HiQLCD 海科数据

HiQLCD Database

Generic Methodology Report

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1. INTRODUCTION

The **HiQLCD** is a Chinese life cycle inventory (LCI) database developed in compliance with the International Reference Life Cycle Data System (ILCD) framework, which is published by Shanghai HiQ Smart Data Co., Ltd. (hereafter named HIQ SMART DATA), a Chinese company specializing in high-quality life cycle assessment (LCA) data solutions. More information on HIQ SMART DATA can be found at HiQLCD - China's Leading LCA Database .

As a comprehensive LCA background database, HiQLCD covers a broad range of product categories - electricity, coal, oil & gas, iron & steel, metal alloys, non-ferrous metals, chemicals, building materials, photovoltaics, lithium batteries, electronic devices, waste treatment, and transportation. HiQLCD is published in three parallel system models to meet diverse LCA needs (**see section 4**): *"Allocation, Cut-off by Classification" (cutoff), "Substitution, Consequential" (consequential), "Allocation, Cut-off, EN15804" (EN15804).*

HiQLCD aims to provide LCA practitioners with localized background data reflecting Chinese industrial production situation, enabling them to conduct LCA studies that are more reliable, better aligned with actual production in the supply chain, and fully compliant with ISO 14040/44 (ISO 2006b; 2006c) for LCA and ISO 14067 (ISO 2018) for product carbon footprint calculations. The generic methodology of HiQLCD also follows the major principles as required in LCA database guidance of ILCD (JRC 2010b) and UNEP (UNEP 2011). To ensure data reliability, HiQLCD adheres to four principles:

- **Representativeness**

Captures regional differences (fine-grained to the provincial level) and variations in production technologies (distinguishing between specific and mixed technologies).
Draws on multiple localized data sources, including industry statistics & standards, as well as enterprise-level production data in the past three years, to ensure China-specific representativeness.

- **Consistency**

Implements uniform rules for metadata & documentation management and processing workflows in accordance with ILCD requirements.

Applies a consistent methodology across datasets within the same industry to enable reliable intra-sector comparisons.

- **Quality assurance**

Considers detailed technical data for each relevant production technology, as well as market-specific and trade-related information for the consumption side.

Enforces a strict quality-control regime covering completeness, consistency, and accuracy; each dataset (both metadata and unit process data) undergoes expert review.

Integrates multi-dimensional quality assessments and uncertainty analyses (e.g. pedigree-matrix scoring, Taylor series expansion, Monte Carlo simulation) to provide comprehensive uncertainty estimates at both the LCI and life cycle impact assessment (LCIA) results level.

- **Transparency**

Fully documents each dataset, including process description, geographic and temporal scope, data sources, assumptions, system boundary, reference unit, authorship, update history, etc.

Retains a complete audit trail of all data processing and operation steps to maximize traceability. This high level of transparency serves as a prerequisite for reproducibility, allowing independent verification of the results.

Update frequency of HiQLCD：

The HiQLCD update policy matches its development stage. Currently, during the rapid expansion phase, regular version updates (dataset updates, e.g., v1.3.0 to v1.4.0) are released approximately every six months. Once the database stabilizes, this frequency will shift to an annual schedule. In addition, maintenance updates (e.g., error fixes, v1.4.0 to v1.4.1) are released more frequently as needed to ensure data quality. Major

version upgrades involving significant architectural changes (e.g., v1.0 to v2.0) are planned to occur every few years.

This document details HiQLCD's overall methodology, covering goal and scope, LCI modelling, system models, and documentation of datasets. It will be updated whenever new or updated data are incorporated in a new release of HiQLCD.

Potential applications of HiQLCD:

- **LCA Data disclosure** (LCA studies, product carbon footprint/PCF reports)
- **Certification schemes** (Environmental Product Declarations/EPDs, carbon labelling)
- **Process optimization** (eco-design, green supply chain management)
- **Policy research** (micro-level decision support)
- **Environmental Communication**

User support and community feedback

HiQLCD provides user support through comprehensive documentation, FAQs, and dedicated helpdesk services to assist users in applying the database effectively. The FAQ page can be accessed at https://www.hiqlcd.com/about#ContactUs. Training sessions, online tutorials, and workshops are organized on demand to strengthen user capacity. Community feedback is collected primarily via structured feedback forms (e.g., for error reporting) and direct communication channels, while broader user interaction is facilitated through offline technical workshops and academic conferences. All feedback, including error reports and suggestions, is systematically reviewed and incorporated into subsequent updates, ensuring continuous improvement of data quality, transparency, and usability.

2. GOAL AND SCOPE OF HIQLCD

This chapter defines the goal and scope of HiQLCD in accordance with ISO 14040 and 14044. Section 2.1 outlines the goal, and Section 2.2 describes the scope. In Section 2.3, the data quality criteria are defined for LCI datasets.

2.1 Goal of HiQLCD

The goal of HiQLCD is to provide representative, consistent, quality-assured, and transparent localized LCI background datasets reflecting Chinese industrial production situation. These datasets enable LCA practitioners to conduct ISO-compliant LCA within the framework of Chinese production systems, as well as global value chains integrated with Chinese industries. Following the ISO standards, the goal of HiQLCD is defined as follows:

Target users. HiQLCD is intended for all practitioners seeking to analyse and report the LCA impact of products and services across China's industries. Potential users include, but are not limited to:

- LCA researchers and consultants, government research organizations, academia
- Operators that conduct product or company footprint research and development
- Service providers (e.g. software developers) that develop tools for footprinting-related decision support
- Database developers that provide secondary data for certain related industries

Intended application. All practical life-cycle-related applications that aim to maintain links towards or are based upon the ISO 14040/44 series (ISO 2006b; 2006c) and related specific standards such as ISO 14067 (Carbon Footprint) (ISO 2018).

2.2 Scope of HiQLCD

This section defines the scope of HiQLCD and the corresponding output datasets.

2.2.1 Functional unit and Reference flows

The functional unit is defined as "quantified performance of a product system for use

as a reference unit" according to ISO 14044 (ISO 2006c). A well-defined functional unit ensures the fair comparison between product systems providing a common function, but it can be varied by the product's application context. In practice, reference flows can be defined accordingly to fulfil different functions in different contexts. To allow for maximum modelling flexibility, multiple flow properties of the reference flow are provided in the database. The general principle applied in HiQLCD is that reference flows of products should reflect 'physical' flows as accurately as possible, while specific product properties are listed separately in the process and/or comment fields. For example, the main reference flow for fuel coal is defined as 1 kg, while the carbon content and low calorific value are given as additional properties. To facilitate data usage, the system supports automatic unit conversion within the same unit group (e.g. mass units). It automatically retrieves and applies the corresponding conversion factors during the calculation process.

2.2.2 System boundaries

System boundaries define the processes, material flows, and energy flows included in the product system represented by a dataset, with the scope determined by the type of dataset requested (e.g. gate-to-gate, cradle-to-gate, or cradle-to-gate + EoL). The specific boundaries applied in HiQLCD datasets are presented in Table 2.1.

Table 2.1: System boundaries of focused section datasets.

Section	Included processes
Coal	Open pit operation: drilling, blasting, loading, crushing, transportation, dumping, pollutant treatment and disposal
	Underground operation: tunnelling, coal extraction, machinery and equipment, underground and in-plant transportation, ventilation, pollutant treatment and disposal
	Raw coal preparation: transportation from coal mines to coal washing plants, storage, crushing, and screening
	Raw coal beneficiation
	Dewatering and drying
Crude oils and natural gases	Onshore processes of exploration and drilling
	Offshore processes of exploration and drilling
	Resource extraction
	Venting and flaring emissions
	Water use and wastewater treatment
	On site pipeline transportation
Electricity	Construction, reinvestments and decommissioning of the energy conversion plant
	Energy conversion process: all relevant material and energy inputs, DeNOx and DeSOx units, maintaining, pollutant treatment and disposal
	Transmission and distribution losses
	Construction and decommissioning of distribution infrastructure
Mining ores and minerals	Open pit operation: drilling, blasting, overburden stripping, ore loading, and transportation
	Underground operation: tunnelling, coal extraction, machinery and equipment, underground and in-plant transportation, ventilation, pollutant treatment and disposal
	Mining construction

	Ore collection
	Ore lifting
Iron & steel	Mining of metal ore
	Self-produced fuels, electricity and thermal energy
	Coke and related reduction media
	Production of auxiliary inputs
	Steelmaking, waste treatment and disposal
Renewable energy power generation equipment (photovoltaic module, wind turbine generator)	Component production
	Assembly
	Decommissioning and disassembling of equipment
End of life (EoL)	Collection and transportation
	Mechanical and chemical (pre-) treatment
	Recycling
	Sludge and slag treatment
	Energy efficiency measures and recovery (electricity/heat)
	Combustion calculation incl. all relevant emissions
	Leachate treatment
	Landfill gas processing
	Infrastructure (incl. wastewater treatment plant, etc.)
Transportation	Energy consumption and emissions
	Infrastructure (incl. road, rail, etc.)
	Facilities (incl. truck, locomotive, etc.)
	Transportation loss

2.2.3 Cut-off rule

“Cut-off” in this part refers to the omission of not relevant life cycle stages, activity types (e.g. investment goods, storage), specific processes and products (e.g. re-granulating of internally recycled polymer production waste before re-melting) and elementary flows from the system model.

Cut-off rules are defined to provide practical guidelines to omit less relevant process chain details while modelling a specific product system. In general, all processes and flows that are attributable to the analysed system (or affected via consequences, in case of consequential modelling) are to be included in the system boundaries as required in ISO 14067:2018 (ISO 2018). However, not all these processes and elementary flows are quantitatively relevant. In this context, relevance is determined based on the significance of the flow's contribution to the overall environmental impact results (identified via iterative screening or expert judgment) and specific requirements of applicable product category rules (PCRs). For the less relevant ones, data of lower quality (“data estimates”) can be used, limiting the effort for collecting or obtaining high quality data for those parts (JRC 2010b). Among these, the irrelevant ones can be entirely cut-off (and the effort that would otherwise be needed to collect the data can be used to focus on obtaining better data for the relevant processes and elementary flows). All relevant material and energy flows in HiQLCD datasets are included as far as possible under PCRs.

As a general rule, material or energy flows may be omitted if data are lacking and they (cumulatively) account for less than 1% of the material and energy flow, and 5% of the environmental impact for each impact category.

2.2.4 Applicable LCIA methods

The calculation of environmental impacts is performed in the so-called LCIA. During the LCIA, all elementary flows are characterized by their contribution to specific impact categories. This allows the overall contribution of multiple elementary flows to a given impact to be quantified. HiQLCD provides comprehensive LCIs, thereby enabling the

application of any relevant LCIA method.

LCIA methods as well as some critical inventory indicators applied in HiQLCD are adopted from ecoinvent 3.10 (Sonderegger T. and Stoikou N. 2023; Ioannidou D. et al. 2021) and include, but are not limited to:

LCIA methods

- CML v4.8 2016
- CML v4.8 2016 no Long-Term (LT) emissions
- Crustal Scarcity Indicator 2020
- Ecological Footprint
- Ecological Scarcity 2021
- Ecological Scarcity 2021 no LT
- Ecosystem Damage Potential
- EF v3.0
- EF v3.0 no LT
- EF v3.1
- EF v3.1 no LT
- EPS 2020d
- EPS 2020d no LT
- IMPACT World+ v2.1, footprint version
- IPCC 2013
- IPCC 2013 no LT
- IPCC 2021
- IPCC 2021 no LT
- ReCiPe 2016 v1.03, endpoint (E)
- ReCiPe 2016 v1.03, endpoint (E) no LT
- ReCiPe 2016 v1.03, endpoint (H)
- ReCiPe 2016 v1.03, endpoint (H) no LT
- ReCiPe 2016 v1.03, endpoint (I)
- ReCiPe 2016 v1.03, endpoint (I) no LT

- ReCiPe 2016 v1.03, midpoint (E)
- ReCiPe 2016 v1.03, midpoint (E) no LT
- ReCiPe 2016 v1.03, midpoint (H)
- ReCiPe 2016 v1.03, midpoint (H) no LT
- ReCiPe 2016 v1.03, midpoint (I)
- ReCiPe 2016 v1.03, midpoint (I) no LT
- TRACI v2.1
- TRACI v2.1 no LT
- USEtox v2.13, endpoint
- USEtox v2.13, endpoint no LT
- USEtox v2.13, midpoint
- USEtox v2.13, midpoint no LT

Inventory indicators of high concern

- Cumulative Energy Demand (CED)
- Cumulative Exergy Demand (CExD)
- EN15804+A2 - Additional impact categories and indicators
- EN15804+A2 - Core impact categories and indicators
- EN15804+A2 - Indicators describing biogenic carbon content at factory gate
- EN15804+A2 - Indicators describing output flows
- EN15804+A2 - Indicators describing resource use
- EN15804+A2 - Indicators describing waste categories
- Inventory results and indicators

Please kindly note that although CML and ReCiPe are more applicable for use in the European context, and TRACI and USEtox work much better for the US context, all of them are applied in HiQLCD, mainly due to the following three facts:

1) The quality of LCI data is considered prioritized over the regional specificity of LCIA methods. HiQLCD's advantage lies in ensuring that the LCI is China-specific, while a selection of various LCIA methods is made available.

2) At the current stage, LCIA methods for China are still missing. As the abovementioned methods are widely adopted within the LCA community, we assume that these characterization factors are supposed to be also applicable in Chinese context. However, more research work in developing China-specific LCIA methods and engagement work with global LCA community should be facilitated in the future.

2.3 Data quality requirements

The data quality of HiQLCD datasets is specified based on data quality indicators (DQI). These indicators cover five key criteria: Technological representativeness, Temporal representativeness, Geographical representativeness, Reliability, and Completeness. Each criterion has five data quality levels, where level 1 represents the highest data quality and level 5 represents the lowest. The definitions of the data quality criteria and quality levels are adapted from *Data Quality Management for Life Cycle Inventories-an Example of Using Data Quality Indicators* (Bo Pedersen Weidema and Marianne Suhr Wesnæs 1996). Table 2.2 shows the definition of each data quality criterion. Table 2.3 gives an overview of the assessment scheme for each data quality criterion and data quality level.

Table 2.2: Definitions of data quality criteria.

Indicator	Description
Technological representativeness	The degree to which the data reflects the actual technology(ies) used.
Temporal representativeness	The degree to which the data reflects the actual time (e.g. year) or age of the activity.
Geographical representativeness	The degree to which the data reflects the actual geographic location of the activity (e.g. country or site).
Reliability	The degree to which the sources, data collection methods and verification procedures used to obtain the data are dependable.
Completeness	The degree to which the data are statistically representative of the relevant activity. Completeness includes the percentage of locations for which data is available and used out of the total number that relate to a specific activity.

	Completeness also addresses seasonal and other normal fluctuations in data.

Table 2.3: Assessment scheme for the determination of data quality criteria and quality levels.

Quality level	**1 - Very good**	**2 - Good**	**3 - Fair**	**4 - Poor**	**5 - Very poor**
Technological representativeness	Data generated from multi-sources using the same technology.	Data generated from few sources using the same technology.	Data generated using a similar but different technology.	Data generated using a different technology.	Data where technology is unknown.
Temporal representativeness	Data with less than 3 years of difference.	Data with less than 6 years of difference.	Data with less than 10 years of difference.	Data with less than 15 years of difference.	Age of data unknown or more than 15 years of difference.
Geographical representativeness	Data from the same area.	Average data from larger area in which the targeted area is included.	Data from area with similar production conditions.	Data from area with slightly similar production conditions.	Data from unknown area or area with very different production conditions.
Reliability	Verified data based on measurement.	Verified data partly based on assumptions or non-verified data based on measurements.	Non-verified data partly based on assumptions.	Qualified estimate (e.g. by industrial expert)	Non-qualified estimate.

Completeness	Data from all relevant process sites over an adequate time period to even out normal fluctuations.	Data from more than 50% of sites and for adequate time periods to even out normal fluctuations.	Data from less than 50% of sites but from adequate time periods to even out normal fluctuations.	Data from more than 50% of sites but from shorter time periods.	Data from less than 50% of sites for shorter time period or representativeness is unknown.

3. LIFE CYCLE INVENTORY MODELLING

3.1 Data collection and validation

3.1.1 Data sources

In HiQLCD, 100% of the data are based on Chinese local sources and compiled from multiple origins. The data sources mainly cover five categories:

1. Authorized enterprise client data;
2. Industry statistical data;
3. Publicly available enterprise data;
4. Peer-reviewed literature data;
5. Co-created and shared data generated through EC-digital's self-developed LCA SaaS tool. Detailed information on the tool can be found in the manual for Steel LCA Tool which is a specialized version developed for steel EPD applications (EC Digital 2025).

3.1.2 Quality check and validation of collected data

During the data collection phase, HiQLCD engages a team of experts to develop and apply a **data quality checklist** to ensure all collected information meets established quality requirements.

a. Balance and rationality checks:

These checks cover mass and energy balances, emission balances, and plausibility assessments. The checks verify whether all relevant process steps, inputs, and outputs are included. As part of the verification, key evaluations include material and energy balances, emission consistency, and chemical element checks. Additionally, process characteristics (e.g. energy efficiency, by-product generation, and substance recirculation) are examined to detect anomalies and ensure data integrity.

To comply with ISO 14046 standards and support accurate water footprinting, HiQLCD implements a strict water balance check for every unit process. The verification ensures that the sum of all water inputs (including pure water and the moisture content of input

materials, calculated via the "water in wet mass" flow property) equals the sum of all water outputs (including emissions to air/water and moisture in output products). This strict mass balance allows for the precise calculation of water consumption, whether defined as evaporative loss (emission to air) or the net difference between withdrawal and discharge.

b. Exception handling:

When irregularities are identified, an iterative review process is initiated with the data provider or internal experts. This process aims to determine whether the issue stems from the data itself, a methodological flaw, or constitutes a special case. Differentiating between isolated anomalies and systemic issues is essential for appropriate resolution.

c. Other technical and contextual checks:

Beyond technical verifications, checks are also conducted against broader principles such as data quality approaches, data source reliability, and alignment with the defined goal and scope (e.g. functional units and system boundaries). These checks ensure overall coherence and that data accurately reflects actual conditions. Specifically, the required level of detail and the inclusion of technological variations are determined by the following criteria:

- **Environmental Significance:** Processes identified as “Key Processes” (contributing significantly to the impact results) are modelled with the highest level of granularity.
- **Technological Representativeness:** Distinct datasets are created for different production technologies (e.g., variations in steel production routes) if they represent a relevant share of the market.
- **Data Availability:** Where primary data is unavailable for non-key processes, representative averages or proxies are used following the data quality hierarchy.

d. Documentation of verification results:

All outcomes of the verification process are recorded in the dataset metadata. A higher level of specificity correlates with a higher data quality rating.

Upon successful completion of all validation checks, the data becomes eligible for

integration into the HiQEditor system, the platform used for developing all HiQLCD datasets. HiQEditor is a proprietary, web-based LCA data management platform specifically developed for the HiQLCD database. It serves as the central hub for data collection, unit process modelling, dataset creation, and quality assurance, ensuring that all data entry and formatting strictly adhere to HiQLCD modelling and quality rules. More detailed information on HiQEditor can be found at https://www.hiqlcd.com/service/editor.

3.1.3 Handling data gaps

Data gap is a recurring challenge in LCA practices, often resulting from limited data access or unavailable information. In such cases, the expert team must evaluate and determine the most appropriate strategy to fill the data gaps while maintaining accuracy and minimizing oversimplification.

As there is no universal solution, each instance must be assessed individually. Commonly applied approaches include:

- **Literature review:** Consulting reports, academic papers, and technical books. While widely used, such sources may lack LCA-relevant data.
- **Stoichiometric calculation:** For chemical reactions, missing data can often be estimated based on stoichiometry and assumed reaction yields.
- **Proxy data:** Data from similar processes or technologies may be used to approximate missing values.
- **Estimated data:** In cases where direct data is unavailable, qualified experts may provide reasoned estimates, ideally supported by one or more of the methods above.
- Industry expert consultation: Direct communication with process engineers, plant operators, or technical associations to obtain specific operational data or validate assumptions. This approach is particularly useful for acquiring non-public data or verifying the representativeness of proxy data.

The selected method for addressing missing data must be documented transparently in accordance with ISO 14044 requirements.

3.2 Development of unit process datasets

Each unit process dataset includes detailed information covering various attributes that define its representativeness and applicability:

- **Geographic scope:** Indicates the region the activity represents. For example, a process may reflect conditions typical of North China. Geographic scope indicates the region the activity represents. HiQLCD prioritizes high geographic granularity for core foundational industries to ensure data precision. For critical sectors like electricity and coal, datasets are specifically developed at the regional or provincial level to capture significant spatial variations in resource quality and energy mix. This approach ensures that regional differences are accurately reflected for these key inputs.
- **Time coverage:** Defines the temporal validity of the dataset, typically expressed as a start and end year. For instance, the dataset "Sulfuric acid, unspecified process" spans from 2023 to 2025. This period reflects either the timeframe of data collection or the duration the dataset is extrapolated to represent. Even if the end date is in the past, the dataset may remain valid if the production methods or supply chains have not significantly changed.
- **Process documentation:** Provides a comprehensive description of the activity, including its purpose, technology, boundaries, and methodological context.
- **Natural resource consumption:** Captures inputs of natural resources, e.g. liters of water required to produce 1 kg of cotton.
- **Emission profile:** Details emissions to the environment, e.g. air pollutants emitted from the combustion of 1 kg of coal in a thermal power plant.
- **Material flow inventory (bill of materials):** Describes inputs and outputs, e.g. raw materials and additives required to produce 1 kg of newspaper.
- **Energy and fuel consumption:** Quantifies energy consumption, including electricity mix used for producing products such as aluminium.
- **Mass, water, and carbon balances:** Tracks flows of materials and carbon (fossil and biogenic). For example, how much biogenic carbon from wood remains stored

in paper products versus how much is released as CO_2.

- **Annual production volume:** Provides context on production scale, e.g. total annual output of hard coal from mines in North China.

Each activity is uniquely identified through a combination of its name, reference product, geographic location, and time coverage. These identifiers are further supplemented by a Universal Unique Identifier (UUID), enabling consistent dataset referencing and integration across systems.

3.2.1 Dataset activity classification

Activities are classified based on their functional roles within the life cycle framework. All activities involve exchanges of inputs and outputs (Fig. 1):

- **Elementary exchanges:** These are flows directly connected to the environment. Inputs include resource extraction (e.g. water from a river, CO_2 uptake by trees), while outputs include emissions to air, water, or soil.
- **Intermediate exchanges:** These refer to material and energy flows exchanged between processes. Output exchanges may include reference products, by(co)-products, or wastes.

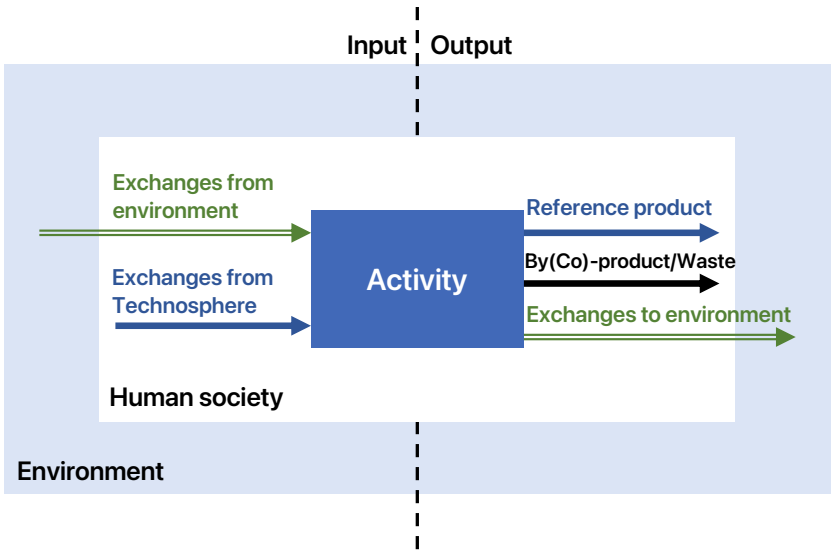


Fig. 1 Inputs and outputs involved in activities

Normal transforming activities (material & energy)

Transforming activities are human activities that transform inputs, so that the output of the activity is different from the inputs (Fig. 2), e.g. a hard coal mine that transforms hard coal in ground to the marketable product hard coal. All activities that are not of those special types are "normal" transforming activities. In HiQLCD, normal transforming processes can be further divided into "**material**" and "**energy**" types, representing activities whose reference outputs are, respectively, materials or energy (excluding energy carriers).

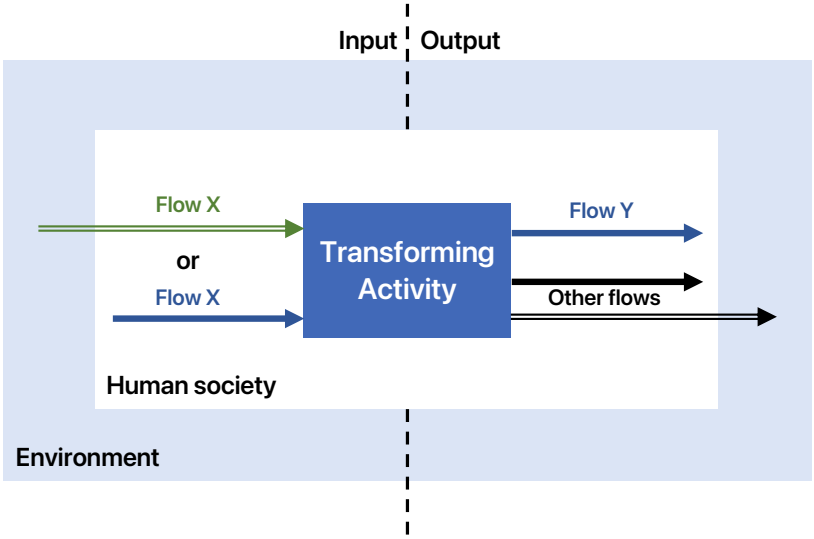


Fig. 2 Transforming activities

Service or processing activities

Service or processing processes enable or support other activities without directly involving the serviced product's material flows (Fig.3). For instance, operating a chainsaw to cut wood involves fuel and equipment use but not the trees themselves as input. The forestry process, in contrast, directly includes the trees. Equipment use, fuel consumption, and associated emissions are tracked as inputs to the service process and indirectly influence the forestry output.

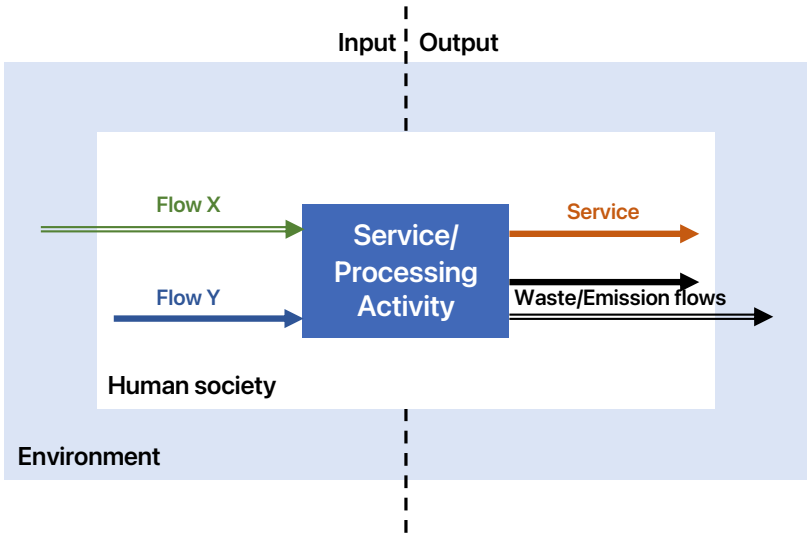


Fig. 3 Service/Processing activities

Infrastructure activities

Infrastructure processes involve the creation and use of long-term capital goods such as buildings, machinery, roads, and production facilities - assets typically with a service life exceeding one year.

Infrastructure processes include construction, maintenance, land use and transformation (if applicable), and end-of-life disposal (Fig. 4). Outputs at the end of service life include waste flows and associated impacts. The mass of infrastructure leaves the construction process together with the waste flows. Therefore, infrastructure products lack direct mass parameters, but can be characterized by attributes such as **service life** and **service capacity**.

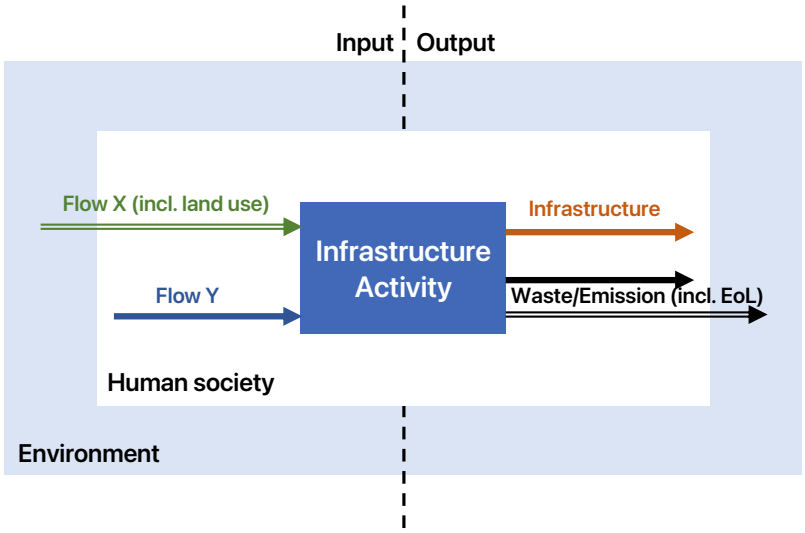


Fig. 4 Infrastructure activities

Waste treatment activities

Waste treatment process manage waste flows, by converting them either into valuable products or released emissions (Fig. 5). When waste is converted into valuable products (e.g. used cooking oil processed into biofuel), the process is considered recycling-oriented. When waste is converted into emissions released to the environment (e.g. treating wastewater and releasing clean water), the process is categorized as final disposal.

Unlike typical production processes, the reference flow in treatment activities is usually on the input side, representing the waste being treated.

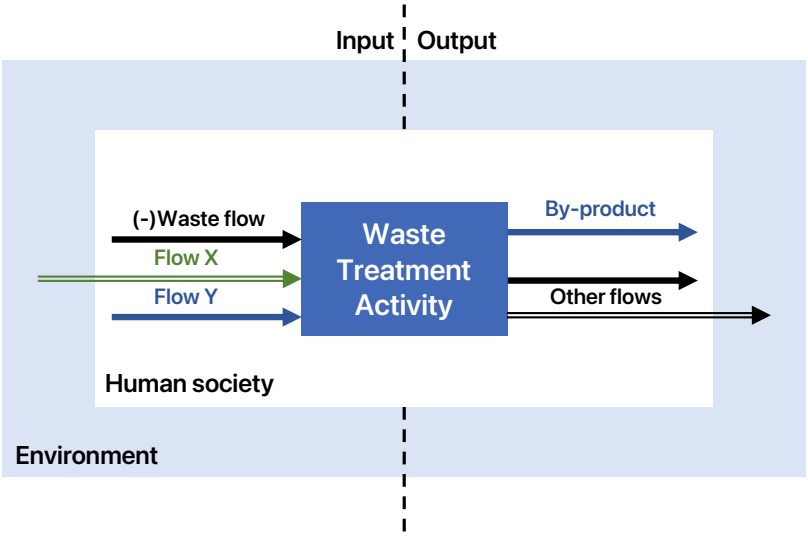


Fig. 5 Waste treatment activities

Transport activities

A transport process is defined as the process of transporting an object from one location to another over a certain distance. Taking the transportation of goods as an example, it is necessary to consider the energy and emissions consumed per unit of mass and distance, as well as the losses of roads and vehicles (Fig. 6).

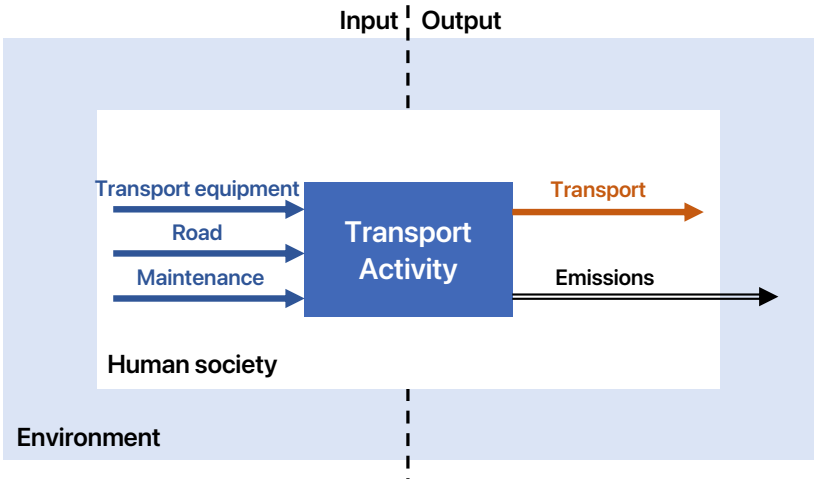


Fig. 6 Transport activities

3.2.2 Mixed dataset

A mixed dataset combines multiple lower-level unit or market datasets into a single, higher-level profile that reflects the weighted average of all included components. Mixing can occur along various dimensions - for example, by geography (e.g. regional or national mix), by technology (production mix), or by consumption patterns (market group). In mixed dataset, we ensure non-confidentiality for production-related data through multi-source aggregation. This approach effectively anonymizes specific company data while simultaneously enhancing the representativeness of the dataset. Key features of a mixed dataset include:

- **Scope definition:** Clear boundaries (region, time period, technology set) over which data are combined.
- **Sharing factors:** Shares or proportions (e.g. production volumes, consumption flows, market shares) used to weight each constituent dataset.
- **Pre-mixed inputs:** Each input dataset already contains its own process inventories, transport chains, and product losses.
- **Metadata documentation:** Descriptions of mixing methodology, data sources for weights, assumptions, and any temporal or technological adjustments.

Production mix

A production mix dataset characterizes the production-volume-weighted average of all relevant production routes or process variants for a given product within a defined

region and timeframe (Fig. 7).

To build this dataset, each individual technology or manufacturing process is first identified (e.g. basic oxygen furnace versus electric arc furnace steelmaking, or conventional thermal power plant versus combined-cycle gas turbines). Next, the relative market or production share of each technology - typically obtained from industry statistics, plant-level surveys, or trade data - is calculated to serve as sharing factors. These factors are then applied to the corresponding process inventories (materials, energy, emissions, and co-products) and aggregated into a single "average" profile. The result is a representative unit process that reflects the real-world mix of technologies in use, smoothing out site-specific variations while preserving key regional and temporal characteristics. Metadata accompanying the dataset should document the sources and reference years of share data, the list of included technologies, any assumptions or data gaps, and the methodology applied for weighting and mixing. By updating the production mix dataset periodically - whenever significant shifts in market shares or new technologies emerge - analysts can maintain an up-to-date average profile that supports consistent and comparable life cycle assessments.

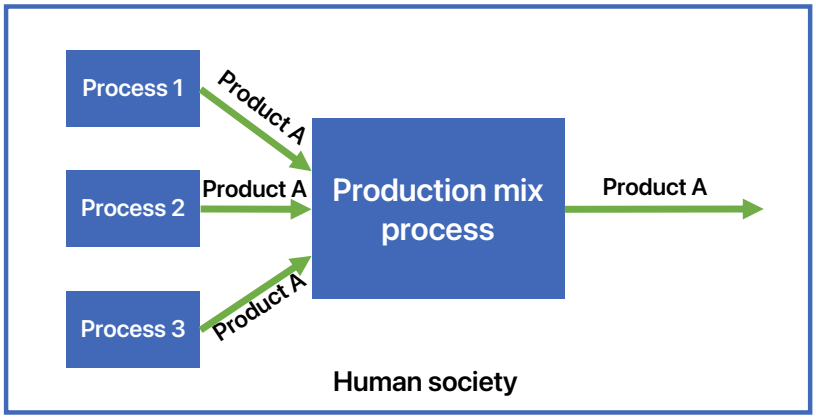


Fig. 7 Production mix processes

Consumption mix (market & market group)

Market

A market dataset represents the composite supply mix of a given product as consumed within a specific geographic area (typically a province or city). Market activities do not transform their inputs, but simply transfer the intermediate output from a transforming

activity to the transforming activities that consume this intermediate output as an input, e.g. from hard coal at the supplier to hard coal at the consumer. It integrates three primary product supply flows, weighted by their share of local consumption (Fig. 8):

- **Local production:** Product units generated and used within the same region ("produce-and-consume in-region").
- **Domestic imports:** Product units manufactured in other regions of the same country and transported into the target region.
- **International imports:** Product units sourced from abroad, including transport from the foreign production site to the national entry port.

To capture real-world logistics, a market dataset also incorporates:

- **Intra-national transport:** Movement of domestic imports from other regions to the target area.
- **Post-port transport:** Movement of international imports from the national entry port to the target area.
- **Losses:** Product losses occurring during transport stages (e.g. spillage, spoilage).

By applying consumption-share weights to each component's life-cycle inventory (production processes, transport chains, and losses), the market dataset yields a representative profile of all pathways through which the product reaches local end-users.

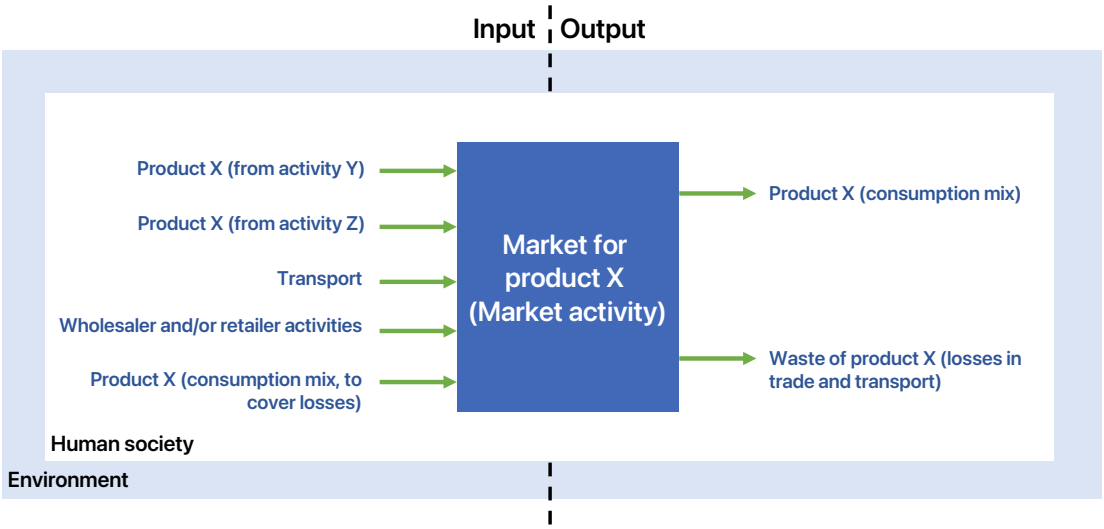


Fig. 8 Market processes

Market group

A market group dataset combines multiple market datasets to represent a larger territorial unit - such as a multi-province region or an entire country - by weighting each constituent market according to its share of total consumption (Fig. 9):

- **Regional market group:** Formed by combining market datasets of all sub-regions (e.g. all provinces in East China), weighted by each province's contribution to national consumption of that product.
- **National market group:** Constructed by combining regional market group datasets (e.g. East, Central, South China), weighted by each region's share of national consumption.

Since each underlying market dataset already incorporates production, import logistics, and transport losses, building a market group requires only the consumption-volume-weighted summation of these pre-mixed profiles - no additional transport or loss modelling is necessary at the group level.

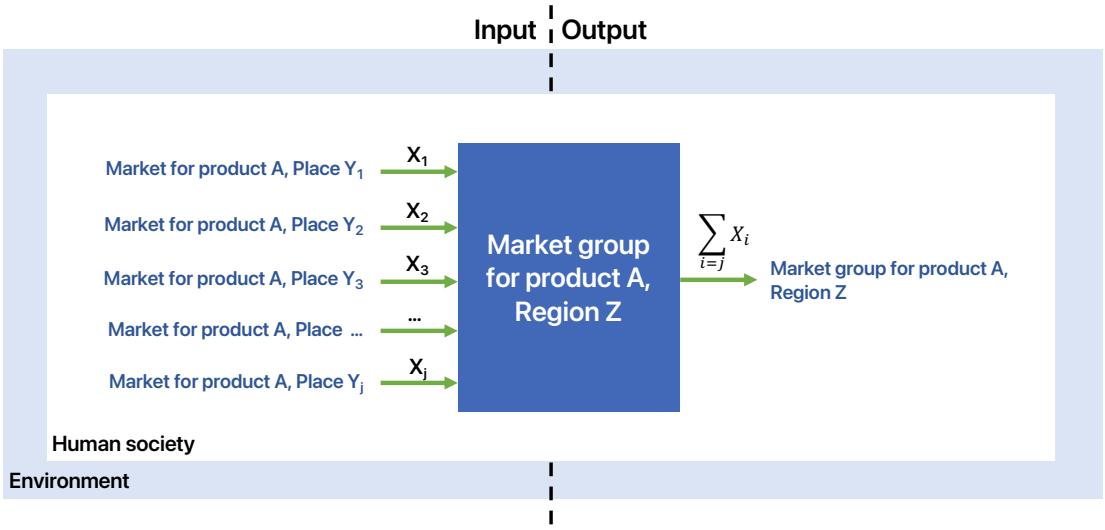


Fig. 9 Market group processes

4. SYSTEM MODELS

HiQLCD is not only an LCI database but also an interconnected LCI data network. Unlinked unit-process datasets in HiQLCD are interlinked by the database service layer: every intermediate input - whether electricity consumption, raw-material use, or road infrastructure - is linked to the corresponding supplier unit processes. As a result, any change in one unit process propagates through nearly all cumulative LCI results. Depending on the magnitude, this ripple effect may be negligible for most datasets but significant for a few.

HiQLCD stores unit-process data as unlinked, multi-output datasets, in which inputs are specified only by product name rather than by supplying activity, and outputs may include multiple products. This format reflects how data providers typically deliver unit processes and how users generally view them.

To compute linked, single-output system datasets, the database applies system-wide modelling rules to derive them from unlinked, multi-output datasets. Both the original multi-output and the derived single-output datasets share the same UUID.

HiQLCD provides three types of system models:

- *Allocation, Cut-off by Classification*
- *Substitution, Consequential*
- *Allocation, Cut-off, EN15804*

Each system model follows specific LCI modelling rules but they all adhere to the fundamental principles of either “Attributional” or “Consequential” modeling (Thomas Schaubroeck et al. 2021; JRC 2010b; Tomas Ekvall 2020; Tomas Ekvall et al. 2020; Rolf Frischknecht et al. 2016).

4.1 Allocation, Cut-off by Classification

The *“Allocation, Cut-off by Classification”* system model belongs to the “attribution system”. This attributional model treats waste producers as fully responsible for waste management (“polluter pays”) and allows recycled materials to enter subsequent

processes burden-free (cut-off). The guiding principle is that primary production bears all upstream burdens; any recycled fraction is credited away from the primary producer. This system model is intended for “situation C” as defined in ILCD handbook (JRC 2010b).

- **Recycled Materials** become burden-free inputs to recycling processes. For example, recycled paper carries only collection and recycling impacts - none of the forestry and pulping burdens of virgin paper.
- **Waste** carries the full burden of its treatment. Valuable by-products (e.g. heat from municipal waste incineration) are cut-off: their benefits are not allocated back to waste producers.

All intermediate exchanges in the database are classified - at the product, not activity, level - as **allocable product**, **recyclable**, or **waste**. This classification dictates how each flow is handled during allocation.

- **Allocable product:** Ordinary (co-)products with economic value; included in allocation.
- **Recyclable:** Materials with no or low economic value that can serve as the input for a recycling activity (e.g. metal scrap, waste paper).
- **Waste:** Materials with no or negative economic value requiring disposal services (e.g. wastewater, contaminated soil, radioactive waste).

Recyclable materials are cut off at the point of entry into recycling or treatment processes and are therefore burden-free for subsequent use. Waste treatment is completely allocated to the waste producer. Any valuable outputs from waste treatment are likewise treated under the cut-off approach and become available without further environmental burdens. Ordinary co-products generated by multifunctional activities are addressed through allocation procedures in accordance with applicable methodological rules.

4.1.1 Multifunctional process

For each multi-output activity, the system first performs a balance check and then

applies allocation factors - either user-defined or default (economic) - to split inputs, emissions, and intermediate flows among the outputs. The choice of allocation method (e.g. economic vs. physical property) depends on scopes and goals of the LCA. After recyclable and waste flows are removed (shifted to the input side), the remaining co-products are allocated according to their defined factors (Fig. 10). For economic allocation, market prices are available in our data manage system HiQEditor, and they are documented in datasets where economic allocation applies. Market prices will be updated every 5 years and the economic allocation will be recalculated.

Datasets of specific sectors within HiQLCD are allocated based on their compliance with PCR requirements. To ensure methodologically consistent results when combining datasets, economic allocation is applied as the primary default rule across the HiQLCD database. Exceptions are made only when physical relationships dictate a different approach (e.g., mass or energy allocation). Crucially, all such deviations are explicitly documented in **Annex A**. This transparency allows practitioners to identify datasets with different allocation rules and assess their compatibility with their specific analysed system.

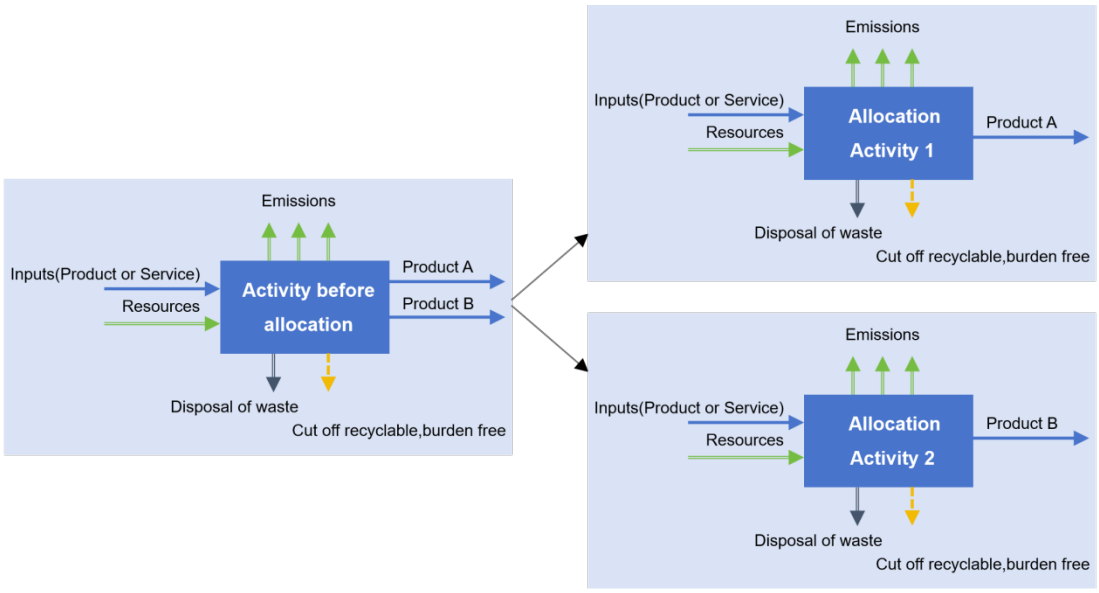


Fig. 10 Allocation of datasets in the cut-off system model

HiQLCD ensures the consistent application of allocation rules: special methods may be defined for individual dataset, while all others default to economic allocation, where

market prices multiplied by output quantities are used to derive revenue shares as allocation factors.

Furthermore, activities that have a material for treatment as an input are not allocated separately (Fig. 11). Allocation properties are not relevant for materials for treatment but only for the materials after the recycling activity or specialty production.

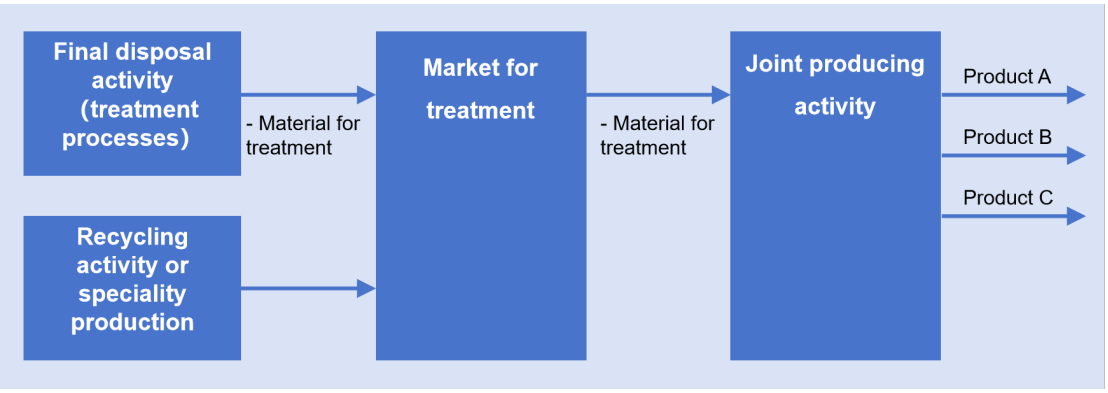


Fig. 11 Allocation of datasets with materials for treatment

4.1.2 Reuse and recycling cut-off

Recyclable outputs are disconnected from primary production by referencing a special *"Product Name, Cut-off"* dataset, which contains no inputs or emissions (burden-free). In the primary production activity, the recycled output is recorded as a negative input, pointing to an empty cut-off process (Fig. 12).

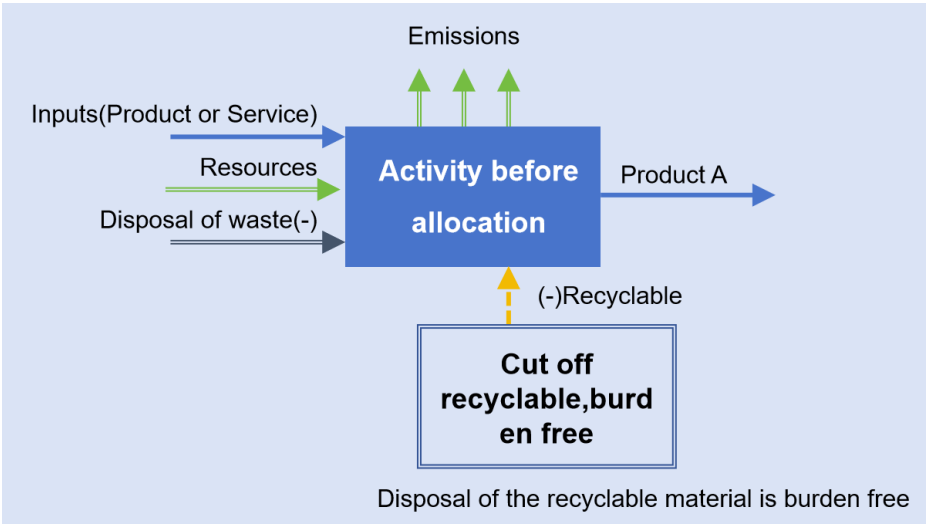


Fig. 12 "Cut-off" of recyclable outputs

The cut-off occurs when the recyclable material leaves the primary production stage.

Downstream recycling processes draw from a market linked to the burden-free recycling dataset (Fig. 13).

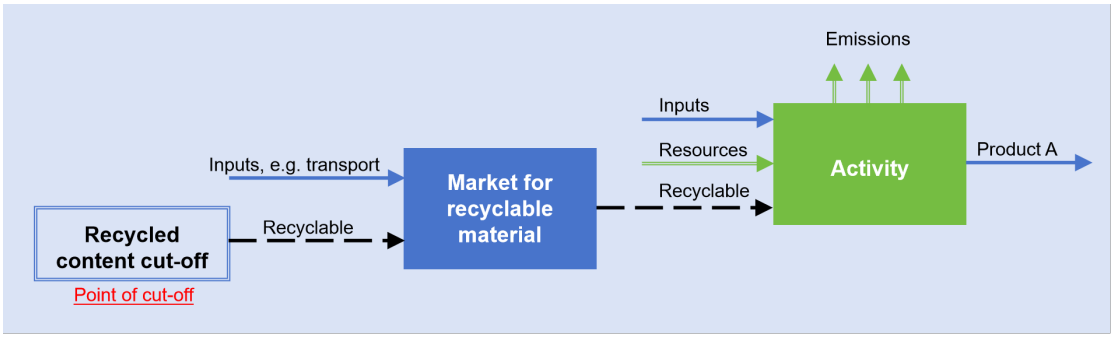


Fig. 13 "Cut-off" of recyclable inputs

Special case: recycling chains

The recycling process in LCI databases may span multiple linked unit processes, with the cut-off typically applied at the start of recycling, but sometimes refined by intermediate forms of recycled material. For example, unsorted post-consumer scrap first undergoes collection and sorting - producing "sorted scrap" - which, like the original scrap, is classified as a burden-free recyclable input (Fig. 14). However, although both scrap and sorted scrap are cut-off from primary production, the recycling chain itself remains modelled: the supply chain for sorted scrap traces back to the initial scrap collection stage, thereby ensuring continuity across the second life cycle and eliminating any artificial boundary between the two material forms.

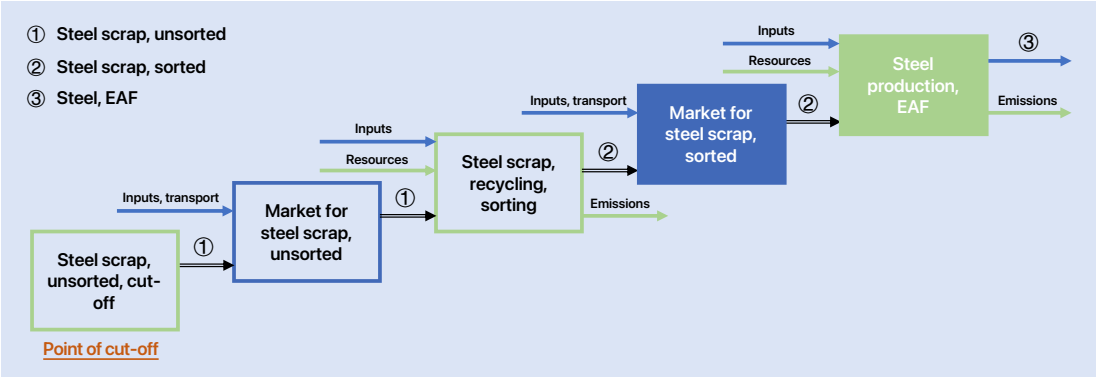


Fig. 14 Recycling chains in the cut-off system model

4.1.3 Waste treatment allocation

Waste outputs are modelled as negative inputs, signifying the need for waste

management services. Waste management processes then provide the corresponding treatment, with their inputs and emissions fully allocated back to the waste-generating activity.

Any non-waste by-products of treatment (i.e. materials with residual value) are cut-off at the end of the waste treatment process and enter the database as burden-free outputs, available for use in other systems (Fig. 15).

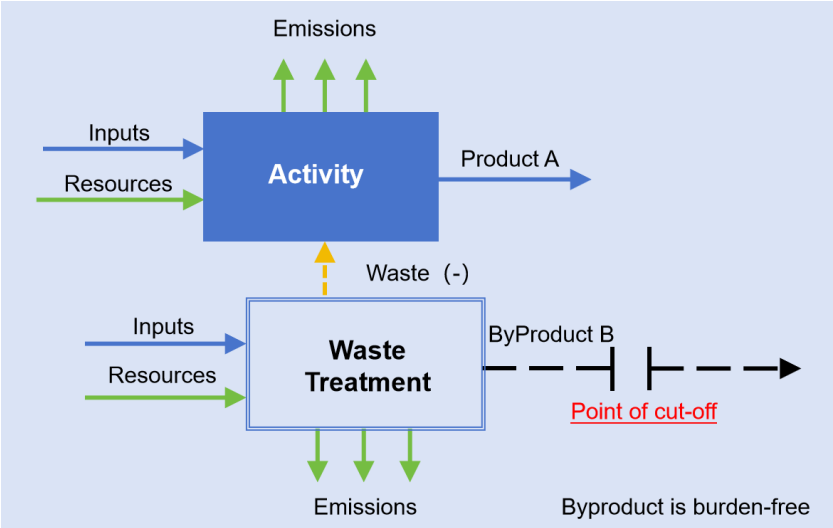


Fig. 15 Cut-off in waste treatment activities

4.2 Substitution, Consequential

The *"Substitution, Consequential"* system model belongs to the broader category of "consequential systems", and resolves multifunctionality through substitution. In this model, all co-products are assumed to replace equivalent products on the market, while these products are also expected to have no large-scale consequences in terms of additionally installed or reduced capacity in the background system or other systems, i.e. not structurally change it. This approach relies on different fundamental assumptions compared to attributional modelling, and is commonly applied in "what-if" analyses and future scenario forecasting, primarily intended for micro-level decision support. This system model is intended for "situation A" as defined in ILCD handbook (JRC 2010b).

There are two core principles in this model:

- **Co-product substitution:** All co-products are modelled as negative outputs (shifted to the input side), and the main process is assigned the full environmental burden of all inputs and emissions. The environmental impacts avoided by displacing equivalent market products are credited to the system. For example, electricity generated from waste incineration is assumed to substitute electricity from conventional sources such as fossil fuels.
- **Equivalent substitution:** Differences in functionality between substituted and superseded products shall be considered either and preferably by substituting the actually superseded amounts (e.g. the amount of Portland cement that the steel making co-product BOF slag actually replaces in cement). Or, as second priority, these differences shall be considered by market value correction of the amount of the substituted function and its inventory, i.e. the ratio of market price between the co-function and the ones it is supposed to supersede.

4.2.1 Multifunctional process

4.2.1.1 Processes with a single reference product

When a process has only one main reference product and additional outputs are considered non-reference co-products, these co-products are modelled as negative inputs. The core process retains all direct inputs and emissions. The environmental burden is assigned solely to the reference product, while the co-products are modelled to replace equivalent products on the market. If for the not required co-function, functionally equivalent alternative processes/products are operated/produced to a sufficient extent, the not required co-function shall be substituted with the average market consumption mix of the processes or products that are superseded, excluding the to-be-substituted process route/product from this mix (Fig.16).

The reasoning for this simplification, compared to full consequential modelling, is that a high effort is required to identify among the potential processes those that are most likely superseded and to calculate the superseded mix. In full consequential modelling, the mix of the most likely superseded processes would need to be identified. The limited

benefit of a potentially more accurate, but also less certain, selection of processes is not found justified.

The market mix is used as a realistic and robust approximation that additionally considers the existence of various secondary consequences and constraints, which can often be assumed to reduce or fully compensate/avoid the theoretical primary consequences. Links between co-products and their original producers are removed. Instead, negative inputs are connected directly to the corresponding market datasets.

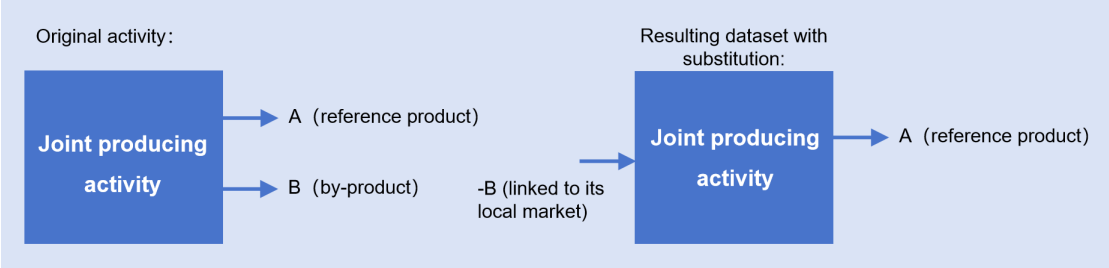


Fig. 16 Original multi-product activity and the resulting database-generated dataset with substitution

4.2.1.2 Joint production processes (multiple reference products)

Compared to the theoretical full consequential model, substitution of the determining co-functions (multiple reference products) shall not be done. If they cannot be identified, the determining co-functions are assumed to be those that jointly contribute more than 50% to the combined market value of all co-functions of the analysed multifunctional process or system. That implies that in fact the main, determining co-functions of the process would be substituted (JRC 2010b).

When there is more than one reference product for an activity, which can happen when there is more than one product output without an alternative production route, the multi-product dataset is duplicated into the same number of activities as there are reference products, since the described procedures are performed for each of the reference products separately, reflecting the consequences of an increased demand for each product separately. Therefore, for processes that produce multiple equally important reference products - such as crude oil and natural gas in oil extraction, or lead and zinc

concentrate in mining - allocation is applied among the reference products. Depending on the study goal and technical relationships, allocation can be based on physical properties (e.g. mass) or economic value.

Any additional by-products beyond the main reference products are handled following the approach in Section 4.2.1.1 - they are modelled as negative inputs substituting market equivalents.

4.2.2 Waste treatment allocation

In the *"Substitution, Consequential"* system model, both recyclable and non-recyclable waste are treated as burdens that require processing. All environmental impacts of the waste treatment process are assigned to the activity that generated the waste.

If valuable by-products are recovered during treatment - such as electricity generated from waste incineration - these are modelled as negative outputs, replacing equivalent market products.

Therefore, for waste and end-of-life treatment, system expansion is applied, substituting the avoided primary production using the recyclability substitution with the average primary route market mix of the market where the secondary good is produced; differences in functionality are considered by substituting the actually superseded amounts or by market value correction (Fig. 17). The simplified substitution of the market mix of primary production is reasoned the same way as the use of the market mix for the general case of multifunctionality, as explained more above. An example is the electricity produced from production waste or end-of-life product incineration with energy recovery. The superseded and to be substituted process is the electricity mix of the market (e.g. country, region, sub-grid) where the waste / end-of-life treatment takes place, excluding the to-be-substituted electricity source.

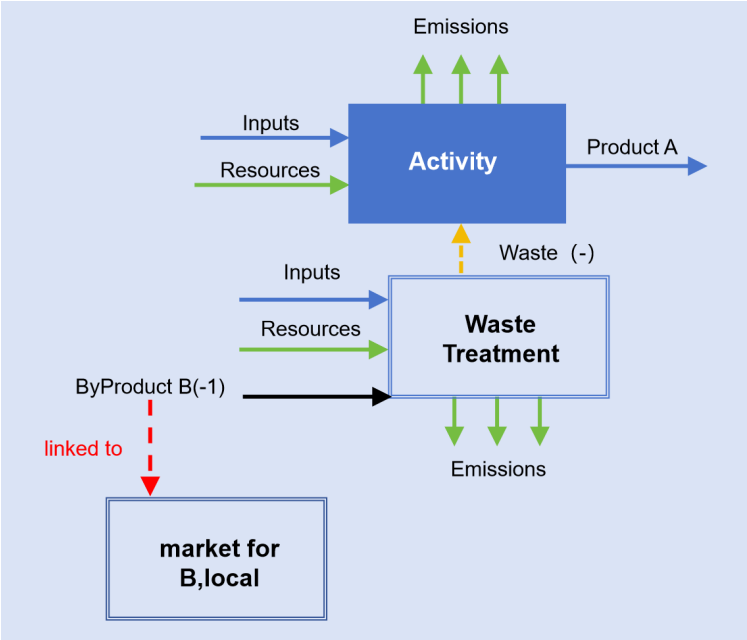


Fig. 17 Substitution in waste treatment activities

Special case: recycling chains

Taking steel recycling as an example, a full recycling chain includes:

1. Steel scrap collection and sorting (into the market)

- Input: Steel scrap, unsorted (negative output)
- Output: Steel scrap, sorted

2. Steel recycling (EAF, 100% scrap input)

- Input: Steel scrap, sorted
- Output: Recycled steel, EAF

In the *"Substitution, Consequential"* model, both sorting and recycling processes treat steel scrap (whether sorted or unsorted) as the input to be processed. The Photovoltaic mounting system production is linked to the recycling chain via a negative input (-1) of unsorted scrap. This notation indicates that the PV system generates scrap as a by-product/waste, which then serves as the feedstock for the sorting process.

The scrap flows through the sorting stage and the market, eventually entering the Steel production (EAF) process. The resulting recycled steel is modelled to displace primary (virgin) steel in the global market. Through this chain-level substitution, the environmental credits (i.e., the avoided impacts of producing virgin steel) are

effectively traced back and attributed to the PV mounting system for providing the recyclable resource."

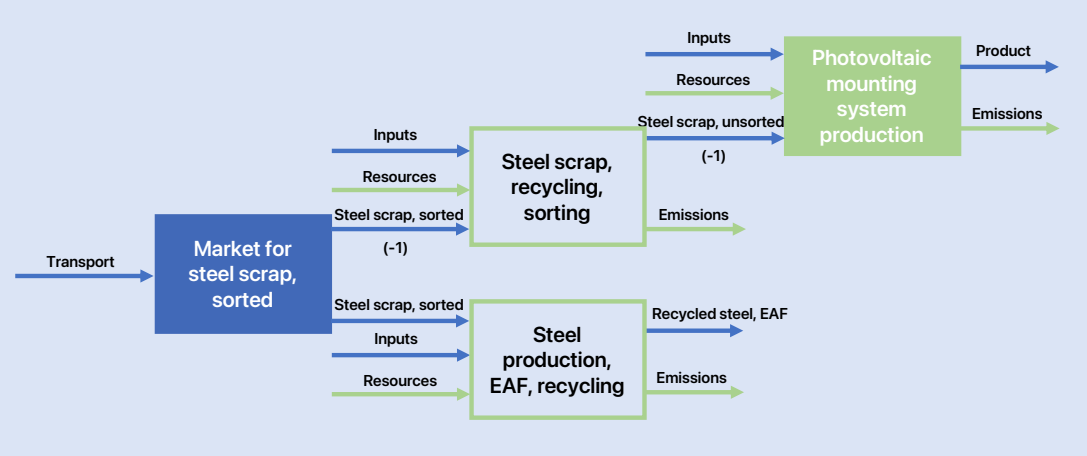


Fig. 18 Recycling chains in the consequential system model

4.3 Allocation, Cut-off, EN15804

The *"Allocation, Cut-off, EN15804"* system model belongs to the attributional system. This system model was developed to meet the needs of Environmental Product Declaration (EPD) practitioners. It complies with the attributional interpretation of EN15804 (CEN/TC 350 2019), ISO21930 (ISO 2017), and ISO14025 (ISO 2006a), providing all life cycle inventory indicators required by these standards and following the *"end-of-waste"* criteria set by the European Commission.

The *"Allocation, Cut-off, EN15804"* system model follows the fundamental principles of the cut-off approach. All intermediate flows are classified into three categories: allocatable product, recyclable, and waste. Their classification determines their allocation method within the modelling framework. Similar to the *"Allocation, Cut-off by Classification"* system model, the producer of waste bears the full burden of waste treatment ("polluter pays"). Recyclable outputs, when used, are burden-free for the user.

The main differences between the *"Allocation, Cut-off, EN15804"* system model and the *"Allocation, Cut-off by Classification"* system model are as follows:

- **Cut-off point:** The boundary between primary and secondary systems is defined and adjusted according to the end-of-waste criteria of EN15804&A2:2019. Following this guidance, the cut-off point in some supply

chains has been adjusted to align with the end-of-waste criteria. In these cases, the product classifications (i.e. allocatable product, recyclable, waste) have been modified, when necessary, to align with the new cut-off point. Further processing that may be required after the material has reached its end-of-waste state no longer belongs to the primary system.

- **Inventory indicators:** The indicators required in EPDs are provided at both the LCI and LCIA levels. The *"Allocation, Cut-off, EN15804"* system model provides LCI and LCIA indicators describing resource use, waste categories, and output flows, and information on biogenic carbon content, aligning with EN15804&A2:2019.

4.3.1 End-of-waste state and cut-off

In LCA supporting Environmental Product Declarations (EPDs), the system boundary in compliance with EN15804&A2:2019 is defined with reference to the "end-of-waste" state. The set of indicators reported in EPDs relates to non-elementary exchanges crossing this boundary, which may be either inputs to or outputs from the studied system. In the *"Allocation, Cut-off, EN15804"* system model, the cut-off point follows the "end-of-waste" criteria.

4.3.1.1 End-of-waste state

Based on the definition of EN15804 and the EU's Waste Framework Directive (European Commission 2008), a material reaches its end-of-waste state when:

- the recovered material, product or construction element is commonly used for specific purposes;
- a market or demand, identified e.g. by a positive economic value, exists for such a recovered material, product or construction element;
- the recovered material, product or construction element fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products;
- the use of the recovered material, product or construction element will not lead to

overall adverse environmental or human health impacts.

Waste treatment processes are in general part of the primary product system, based on the "polluter pays" principle. Further processing that may be required after the material has reached its end-of-waste state does not belong to the primary system. For example, in the *"Allocation, Cut-off, EN15804"* system model, recycling activities of metals at the refinery or the remelting furnace are beyond this end-of-waste state. Materials for recycling, materials for energy recovery and exported energy are calculated on the amounts "leaving the system boundary when they have reached their end-of-waste state".

In real-world practice, the exact point at which a material flow passes the end-of-waste state is determined on a case-by-case basis, in many cases depending on when a specified composition or properties are achieved. Where recycled materials that have not reached the end-of-waste state are mixed with raw materials that undergo chemical transformation in a process that produces a single product, allocation of other process inflows and outflows between treatment of the waste and product manufacture also requires case-by-case treatment, if possible. Such case-by-case treatment is not possible in a generic database; therefore, assumptions are made in HiQLCD.

4.3.1.2 End-of-waste state in "Allocation, Cut-off, EN15804"

Based on the end-of-waste criteria mentioned above, the cut-off point in some supply chains was adjusted and by-product classifications were modified, when necessary, to align with the new cut-off point. For example, in the *"Allocation, Cut-off by Classification"* system model, "iron scrap, unsorted" is considered as recyclable, while in the *"Allocation, Cut-off, EN15804"* system model, "iron scrap, unsorted" is a waste and it is only after the sorting activity that it becomes a recyclable product, with a market for it and with properties compliant to legal technical specifications.

As a result of the modification of the cut-off point, the modelling in some datasets had to change to adapt to the new by-product classifications. For example, the reference flow of process *"Steel scrap, recycling, sorting"* in the *"Allocation, Cut-off by*

Classification" system model is "1kg Steel scrap, sorted", while in the *"Allocation, Cut-off, EN15804"* system model, the process is modified and the reference flow is set as "-1kg Steel scrap, unsorted" to meet the end-of-waste criteria (Fig. 19).

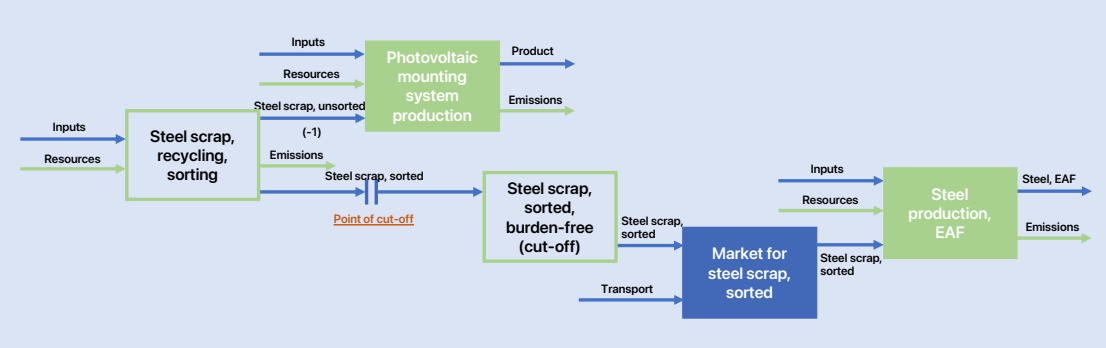


Fig. 19 Adjusted cut-off point in the EN15804 system model based on the "end-of-waste" criteria

4.3.2 Multifunctional process

The *"Allocation, Cut-off, EN15804"* system model follows the allocation rules prescribed in EN15804&A2:2019. After recyclable and waste flows are removed (shifted to the input side), the remaining allocatable products are allocated according to their defined factors. When products, such as blast furnace slag and fly ash, contribute minimally to the revenue of the activities producing them, they are not allocated any impacts from the producing activity (CEN/TC 51 2022). In this case, the consumers of these products receive them burden-free.

4.3.3 Inventory indicators

According to EN15804&A2:2019, three groups of Life Cycle Inventory indicators and biogenic carbon information are required to be declared to improve transparency of the description of the environmental performance of products. In the *"Allocation, Cut-off, EN15804"* system model of HiQLCD, the indicators describe resource use, waste categories, and output flows, and provide information on biogenic carbon content. The list below provides an overview of the LCI indicators included in the system model:

- Use of secondary material (SM)
- Renewable secondary fuels (RSF)

- Non-renewable secondary fuels (NRSF)
- Materials for recycling (MFR)
- Materials for energy recovery (MER)
- Exported energy-electricity (EEE)
- Exported energy-heat (EET)
- Use of renewable primary energy resources used as raw materials (PERM)
- Use of non-renewable primary energy resources used as raw materials (PENRM)
- Use of renewable primary energy excluding renewable primary energy resources used as raw materials (PERE)
- Use of non-renewable primary energy excluding renewable primary energy resources used as raw materials (PENRE)
- Total use of renewable primary energy resources (PERT)
- Total use of non-renewable primary energy resources (PENRT)
- Net use of fresh water (FW)
- Hazardous waste disposed (HWD)
- Non-hazardous waste disposed (NHWD)
- Intermediate and low-level radioactive waste disposed (ILLRW)
- High-level radioactive waste disposed (HLRW)
- Biogenic carbon content in product (BCCP)
- Biogenic carbon content in accompanying packaging (BCCAP)

In HiQLCD, the calculation of inventory indicators follows a hybrid methodology adapted from the ecoinvent implementation framework(Sonderegger T. and Stoikou N. 2023; Ioannidou D. et al. 2021). Specifically, these indicators are derived through two distinct approaches depending on the category: some are calculated using specific "elementary flows" via a characterization-like method (similar to LCIA), while others are derived directly from physical "flow properties" (e.g., biogenic carbon content).

To model these indicators, elementary flows and properties have been used, depending on whether the indicator is a characteristic respectively of the process (e.g. use of secondary material) or the product (e.g. biogenic carbon). For instance, the carbon

content is calculated based on "Flow Properties" rather than being an independent inventory flow. Specifically: (1) For biogenic carbon content in product (BCCP): It is calculated using the "Carbon content, non-fossil" property of the product flow, which is pre-defined. (2) For biogenic carbon content in accompanying packaging (BCCAP): It is derived from the "Carbon content, non-fossil" properties of the specific packaging material inputs/outputs (intermediate flows), combined with mass balance calculations. The indicators are calculated considering the cut-off point defined in the previous paragraph. For example, the resource output flows are calculated on the amounts “leaving the system boundary when they have reached their end-of-waste state.” (Fig. 20)

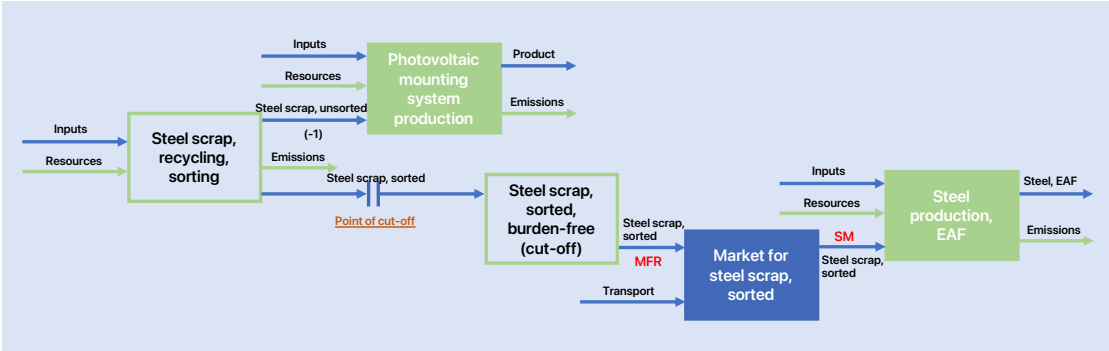


Fig. 20 Flows that are considered in the calculation of the two indicators: materials for recycling (MFR) and use of secondary material (SM)

5. REVIEW AND DOCUMENTATION

5.1 Review procedures and quality assurance

HiQLCD has set up a review and validation procedure within its database management scheme for quality assurance based on the two quality check layers:

1) Internal Quality Checks: Acting as the primary filtration mechanism, this layer involves iterative reviews by the development team and strategic academic partners. Its goal is to resolve technical errors, ensure model robustness, and verify methodological consistency before the data is finalized.
2) External Quality Checks: Serving as the final gatekeeper, this layer involves independent third-party auditing bodies. Its purpose is to provide an objective assessment of the database's transparency and representativeness, ensuring it meets international standards without bias.

The detailed procedures and roles within these two layers are described below.

Internal quality checks：

- **First-party internal review**: The first-party internal audit team is drawn from the database development team, with the audit scope primarily covering data quality and model integrity.
- **Second-party internal review**: The second-party internal audit team consists of audit experts, with the audit scope focusing on sector-specific reviews and the scientific robustness of the models. Depending on the type of data and its intended use, the specific domain of expertise, and whether the data originates from internal or external sources and/or institutions, our partners (such as the Tiangong team at Tsinghua University, the Chinese Academy of Sciences, as well as other academic and industry experts), or independent organizations, will provide a second round of quality review. The selection process is flexible and needs-driven. The number of reviewers is determined by the complexity of the dataset and the specific industrial domain involved. The primary criterion is to ensure that sufficient

domain expertise is secured to validate the technical accuracy of the data. Therefore, we invite as many relevant experts as necessary to ensure a robust review, without a pre-defined numerical cap.

A checklist of general aspects (including technical information, balance checks, and plausibility checks) has been prepared (**available in 3.1.2**) for the collected data and the unit process to ensure the data quality requirements.

In the rationality check, the basic principle is to avoid excessively high or low values and/or missing emissions. Therefore, plausibility and error checks must be carried out not only at the unit process level but also at the supply chain level. These plausibility and error checks are critically discussed and optimized together with internal LCA experts, industrial clients, and our academic cooperation partners.

For typical processes/products, representative emission data are available from standards, industry research reports, peer-reviewed publications, and other databases. These indicators are used to cross-check and compare similar processes. New or updated data in HiQLCD are double-checked by the data developer against existing or comparable datasets on a case-by-case basis.

The audit focus differs between the first-party internal audit and the second-party internal audit. The first-party internal audit covers four aspects, while the second-party internal audit covers three aspects, as shown in the table below.

Table 5.1 First-party internal review

	Content	Description	Purpose
Data Quality Control	Background data selection	Whether the data sources are reliable and consistent with the system boundaries and technological processes; and whether the geographical, temporal, and technological representativeness is sufficient	Ensure that the background data are representative and consistent
	Data and unit consistency	Whether background data and foreground data are harmonized, and whether units and	Ensure consistency and accuracy of calculation results

		measurement methods of material and energy flows are consistent	
	Data completeness	Whether all inputs/outputs are fully covered; avoid omissions of key flows	Ensure data completeness within the system boundary
	Data accuracy and precision	Whether the data sources are reliable, the margin of error is acceptable, and the measurement methods are accurate	Improve data reliability and reduce systematic bias
	Uncertainty analysis	Whether the uncertainty analysis and sensitivity analysis of impacts are sufficient and reasonable	Ensure stability and transparency of results
Scientific Validity and Rationality of Models	System boundaries	Whether system boundaries are comprehensively defined and clearly described	Ensure that the product system is fully covered
	LCI modelling methodology	Whether the modelling process follows LCA principles; whether parameter settings, formulas, and logical relationships are scientifically sound	Ensure modelling is theoretically valid and can be verified
	Mass and energy balance	Whether quality, energy, and elements are conserved; whether input/output substances are reasonably balanced	Avoid omissions of key input/output flows, false emissions, or overestimation of energy efficiency
	Functional Unit / Declared Unit	Whether functional units or declared units are clearly defined; whether they comply with ISO standards, industry guidelines, or PCR requirements	Ensure comparability
Model Completeness	Emission profiles and cut-off points	Whether there are unmodelled emissions, unlinked upstream/downstream processes, or omissions of transport/waste treatment, etc.	Ensure model completeness and coverage of the life cycle
	Energy and resource output modelling	Whether co-products such as surplus heat, steam, or electricity are included; whether energy recovery or material recycling inputs are reasonably modelled	Ensure complete representation of system inputs and outputs, and avoid overestimation of benefits
Database Documentation	Data source referencing	Whether each dataset has a clearly identified provider or	Ensure clarity of data sources to facilitate

		defined responsibility	traceability and accountability
	Nomenclature consistency	Whether the names of various materials, energy flows, and processes comply with a unified nomenclature	Ensure consistency across datasets to avoid ambiguity and duplication
	Systematic documentation of resource flows, emission flows, and energy flows	Whether resource inputs, emissions, and energy flows are completely recorded, and whether the units and attributes are clearly specified	Enhance data transparency to ensure balance and comparability
	Background description, data sources, and references for each process	Whether necessary background information and reliable references are provided for each process	Ensure data transparency and scientific validity to facilitate verification and reuse
	Referencing style consistency	Whether the documentation and data citation formats are consistent and compliant with standards	Ensure consistency across datasets to facilitate academic and industry referencing

Table 5.2 Second-party internal review

	Content	Description	Purpose
Data Quality Control	Background data selection	Whether data sources are reliable; whether system boundaries and data flows (location, time, technical representativeness) are appropriate	Ensure that the background data are representative and consistent
	Data and unit consistency	Whether background data and foreground data are harmonized, and whether units and measurement methods of material and energy flows are consistent	Ensure consistency and accuracy of calculation results
	Data completeness	Whether input/output flows are fully covered, avoiding omissions of key data or boundary gaps	Avoid system boundary “leakage” and ensure completeness
	Data accuracy and precision	Whether the data sources are reliable, the margin of error is acceptable, and the measurement	Improve data reliability and reduce systematic bias

		methods are accurate	
	Uncertainty analysis	Whether uncertainty and sensitivity analyses have been conducted	Ensure stability and transparency of results
	Technological status (advanced / conventional / mature / pilot / laboratory)	Whether the model accurately reflects the industrial level or the research and development stage	Ensure that the model is closely aligned with reality
	Process integration	Whether the process is an independent unit or embedded within other process systems	Clearly define the system boundaries and the scope of modelling
	Calculation (average value or specific value)	Whether the data represent industry averages or specific values from enterprises/installations	Ensure methodological transparency and result comparability
	Critical processes	Whether the main production steps are accurately represented at the modelling level	Ensure that the modelling covers the core processes.
	Types and quantities of reactants/products	Whether the inputs/outputs are complete and reasonable, and whether the units are consistent	Ensure material balance and accuracy
	Chemical reaction efficiency and yield	Whether the reaction pathway is consistent with theory and practice, and whether the yield is realistic	Avoid overestimation or underestimation of efficiency
	By-products, wastes, and residues	Whether their destinations (recycling/treatment/emission) are modelled	Avoid missing environmental emissions
	Looping flows (e.g. internal recycled materials)	Whether they are included within the system boundary and whether the pathways are complete	Ensure completeness of material circulation
	Auxiliary materials and utilities	Whether auxiliary inputs such as steam, water, and electricity are modelled	Ensure comprehensive coverage of system inputs
	End-of-pipe treatment	Whether end-of-pipe control inputs such as lime and ammonia are realistic and reasonable	Ensure the credibility of pollution control processes
Scientific Validity and Rationality of Models	Technological status and process logic	Whether the model reflects actual processes or industry average levels, and whether the process is realistic and representative	Ensure that the model is realistic and representative
	Industry-specific allocation methods	Whether industry-common allocation methods (e.g., co-product treatment in the steel	Ensure that the methodology complies with industry standards

		industry) have been correctly applied	and avoids bias
	Appropriateness of substitution assumptions	Whether substitution modelling is consistent with industry logic, e.g., whether recycled aluminium substitutes primary aluminium.	Avoid misleading mitigation effects and maintain scientific validity
	Co-product and system expansion modelling	Whether the allocation/substitution of co-products has been considered, and whether system expansion is applied appropriately	Reduce system bias and prevent misleading results
	Energy balance (LHV/HHV)	Whether the model correctly represents all energy inputs (electricity, heat, fuels)	Avoid omissions or overestimation of energy efficiency
	Mass balance	Whether inputs equal outputs, and whether total mass is conserved	Prevent data omissions or falsifications
	Element balance (carbon / metals, etc.)	Whether key elements are conserved and whether recycling flows are modelled	Ensure element conservation and recycling
	Chemical reaction equations	Whether the reaction equations are balanced and consistent with actual processes	Ensure mass and energy conservation
	Modelling methods for waste and recycled materials	Whether waste is incorrectly modelled as primary material, and whether recycling processes reflect industry practices	Avoid underestimation or overestimation of the environmental burdens associated with recycling
Abnormal data review	Functional unit	Whether the functional unit is clearly defined and compliant with ISO standards	Ensure comparability
	System boundary integrity	Whether upstream processes (e.g., resource extraction) are connected and discontinuities are avoided	Ensure full life cycle coverage
	Fuel modelling defects	Whether only fuel inputs are modelled while combustion emissions are ignored	Avoid underestimation of GHGs
	Transport modelling	Whether transport distances represent actual or typical conditions	Avoid underestimation / overestimation of transport impacts
	Substitution	Whether recycling or co-product modelling is reasonable	Avoid misleading benefits
	Wastewater treatment	Whether wastewater and its treatment are modelled	Prevent omission of water-related impacts
	Secondary material	Whether recycled materials are	Avoid biased results

	modelling	mistakenly treated as “burden-free”	
	Co-product allocation / system expansion	Whether allocation or system expansion is applied appropriately	Avoid introduction of irrelevant functions
	Energy outputs	Whether steam, residual heat, electricity, etc. are correctly modelled	Ensure reasonable energy efficiency
	Waste / residue treatment	Whether impacts are overestimated, or recycled materials are incorrectly modelled as primary materials	Ensure modelling rationality

External quality checks：

External review is conducted by an independent external auditing body or company. The external review of the database involves three roles:

- The HiQLCD team: Responsible for providing all necessary information, responding to review comments, and ensuring that content is updated in accordance with the quality assurance procedures.
- Independent external review experts: Composed of the audit team from the external auditing body/company, responsible for evaluating the data sources of the database model, the modelling methodology, and the documentation quality. They perform checks based on independent samples and provide discussions and feedback to the original data team.
- Internal Quality Assurance team of HiQLCD: Implements a multi-level quality control process, including responding to issues, updating the database, and re-review by experts.

The external review of an LCI database focuses on five aspects: methodological consistency, pathway consistency, data completeness, geographical representativeness, and accuracy of classification and activity types, as shown in the table below.

Table 5.3 External review

	Content	Description
Methodological consistency	Consistency	Verify whether the model complies with database modelling guidelines and ISO 14044 requirements, especially regarding allocation, system boundaries, cut-off rules, and consistency of LCIA method application
	Compatibility with the LCIA methods	Check whether data items correspond to LCIA methods (e.g., EF3.1, ReCiPe, CML), ensuring applicability for subsequent impact calculation
Pathway Consistency	Consistency of supply chain modelling pathway	Verify whether products or activities are fully traced back to raw material extraction or primary energy; missing links may cause system incompleteness or underestimated impacts
	Consistency of background data referencing	Ensure that electricity, transport, fuels, and other background data are referenced from the same version of the database, with consistent sources
	Consistency of technical pathway logic	Verify whether modelling steps (e.g., reactions, separations, treatments) form a continuous technical chain without skipped steps or illogical process links
Data Completeness	Mass and energy balance	Check whether inputs and outputs are balanced (e.g., total mass/energy before and after allocation), and whether abnormal losses or missing data exist
	Completeness of flow coverage	Verify whether all major raw materials, energy, water, emission flows, co-products, by-products, and waste flows are included
	Completeness of metadata	Ensure that each dataset contains complete metadata, including units, time, region, technology description, data sources, and modelling assumptions
	Completeness of emissions and waste flows	Verify whether key emissions and waste flows such as CO_2, NOx, wastewater, and solid waste are fully represented, including their treatment processes
Geographical compliance	Regional representativeness	Verify whether the dataset corresponds to the actual background of the target region (e.g., electricity mix, technical pathways, regulatory requirements)
	Consistency of regional flows	Ensure that the selected background processes (e.g., transport, electricity) are consistent with the target region and avoid using “default global” data
	Cross-regional treatment consistency	Whether the allocation of data involving multiple countries or regions has been handled appropriately, and whether the modelling logic of export/import processes is consistent
Accuracy of classification and activity	International classification consistency	Whether the classification assigned to the dataset corresponds to the represented technological activity, avoiding classification errors that may affect data

type	(ISIC/NACE)	filtering and allocation
	Accuracy of activity type labelling	Whether the dataset is accurately labelled as “energy”, “material”, “process”, etc., to ensure correct identification within the system
	Rationality of industry classification logic	Check whether the dataset is assigned to the correct industry review team or activity scope, avoiding mismatches in professional alignment

Reviewer qualifications:

- Domain Expert: requires at least 5 years of professional experience, with deep proficiency in specific industry technologies, production routes, and environmental impact assessment, and the ability to analyze complex datasets.
- LCA Expert: requires 5 years of specialized experience in LCA, with a solid theoretical foundation, familiarity with the products or processes involved in the database, and the ability to effectively identify technical issues or inconsistencies in the dataset.

Each dataset in HiQLCD undergoes a comprehensive review process involving both internal and external review. Typically, the review is conducted by a paired team consisting of at least one LCA expert and one domain expert.

5.2 Nomenclature

Consistent nomenclature is an essential aspect of the database quality. To ensure standardization, the nomenclature used in HiQLCD is primarily based on the guidance of the ILCD Handbook (JRC 2010c), ensuring general consistency with international standards. Consequently, any database object, including impact characterization factors, flow properties, flows, and processes, must be properly named. If a new process or a new flow is created because it is not available in the database, consistency with existing activities or flows will be kept.

5.2.1 Process nomenclature

The process nomenclature of HiQLCD encompasses 11 critical dimensions: product

name, technological pathways/process routes, material/composition, shape/physical state, specifications (quantitative), application scope, fuel type, product quality (qualitative), standards, sources, and supplementary annotations. This structured nomenclature enables precise characterization of activities and unambiguous differentiation between distinct processes.

All dimensions are equally essential and mutually reinforcing, collectively forming an integrated descriptive framework. For instance, a process name may be formulated as: "*Single-Si photovoltaic cell; TOPCon technology; N-type; 210mm*210mm*". This example demonstrates how multidimensional descriptors explicitly capture critical production characteristics and provides a detailed information foundation for dataset.

Dimension definitions:

- **Product name**: Specific output product or service associated with the activity.
- **Technological Pathway/Process Route**: Technology or process associated with the production or service.
- **Material/composition**: Materials or ingredients of the product.
- **Shape/physical state**: Final product morphology (solid, liquid, gas) or geometric configuration (sheet, tube, wire).
- **Specifications (quantitative)**: Critical parameters (e.g. diameter, length, power ratings) for product.
- **Application scope**: Function scenarios of the product (e.g. agriculture equipment, industrial equipment).
- **Fuel type**: The type of fuel used in production, especially for power generation, equipment, and transportation.
- **Product quality (qualitative)**: Quality characteristics or grade of the product, such as high density, no impurities, food grade, etc.
- **Standard**: Regulations or standards met by product or service (e.g. CN IV, CN V for vehicles).
- **Source**: Feedstock origins of product (virgin/recycled, biomass/fossil-based source).
- **Supplementary annotations**: Information that cannot be classified into other

dimensions but is very important for products.

5.2.2 Flow nomenclature

The flows in HiQLCD are arranged in a hierarchy for storage, which is structured according to technical aspects (for non-elementary flows and natural resources) and according to emission compartments air, water and soil.

In general, all relevant LCI elementary flows (resources and emissions) in HiQLCD are pre-defined. Therefore, the number of elementary flows that must be newly defined by the user is few to none.

Flow name structure consisting of a basic name and additional fields for further specifying flow information, which is mainly used for product and waste flows.

- **Basic name**: A general descriptive name that conforms to commonly used industrial terminology. Abbreviations should only be employed if they are already widely accepted and recognized.
- **Additional fields**: Materials/ingredients, content, or other parameters which reflect the properties possessed by the product itself (e.g. Iron ore, 45%Fe).

5.3 Documentation of flows

The documentation of flows is an important component of the inherent documentation of processes and LCI results. Flow documentation is an integral part due to the direct influence of the flow properties to the results of LCI and LCIA.

A customized nomenclature is applied in HiQLCD. These flows are named using a structured format to precisely reflect the specific characteristics of the Chinese supply chain.

Flows in HiQLCD are (if suitable) documented by:

- Reference quantity
- Flow name and synonyms
- Classification
- Type (allocatable product, recyclable product, waste)
- CAS number

- Flow properties
- Chemical formula (if suitable)
- Field for general comments to add further information

5.4 Documentation of datasets

HiQLCD strictly adopts the International Life Cycle Data System (ILCD) format (JRC 2010a) as the underlying data structure to facilitate international data exchange. The ILCD format was developed by the European Commission and aims to facilitate the exchange of LCI/LCA datasets through an international standardized data format.

For each aggregated LCI dataset, we provide a broad list of process meta data that describe the process, modelling approaches and validation, administrative information, and the inputs and outputs for the respective aggregated process. Additionally, to the process meta data, flow meta data, flow properties, unit group data, sources data, and contact data are provided for each aggregated LCI dataset.

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Annex A: Dataset Allocation Information

Process name	**System model**	**Co/By-product**	**Flow property selected for allocating**
Petroleum and gas production, thickened oil field<70%, Hot Water Flooding (HWF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum; Natural gas, high pressure	Calorific Value
Petroleum and gas production, thickened oil field 70%~80%, Hot Water Flooding (HWF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum; Natural gas, high pressure	Calorific Value
Petroleum and gas production, thickened oil field>80%, Hot Water Flooding (HWF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum; Natural gas, high pressure	Calorific Value
Petroleum and gas production, thickened oil field<70%, Steam Flooding (SF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum; Natural gas, high pressure	Calorific Value
Petroleum and gas production, thickened oil field 70%~80%, Steam Flooding (SF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum; Natural gas, high pressure	Calorific Value
Petroleum and gas production, thickened oil field>80%, Steam Flooding (SF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum; Natural gas, high pressure	Calorific Value

Petroleum and gas production, low permeability oil field<80%, Water Flooding (WF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, low permeability oil field 80~90%, Water Flooding (WF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, low permeability oil field>90%, Water Flooding (WF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, low permeability oil field<80%, Gas Flooding (GF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, low permeability oil field 80~90%, Gas Flooding (GF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, low permeability oil field>90%, Gas Flooding (GF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, thickened oil field<70%, Hot Water Flooding (HWF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value

Petroleum and gas production, thickened oil field 70~80%, Hot Water Flooding (HWF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, thickened oil field>80%, Hot Water Flooding (HWF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, thickened oil field<70%, Steam Flooding (SF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, thickened oil field 70~80%, Steam Flooding (SF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, thickened oil field>80%, Steam Flooding (SF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, low permeability oil field<80%, Water Flooding (WF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, low permeability oil field 80~90%, Water Flooding (WF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value

Petroleum and gas production, low permeability oil field>90%, Water Flooding (WF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, low permeability oil field<80%, Gas Flooding (GF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, low permeability oil field 80~90%, Gas Flooding (GF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, low permeability oil field>90%, Gas Flooding (GF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, thickened oil field, Hot Water Flooding (HWF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, thickened oil field, Steam Flooding (SF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, low permeability oil field, Water Flooding (WF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value

Petroleum and gas production, low permeability oil field, Gas Flooding (GF), offshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, thickened oil field, Hot Water Flooding (HWF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, thickened oil field, Steam Flooding (SF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, low permeability oil field, Water Flooding (WF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Petroleum and gas production, low permeability oil field, Gas Flooding (GF), onshore	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Petroleum；Natural gas, high pressure	Calorific Value
Renewable diesel, made from animal fat	Allocation, Cut-off by Classification; Allocation, Cut-off, EN15804	Renewable diesel; Meat and bone meal	Calorific Value
Diesel, coal-based synthesis	Allocation, Cut-off by Classification; Allocation, Cut-off, EN15804	Diesel; Liquefied natural gas; Sulfur; Liquefied petroleum gas; Naphtha	Calorific Value
Biodiesel, made from animal fat	Allocation, Cut-off by Classification;	Biodiesel; Meat and bone meal	Calorific Value

	Allocation, Cut-off, EN15804		
Methanol, made by coke oven gas	Allocation, Cut-off by Classification; Allocation, Cut-off, EN15804	Methanol; Steam, low pressure	Calorific Value
1,3-Butadiene, one-step process	Allocation, Cut-off by Classification; Allocation, Cut-off, EN15804	Butadiene; Butene; Ethylene; Acetaldehyde; Propylene; Hydrogen	Calorific Value
1,3-Butadiene, two-step process	Allocation, Cut-off by Classification; Allocation, Cut-off, EN15804	Butadiene; Butene; Ethylene; Propylene; Hydrogen	Calorific Value
Iron concentrate, three-stage closed-circuit crushing- two-stage grinding- two-stage creening- three-stage magnetic separation- one-stage filtration, TFe 64%	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Magnetite concentrate；Titanium concentrate	Iron content; Titanium content
Iron concentrate, dry tailing disposal, wet magnetic separation, TFe 60%	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Magnetite concentrate；Titanium concentrate	Iron content; Titanium content
Vanadium-titanium magnetite, wet tailing disposal - magnetic separation - flotation, iron concentrate, TFe 60%	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Magnetite concentrate；Titanium concentrate	Iron content; Titanium content
Vanadium-titanium magnetite, three-stage crushing - semi-autogenous grinding - ball milling - tower milling - multi-stage magnetic separation iron concentrate process, iron concentrate, TFe 57%	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Magnetite concentrate；Titanium concentrate	Iron content; Titanium content
Iron concentrate, dry selection - grinding - magnetic flotation	Allocation, Cut-off by Classification;	Magnetite concentrate；	Iron content; Copper

combined beneficiation process, TFe 63.5%	Substitution, Consequential; Allocation, Cut-off, EN15804	Hematite concentrate; Copper concentrate	content
Premium thermal coal, medium thermal coal, dry cleaning of coal	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium thermal coal; Medium thermal coal	Calorific Value
Premium thermal coal, medium thermal coal, coal jigging	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium thermal coal; Medium thermal coal	Calorific Value
Premium thermal coal, medium thermal coal, heavy medium coal preparation	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium thermal coal; Medium thermal coal	Calorific Value
Premium thermal coal, medium thermal coal, coal flotation	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium thermal coal; Medium thermal coal	Calorific Value
Premium thermal coal, medium thermal coal, integrated coal preparation by jigging and heavy medium	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium thermal coal; Medium thermal coal	Calorific Value
Premium thermal coal, medium thermal coal, integrated coal preparation by jigging and flotation	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium thermal coal; Medium thermal coal	Calorific Value
Premium thermal coal, medium thermal coal, integrated coal preparation by heavy medium and flotation	Allocation, Cut-off by Classification; Substitution, Consequential;	Premium thermal coal; Medium thermal coal	Calorific Value

	Allocation, Cut-off, EN15804		
Premium thermal coal, medium thermal coal, integrated coal preparation by heavy medium, jigging and flotation	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium thermal coal; Medium thermal coal	Calorific Value
Premium coking coal, medium coking coal, coal jigging	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium coking coal; Medium coking coal	Calorific Value
Premium coking coal, medium coking coal, heavy medium coal preparation	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium coking coal; Medium coking coal	Calorific Value
Premium coking coal, medium coking coal, integrated coal preparation by jigging and flotation	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium coking coal; Medium coking coal	Calorific Value
Premium coking coal, medium coking coal, integrated coal preparation by heavy medium and flotation	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium coking coal; Medium coking coal	Calorific Value
Premium coking coal, medium coking coal, integrated coal preparation by heavy medium, jigging and flotation	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium coking coal; Medium coking coal	Calorific Value
Premium coal, medium coal, coal jigging	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium coal; Medium coal	Calorific Value

Premium coal, medium coal, heavy medium coal preparation	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium coal; Medium coal	Calorific Value
Premium coal, medium coal, integrated coal preparation by jigging and flotation	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium coal; Medium coal	Calorific Value
Premium coal, medium coal, integrated coal preparation by heavy medium and flotation	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium coal; Medium coal	Calorific Value
Premium coal, medium coal, integrated coal preparation by heavy medium, jigging and flotation	Allocation, Cut-off by Classification; Substitution, Consequential; Allocation, Cut-off, EN15804	Premium coal; Medium coal	Calorific Value

Annex B: Abbreviations

BOF	Basic Oxygen Furnace
CAS	Chemical Abstracts Service
CED	Cumulative Energy Demand
CN	China
DQI	Data Quality Indicator
EAF	Electric Arc Furnace
EPD	Environmental Product Declaration
EU	European Union
ILCD	International Life Cycle Data system
IPCC	The Intergovernmental Panel on Climate Change
ISO	International Organization of Standardization
ISIC	International Standard Industrial Classification
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LT	Long-Term Emission
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne
PCF	Product Carbon Footprint
PCR	Product Category Rule
UNEP	United Nations Environment Programme
UUID	Universally Unique Identifier