

Advancing LCA Data Interoperability through a Unified Foundational Framework

Yang Hang

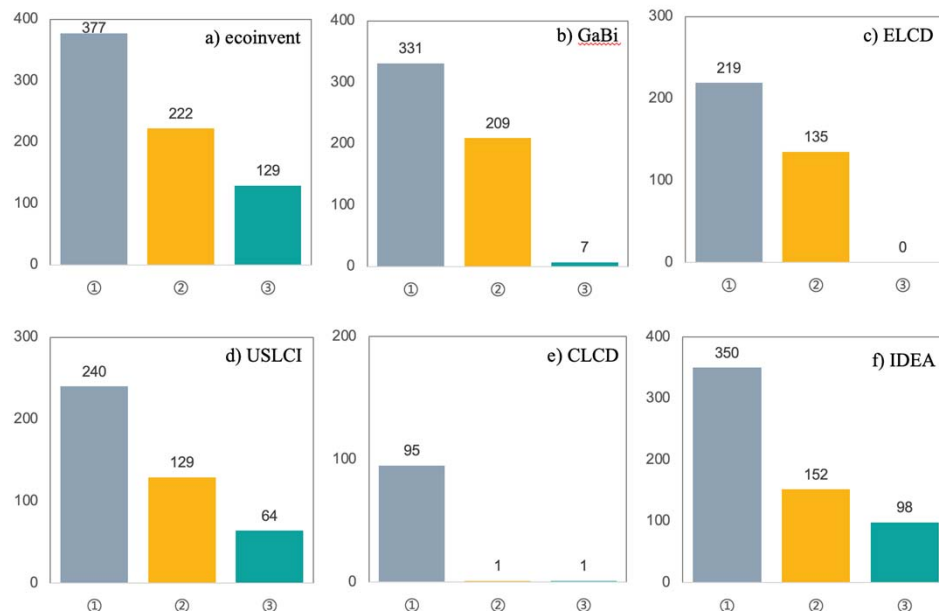
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Carbon Footprint Alliance



Critical challenges: Traceability and transparency



Untraceable and inaccessible data sources

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RESEARCH ARTICLE

Shedding light on the shadows
Transparency challenge in background life cycle inventory data

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Abstract
Life cycle assessment (LCA) hinges on the transparency and reliability of inventory data. However, the transparency of background life cycle inventory (LCI) data sources remains unexamined. This research assesses data transparency in mainstream LCI databases using a two-step examination system based on source findability and accessibility. Six major databases (ecoinvent, GaBi, U.S. Life Cycle Inventory Database, European Life Cycle Database, Inventory Database for Environmental Analysis, and Chinese Life Cycle Database) were analyzed by sampling processes and tracing their sources. The results reveal widespread transparency issues, with only 40%–60% of sampled processes having findable sources and <5% being fully accessible in certain databases. Incomplete documentation and complex cross-referencing between processes and sources posed key barriers. The lack of transparency undermines LCA credibility and necessitates reconstructing databases for enhanced traceability. Although a preliminary study, these findings highlight the challenge of data transparency and provide a methodology to evaluate databases. This drives collective action to uphold transparency standards, restoring trust in LCA as a sustainability decision-making tool.

KEYWORDS
background database, data accessibility, data findability, data transparency, life cycle assessment, life cycle inventory

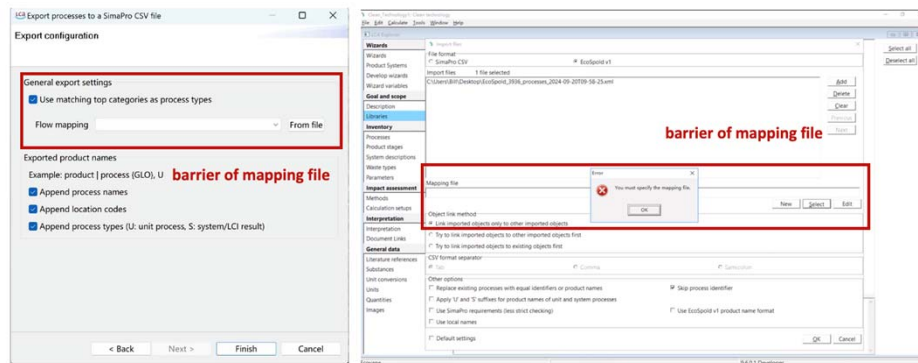
1 | INTRODUCTION

Life cycle assessment (LCA) is pivotal in environmental decision-making and policy formulation, offering a comprehensive framework to assess the environmental impacts of products and services throughout their life cycle (Finnveden et al., 2009). While LCA is a powerful tool for holistic

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Critical challenges: Data conversion



Segregation between software and data formats

No	Location	Description	Additional information
1	..vecoinvent_38_cutoff_3011_with_m...	Cannot find process	electricity, high voltage
2	..vecoinvent_38_cutoff_3011_with_m...	Cannot find process	heat, district or industrial, natural gas
3	..vecoinvent_38_cutoff_3011_with_m...	Cannot find process	blast furnace gas
4	..vecoinvent_38_cutoff_3011_with_m...	Cannot find process	electricity, high voltage, renewable energy products
5	..vecoinvent_38_cutoff_3011_with_m...	Cannot find unit	Bq
6	..vecoinvent_38_cutoff_3011_with_m...	Cannot find unit	s

No	Location	Description	Additional information
1	..vecoinvent_391_cutoff_upr_n3_2023	Cannot find process	electricity, high voltage
2	..vecoinvent_391_cutoff_upr_n3_2023	Cannot find process	heat, district or industrial, natural gas
3	..vecoinvent_391_cutoff_upr_n3_2023	Cannot find process	electricity, high voltage, renewable energy products
4	..vecoinvent_391_cutoff_upr_n3_2023	Cannot find process	blast furnace gas
5	..vecoinvent_391_cutoff_upr_n3_2023	Cannot find unit	Bq
6	..vecoinvent_391_cutoff_upr_n3_2023	Cannot find unit	s

No	Location	Description	Additional information
1	..vecoinvent_v3.10 Cutoff Unit-Processes	Cannot find process	heat, district or industrial, natural gas
2	..vecoinvent_v3.10 Cutoff Unit-Processes	Cannot find process	electricity, high voltage
3	..vecoinvent_v3.10 Cutoff Unit-Processes	Cannot find process	blast furnace gas
4	..vecoinvent_v3.10 Cutoff Unit-Processes	Cannot find process	electricity, high voltage, renewable energy products
5	..vecoinvent_v3.10 Cutoff Unit-Processes	Cannot find unit	s
6	..vecoinvent_v3.10 Cutoff Unit-Processes	Cannot find unit	Bq

Flow	Category	Amount	Unit	Costs/Reven...	Uncertainty	Avoided waste	Provider	Data quality	Location	Description
electricity, low voltage	C-Electricity, gas, steam and...	0.04000	ITS kWh	0.04000	ITS kWh				CH	Energy use f...
inverter, 230W	C-Manufacturing/230WManuf...	2.40000	ITS Item(s)	2.40000	ITS Item(s)				CH	Literature, 1...
photovoltaic laminate, m...	C-Manufacturing/26Manuf...	23.47400	ITS m2	1.394364	ITS m2				CH	Calculation...
photovoltaic module, bal...	F-Construction/43Special...	22.79000	ITS m2	115.4230	ITS m2				CH	Calculation...
photovoltaic, electric inv...	F-Construction/43Special...	1.00000	ITS Item(s)	71.43105	ITS Item(s)				CH	LiteratureTh...

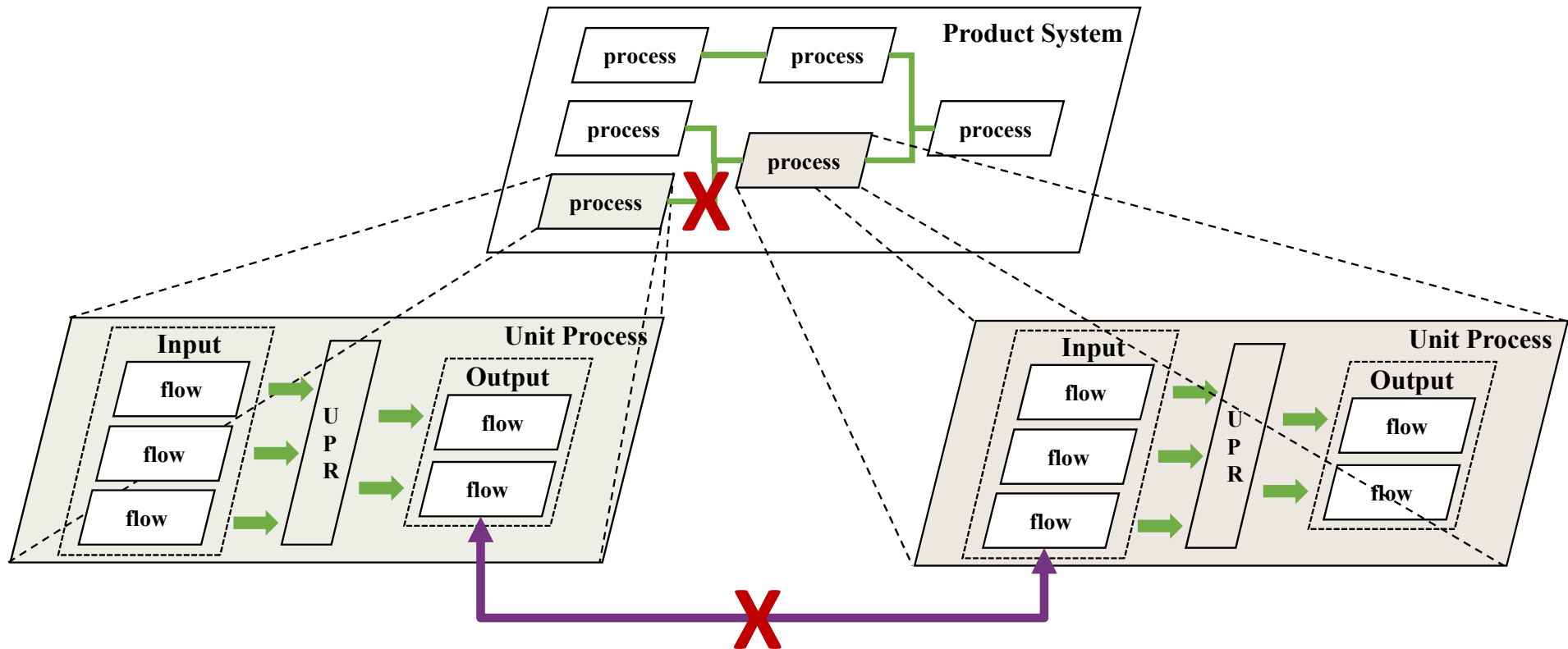
Flow	Category	Amount	Unit	Costs/Reven...	Uncertainty	Avoided gns...	Provider	Data quality	Location	Description
photovoltaic facade ins...	C-Manufacturing/33.Repa...	1.00000	ITS Item(s)	1.439554	ITS Item(s)				CH	

Inputs from nature	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Inputs from technosphere materials/Fuels								
photovoltaic laminate, multi-Si wafers		23.474	m2	Lognormal	1.320864			Calculation, 2% of mass, 1% rejects
inverter, 230W		2.4	g	Lognormal	1.22140275			Calculation, 2% of mass, 1% rejects
photovoltaic module, building-integrated, for facade material		22.79	m2	Lognormal	1.22140275			Literature, 1 repeat in the
electricity, low voltage		0.1440000000000002	MJ	Lognormal	1.22140275			Calculation with m2 per
photovoltaics, electric installation for 30kW module, at building		1.0	g	Lognormal	2.05671542			Energy use for erection

Outputs to air	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Emissions to water								
Emissions to soil								
Final waste flows								
Non-material emissions								
Social issues								
Economic issues								
Outputs to technosphere Waste and emissions to treatment								

Errors and information loss in data conversion

Critical challenges: Interoperability

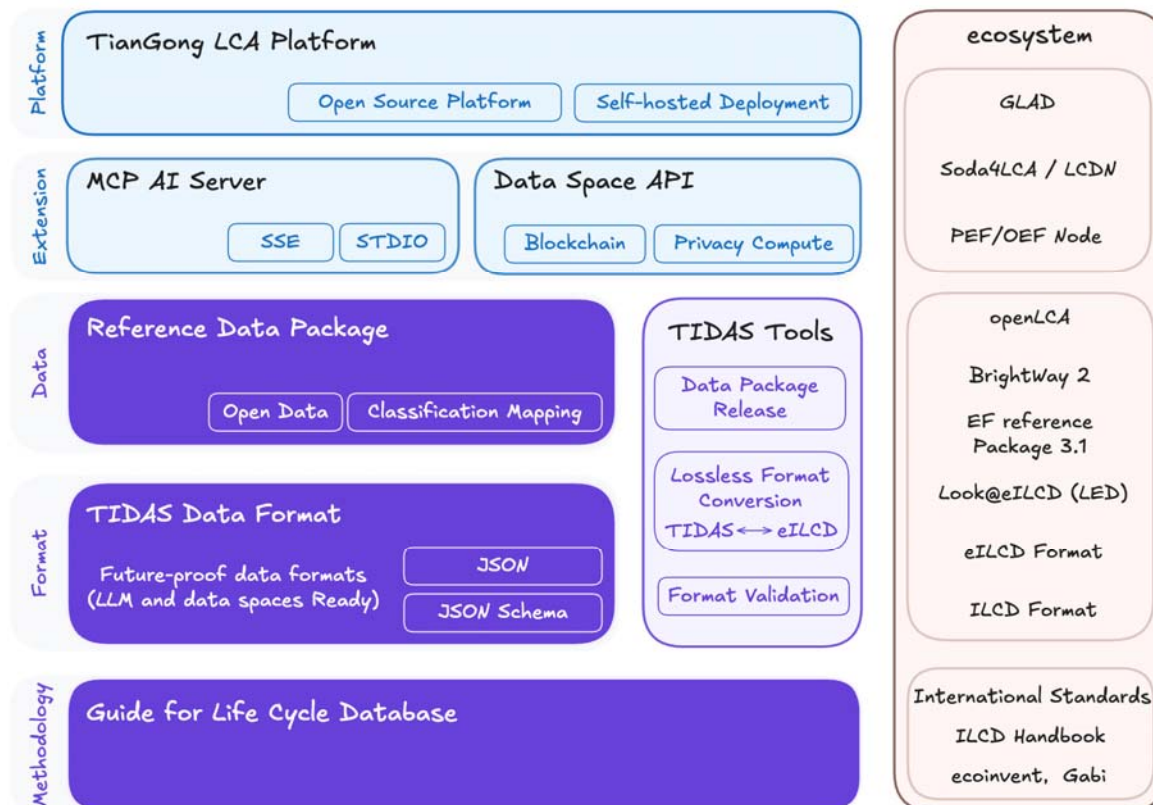


Inconsistent foundational data and lack of interoperability

How to ...

- **Make all the LCA data interoperable?**
 - E.g., battery: e for mining, CM for chemicals, and TG for manufacturing?
- **End the endless mapping and save resources (time, labor..)?**
 - Limited, agreed options to map against?
- **Enable (and motivate!) more stakeholders to cooperate?**
 - Standardized, safe, and cheap solutions to make data providers easier?
 - Then maybe more providers?
- **Establish REAL cooperation in the LCA community?**
 - High quality and impactful LCA, and economically beneficial?

TianGong Data System - TIDAS



- **Open Source**

- Globally open-source, free of use

- **Ready to Use**

- Data, toolkits, and platform, available out of the box

- **International Compatibility**

- Lossless conversion and interoperability with international data systems such as ILCD

Guide for Life Cycle Database



<https://www.carbonfootprint.network>

TIDAS data format – JSON Schema

```
{
  "$schema": "http://json-schema.org/draft-07/schema#",
  "type": "object",
  "properties": {
    "processDataSet": {
      "type": "object",
      "properties": {
        "processInformation": { ""
      },
      "modellingAndValidation": { ""
    },
    "administrativeInformation": { ""
  },
  "exchanges": {
    "type": "object",
    "properties": {
      "exchange": { ""
    },
    "common:other": { ""
  },
  "required": [ ""
],
  "LCIAResults": {
    "type": "object",
    "properties": {
      "LCIAResult": { ""
    },
    "common:other": { ""
  },
  "required": [ ""
],
}
```

Conversion WITHOUT ANY
information loss

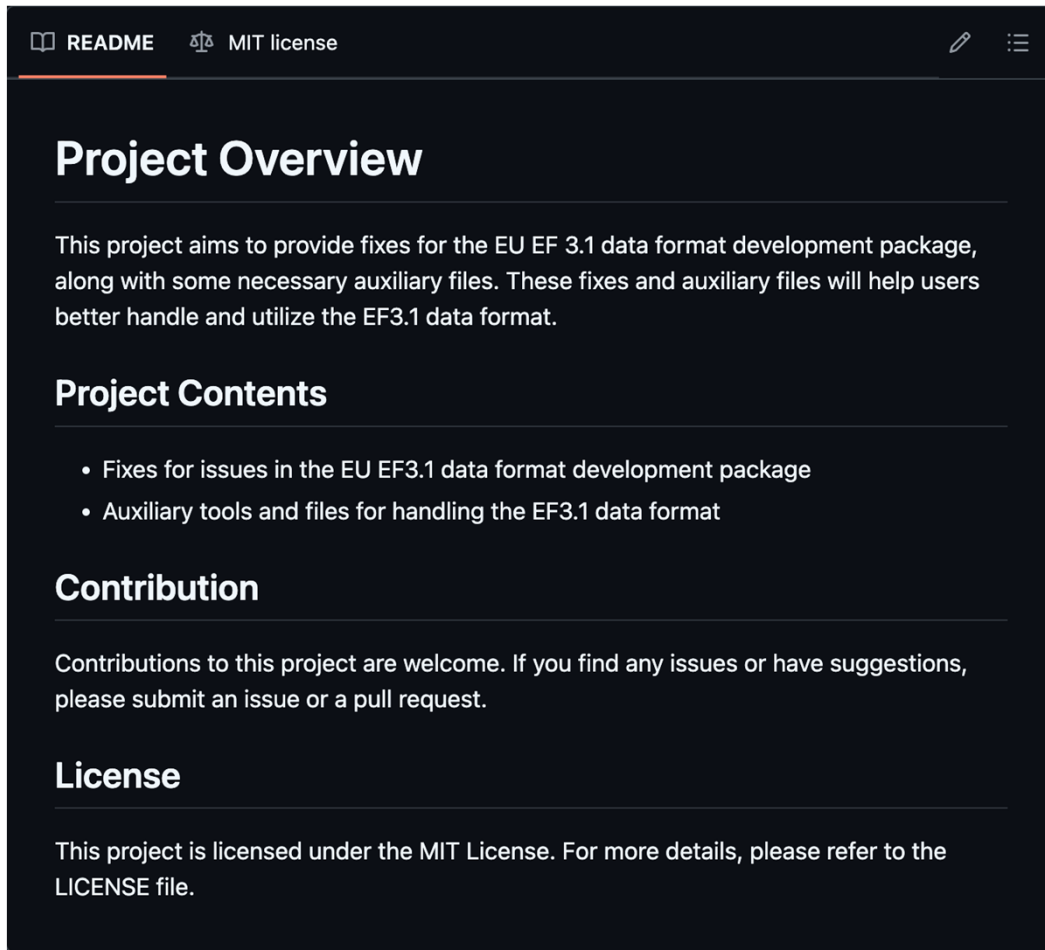
ILCD

ILCD Format 1.1 Documentation – Process data set

Field name	Element/attribute name	Requ.	Occ.	Data type	Definition
Process data set	processDataSet	m	[1,1]		Data set for unit processes, partly terminated systems, and LCI results. May contain LCIA results as well.
version	@version	m		SchemaVersion	Indicates, which version of the ILCD format is used
location	@locations	m		String	contains reference to used location table for this dataset
Meta data only	@metaDataOnly	o		boolean	Indicates whether this data set contains only meta data (no exchanges section).
Process information	processInformation	m	[1,1]		Corresponds to the ISO/TS 14048 section "Process description". It comprises the following six sub-sections: 1) "Data set identification and overarching information items, 2) "Quantitative reference", 3) "Time", 4) "Geography", 5) "Technology" and 6) "Mathematical relations".
Key Data Set Information	dataSetInformation	m	[1,1]		General data set information. Section covers all single fields in the ISO/TS 14048 "Process description", which are not part of the other sub-sections. In ISO/TS 14048 no own sub-section is foreseen for these entries.
UUID of Process data set	UUID	m	[1,1]	UUID	Automatically generated Universally Unique Identifier of this data set. Together with the "Data set version", the UUID uniquely identifies each data set.
Name	name	r	[0,1]		General descriptive and specifying name of the process.
Base name	baseName	r	[1,1]	StringMultiLang	General descriptive name of the process and/or its main good(s) or service(s) and/or its level of processing.
Treatment, standards, routes	treatmentStandardsRoutes	r	[0,1]	StringMultiLang	Specifying information on the good, service, or process in technical term(s): treatment received, standard fulfilled, product quality, use information, production route name, educt name, primary / secondary etc. Separated by commas.
Mix and location types	mixAndLocationTypes	r	[0,1]	StringMultiLang	Specifying information on the good, service, or process whether being a production mix or consumption mix, location type of availability (such as e.g. "to consumer" or "at plant"). Separated by commas.
Quantitative product or process properties	functionalUnitFlowProperties	r	[0,1]	StringMultiLang	Further, quantitative specifying information on the good, service or process in technical term(s): qualifying constituent(s)-content and / or energy-content per unit etc. as appropriate. Separated by commas. (Note: non-qualifying flow properties, CAS No, Synonyms, Chemical formulas etc. are documented exclusively in the "Flow data set".)
Other content	other	o	[0,1]		May contain arbitrary content.
Identifier of sub-data set	identifierOfSubDataSet	o	[0,1]	String	Identifier of a sub-set of a complete process data set. This can be the life cycle stage that a data set covers (such as used in EPOs for modular LCI reporting, with the inventory split up into "resource extraction stage", "production stage", "use stage" and "end-of-life stage"). Or it can be e.g. the type of emission source from which the elementary flows of the Inputs and Outputs stems (e.g. "incineration-related", "transport-related", etc.). Together with the field "Complementing processes" this allows to split up a process data set into a number of clearly identified data sets, each carrying only a part of the inventory and that together represent the complete inventory. Care has to be taken when naming the reference flow, to avoid misinterpretation.
Synonyms	synonyms	o	[0,1]	ETMultiLang	Synonyms / alternative names / brands of the good, service, or process. Separated by semicolon.
Complementing processes	complementingProcesses	o	[0,1]		"Process data set(s)" that complement this partial / sub-set of a complete process data set, if any and available as separate data set(s). The identifying name of this sub-set should be stated in the field "Identifier of sub-data set".
Classification information	classificationInformation	r	[0,1]	GlobalReferenceType	reference to one complementing process
Classification	classification	r	[0,n]		Hierarchical classification of the good, service, or process. (Note: This entry is NOT required for the identification of a Process. It should nevertheless be avoided to use identical names for Processes in the same category.
Classification system name	@name	r		string	Optional statistical or other classification of the data set. Typically also used for structuring LCA databases.
Classes	@classes	r		anyURI	Name of the classification system.
Class name	class	r	[1,n]		URL or file name of a file listing all classes of this classification system. (Notes: the referenced file has to be in form of the "ILCDClassification.xml" format. If a classification file is specified, the "class" entry should correspond to the classes defined in the classification file.)
Hierarchy level	@level	r		LevelType	Name of the class.
					If more than one class is specified in a hierarchical classification system, the hierarchy level (1,2,...) could be specified with this attribute of class.

JSON-LD & Others

Reference data package



The screenshot shows the GitHub README for the 'EF-reference-package-3.1-Correction' project. The page has a dark theme. At the top, there are tabs for 'README' and 'MIT license'. The main content is divided into sections: 'Project Overview', 'Project Contents', 'Contribution', and 'License'. The 'Project Overview' section states that the project aims to provide fixes for the EU EF 3.1 data format development package. The 'Project Contents' section lists two items: 'Fixes for issues in the EU EF3.1 data format development package' and 'Auxiliary tools and files for handling the EF3.1 data format'. The 'Contribution' section mentions that contributions are welcome and provides instructions on how to submit issues or pull requests. The 'License' section states that the project is licensed under the MIT License.

README MIT license

Project Overview

This project aims to provide fixes for the EU EF 3.1 data format development package, along with some necessary auxiliary files. These fixes and auxiliary files will help users better handle and utilize the EF3.1 data format.

Project Contents

- Fixes for issues in the EU EF3.1 data format development package
- Auxiliary tools and files for handling the EF3.1 data format

Contribution

Contributions to this project are welcome. If you find any issues or have suggestions, please submit an issue or a pull request.

License

This project is licensed under the MIT License. For more details, please refer to the LICENSE file.

■ Seamless compatibility with EU EF 3.1 reference data package

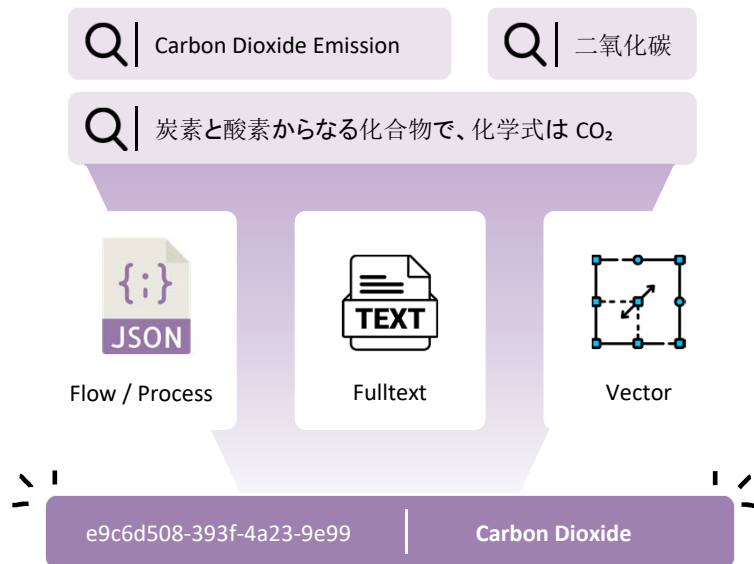
○ and corrected!

- ✓ Formatting issues
- ✓ Duplications
- ✓ Multilingual support (Chinese)

Project URL: <https://github.com/linancn/EF-reference-package-3.1-Correction>

Change log URL: <https://github.com/linancn/EF-reference-package-3.1-Correction/commit/3f3ab45a77925614079d2bbf5f2ac617b3d0f9fd>

Extension – MCP AI Server



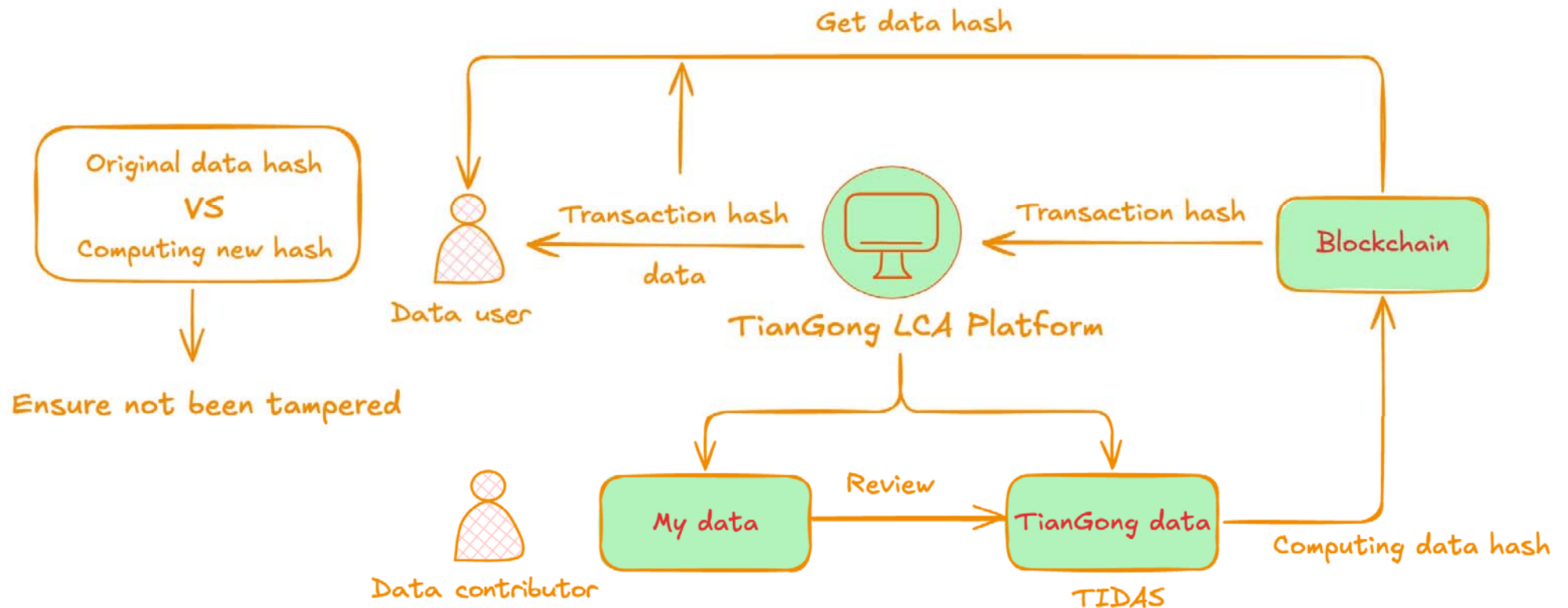
id	uuid	v...	b...	json	jsonb
000367a6-c3a5-4bd4-877d-971da7f0401a	1.1.0			{	{
0004100f-f198-4c21-948a-40504e726124	01.01.000			{	{
000b821d-28df-47f3-bcc9-ea28377e8a3d	1.1.0			{	{
000c41b8-3d7b-4cb2-be1a-c754ac10a43c	1.1.0			{	{
000de299-b43a-4718-a1b8-341222746176	1.1.0			{	{
0015f822-e38c-47d2-8109-2d4bb38dd73e	1.1.0			{	{
001af4d3-aa4a-40cd-870e-606fb03421cc	1.1.0			{	{
001f1151-85ad-4030-95e8-93c9bacf70a1	1.1.0			{	{
001f61e3-30b0-42eb-816e-57b963a1a24b	01.01.000			{	{
001f992c-0cca-49b5-84e1-f447652e019b	1.1.0			{	{
002294ef-86ed-46d3-b78c-54b8eb8d4f4	01.01.000			{	{
00253765-9455-4f05-9eea-6b4448a26eb	1.1.0			{	{
00260612-2051-4cb5-8910-39f1fc3c712d	1.1.0			{	{
0027a360-c0c7-4192-be76-79d931373d62	1.1.0			{	{



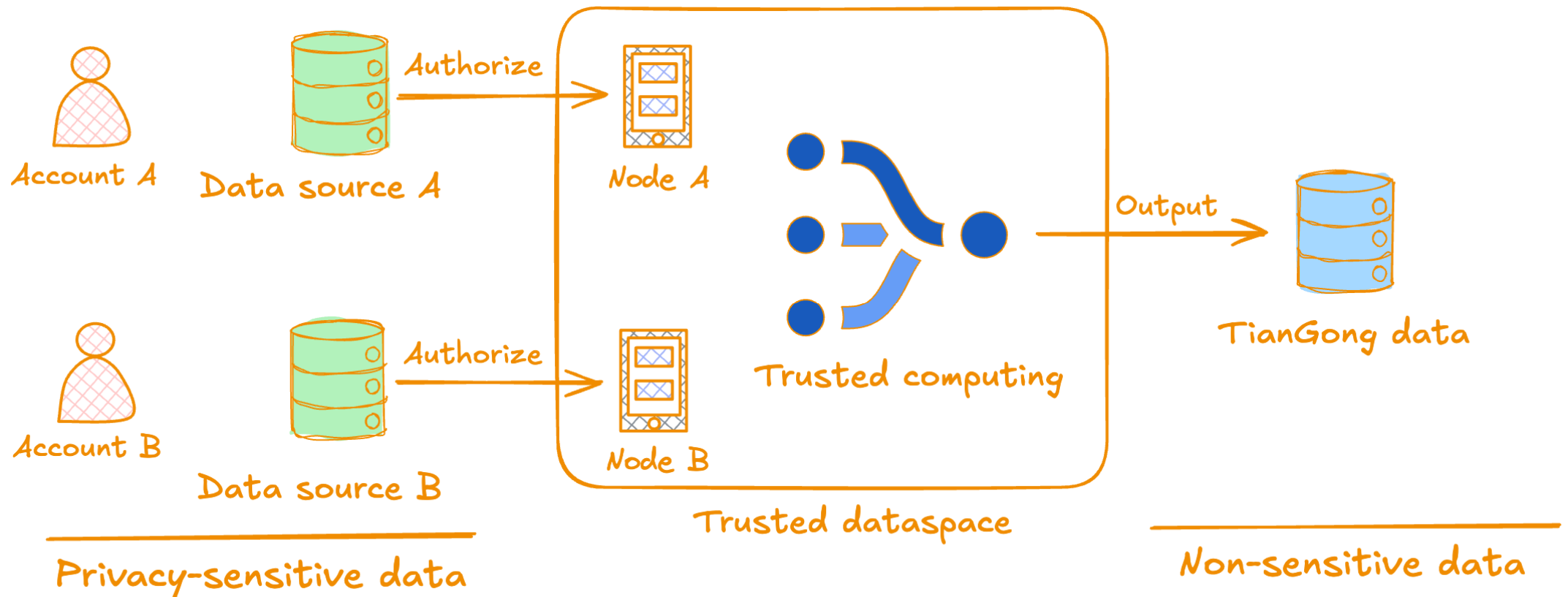
MCP Server



Extension – blockchain and dataspace



Extension – blockchain and dataspace



Platform – TianGong LCA

<https://lca.tiangong.world>

The left screenshot displays the '单元过程' (Unit Process) page. It features a sidebar with navigation options: '我的数据' (My Data), '天工数据' (TianGong Data), '单元过程' (Unit Process), '流' (Flow), '流属性' (Flow Attribute), '单位' (Unit), '数据源' (Data Source), and '联系人' (Contact). The main content area shows a table of unit processes with columns for '序号' (Serial Number), '名称' (Name), and '分类' (Category).

序号	名称	分类
1	市政污水处理; 污泥; 加热干燥	End-of-life treatment > Waste water treatment
2	工业硅生产; 99%的单质硅; 碳质还原法	Materials production > Metals and semimetals
3	预处理土壤; 土壤调理; 生物堆; 土壤修复; 异位	Other Services > Repair and maintenance
4	碳酸锂生产; 电池级碳酸锂; 离子交换法; 阿根廷奥拉罗兹盐湖卤水	Materials production > Inorganic chemicals
5	大黄鱼成鱼养殖; 大黄鱼成鱼; 网箱养殖; 配方饲料和新鲜杂鱼	Materials production > Food and renewable raw materials
6	三元锂电池火法-湿法联合回收技术物质清单	End-of-life treatment > Material recycling

The right screenshot shows the '创建单元过程' (Create Unit Process) form. It includes tabs for 'Process Information', 'Modelling And Validation', 'Administrative Information', and 'Exchanges'. The 'Process Information' tab is active, showing fields for 'Base Name', 'Classification' (with Level 1, 2, and 3 dropdowns), and 'General Comment'. Each field has a '+ Add' button. The form also includes '取消' (Cancel) and '提交' (Submit) buttons at the bottom right.

TIDAS ecosystem



A community-driven project led by Tsinghua University with **43 investigators** and **180+ researchers** to develop and maintain **open, transparent** LCA background database in China: **TianGong Database**.

<https://www.tiangong.earth>



Tian Gong Kai Wu



The Tiangong Kaiwu (天工開物), or The Exploitation of the Works of Nature was a Chinese encyclopedia compiled by Song Yingxing. It was published in May 1637.

The Tiangong Kaiwu is an encyclopedia covering a wide range of technical issues. It featured detailed illustrations that were valuable for historians in understanding many early Chinese industrial processes.

TIDAS ecosystem

**ANT GROUP**

数据可信协作平台

pdAdmin

协作节点

数据治理与中间发布

数据管理

数据目录

开放共享计算

隐私计算项目

风险管理

数据水印溯源

系统管理

协作节点管理

其他

我审批的任务

我发起的任务

成员管理

账号设置

计算/存储资源管理

开放协作概况

核心指标

共享数据总量

3

共享数据申请总次数

5

数据协作项目总个数

13

开放数据领域分布

数据总量 81

开放数据领域分布图

租户开放数据量排行

开放数据申请次数排行

最新流通岛共享数据

数据名称

数据领域

数据开放等级

数据开放等级图

HiQ Editor

钢铁, Q235B, 混合技术

身份ID: 13b69e8b-133a-4102-abd9-e56d17913d96

参考单位: kg

参考产品: 钢铁, Q235B

地理位置: China

引用次数: 0

基本信息

管理信息

建模与验证

LUP过程

LCA计算结果

LCAI计算结果

通用信息

身份ID

13b69e8b-133a-4102-abd9-e...

关联ID

cv98e17d-4792-4d54-9020-3c4de420ba32

数据产品分类

41121: 钢铁或其他金属材料

参考产品

钢铁, Q235B

数据名称

钢铁

技术路线/工艺路线

Q235B

材料/成分

Q235B

形状/状态

Q235B

规格型号 (数量)

Q235B

用途

Q235B

燃料类型

Q235B

产品品质 (属性)

Q235B

标准

Q235B

来源

Q235B

补充说明

Q235B

混合技术

Original UUID

数据标识

描述深度

描述范围

参考单位

kg

数据值

描述范围

描述范围

产品/过程说明信息

活动说明信息

活动开始边界

活动结束边界

同义词

描述

标签

行业

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钢铁, Q235B, 混合技术

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Q235B

材料/成分

Q235B

形状/状态

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规格型号 (数量)

Q235B

用途

Q235B

燃料类型

Q235B

产品品质 (属性)

Q235B

标准

Q235B

来源

Q235B

补充说明

Q235B

混合技术

Original UUID

数据标识

描述深度

描述范围

参考单位

kg

数据值

描述范围

描述范围

产品/过程说明信息

活动说明信息

活动开始边界

活动结束边界

同义词

描述

标签

行业

TIDAS ecosystem

Carbon Footprint Alliance (CFA)



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碳足迹产业技术创新联盟
Carbon Footprint Alliance

