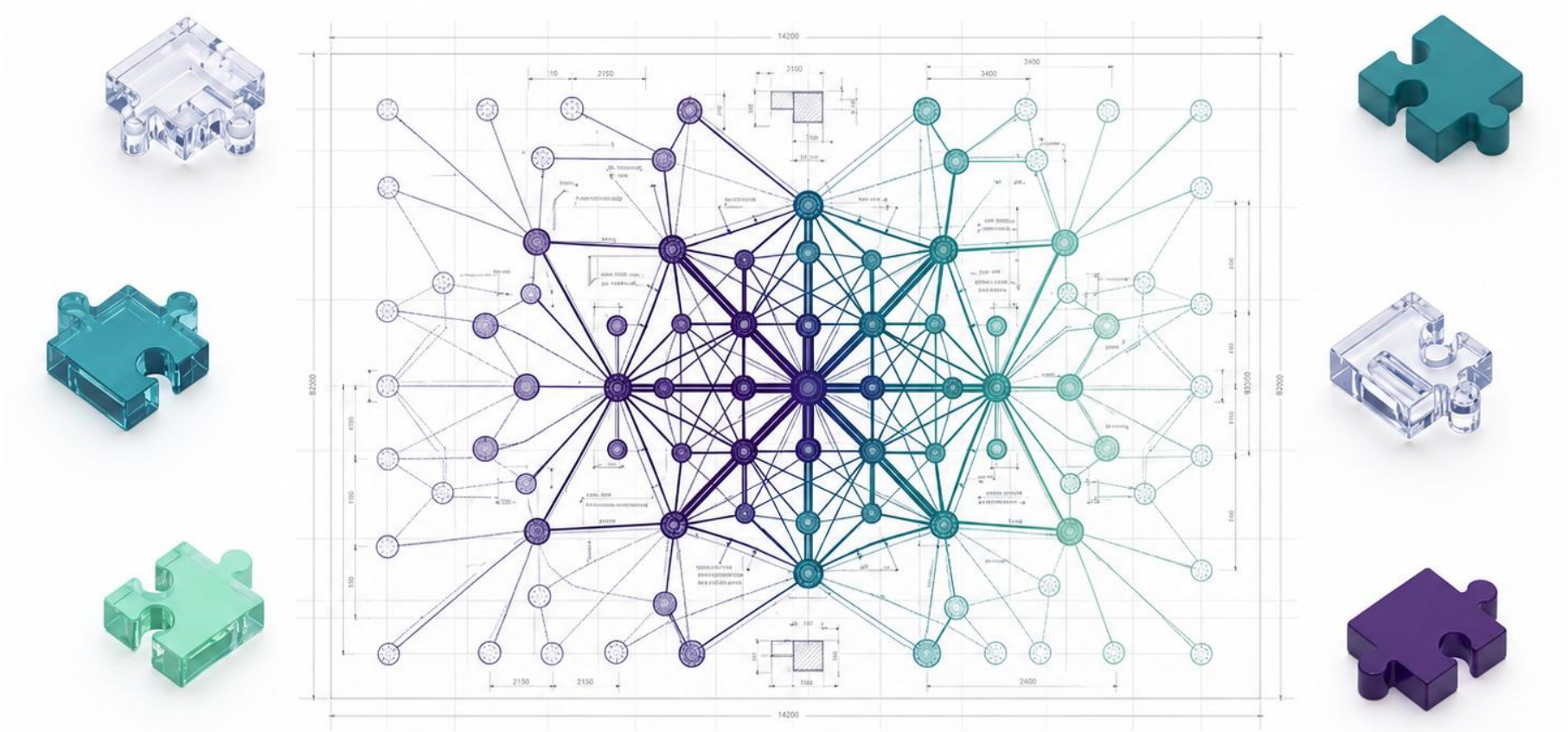
System-level technology description

Capturing technological systems in a structured and comprehensive way.

From database to infrastructure

Evolving from a database toward a broader data infrastructure.

14 The TianGong way to build an LCA database:
building the backbone first, improving data next



The TianGong Way

Database building prioritizes system completeness.

Build the backbone first, then fill in the details.

15 TianGong: A public good for a green future

Non-profit, open-source

TianGong is a non-profit, open-source initiative

Not a proprietary product

It is not a closed proprietary product

Open to the world

Data, methods, and toolchains are openly accessible

Serving researchers, policymakers, and database developers

An open public good

TianGong is not a closed database, but an open public good for green transition.



63 investigators and 311 researchers

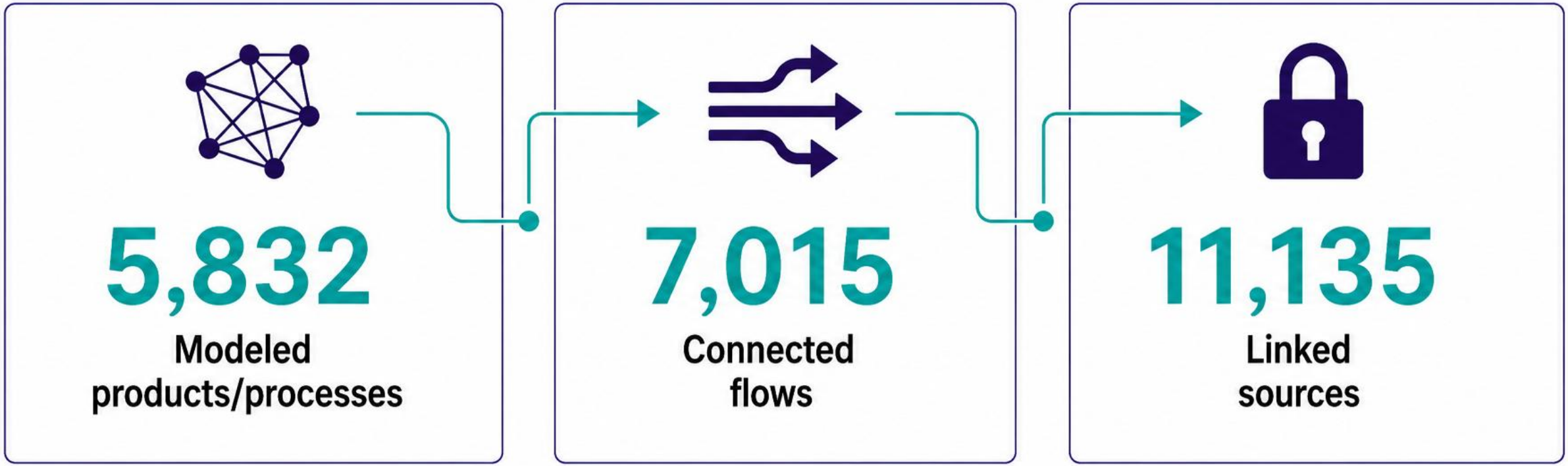
started in March 2023

16 TianGong now has the first “computable technology matrix”

June 26, 2026

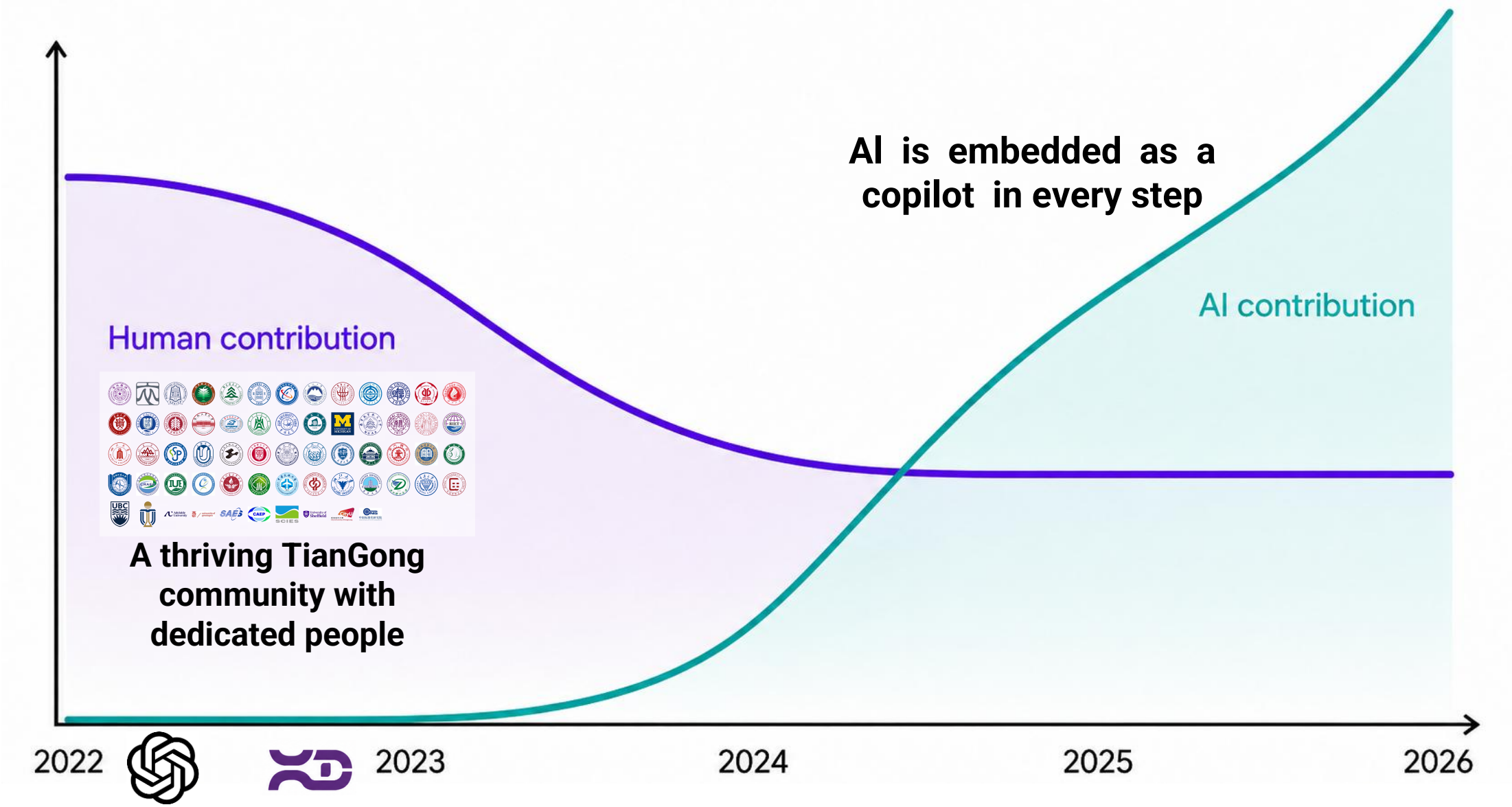
Not perfect data

But a basic structure for computation

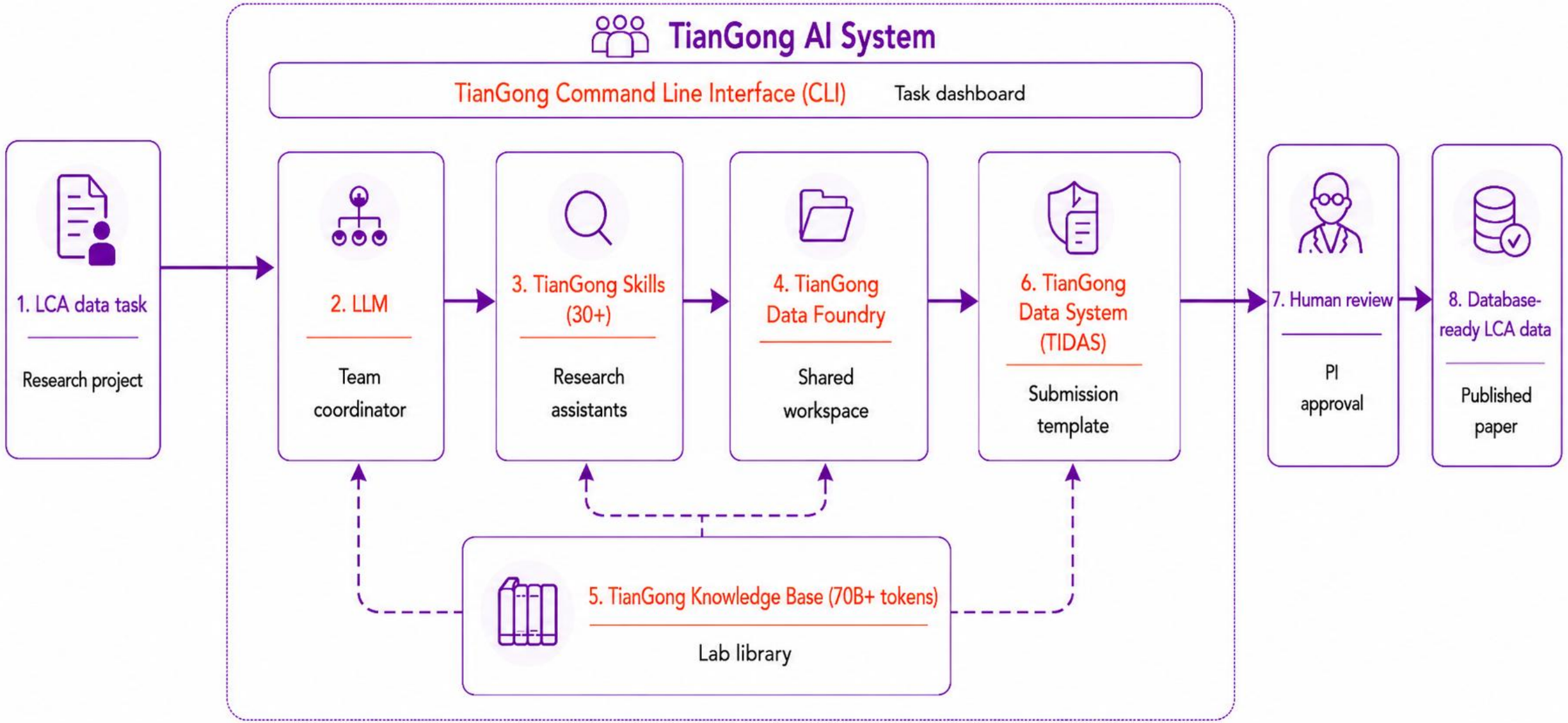


We can already compute; higher quality will come with iteration.

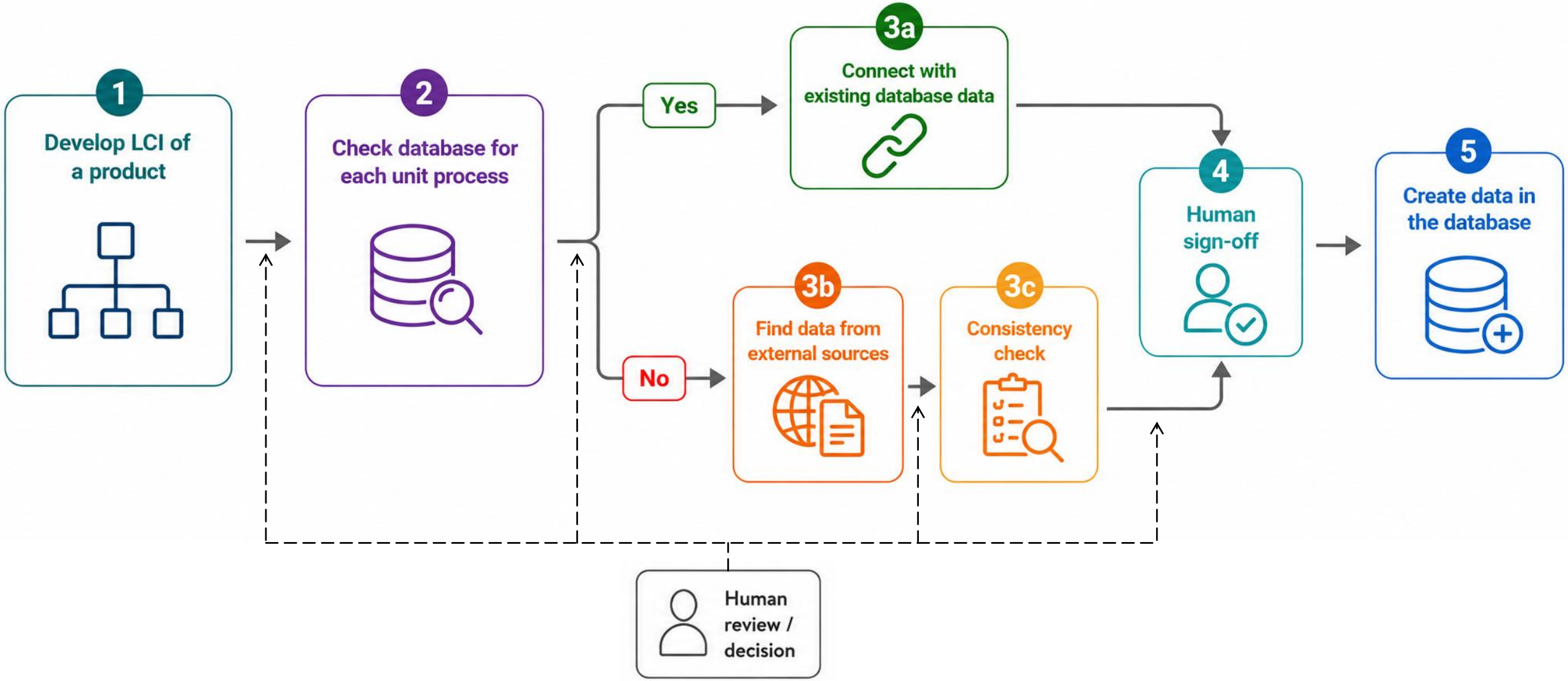
How did we get here? Human and AI collaboration



18 TianGong AI infrastructure, using research lab as an analogy

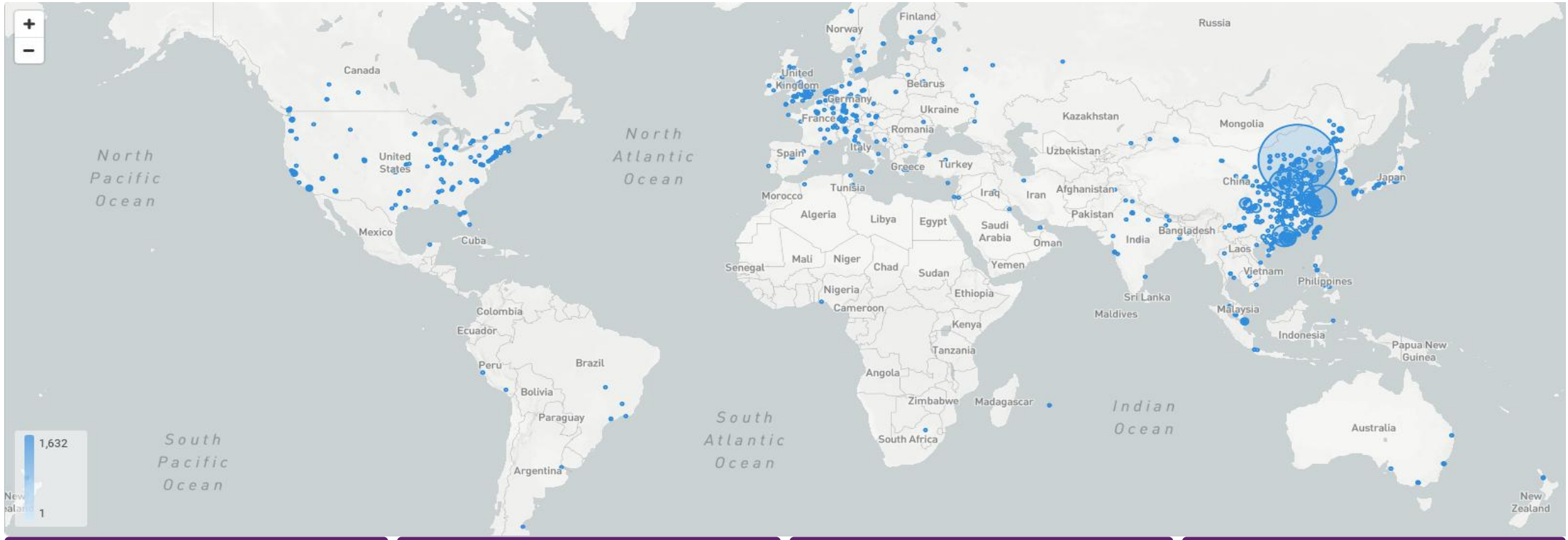


19 AI-assisted LCA database development



20 Who are using the TianGong Database

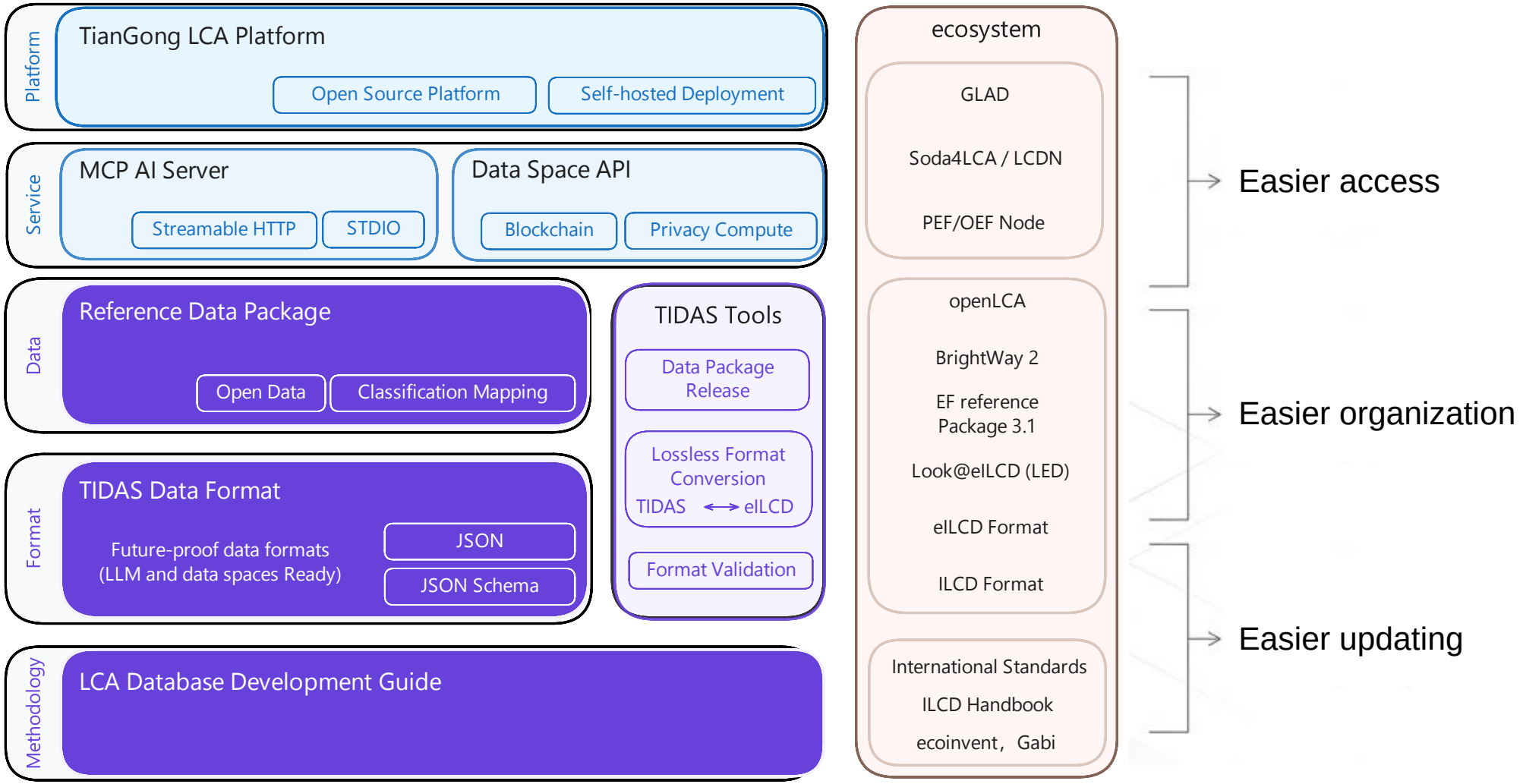
https://lca.tiangong.earth/



Unique Visitors	Countries & Regions	Platform Interactions	Downloads
32,000+	**100+**	**8,590,000+**	**37,000+**

What's next for TianGong?

from database to data infrastructure: TianGong Data System (TIDAS)



Fusion multiple LCA datasets with TianGong system

Fusion is not 1-to-1 mapping. It is dataset reconstruction from all evidence

1 Challenge: Cross-Database Interoperability

Different data schemas
EcoSpold1, JSON-LD, ILCD, etc.

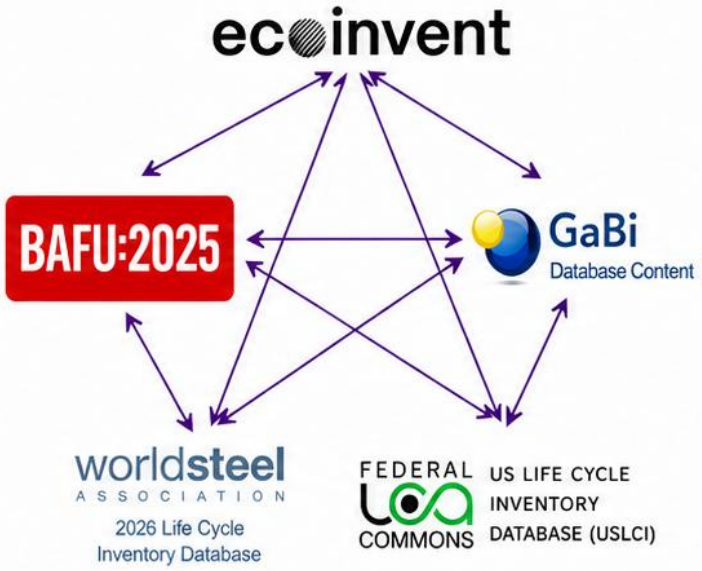
Different formats
XML, JSON, CSV, etc.

Different nomenclatures
water (unspecified) vs. ground water

Different UUID / coding systems

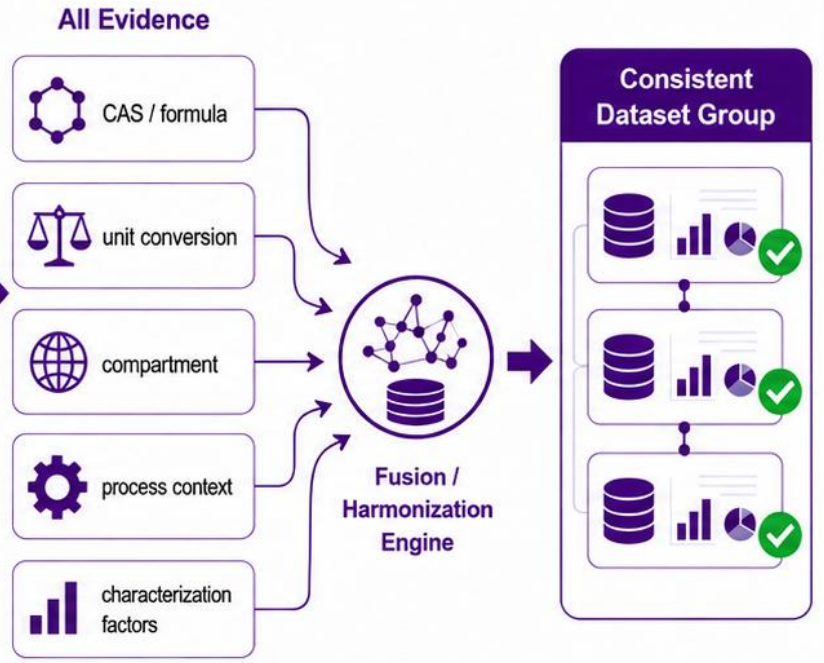
Source	UUID	Name	Location / Context
BAFU	23a8ca25-ca6d-5d8e-9410-7fc3d403ded4	Carbon dioxide, fossil	emissions to air / high. pop.
EF 3.1	08a91e70-3ddc-11dd-9c12-0050c2490048	carbon dioxide (fossil)	Emissions to air / urban air close to ground

2 Current Practice: 1-to-1 Mapping



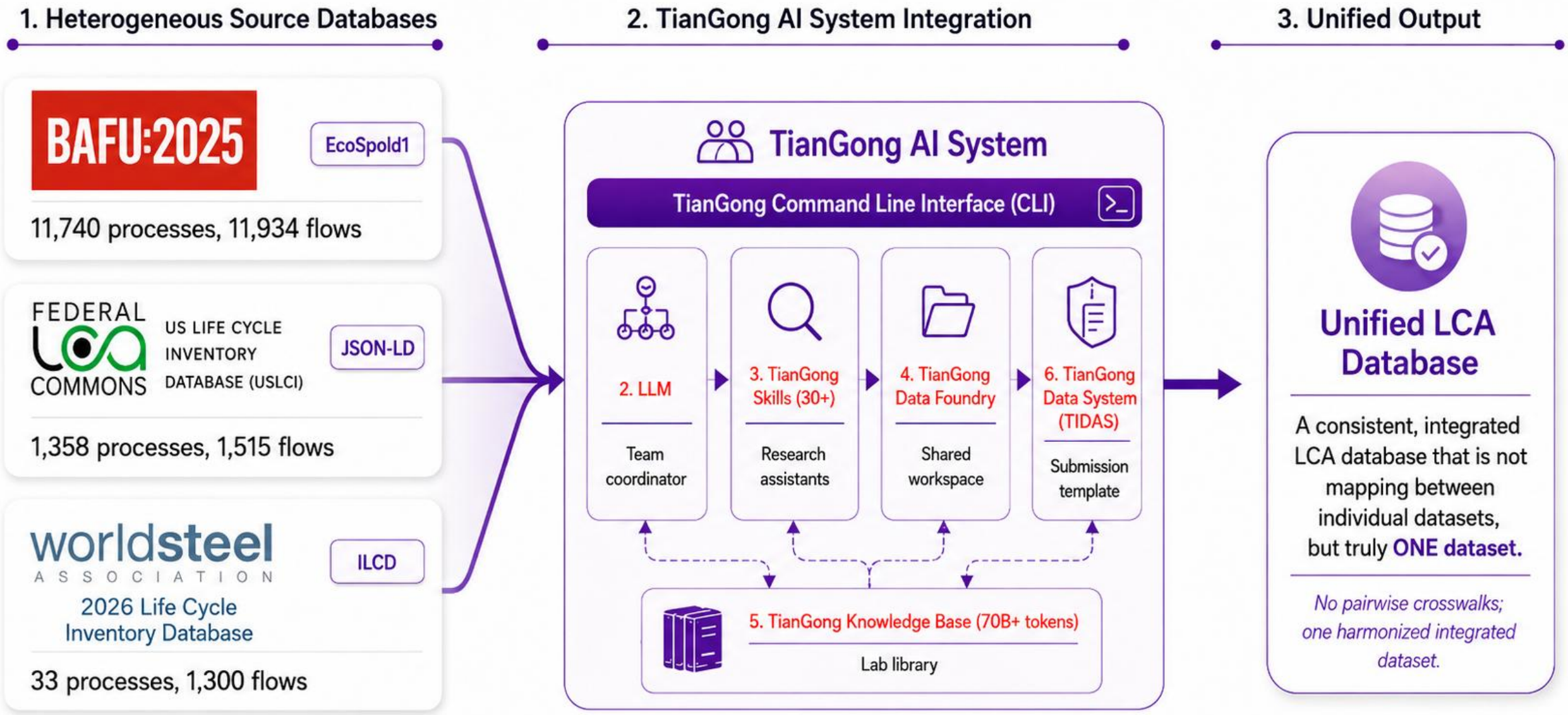
Pairwise crosswalks become increasingly complex.

3 Ultimate Solution: Fusion with All Evidence



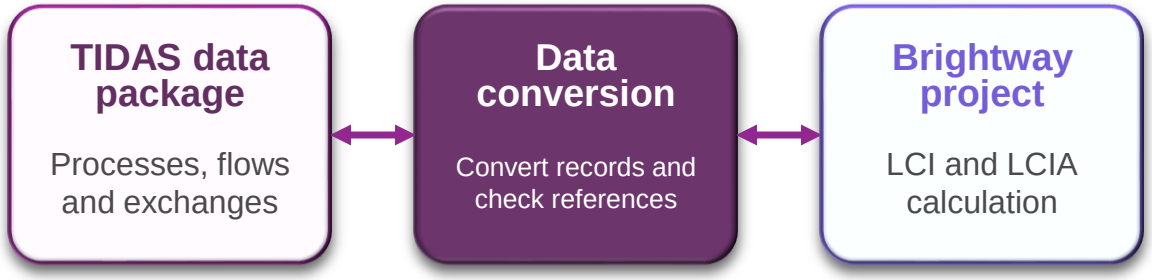
One harmonized integrated dataset group.

First step towards a globally consistent open LCA database



TIDAS–Brightway data exchange

A working tool for connecting TIDAS with Brightway



Controlled test results

- ✓ **Full round trip completed**
- ✓ **LCI results remained consistent after conversion**

```
TIDAS <-> BRIGHTWAY | LOCAL ROUND-TRIP TEST
Synthetic data | Real Brightway execution | Local workflow
Run: 2026-09-19T19:59:10+08:00
tidas-bw 0.1.0 | bw2data 4.7 | bw2calc 2.5.0

[PASS] IMPORT       TIDAS package -> Brightway
       Project:     tidas-brightway-demo
       Databases:   demo-production (2 processes)
                    demo-biosphere (2 elementary flows)

[PASS] CALCULATION  LCI + LCIA completed in Brightway
       Demand:      1 kg widget | electricity input: 2.5 kWh
       LCI:         CO2 = 1.25 kg | Water = 0.01 m3
       Test LCIA:   3.125 (synthetic factor = 2.5)
       Numerical check against analytical values: PASS

[PASS] EXPORT BACK  Brightway -> TIDAS package
       Round-trip:  16/16 JSON records unchanged
       Validation:  tidas-bw schema + strict references passed

RESULT: IMPORT / CALCULATION / EXPORT BACK -- ALL PASSED
Scope: synthetic local demo; no real-world or online-platform claim.
```

Local round-trip test using the Brightway Python API

Validate and refine with real datasets, focusing on numerical precision, uncertainty and licensing metadata

https://github.com/jianchuanqi/tidas-bw

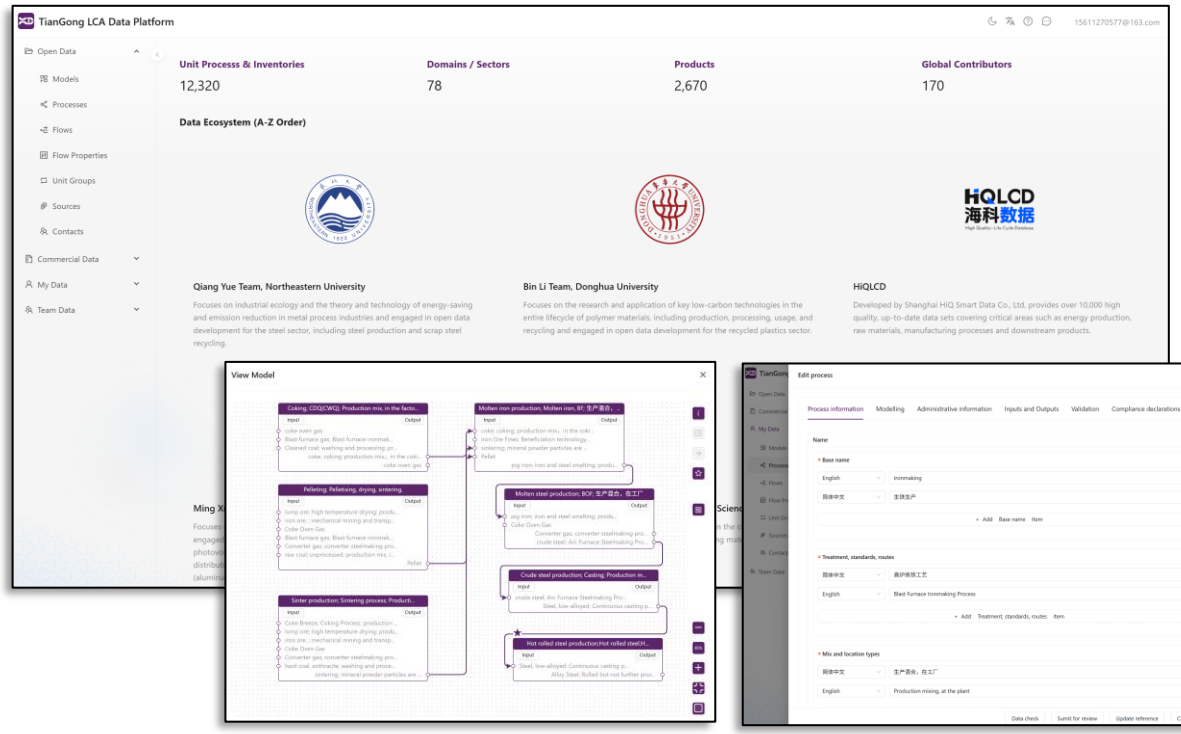
25 TianGong LCA Platform — Data curation & publishing

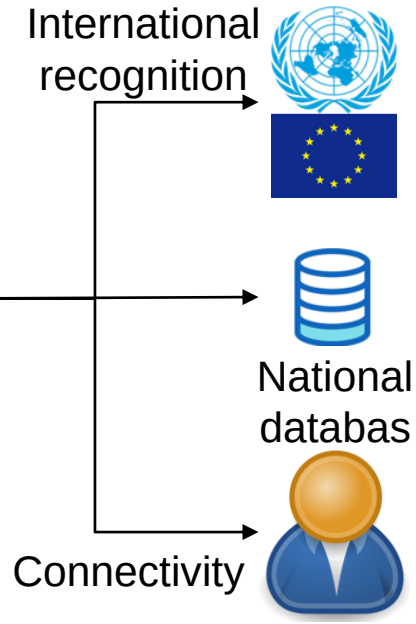


68 datasets
5,231 users

https://lca.tiangong.earth/

- **Integrated data ecosystem**
  - Open and commercial datasets in one platform
- **Standardized data publication**
  - Based on TianGong data publication guideline
- **Broad connectivity**
  - Interoperability with international and national database





University-industry partnership

Carbon Footprint Alliance (CFA)

A university-industry partnership

https://www.carbonfootprint.network/

Help build the Global LCA Platform with TianGong experience

- **One-stop platform** for LCA
- Promotes global **accessibility**, **interoperability**, and **capacity**
- Ensures **ambitious applicability of LCA** to support policies

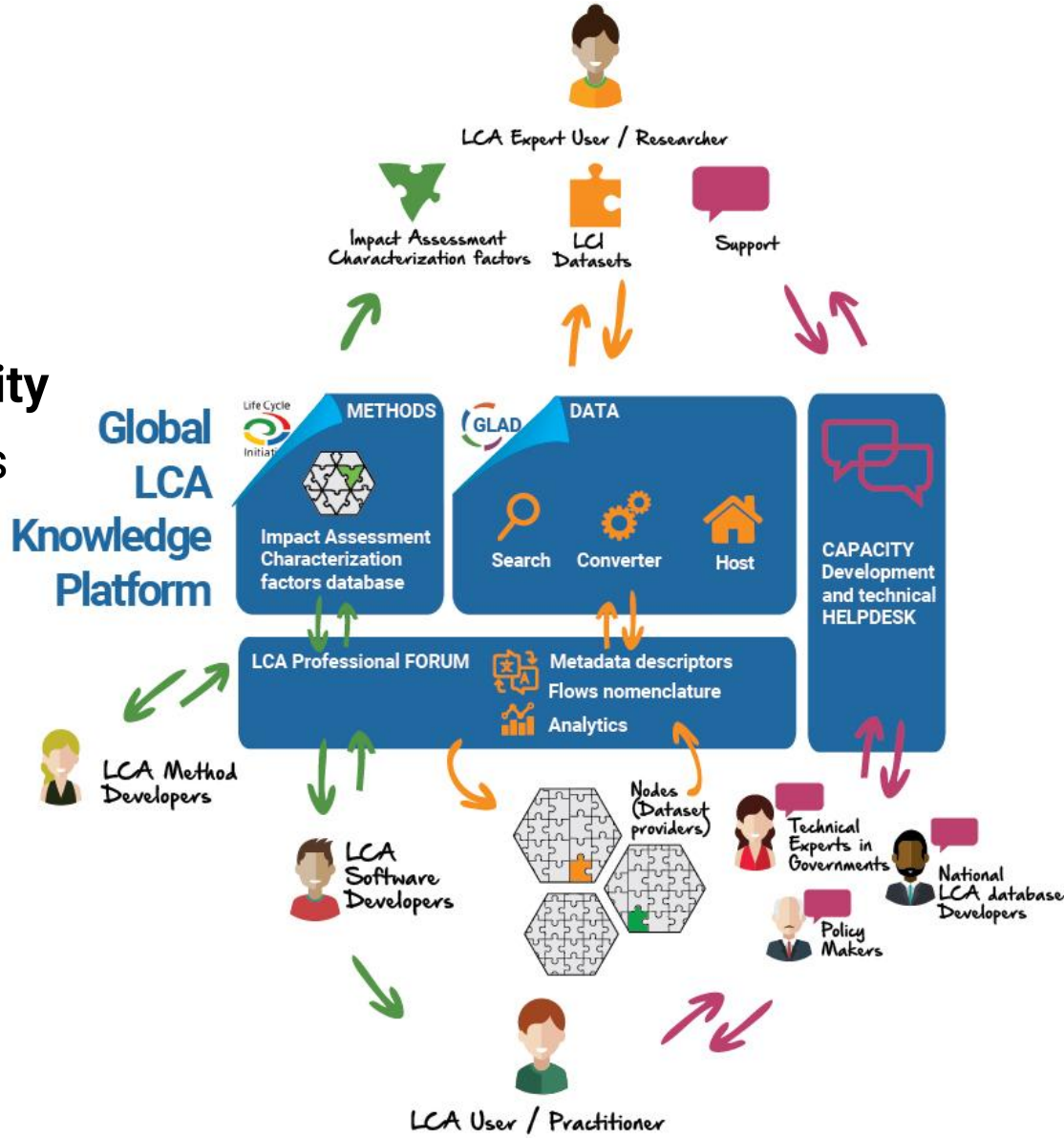


First workshop @
Tsinghua Italy Campus
July 10-11, 2025, Milan, Italy



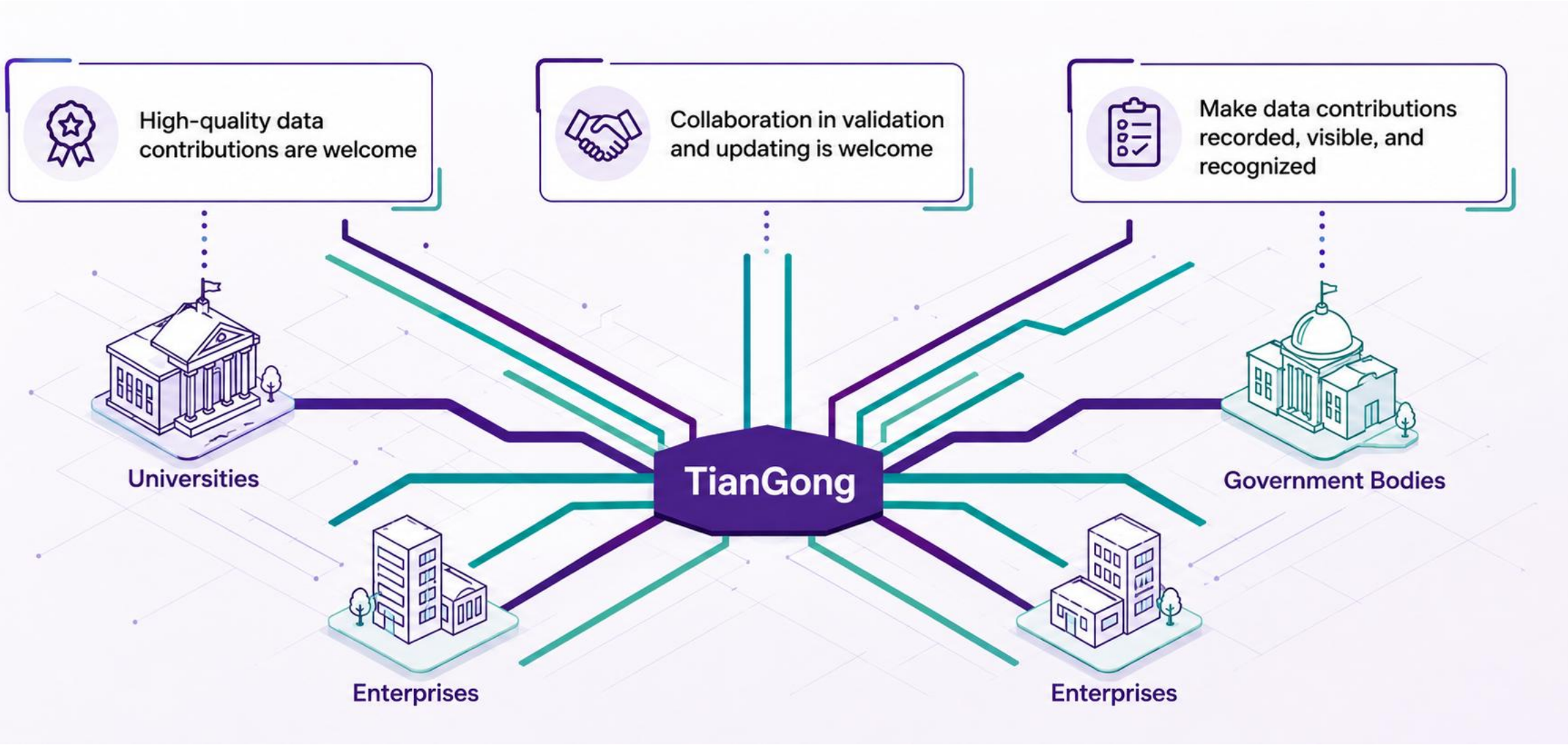
Second workshop @
TianGong Forum
March 25, 2026, Nanjing, China

Third Workshop: October 20-21, 2026, Milan, Italy



Source: UNEP LCI

TianGong is an open community; everyone is welcome





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碳足迹产业技术创新联盟
Carbon Footprint Alliance

TianGong