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**China Automotive Life Cycle  
Database ( CALCD 3.0 )  
Instruction Manual**

October, 2025

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## Foreword

Life Cycle Assessment (LCA) is a highly data-intensive approach requiring extensive foundational data across multiple layers. The quality of data is a critical prerequisite for automotive LCA, as its reliability directly influences the credibility and functionality of LCA outcomes. Historically, China's automotive industry has drawn upon international LCA databases. However, notable disparities in resource and environmental baselines, as well as production technologies, have led to significant discrepancies in assessment results. To bolster accuracy and credibility in automotive LCA while minimizing dependency on external databases, Automotive Data Center, under the direction of MIIT, MEE, and CNCA, has developed the China Automotive Life Cycle Database (CALCD). CALCD is a process-oriented, industry-representative database reflecting the average performance of China's automotive sector. It encompasses essential process models, critical product datasets, major automotive components, and key manufacturing processes. CALCD serves as a foundational resource for LCA studies, green design product submissions, China Eco-Car certification, and low-carbon initiatives within China's automotive industry.

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# 1 Overview

## 1.1 General Information

Automotive Data Center, as an authoritative third-party organization in the automotive industry, has been committed to promoting the application of Life Cycle Assessment (LCA) methodology within the sector. Since 2012, under the guidance of the Ministry of Industry and Information Technology (MIIT), the Certification and Accreditation Administration of China (CNCA), and other relevant authorities, Automotive Data Center has carried out the construction of the automotive life cycle assessment system. It has developed the authoritative China Automotive Life Cycle Database (CALCD), which includes core models of China's basic processes and products, key automotive components, manufacturing processes, and more. The database comprises carbon footprint data for over 8,000 vehicle models, 242 types of component manufacturing (excluding materials), 242 types of component manufacturing (including materials), 42 categories across 11 types of process emissions, and approximately 140 types of basic energy and material emissions. With a reference sample total of about 42,000 data entries, the database provides critical data support for life cycle assessment research in the automotive industry.

## 1.2 Background and Benefits

Life Cycle Assessment (LCA), as an international standard method for systematically and quantitatively evaluating the comprehensive environmental impact of products, provides a consistent analytical framework and environmental data support for relevant decision-making processes. It has been widely applied worldwide. The quality of data is the primary constraint on the application of the LCA method. The CALCD database is established based on actual production processes and represents the average level of China's automotive industry. This document aims to elaborate on the data quality information of the China Automotive Life Cycle Database, including data scope, data sources, data quality control, and data review, to better support the application of the LCA method in the automotive industry, including:

- ✓ Supporting environmental policy implementation: Studies on vehicle carbon footprints, carbon neutrality benchmarks, and regulatory frameworks;
- ✓ Application of Corporate Environmental Strategy: Corporate Carbon Peak and Carbon Neutrality Strategic Planning;
- ✓ Application of Product Development and Procurement: Ecodesign and Green Product Development Based on LCA;
- ✓ Consumer Decision: Eco-friendly Vehicle Certification, Carbon

Footprint Certification, Promoting Green and Low-carbon Vehicle Consumption.

## 2 Scope of Data

### 2.1 Environment Burden

The environmental burden refers to the resource consumption, energy consumption, and emissions to air, water, soil, and solid waste, as well as intangible data, during the production processes of materials and energy. Significant variations in environmental load exist depending on the type of material and energy production, primarily including but not limited to:

➤ Energy Consumption: Primary energy (coal, oil, natural gas), other energy sources or energy carriers;

➤ Resource Consumption: Consumption of ferrous metals such as iron and manganese, non-ferrous metals such as copper, aluminum, and lead-zinc, non-metallic resources such as limestone and gypsum, water resource consumption, and land resource occupation and utilization;

➤ Carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), particulate matter (PM<sub>10</sub>, PM<sub>2.5</sub>), hydrogen sulfide (H<sub>2</sub>S), sulfur oxides (SO<sub>x</sub>), non-methane volatile organic compounds (NMVOC), ammonia (NH<sub>3</sub>), nitrogen oxides (NO<sub>x</sub>), dimethyl sulfide (DMS), sulfur dioxide (SO<sub>2</sub>), radioactive inert gases, radioactive aerosols, exhaust gases, fluorides, cadmium (Cd), chromium (Cr), mercury (Hg), copper (Cu),

nickel (Ni), lead (Pb), arsenic (As), zinc (Zn), vanadium (V), soot, sulfur hexafluoride (SF<sub>6</sub>), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), etc..

➤ **Water Pollutants:** Suspended solids, petroleum hydrocarbons, fluorides, sulfides, ammonia nitrogen, nitrogen, phosphorus, fluoride ions, chromium, hexavalent chromium, cadmium, lead, copper, zinc, nickel, manganese, iron, mercury, silver, arsenic, cyanides, volatile phenols, chemical oxygen demand (COD), biochemical oxygen demand (BOD), benzene, polycyclic aromatic hydrocarbons (PAHs), etc..

➤ **Solid waste emissions:** mining gangue, dust and sludge, radioactive solid waste, slag, fly ash, industrial waste (tailings), furnace slag, etc.

➤ **Non-material emissions:** noise, radioactive emissions, etc.

## 2.2 System Boundary

The system boundary for material production is shown in Figure 1, encompassing processes such as resource extraction, transportation, and material production.

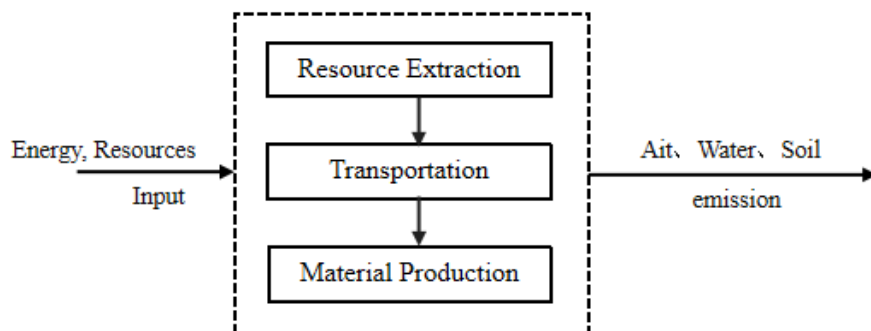


Figure 1 Material Production System Boundary

The system boundary of fuel production encompasses three aspects: the cultivation/collection phase, production, and transportation/storage and distribution phases, as shown in Figure 2. The infrastructure for fuel production is excluded from the system boundary.

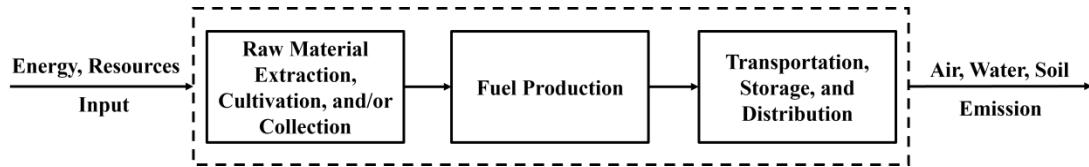


Figure 2 Fuel Production System Boundary

The production of electricity includes upstream fuel production, electricity generation in power plants, and power distribution processes. Additionally, for the energy sector, infrastructure is particularly relevant when considering certain renewable energy sources (e.g., solar energy), as most of their impacts arise from infrastructure rather than the energy generation phase. Therefore, energy production infrastructure (including electricity and fuel) is included in the scope of analysis, as shown in Figure 3.

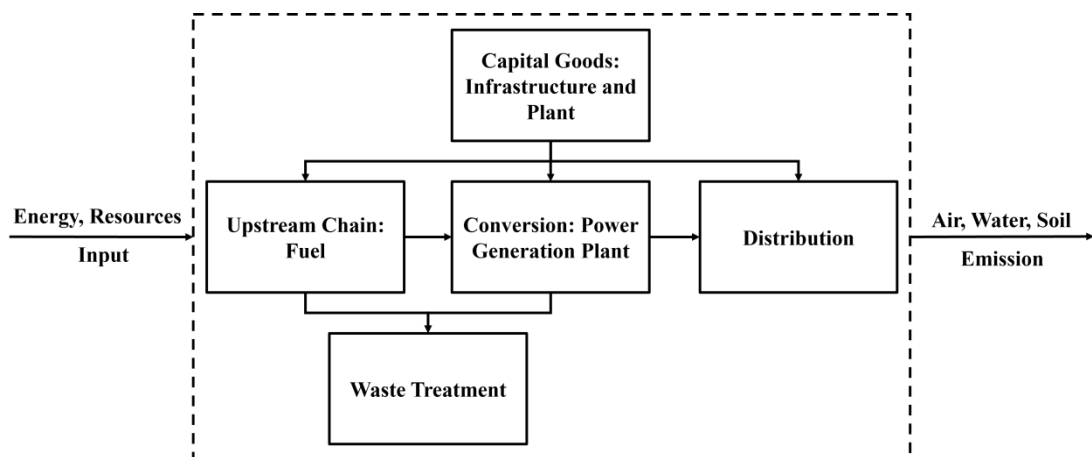


Figure 3 Electricity Production System Boundary

## 2.3 Data Name and Categorization

### 2.3.1 Material

The CALCD database covers 27 types of automotive constituent materials, as shown in Table 1.

Table 1 Automotive Material Type

Material category	Material type	Location	Name of LCI dataset
Steel	Steel and iron	CN	Steel
Cast Iron	Steel and iron	CN	Cast Iron
Aluminum and Aluminum Alloys	Light Metals	CN	Cast Aluminum Alloy (ZL109)
	Light Metals	CN	Deformed Aluminum Alloy (6061)
	Light Metals	CN	Primary Aluminum
	Light Metals	CN	Forged Aluminum Alloy (6061)
Magnesium and Magnesium Alloys	Light Metals	CN	Casting of magnesium alloy (AM60)
	Light Metals	CN	Cast Magnesium Alloy (AZ31)
Copper and Copper Alloys	Heavy Metals	CN	Copper and Copper Alloys
Platinum	Heavy Metals	CN	Platinum
Lead	Other Materials	CN	Lead
Thermoplastics	Polymers	CN	Polypropylene (PP)
	Polymers	CN	Polyethylene (PE)
	Polymers	CN	Polycarbonate (PC)
	Polymers	CN	Polyvinyl Chloride (PVC)
Duromers	Polymers	CN	Thermosetting Plastics
Rubber	Polymers	CN	Rubber
Textiles	Polymers	CN	Fabric
Ceramics/Glass	Other Materials	CN	Glass
Sulfuric acid	Other Materials	CN	Sulfuric acid
Fiberglass	Other Materials	CN	Fiberglass
Lithium Iron Phosphate (LFP)	Other Materials	CN	Lithium Iron Phosphate (LiFePO <sub>4</sub> )

Material category	Material type	Location	Name of LCI dataset
Lithium Nickel Cobalt Manganese Oxide	Other Materials	CN	Lithium Nickel Cobalt Manganese Oxide
Lithium Manganate	Other Materials	CN	Lithium Manganate
Graphite	Other Materials	CN	Graphite
Electrolyte: Lithium hexafluorophosphate	Other Materials	CN	Lithium Hexafluorophosphate
Refrigerants	Fluids	CN	Refrigerants

### 2.3.2 Fuel/Energy

The CALCD database covers 9 types of fuels/energy, including primary fuels used in vehicles and major energy sources utilized in production processes, as shown in Table 2.

Table 2 Fuel/Energy Summary Table

No.	Fuel/Energy Type
1	Gasoline
2	Diesel
3	Fuel Oil
4	Natural Gas
5	Coal
6	Steam
6.1	Low-Pressure Steam
6.2	Medium-Pressure Steam
7	Compressed Air
8	Electricity

### 2.3.3 Processing Stage

The CALCD database includes 13 automotive manufacturing processes, such as stamping, injection molding, die casting, and casting, as shown in Table 3.

Table 3 Summary Table of Automotive Processing Technologies

No.	Automotive Manufacturing Processes
<b>1</b>	Stamping
<b>2</b>	Injection Molding
<b>3</b>	Die Casting
<b>4</b>	Casting
<b>5</b>	Sewing
<b>6</b>	Hot Stamping
<b>7</b>	Powder Metallurgy
<b>8</b>	Painting
<b>9</b>	Welding
<b>10</b>	Machining
<b>11</b>	Forging
<b>12</b>	Surface Treatment
<b>13</b>	Tire Manufacturing

### 2.3.4 Transportation Process

The CALCD database includes one transportation process, comprising light truck and heavy truck transportation, as shown in Table 4.

Table 4 Summary Table of the Transportation Process

No.	Transportation Process
<b>1</b>	Road Transportation
1.1	Light-duty Truck Transportation
1.2	Heavy-duty Truck Transportation

### 2.3.5 Usage Process

The CALCD database includes vehicle maintenance and repair data, as well as fuel consumption and emission data during actual operation for both passenger and commercial vehicles, as shown in Table 5.

Table 5 The Reference Table for the Replacement Frequency of Automotive Parts

No.	Material Name	Washer fluid for applicable M1 vehicles except pure electric passenger cars	BEV
1	Tire	2	2
2	Lead Battery	2	2
3	Lubricant	29	8
4	Brake Fluid	2	2
5	Coolant	2	2
6	Refrigerant	1	1
7	detergent solution	14	14

Table 6 Fuel Consumption and Emission Data Table for Vehicle Operation

No.	Data Category	Note
1	Fuel Consumption Data	Fuel/electricity consumption data for all mass-produced models.
2	Emission Data	CO、THC、NMHC、NO <sub>x</sub> 、CO <sub>2</sub> 、CH <sub>4</sub> 、N <sub>2</sub> O、PM、PN

## 2.4 Geographical Range

The geographical scope of the data primarily covers China, while some energy inventory data is regionalized based on production, dispatch, and usage.

## 2.5 Time Range

The inventory data time is based on the following two scenarios:

(1) Process material and energy consumption data for material production and manufacturing are typically updated every 2–3 years. For materials produced using highly mature technologies, such as steel, copper, aluminum, and lead-zinc, where no breakthrough technologies have

emerged, the existing process data remain relatively stable. Consequently, the update cycle is longer, usually 5 years or more. The latest data reflects production levels as of 2021.

(2) Energy production data, updated annually, with the most recent data available for 2021.

### **3 Reference**

Global Guidance Principles For Life Cycle Assessment Database

## **4 Terms and Definitions**

### **4.1 Life Cycle**

A sequence of interrelated phases within a product system, spanning from the acquisition of raw materials from natural resources to the end-of-life disposal stage.

[GB/T 24044—2008, Definition 3.1]

### **4.2 Life Cycle Assessment, LCA**

Inventory and assessment of life cycle inputs, outputs, and associated environmental impacts of a product system.

[GB/T 24044—2008, Definition 3.2]

### **4.3 Life Cycle Inventory Analysis (LCI)**

The inventory analysis phase in life cycle assessment (LCA), where data

on inputs and outputs across the product's full life cycle is systematically compiled and quantified.

#### **4.4 Life Cycle Impact Assessment (LCIA)**

The life cycle impact assessment (LCIA) phase involves understanding and evaluating the significance of potential environmental impacts associated with a product system across its full life cycle.

#### **4.5 Functional Unit**

The functional unit represents the quantified performance of a product system to be used as a reference

[GB/T 24044—2008, Definition 3.20]

#### **4.6 Reference Flow**

The amount of process outputs necessary to achieve the function of one functional unit within the defined product system.

#### **4.7 System Boundary**

Identify which unit processes are part of the product system through a set of criteria.

[GB/T 24044—2008, Definition 3.32]

#### **4.8 Elementary Flow**

The material or energy that is extracted from the environment and enters

the studied system without undergoing any human transformation, or the material or energy that leaves the studied system and enters the environment without undergoing further human transformation.

[GB/T 24044—2008, Definition 3.32]

## **5 Methodologies and Findings**

### **5.1 Material**

#### **5.1.1 Steel**

##### **( 1 ) Functional Unit**

The functional unit of steel refers to the 1 kg steel product produced by the plant.

##### **( 2 ) Process Step Description**

The steel production process includes key stages such as iron ore mining, beneficiation, sintering, ironmaking (BF), steelmaking (BOF, EAF), and initial rolling, as well as the production processes for related auxiliary materials (metallurgical lime, metallurgical coke, ferrosilicon). It also accounts for the environmental load associated with the transportation of primary raw materials (e.g., ore, coal). However, the manufacturing of production equipment and the construction of plant infrastructure are excluded from the system boundary. Each stage provides corresponding cradle-to-gate data. Due to the insufficient supply of scrap steel in China, the proportion of EAF steel is less than 10%, and most steel materials are

produced using the long process (BF-BOF). The steel inventory is therefore calculated as an arithmetic weighted average based on the proportions of these two processes.

### ( 3 ) Data Description

#### ■ Data Sources Representative

The lifecycle data of steel mainly comes from surveys conducted at over 70 large steel plants in China. Additionally, emissions data was partially calibrated and supplemented based on the national steel industry emission standards and the first national pollution source census industrial pollution source emission factor handbook.

#### ■ □ Geographical Representative

The geographical representative of steel production is China.

#### ■ □ Time Representative

The comprehensive survey of 70 steel production enterprises began in 1998, with key data updates carried out in 2005, 2010, 2017, and 2023. The updated data primarily includes material, energy, and pollutant emission inventories. The updates mainly focus on the ironmaking and steelmaking processes, which account for over 80% of the energy consumption in the entire steel production process. Other processes, such as mining and metallurgical lime production, have also been partially updated.

#### ■ □ Technical Representative

The production technology of steel materials involves the BF-BOF process

and the EAF process, with the average technological level in China.

#### ( 4 ) Boundary

The system boundary of steel production is shown in Figure 1.

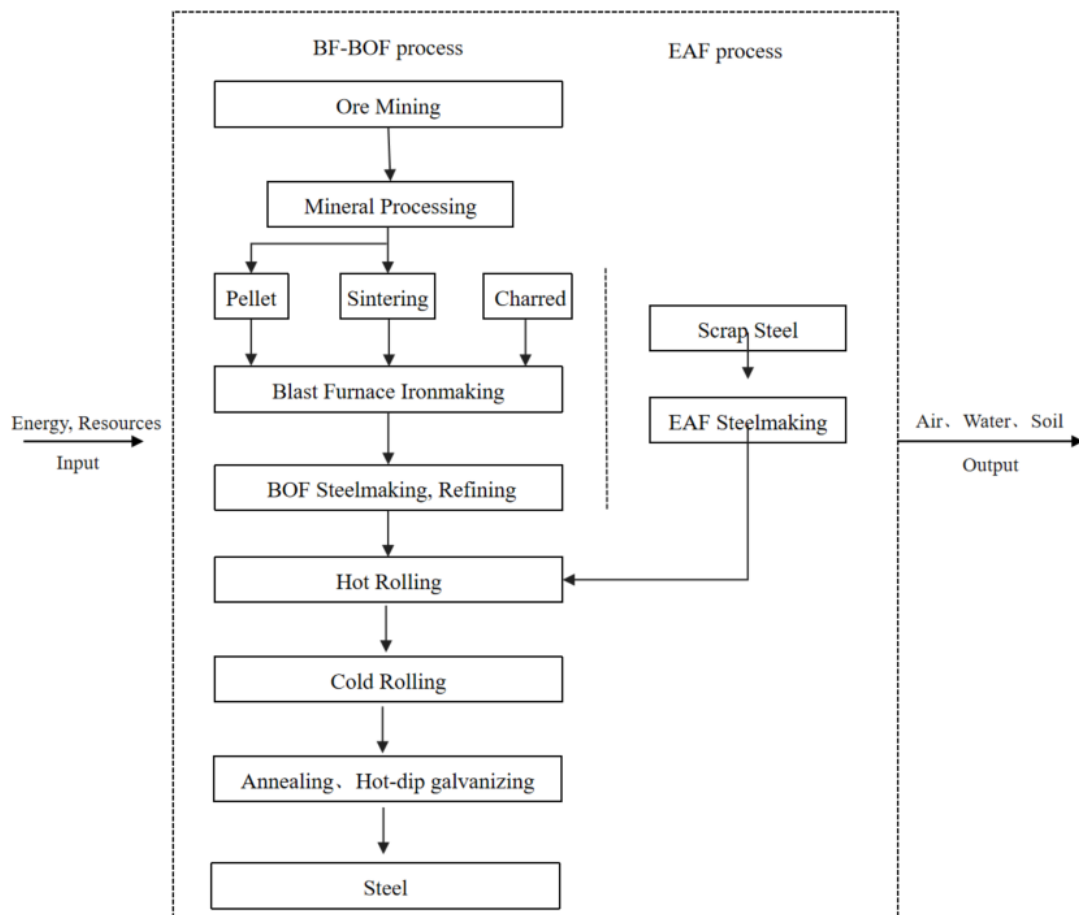


Figure 1 System Boundary of Steel Production

#### ( 5 ) Computational Models and Other Practices

The process-oriented material flow balance correlation method.

### 5.1.2 Cast Iron

#### ( 1 ) Functional Unit

The functional unit of cast iron refers to the 1 kg of cast iron product

produced by the plant.

## ( 2 ) Process Step Description

The environmental burden of the processes from iron ore mining, iron ore beneficiation, sintering, and blast furnace (BF) ironmaking, including the production of related auxiliary materials and the transportation of key raw materials (such as ores and coal); excluding the manufacturing of production equipment, plant construction, and other infrastructure from the system boundary.

## ( 3 ) Data Description

### ■ Data Sources Representative

The lifecycle data for steel primarily comes from a survey of over 70 large steel plants in China, with supplementary emissions data correction and enhancement based on the national steel industry emission standards and the first national pollution source census industrial pollution source emission coefficient manual.

### ■ Geographical Representative

The geographical representative of steel production is China.

### ■ Time Representative

2017-2023.

### ■ Technical Representative

The average technological proficiency in China.

#### ( 4 ) Boundary

The system boundary of cast iron production is shown in Figure 2.

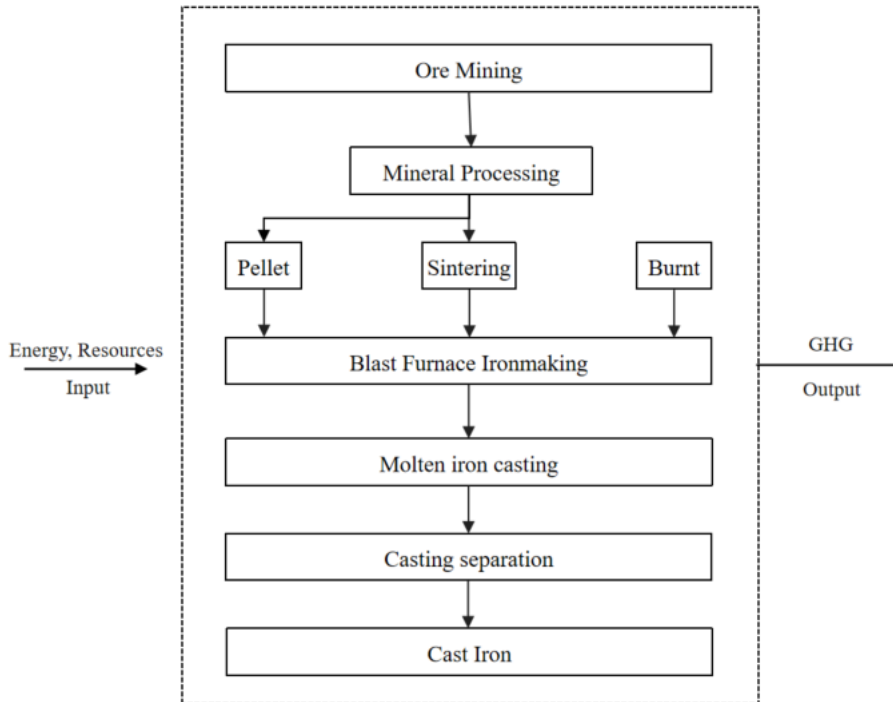


Figure 2 System Boundaries of Cast Iron Production

#### ( 5 ) Computational Models and Other Practices

The Process-Oriented Material Flow Balance Correlation Method.

### 5.1.3 Aluminum and Aluminum Alloys

The data for aluminum and aluminum alloys represent the average values for cast aluminum alloys, wrought aluminum alloys, forged aluminum alloys, and primary aluminum. Detailed data for cast aluminum alloys, wrought aluminum alloys, forged aluminum alloys, and primary aluminum are as follows.

### 5.1.3.1 Cast Aluminum Alloy ( ZL109 )

#### ( 1 ) Functional Unit

The functional unit for cast aluminum alloy (ZL109) refers to 1 kg of cast aluminum alloy (ZL109) product produced by the plant.

#### ( 2 ) Process Step Description

From cradle to gate (product), the typical aluminum production process in China (sintering and combined methods for alumina production): This includes bauxite mining, alumina production, cryolite-alumina molten salt electrolysis, electrolysis of aluminum liquid for purification (removal of impurities) and casting into aluminum ingots, casting processes, production of auxiliary materials (carbon anodes or anode paste), and transportation of key materials. However, the manufacturing of production equipment, construction of plant facilities, and other infrastructure are excluded from the boundary.

#### ( 3 ) Data Description

##### ■ Data Sources Representative

The statistical data from the Non-Ferrous Metals Industry Yearbook (2003-2020) will serve as the primary reference. For certain non-statistical process data, the sources are based on surveys of the production processes and technical indicators of existing typical enterprises. Due to the fact that environmental monitoring in China's aluminum industry is integrated with

the overall non-ferrous metals industry system, pollution emissions at specific production stages are based on internal statistical data obtained from enterprise surveys.

#### ■ Geographical Representative

The geographic representativeness of cast aluminum alloy (ZL109) production is China.

#### ■ Time Representative

The authoritative industry statistical yearbooks and corporate survey data (initially from 2003 and 2010) were updated twice in 2013-2014 for key data, with another update in 2022. The updated data primarily includes the material inventory, energy inventory, and pollutant emission inventory.

#### ■ Technical Representative

The typical aluminum production processes in China (Sintering method and combined method for alumina production).

### ( 4 ) Boundary

The system boundary for the production of cast aluminum alloy (ZL109) is shown in Figure 3.

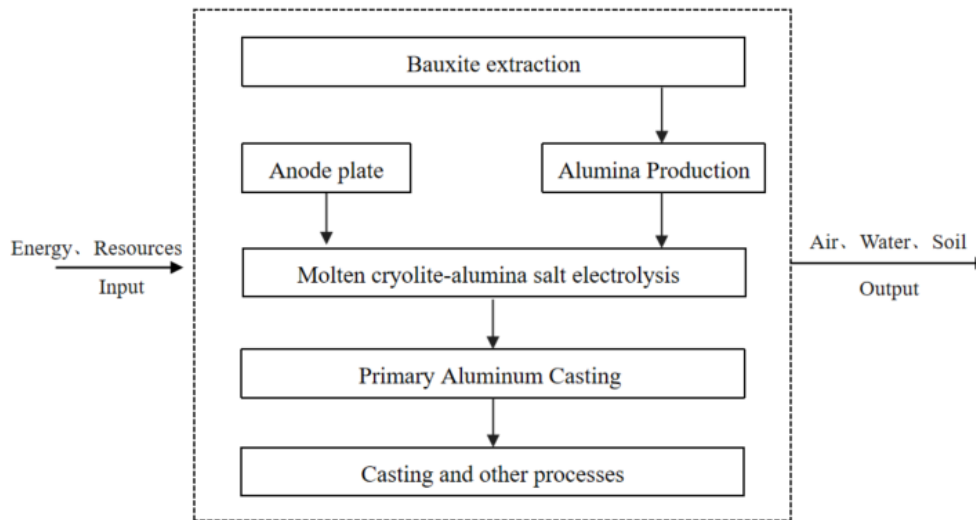


Figure 3 System Boundary of Cast Aluminum Alloy (ZL109) Production

## ( 5 ) Computational Models and Other Practices

Based on the aluminum alloy matrix, alloying element proportions, alloying methods, and energy consumption calculations.

### 5.1.3.2 Deformed Aluminum Alloy (6061)

#### ( 1 ) Functional Unit

The functional unit of deformed aluminum alloy (6061) refers to the 1 kg of deformed aluminum alloy product produced by the plant.

#### ( 2 ) Process Step Description

From Cradle to Gate (Product), typical aluminum production process in China (Sintering and Combined Method for alumina production): This includes bauxite mining, alumina production, cryolite-alumina molten salt electrolysis, electrolysis of aluminum liquid after purification (impurity removal) and casting into aluminum ingots, extrusion process, production

of auxiliary materials (carbon anodes or anode paste), and transportation of key materials. However, the manufacturing of production equipment, construction of plants, and other infrastructure are not included within the system boundary.

### ( 3 ) Data Description

#### ■ □Data Sources Representative

The statistical data from the China Nonferrous Metals Industry Yearbook (2010-2020) serves as the primary reference. For non-statistical process data, it is derived from research on the production processes and technical specifications of existing typical enterprises. Due to the integration of environmental monitoring in China's aluminum industry with the broader nonferrous metals sector, the pollution emissions at specific production stages are based on internal statistical data obtained through surveys of enterprises.

#### ■ □Geographical Representative

The geographic representative of deformation aluminum alloy (6061) production is China.

#### ■ □Time Representative

Authoritative industry statistical yearbooks and corporate survey data (initially from 2003 and 2010) were updated twice in 2013-2014 for key data, with a further update in 2022. The updated data primarily include material inventories, energy inventories, and pollution emission

inventories.

■ □ Technical Representative

Typical Aluminum Production Processes in China (Sintering Method and Combined Method for Alumina Production).

( 4 ) Boundary

The system boundary for the production of deformed aluminum alloy (6061) is shown in Figure 4.

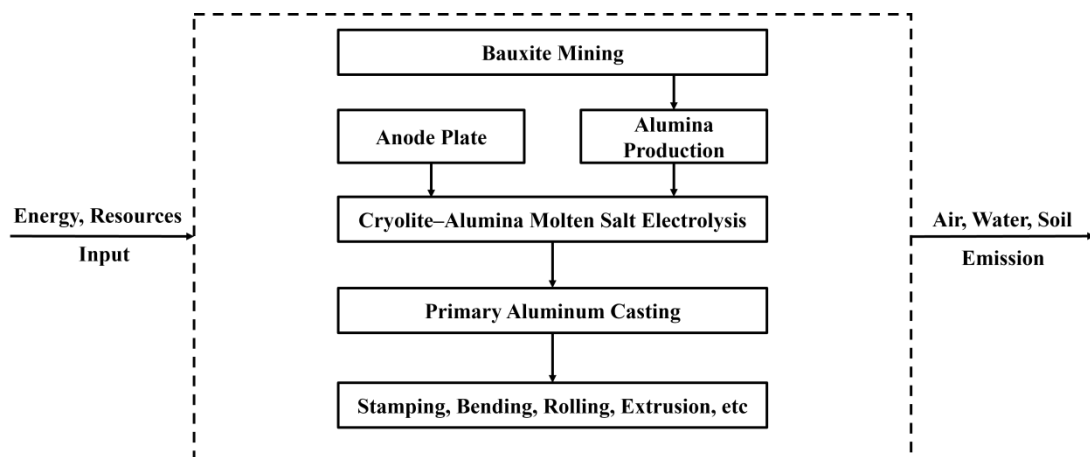


Figure 4 System Boundary for the Production of Wrought Aluminum Alloy (6061)

( 5 ) Computational Models and Other Practices

Based on the aluminum alloy matrix, alloy element ratio, alloying method, and energy consumption calculation

5.1.3.3 Primary Aluminum

( 1 ) Functional Unit

The functional unit of primary aluminum refers to 1 kg of wrought aluminum alloy product produced by the plant.

## ( 2 ) Process Step Description

From cradle to gate (product), the typical aluminum production process in China (including the sintering method and the combined method for alumina production): This encompasses bauxite mining, alumina production, cryolite-alumina molten salt electrolysis, purification (impurity removal) of electrolytic aluminum liquid and casting into aluminum ingots, extrusion processes, production of auxiliary materials (carbon anodes or anode paste), and the transportation processes of major materials. However, the manufacturing of production equipment, construction of facilities, and other infrastructure are excluded from the boundary scope.

## ( 3 ) Data Description

### ■ □Data Sources Representative

The statistical data from the Yearbook of Nonferrous Metals Industry (2003–2020) serves as the primary reference. For certain non-statistical process data, sources include surveys of production processes and technical indicators from representative enterprises. Since environmental monitoring in China's aluminum industry is integrated with the broader nonferrous metals sector, pollution emissions during specific production stages are based on internal statistical data obtained through enterprise surveys.

### ■ □Geographical Representative

The geographical representativeness of primary aluminum production is

China.

■ □ Time Representative

Authoritative industry statistical yearbooks and enterprise survey data (initially dated 2003 and 2010) were updated twice for key data during 2013–2014 and again in 2022. The updated data primarily include material inventories, energy inventories, and pollutant emission inventories.

■ □ Technical Representative

Typical Aluminum Production Processes in China (Sintering and Combined Methods for Alumina Production).

( 4 ) Boundary

The system boundary for primary aluminum production is shown in

Figure 5.

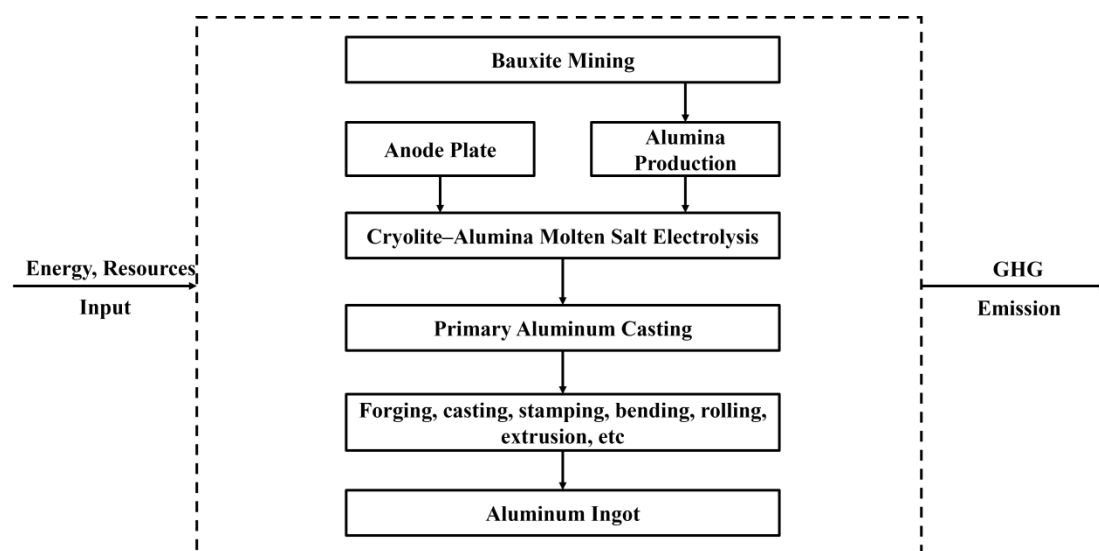


Figure 5 System Boundary of Primary Aluminum Production

( 5 ) Computational Models and Other Practices

Based on the aluminum alloy matrix, alloy element ratio, alloying method,

and energy consumption calculation.

#### 5.1.3.4 Forged Aluminum Alloy (6061)

##### ( 1 ) Functional Unit

The functional unit of forged aluminum alloy (6061) represents the production of 1 kg of forged aluminum alloy (6061) by the factory.

##### ( 2 ) Process Step Description

Cradle-to-gate (product), typical aluminum production processes in China (Bayer-Sintering combined process): including bauxite mining, alumina production, cryolite-alumina molten salt electrolysis, purification (impurity removal) of electrolytic aluminum liquid and casting into aluminum ingots, forging processes, production of auxiliary materials (carbon anodes or anode paste), and the transportation of major materials. Equipment manufacturing and infrastructure construction, such as plant buildings, are excluded from the system boundary.

##### ( 3 ) Data Description

###### ■ □ Data Sources Representative

The statistical data from the Yearbook of Nonferrous Metals Industry (2003-2020) serves as the primary reference. For certain non-statistical process data, information is sourced from surveys on production processes and technical indicators of representative enterprises. Since environmental monitoring of the aluminum industry in China is integrated with the overall

nonferrous metals industry, pollution emissions at specific production stages are based on internal statistics obtained through enterprise surveys.

■ □ Geographical Representative

The geographic representative of forged aluminum alloy (6061) production is China.

■ □ Time Representative

Authoritative industry statistical yearbooks and enterprise survey data (initially from 2003 and 2010) were updated in 2013-2014 for key data. The data was further updated in 2022, with the updates primarily including material inventories, energy inventories, and pollutant emission inventories.

■ □ Technical Representative

The typical aluminum production processes in China (sintering method and combined method for producing alumina and cryolite – alumina molten salt electrolysis process for producing primary aluminum).

( 4 ) Boundary

The system boundary of forged aluminum alloy (6061) production is shown in Figure 6.

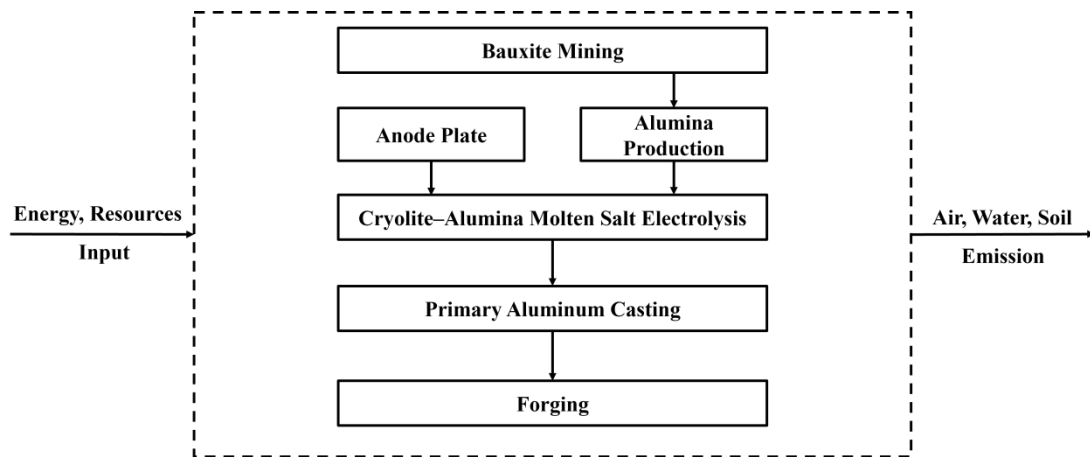


Figure 6 System Boundary for the Production of Forged Aluminum Alloy (6061)

### ( 5 ) Computational Models and Other Practices

The calculation is based on the aluminum alloy matrix, the alloy element ratio, alloying method, and energy consumption.

#### 5.1.4 Magnesium and Magnesium Alloys

The data for magnesium and magnesium alloys represent the average results of cast magnesium alloy (AM60) and cast magnesium alloy (AZ31).

The following are the detailed data descriptions for cast magnesium alloy (AM60) and cast magnesium alloy (AZ31).

##### 5.1.4.1 Casting of magnesium alloy (AM60)

#### ( 1 ) Functional Unit

The functional unit of cast magnesium alloy (AM60) refers to the 1 kg of cast magnesium alloy (AM60) product produced by the factory.

#### ( 2 ) Process Step Description

From cradle to gate (product), starting from the extraction of dolomite to

the production of raw magnesium ingots, including five stages: dolomite mining, dolomite calcination, batching and pelletizing, reduction and crude magnesium refining, and casting processes. The production of main auxiliary materials such as ferrosilicon and fluorite powder is also included. However, the manufacturing of production equipment, plant construction, and other infrastructure are excluded from the system boundary.

### ( 3 ) Data Description

#### ■ □Data Sources Representative

The material and energy consumption data are based on field surveys of typical enterprises and statistical data from the China Magnesium Association. Since most of the magnesium production plants using the Pijiang method in China are privately owned and have not yet established relevant pollutant emission monitoring systems, pollutant emission data are calculated based on fuel consumption and process conditions, with the emissions from combustion and process stages estimated accordingly.

#### ■ □Geographical Representative

The geographical representation of cast magnesium alloy (AM60) production is China.

#### ■ □Time Representative

The comprehensive corporate survey was initially conducted in 2003 and 2005. Key data was updated in 2013-2014, and further updates were made in 2022-2023. The updated data mainly includes the material inventory,

energy inventory, and pollution emission inventory, among others.

■ □ Technical Representative

The Pi-Jiang process and casting process.

( 4 ) Boundary

The system boundaries for the production of cast magnesium alloy (AM60) are shown in Figure 7.

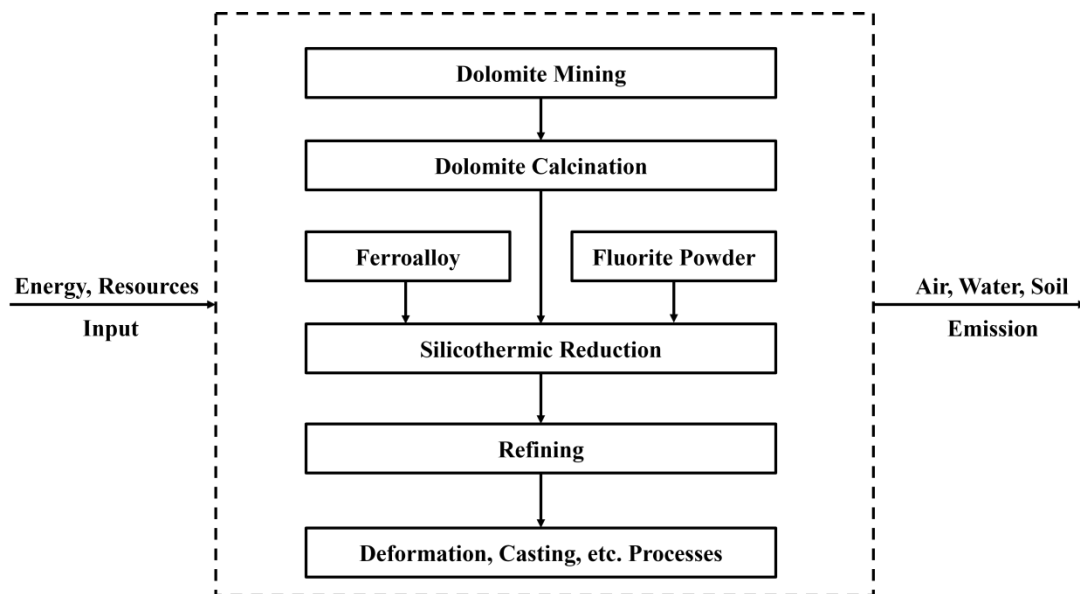


Figure 7 System Boundary for the Production of Cast Magnesium Alloy (AM60)

( 5 ) Computational Models and Other Practices

Based on the magnesium alloy matrix, alloying element ratio, alloying method, and energy consumption calculations.

5.1.4.2 Cast Magnesium Alloy (AZ31)

( 1 ) Functional Unit

The functional unit of cast magnesium alloy (AZ31) refers to 1 kg of cast

magnesium alloy (AZ31) product produced by the factory.

## ( 2 ) Process Step Description

The process from cradle to gate (product) starts with the mining of dolomite and ends with the production of raw magnesium ingots. This includes five stages: dolomite mining, dolomite calcination, batching and pelletizing, reduction, and crude magnesium refining, as well as casting processes. The production of main auxiliary materials such as ferrosilicon and fluorite powder is also included. However, the manufacturing of production equipment, plant construction, and other infrastructure are excluded from the boundary scope.

## ( 3 ) Data Description

### ■ □ Data Sources Representative

The material and energy consumption data are based on field research of typical enterprises and statistics from the China Magnesium Association. As most magnesium production plants using the Pijiang method are privately owned and have not yet established relevant pollutant emission monitoring systems, the pollutant emission data are calculated based on fuel consumption and process conditions, taking into account emissions from combustion and process operations.

The data has been partially corrected and supplemented based on the Manual of Emission and Pollution Coefficients for Industrial Pollution Sources from the First National Pollution Source Census.

■  Geographical Representative

The geographic representation of the production of cast magnesium alloy (AZ31) is China.

■  Time Representative

The comprehensive corporate survey was initially conducted in 2003 and 2005. Key data were updated in 2013-2014, and again in 2022-2023. The updated data mainly include the materials inventory, energy inventory, and pollution emissions inventory.

■  Technical Representative

The Pi-Jiang process and casting process.

#### ( 4 ) Boundary

The system boundaries of the cast magnesium alloy (AZ31) production are shown in Figure 8.

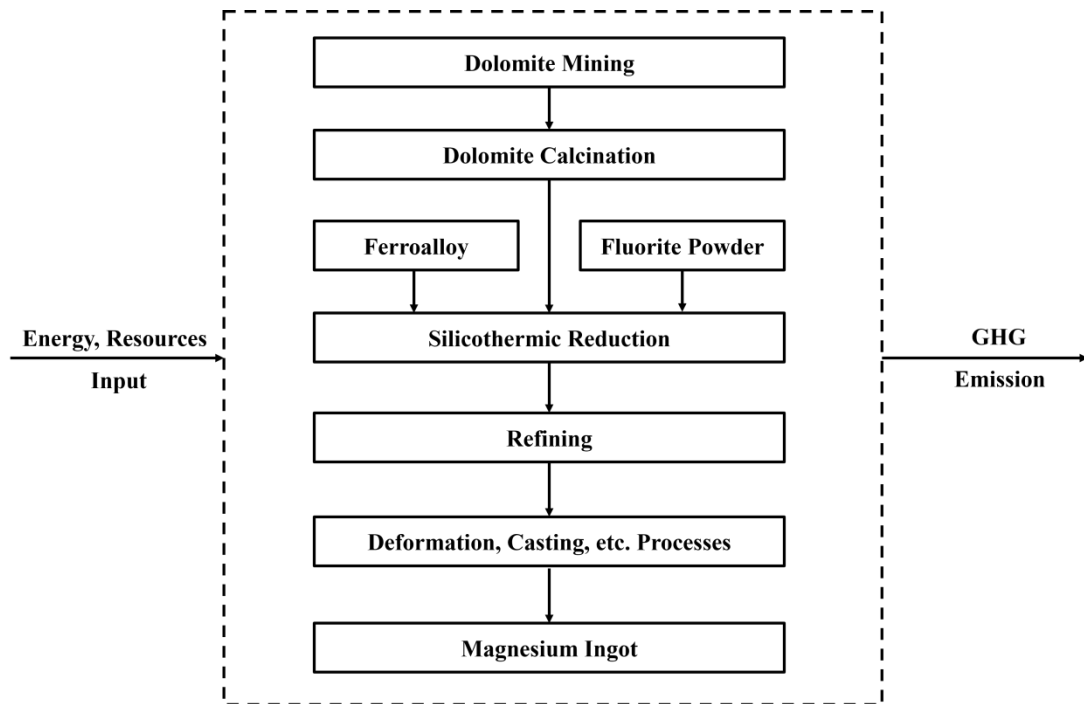


Figure 8 System Boundaries for the Life Cycle Assessment of Cast Magnesium Alloy (AZ31) Production

### ( 5 ) Computational Models and Other Practices

Based on the magnesium alloy matrix, alloying element proportions, alloying methods, and energy consumption calculations.

## 5.1.5 Copper and Copper Alloys

### ( 1 ) Functional Unit

The functional unit for copper and copper alloys refers to 1 kg of copper and copper alloy products produced by the factory.

### ( 2 ) Process Step Description

From cradle to gate, including copper mining (open-pit and underground), copper ore beneficiation, and copper smelting (pyrometallurgical and hydrometallurgical processes). However, the manufacturing of production

equipment and the construction of facilities are excluded from the boundary scope.

#### ( 4 ) Data Description

##### ■ □Data Sources Representative

Data verification was conducted with reference to the Yearbooks of China's Nonferrous Metals Industry from previous years.

Some data were corrected and supplemented based on the Emission Factors Manual for Industrial Pollution Sources from the First National Pollution Source Census.

##### ■ □Geographical Representative

The geographical representative of copper and copper alloy production is China.

##### ■ □Time Representative

The energy inventory was updated in 2017, the material inventory dates back to 2014, and the data was updated between 2022 and 2023.

##### ■ □Technical Representative

#### Pyrometallurgical and Hydrometallurgical Copper Smelting

#### Processes

#### ( 4 ) Boundary

The system boundary of copper and copper alloy production is shown in Figure 9.

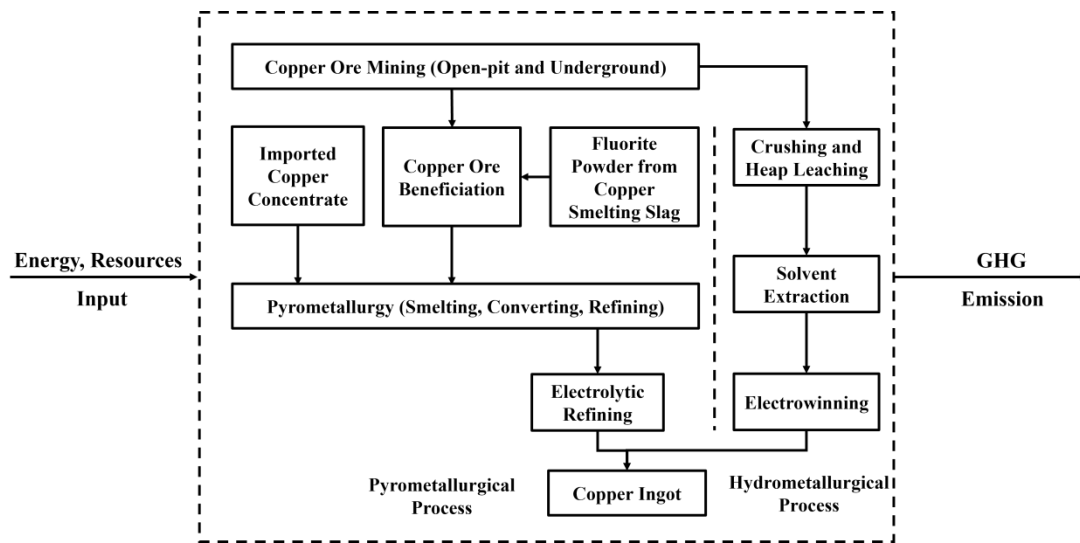


Figure 9 System Boundary of Copper and Copper Alloy Production

### ( 5 ) Computational Models and Other Practices

A Process-Oriented Material Flow Balance Correlation Method.

## 5.1.6 Platinum

### ( 1 ) Functional Unit

The functional unit of platinum refers to 1 kg of platinum product produced by the plant.

### ( 2 ) Process Step Description

From cradle to gate (product): This includes platinum ore mining (open-pit mining, underground mining), beneficiation, and smelting enrichment processes. However, manufacturing of production equipment, plant construction, and other infrastructure are not included within the boundary.

### ( 3 ) Data Description

#### ■ □ Data Sources Representative

The statistical data from the "China Nonferrous Metals Industry Yearbook

(2010-2020)" serves as the primary reference. For non-statistical process data, the information is derived from existing literature research.

The statistical data from the "China Nonferrous Metals Industry Yearbook (2010-2020)" includes operational indicators, material and energy consumption metrics, and pollution emission data based on the results of the First National Pollution Source Census Industrial Pollution Source Emission Coefficients Manual. Some process data is sourced from surveys of typical enterprises.

Data correction and supplementation were carried out with reference to the First National Pollution Source Census Industrial Pollution Source Emission Coefficients Manual.

■  Geographical Representative

The geographic representative of platinum production is China.

■  Time Representative

2022.

■  Technical Representative

Sintering Machine - Blast Furnace Process and Water Outlet

Mountain Method.

( 4 ) Boundary

The system boundary for platinum production is shown in Figure 10.

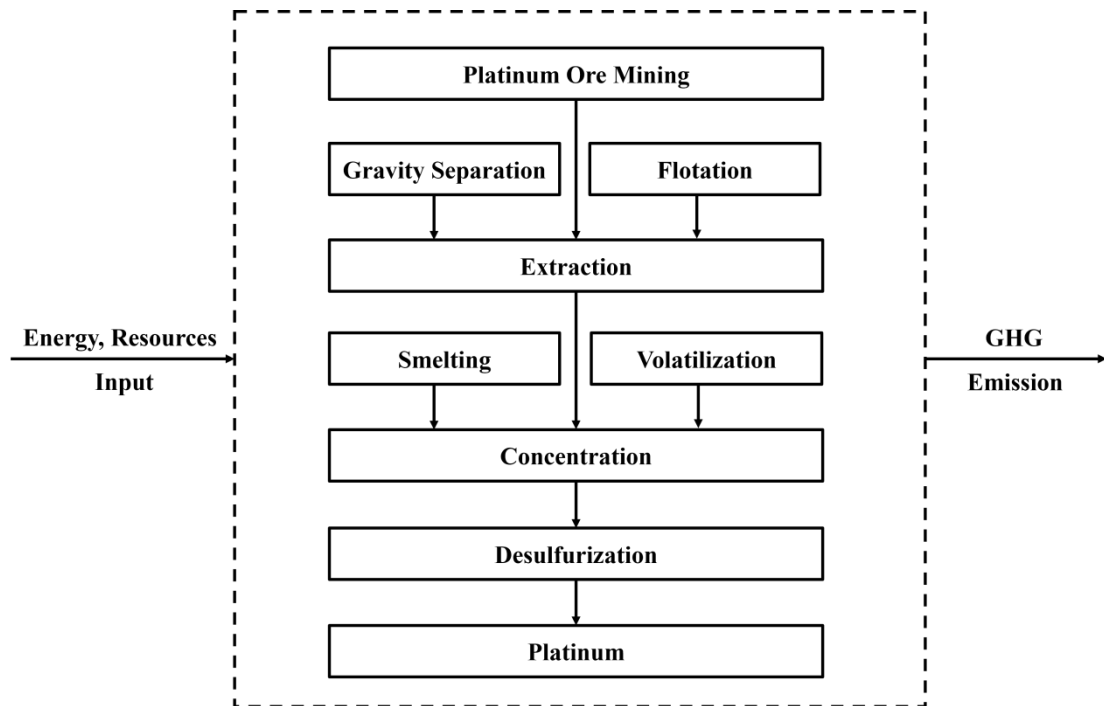


Figure 10 System Boundary of Platinum Production

## ( 5 ) Computational Models and Other Practices

The process-oriented material flow balance correlation method.

### 5.1.7 Lead

#### ( 1 ) Functional Unit

The functional unit of refined lead refers to 1 kg of refined lead product produced by the factory.

#### ( 2 ) Process Step Description

From cradle to gate (product), typical lead smelting process in China: including lead-zinc ore mining (open-pit, shaft mining), beneficiation, pyrometallurgical smelting (sintering machine - blast furnace process, Shui Kou Shan method). The production equipment manufacturing, plant construction, and other infrastructure are excluded from the boundary

scope.

### ( 3 ) Data Description

#### ■ □Data Sources Representative

The statistical data from the China Nonferrous Metals Industry Yearbook (2010-2020) is used as the primary reference. For non-statistical process data, sources include existing literature reviews.

The statistical data from the China Nonferrous Metals Industry Yearbook (2010-2020) encompasses operational indicators and material and energy consumption for mining and smelting, while pollution emission data is based on the findings from the First National Pollution Source Census Industrial Pollution Source Emission Coefficients Handbook. Some process data is derived from surveys of typical enterprises.

Certain data have been corrected and supplemented based on the First National Pollution Source Census Industrial Pollution Source Emission Coefficients Handbook.

#### ■ □Geographical Representative

The geographic representation of lead production is China.

#### ■ □Time Representative

2022

#### ■ □Technical Representative

### Sintering Machine - Blast Furnace Process and Water Mouth

## Mountain Method Process.

### ( 4 ) Boundary

The system boundaries of lead production are shown in Figure 11.

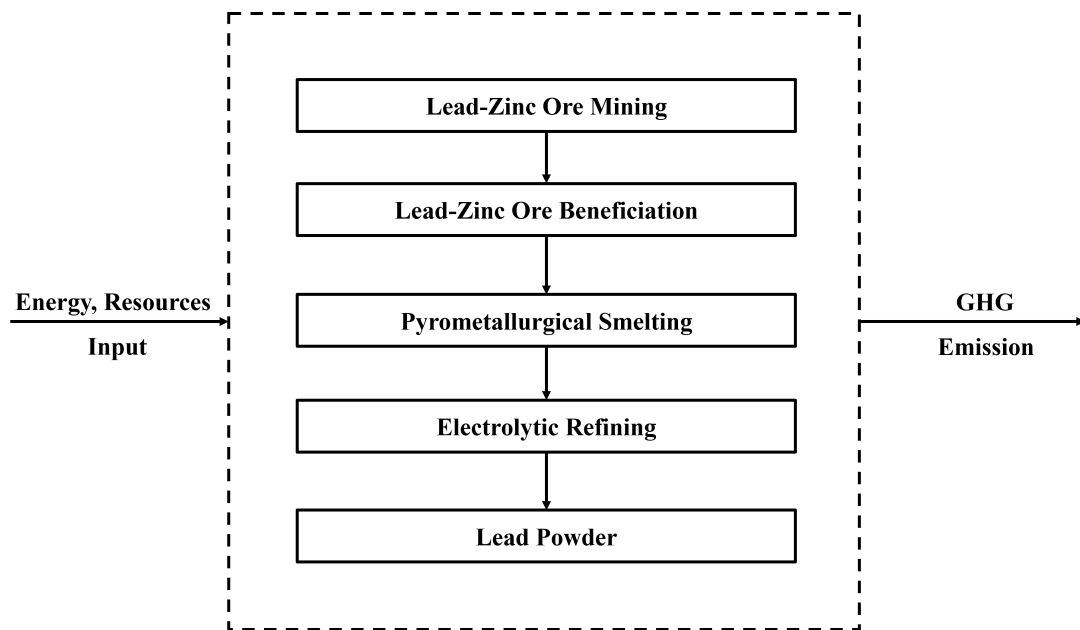


Figure 11 System Boundary of Lead Production from Refined Lead

### ( 5 ) Computational Models and Other Practices

The process-oriented material flow balancing correlation method.

#### 5.1.8 Thermoplastic

The thermoplastic data is obtained by averaging data from polypropylene (PP), polyethylene (PE), polycarbonate (PC), and polyvinyl chloride (PVC). Below are the detailed data specifications for polypropylene (PP), polyethylene (PE), polycarbonate (PC), and polyvinyl chloride (PVC).

##### 5.1.8.1 Polypropylene (PP)

### ( 1 ) Functional Unit

The functional unit of polypropylene (PP) refers to 1 kg of polypropylene (PP) product produced by the factory

## ( 2 ) Process Step Description

From cradle to gate (product), including stages such as crude oil extraction, separation, naphtha cracking, and polymer production, as well as the associated transportation processes; the manufacturing of production equipment, plant construction, and other infrastructure are not included within the boundary scope.

## ( 3 ) Data Description

### ■ □Data Sources Representative

The data validation refers to the China Plastics Industry Yearbook, surveys of typical enterprises, literature reviews, and production technical manuals. Some data corrections and supplementation were made with reference to the Industrial Pollution Source Emission and Discharge Coefficient Manual from the first national pollution source census.

### ■ □Geographical Representative

The geographic representation of polypropylene (PP) production is China.

### ■ □Time Representative

2012-2014. Material and energy flows are sourced from literature data. The energy flow inventory data was updated to 2012, and further updated for 2021-2023. The updates primarily include inventories for lime, energy, and pollutant emissions.

## □ Technical Representative

The domestic ring-pipe method, the average technical level in China.

### ( 4 ) Boundary

The system boundaries for polypropylene (PP) production are shown in Figure 12.

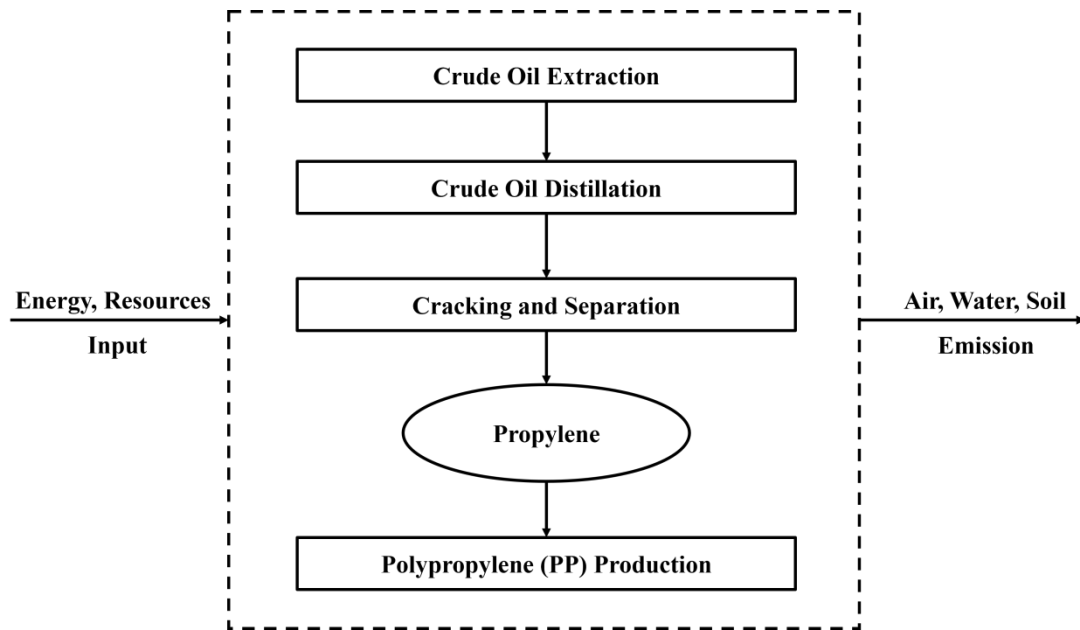


Figure 12 System Boundary of Polypropylene (PP) Production

### ( 5 ) Computational Models and Other Practices

The process-oriented material flow balance correlation method.

#### 5.1.8.2 Polyethylene (PE)

##### ( 1 ) Functional Unit

The functional unit for polyethylene (PE) is defined as 1 kg of PE manufactured at the production facility.

##### ( 2 ) Process Stage Description

Cradle-to-gate system boundary covering crude oil extraction, separation, naphtha cracking, polymer production, and associated transportation. Infrastructure such as production equipment manufacturing and plant construction is excluded.

### ( 3 ) Data Description

#### ■ □Data Source Representative

The data validation is based on the China Plastics Industry Yearbook, surveys of typical enterprises, literature review, and production technical manuals. Some data have been corrected and supplemented with reference to the Industrial Pollution Source Emission Coefficient Manual from the First National Pollution Source Census.

#### ■ □Geographical Representative

The geographical representative of polyethylene (PE) production is China.

#### ■ □Time Representative

2012-2014: Material and energy flows are sourced from literature data. The energy flow inventory was updated to 2012 and further revised from 2021 to 2023. The updated data mainly include lime inventory, energy inventory, and pollutant emission inventory.

#### ■ □Technical Representative

Low-density method production, China's average technical level.

### ( 4 ) Boundary

The system boundary of polyethylene (PE) production is shown in Figure 13.

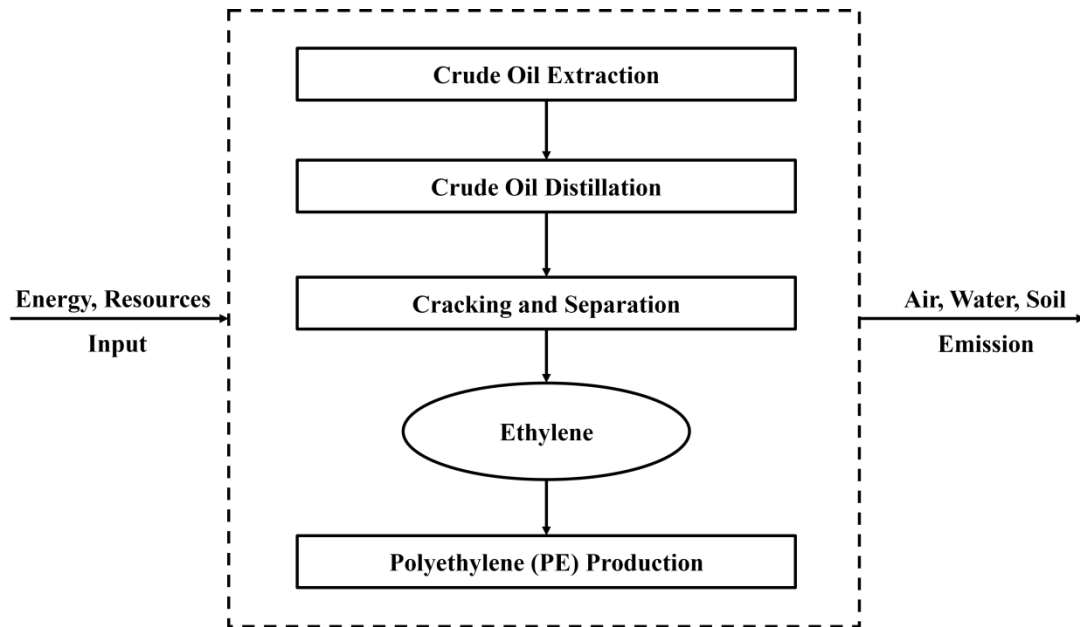


Figure 13 System Boundary of Polyethylene (PE) Production

## ( 5 ) Computational models and other conventions

### Process-Oriented Material Flow Balance Linking Approach

#### 5.1.8.3 Polycarbonate (PC)

##### ( 1 ) Functional Unit

The functional unit of polycarbonate (PC) refers to 1 kg of polycarbonate (PC) product produced by the factory.

##### ( 2 ) Description of Process Steps

From cradle to gate, the system boundary encompasses crude oil extraction, propylene production, propylene oxide production, and polymer production. The study includes the consumption of Cl<sub>2</sub>, lime, and other

materials used in the propylene oxide production process; however, production equipment manufacturing, plant construction, and other infrastructure are excluded from the system boundary.

### ( 3 ) Data Description

#### ■ □Data Sources Representative

The data validation refers to the China Plastic Industry Yearbook, typical enterprise surveys, literature research, and production technology manuals. Some data corrections and supplements were made with reference to the Industrial Pollution Source Emission Coefficients Manual from the first national pollution source census.

#### ■ □Geographical Representative

The geographic representative of polycarbonate (PC) production is China.

#### □Time Representative

2021-2023

#### ■ □Technical Representative

The average technological level of certain petroleum processes in China.

### ( 4 ) Boundary

The system boundary for polycarbonate (PC) production is shown in Figure 14.

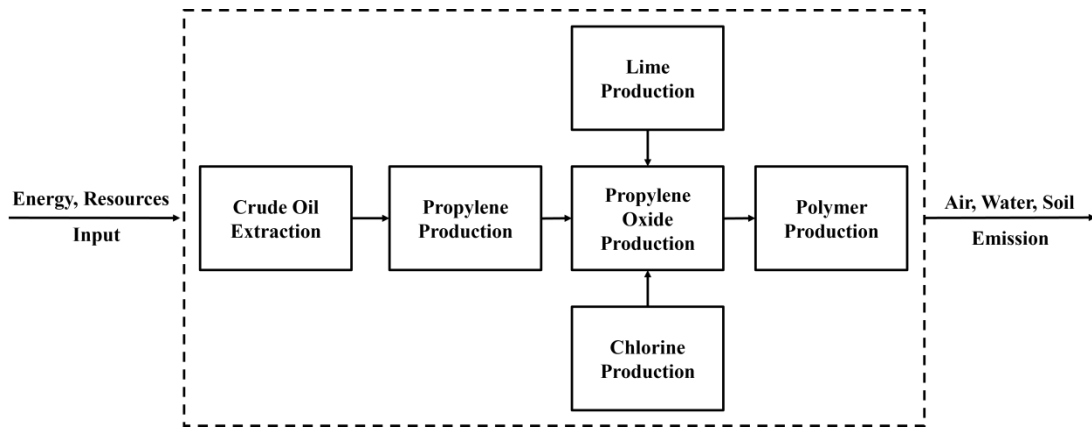


Figure 14 System Boundary for the Production of Polycarbonate (PC)

## ( 5 ) Computational models and other conventions

The process-oriented material flow balance correlation method.

### 5.1.8.4 Polyvinyl Chloride (PVC)

#### ( 1 ) Functional Unit

The functional unit of polyvinyl chloride (PVC) is defined as 1 kg of PVC product produced by the factory.

#### ( 2 ) Process Step Description

From cradle to gate, the process is mainly divided into two methods: the ethylene method (19% share) and the carbide method (81% share). The ethylene method for PVC production includes petroleum techniques such as crude oil extraction, separation, and naphtha cracking. The carbide method for PVC production involves processes such as coal mining, coke production, and carbide production. The manufacturing of production equipment, plant construction, and other infrastructure are excluded from the boundary scope.

### ( 3 ) Data Description

#### ■ □Data Sources Representative

The data validation is based on the China Plastic Industry Yearbook, surveys of typical enterprises, literature research, and production technology manuals. Some data corrections and supplementation were made with reference to the "Manual of Emission Coefficients for Industrial Pollution Sources" from the First National Pollution Source Census.

#### ■ □Geographical Representative

The geographical representative of polyvinyl chloride (PVC) production is China.

#### ■ □Time Representative

The material and energy consumption of the petroleum ethylene process are primarily derived from the China Plastics Industry Yearbook and literature research (time boundary: 2001). The acetylene process data is based on enterprise survey reports (2005), while the energy consumption inventory data has been updated to 2010, with further updates conducted for 2021-2023.

#### ■ □Technical Representative

The Calcium Carbide Process and the Ethylene Process.

### ( 4 ) Computational models and other conventions

The process-oriented material flow balance correlation method. The

mixture of the carbide method (81% by weight) and the ethylene method (19% by weight), representing the average technological level in China.

### ( 5 ) Boundary

The system boundary of polyvinyl chloride (PVC) production is shown in Figure 15.

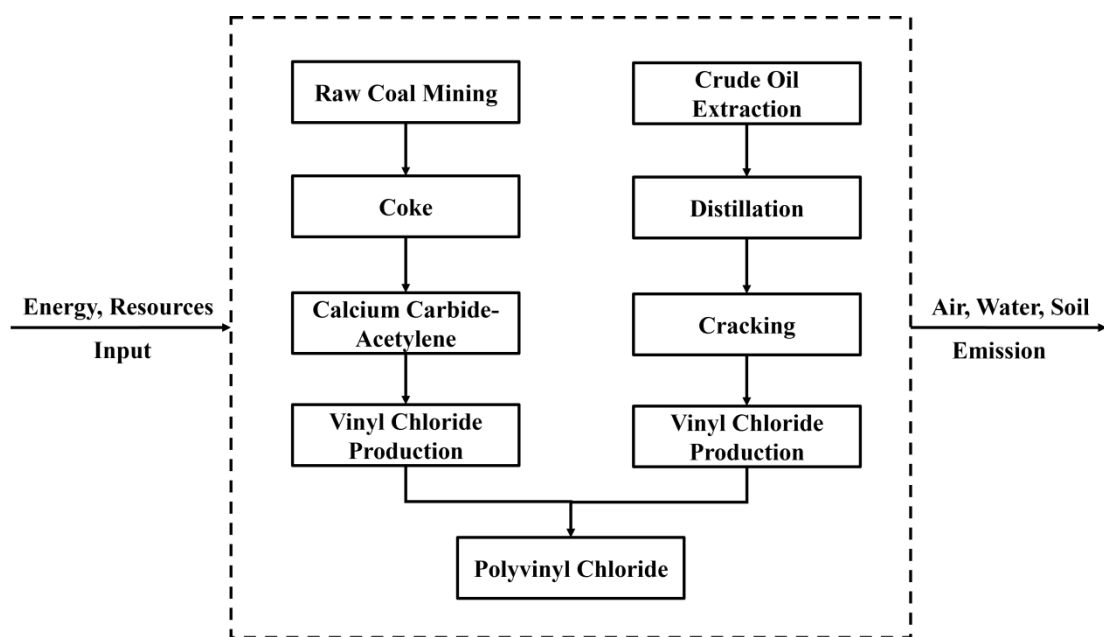


Figure 15 System Boundary for the Production of Polyvinyl Chloride (PVC)

## 5.1.9 Thermosetting Plastics

### ( 1 ) Functional Unit

The thermosetting plastics primarily refer to polyurethane (PU) data, where the functional unit of polyurethane (PU) is defined as 1 kg of polyurethane (PU) product produced by the factory.

### ( 2 ) Process Step Description

From cradle to gate (product), including processes such as crude oil

extraction, crude oil distillation, cracking, and separation.

### ( 3 ) Data Description

#### ■ □Data Sources Representative

The data validation is based on the China Plastic Industry Yearbook, typical enterprise surveys, literature research, and production technology manuals. Partial data correction and supplementation were conducted with reference to the Industrial Pollution Source Emission Coefficient Handbook from the First National Pollution Source Census.

#### ■ □Geographical Representative

The geographical representation of polyurethane (PU) production is  
China.

#### ■ □Time Representative

2021-2023

#### ■ □Technical Representative

The large-scale production by the continuous process.

### ( 4 ) Boundary

The system boundary for polyurethane (PU) production is shown in Figure 16.

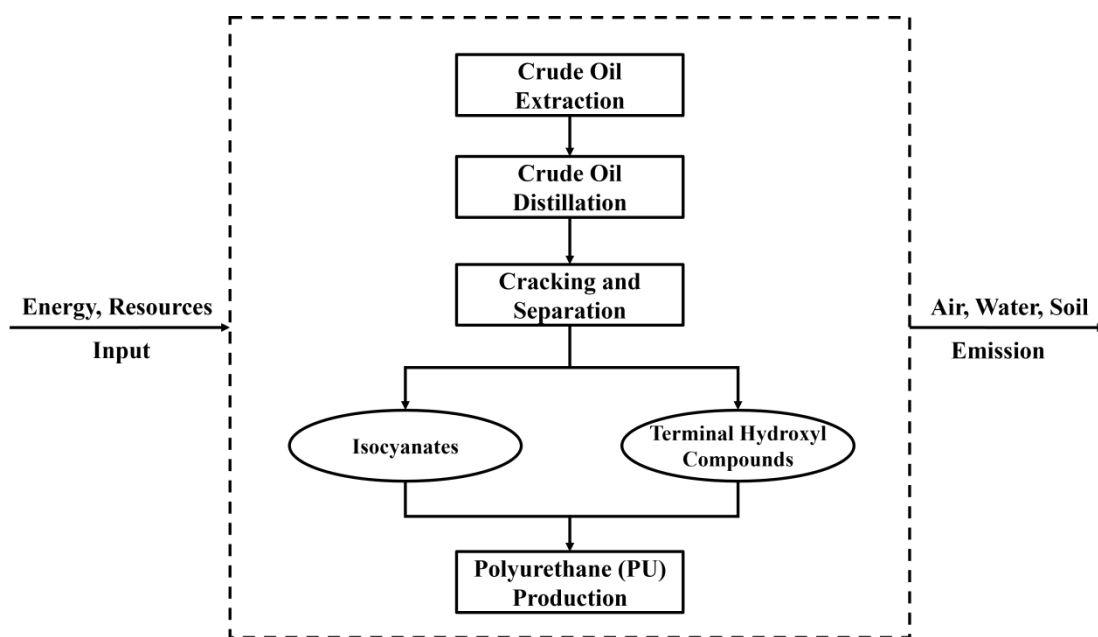


Figure 16 System Boundary of the Life Cycle of Polyurethane (PU)

## 5.1.10 Rubber

### ( 1 ) Functional Unit

The functional unit of rubber refers to 1 kg of rubber product produced by the factory.

### ( 2 ) Process Step Description

From cradle to gate (product), including processes such as plasticization, mixing, molding, vulcanization, and finishing.

### ( 3 ) Data Description

#### ■ □ Data Sources Representative

The foundational data is derived from surveys of rubber manufacturing enterprises and carbon footprint calculations validated through comparison with relevant industry literature. In 2021, a

comparative verification of energy consumption data for rubber production processes was conducted with Zhu Bo and others from the China Industrial Rubber Association. The data generally represents the industry average level.

□ Geographical Representative

The geographical representative of rubber production is China.

■ □ Time Representative

2021-2023

■ □ Technical Representative

Polymerization Production

( 4 ) Boundary

The system boundaries of rubber production are shown in Figure 17.

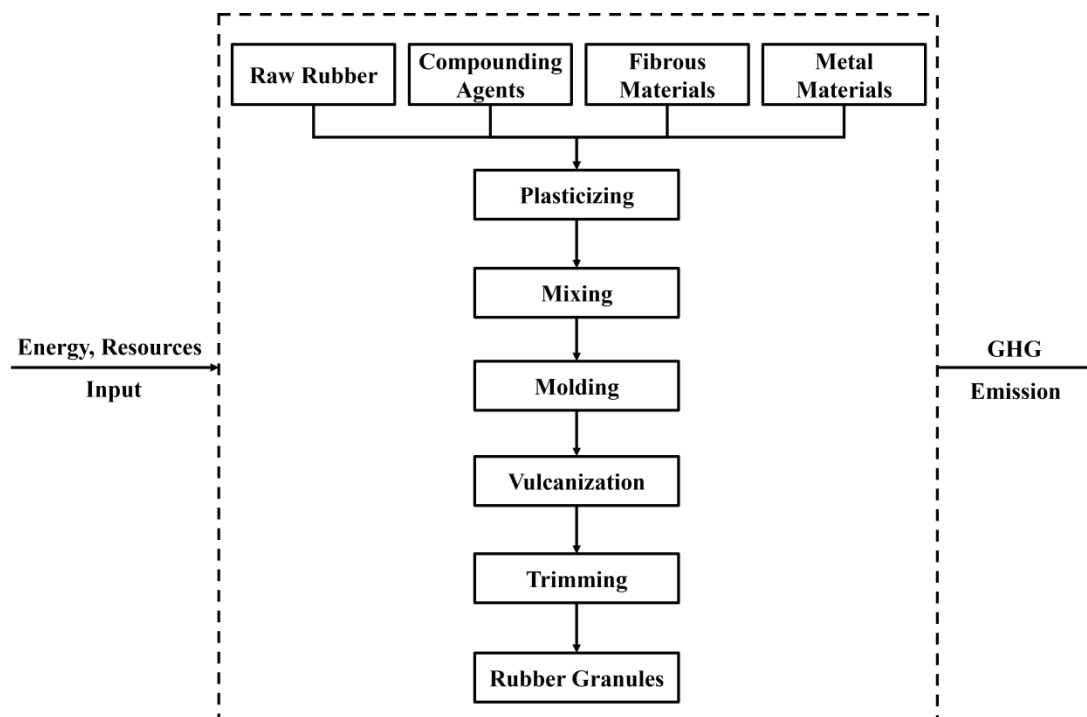


Figure 17 System Boundary of Rubber Material Production

## 5.1.11 Fabric

### ( 1 ) Functional Unit

The functional unit of the fabric is defined as 1 kg of fabric product manufactured by the factory.

### ( 2 ) Process Step Description

From cradle to gate, PVC fabric raw material production via the ethylene route includes textile processing. The ethylene-based PVC production encompasses crude oil extraction, separation, and naphtha cracking. Infrastructure, including production equipment manufacturing and plant construction, is excluded from the system boundary.

### ( 3 ) Data Description

#### ■ □ Data Sources Representative

Data validation is based on the China Plastic Industry Yearbook, representative enterprise surveys, literature review, and production technology manuals. Some data were adjusted and supplemented with reference to the Industrial Pollution Source Emission Factors Manual from the First National Pollution Source Census.

#### ■ □ Geographical Representative

The geographical representative of fabric production is China.

#### ■ □ Time Representative

The material and energy consumption data for the petrochemical ethylene

process are primarily sourced from the China Plastics Industry Yearbook and literature review (cutoff year: 2001). Textile process data are derived from enterprise survey reports (2008). Energy consumption inventory data were last updated in 2010, with subsequent updates from 2021 to 2023。

■ □ Technical Representative

The ethylene process combined with textile technology.

( 4 ) Computational models and other conventions

Process-oriented material flow balance correlation method, carbide method (81% by weight) and ethylene method (19% by weight), average technological level in China。

( 5 ) Boundary

The system boundary of fabric production is shown in Figure 18.

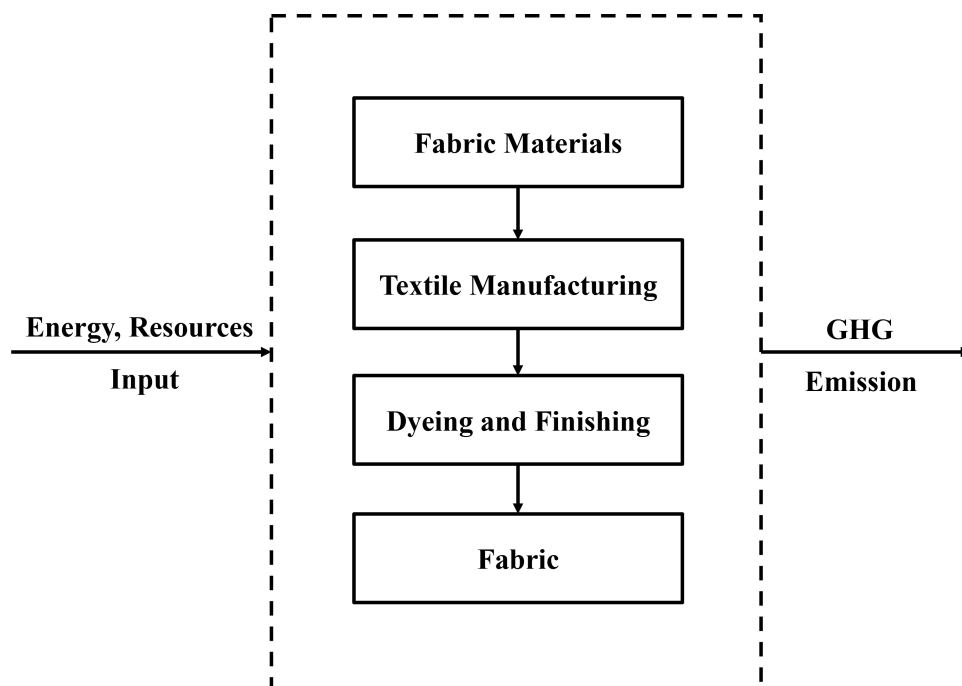


Figure 18 System Boundary of Fabric Production.

## 5.1.12 Ceramics/Glass

### ( 1 ) Functional Unit

The functional unit of glass is defined as 1 kg of glass product produced by the factory.

### ( 2 ) Process Step Description

The boundary of the system includes the entire process from cradle to gate (glass), covering raw material extraction (such as silica sand), float glass production process (batching, melting, forming, cutting, and packaging), and material transportation. The manufacturing of production equipment, factory construction, and other infrastructure are not included within the boundary.

### ( 3 ) Data Description

#### ■ □ Data Sources Representative

The glass baseline data is derived from industry research and data exchange with typical enterprises such as Fuyao Glass. In-depth discussions were held with Dr. Jiang Ji from Fuyao Components and Mr. Liu Chengpeng, a company representative from Fuyao Glass, regarding the glass carbon footprint data. Some data was updated and corrected, and the carbon footprint data is considered to represent the industry average level.

#### ■ Geographical Representative

The geographic representative of glass production is China.

□ Time Representative

BOM list Timeline: 2009-2010, Energy Update List: 2017, Data Maintenance from 2021 to 2023。

■ □ Technical Representative

The float glass process, the average technical level in China.

( 4 ) Boundary

The system boundary for glass production is shown in Figure 19.

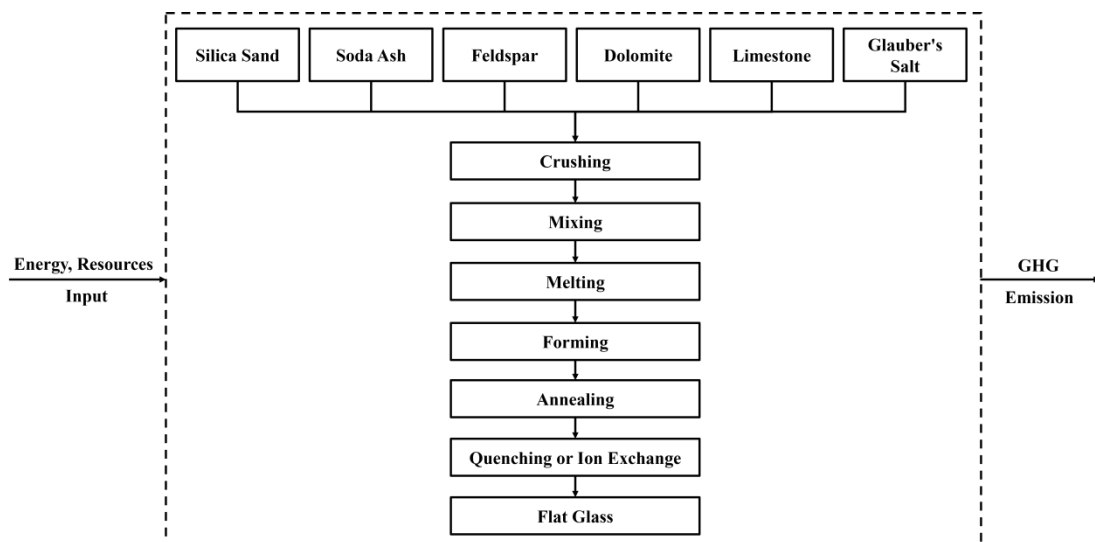


Figure 19 System Boundary of Glass Production

( 5 ) Computational models and other conventions

The Process-Oriented Material Flow Balance Correlation Method.

**5.1.13 Sulfuric acid**

( 1 ) Functional Unit

The functional unit of sulfuric acid refers to 1 kg of 98% concentrated sulfuric acid produced by the factory.

## ( 2 ) Process Step Description

The process from ore (pyrite, sulfur) mining, beneficiation, transportation, to sulfuric acid production; where metallurgical flue gas-based acid production only includes the sulfuric acid production process, excluding the mining, production, and allocation of metallurgical raw materials; and the manufacturing of production equipment, construction of plants, and other infrastructure are not included within the boundary scope.

## ( 3 ) Data Description

### ■ Data Sources Representative

The basic data is sourced from enterprise research, literature, and statistical yearbooks. After communication with well-known sulfuric acid producers such as BASF and Dow Chemical, the obtained data has been validated by the Petrochemical Federation and is considered to represent the industry average level

### ■ Geographical Representative

The geographical representative of sulfuric acid production is China.

### ■ Time Representative

2021-2023.

### ■ Technical Representative

The sulfur-based acid production (45.6%), pyrite-based acid production (20.7%), and metallurgical flue gas-based acid production (32.6%)

represent the average technological level in China.

#### ( 4 ) Boundary

The system boundary for sulfuric acid production is shown in Figure 20.

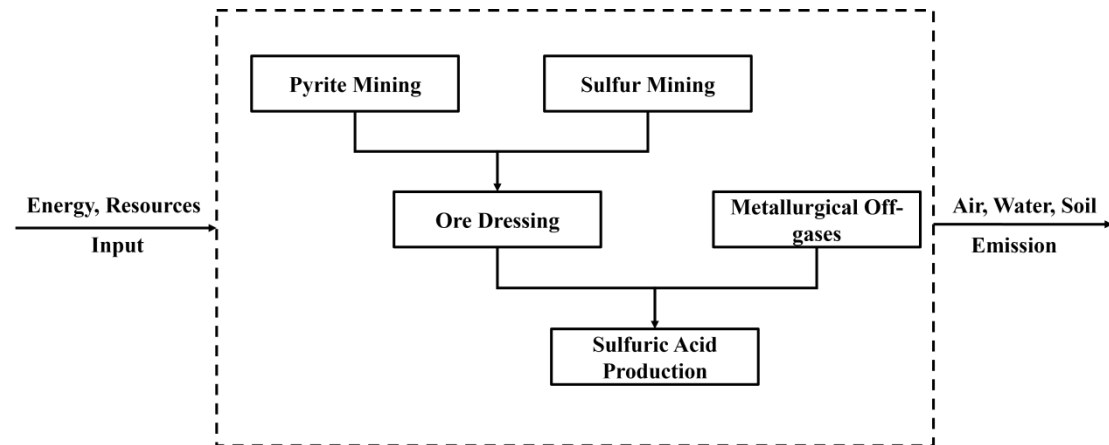


Figure 20 System Boundary of Sulfuric Acid Production

### 5.1.14 Fiberglass

#### ( 1 ) Functional Unit

The functional unit of fiberglass refers to the 1 kg of fiberglass product produced in the factory.

#### ( 2 ) Process Step Description

From cradle to gate (fiberglass), including the extraction of raw materials such as silica sand, the high-strength glass production process (including batching, melting, molding, cutting, and packaging), and the material transportation process; while the manufacturing of production equipment and the construction of plant infrastructure are excluded from the boundary scope.

#### ( 3 ) Data Description

■ □ Data Sources Representative

The glass baseline data is derived from industry research and data exchanges with typical enterprises such as Fuyao Glass. In-depth discussions were held with Dr. Jiang Ji from Fuyao Glass's automotive parts division and Liu Chengpeng, a company representative, regarding the glass carbon footprint data. Some data were updated and revised during these communications. The carbon footprint data is generally representative of the industry average.

■ □ Geographical Representative

The geographical representation of fiberglass production is China.

■ □ Time Representative

BOM List Time: 2009-2010, Energy Update List: 2017, Data Maintenance from 2021 to 2023.

■ □ Technical Representative

The float glass process combined with composite fibers, representing the average technical level in China.

( 4 ) Boundary

The system boundary for fiberglass production is shown in Figure 21.

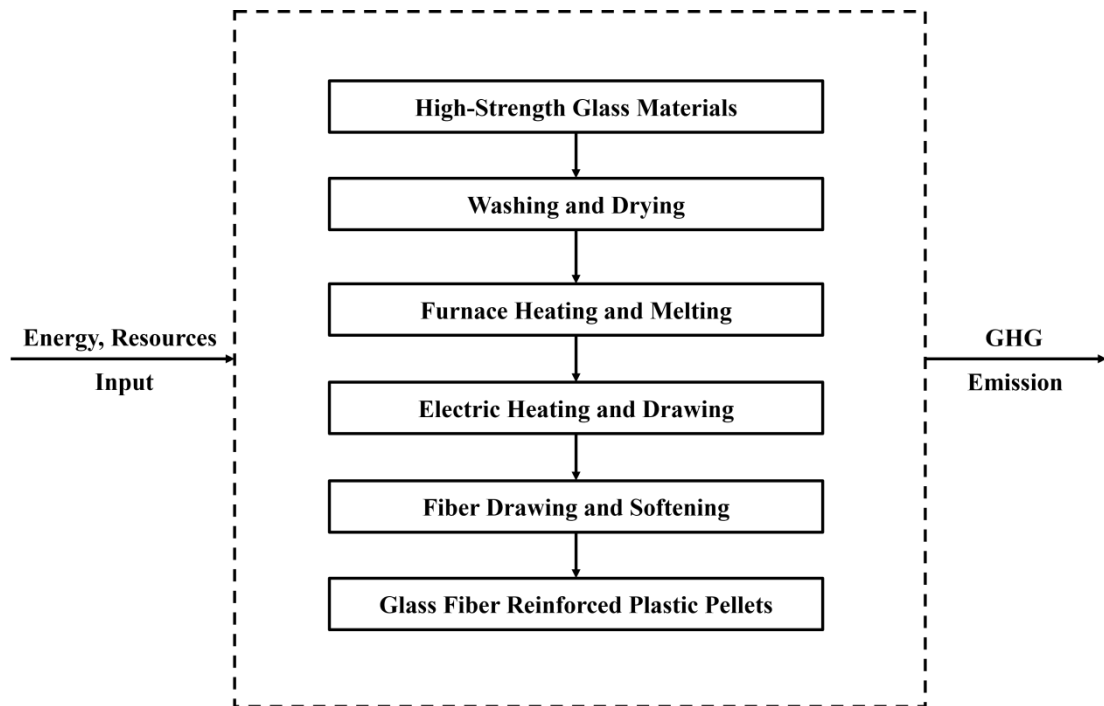


Figure 21 System Boundary for Fiberglass Production

### ( 5 ) Computational models and other conventions

The process-oriented material flow balance correlation method.

## 5.1.15 Lithium Iron Phosphate (LiFePO<sub>4</sub>)

### ( 1 ) Functional Unit

The functional unit of lithium iron phosphate (LFP) refers to 1 kg of LFP product produced by the factory.

### ( 2 ) Process Step Description

From cradle to gate (product), including processes such as blending, spray drying, sintering, crushing, mixing, and baking.

### ( 3 ) Data Description

#### ■ Data Sources Representative

In May 2022, a data research trip was conducted to EVE Energy, focusing

on the production process, distribution of production areas, and energy consumption of lithium iron phosphate. The effectiveness of carbon emission data for lithium iron phosphate was also verified.

In July 2022, a visit to BYD was conducted for communication, focusing primarily on the process flow of lithium iron phosphate, the layout of production sites, and the use of equipment. This indirectly supported the scientific validity of the carbon emission factor of lithium iron phosphate.

■  Geographical Representative

The geographic boundary for lithium iron phosphate (LFP) production is China.

■  Time Representative

2021-2023.

■  Technical Representative

The technical representative aligns with China's average standard.

( 4 ) Boundary

The system boundary for LFP production is shown in Figure 22.

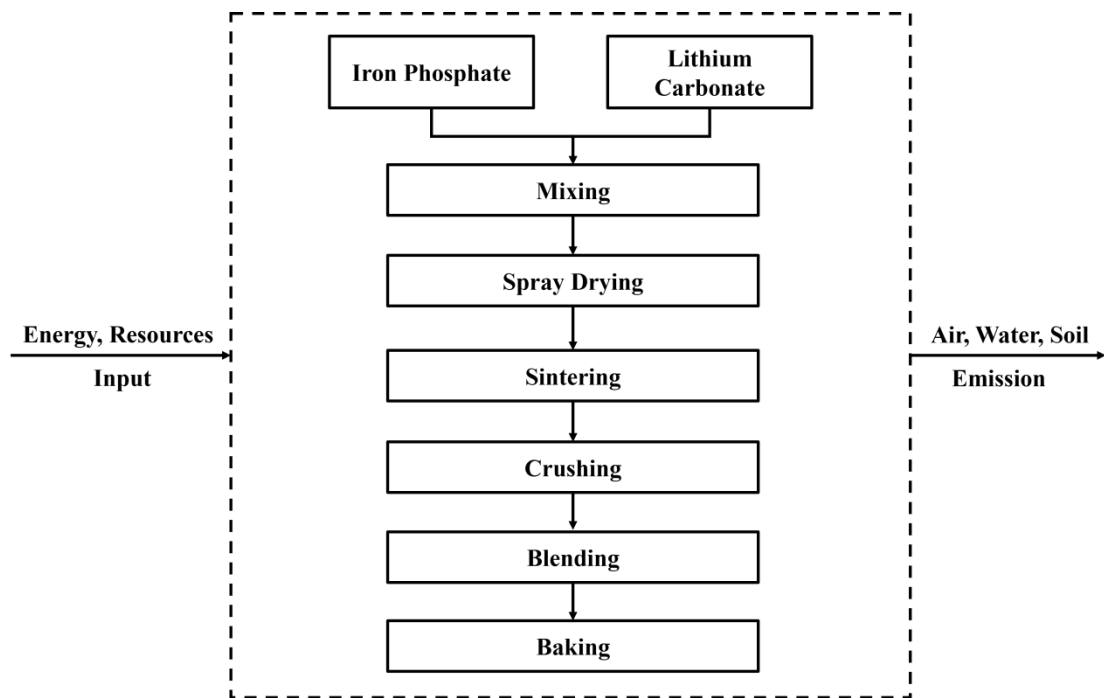


Figure 22 System Boundary for LFP Production

### ( 5 ) Computational models and other conventions

Hybrid inventory algorithm, integrating energy input-output analysis with process-based material flow balance methodology.

## 5.1.16 Lithium Nickel Cobalt Manganese Oxide

### ( 1 ) Functional Unit

The functional unit of lithium nickel cobalt manganese oxide is defined as 1 kg of lithium nickel cobalt manganese oxide product produced by the factory.

### ( 2 ) Process Step Description

From cradle to gate, including processes such as mixing, sintering, crushing, de-ironing, screening, and packaging. The manufacturing of production equipment and the construction of plant infrastructure are

excluded from the boundary.

### ( 3 ) Data Description

#### ■ Data Sources Representative

In July 2022, a data survey was conducted at Greenmei, focusing primarily on the production processes, regional distribution, and energy consumption of nickel-cobalt-manganese lithium. This research provided strong support for the scientific validity of the carbon emission factor data for nickel-cobalt-manganese lithium.

In April 2023, an on-site visit was conducted at Tianyi Lithium, where discussions focused on the current development status, production processes, and future trends of nickel-cobalt-manganese lithium. This further ensured the effectiveness of the carbon emission factor data for nickel-cobalt-manganese lithium.

#### ■ Geographical Representative

The geographic scope of lithium nickel cobalt manganese oxide production is China.

#### ■ Time Representative

2021-2023.

#### ■ Technical Representative

The representative of the average technological level in China.

### ( 4 ) Boundary

The system boundary for the production of nickel-cobalt-manganese lithium battery is shown in Figure 23.

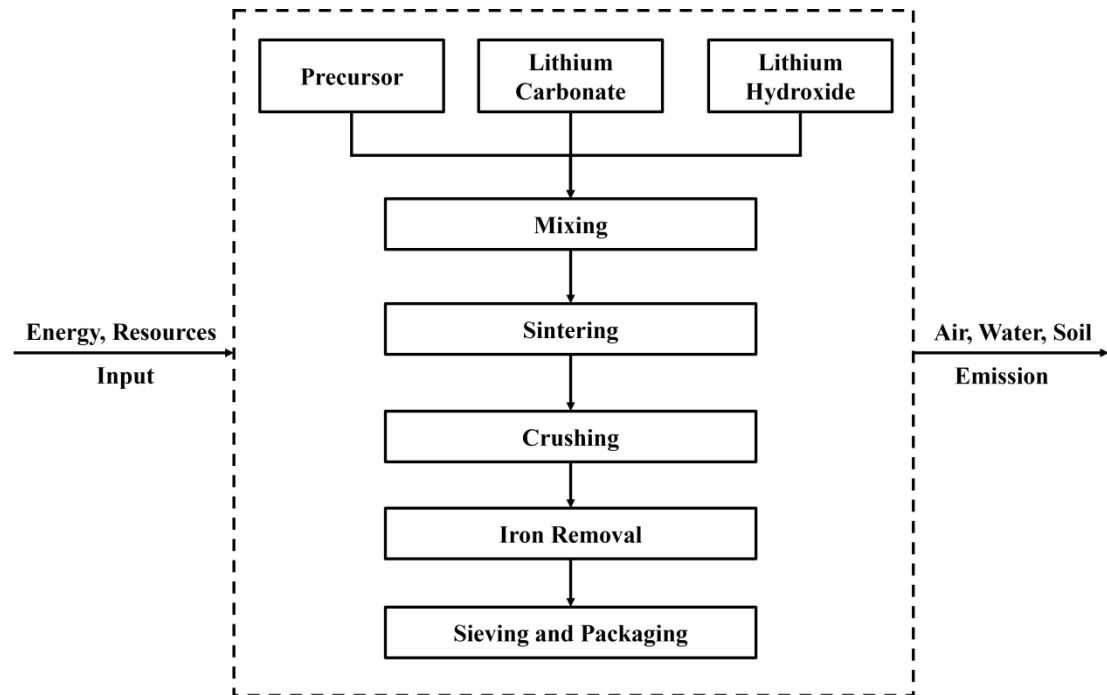


Figure 23 System Boundary of Lithium Manganese Oxide Production

## ( 5 ) Computational models and other conventions

Hybrid inventory algorithm, based on energy input-output tables and process-based material flow balance association method.

### 5.1.17 Lithium Manganate

#### ( 1 ) Functional Unit

The functional unit of lithium manganese oxide refers to 1 kg of lithium manganese oxide product produced by the factory.

#### ( 2 ) Process Step Description

The process includes mixing, roasting, grinding, screening, and other steps.

However, the manufacturing of production equipment, construction of

plants, and other infrastructure are not included within the boundary scope.

### ( 3 ) Data Description

#### ■ Data Sources Representative

In November 2021, a visit was made to Boshitech for discussions primarily focused on the power of production equipment, production processes, and energy consumption related to lithium manganese oxide (LMO) materials. The information provided by Boshitech offered strong support for the accuracy of the data.

#### Geographical Representative

The geographical scope of lithium manganese oxide (LMO) production is limited to China.

#### ■ Time Representative

The data covers the period from 2021 to 2023.

#### ■ Technical Representative

The data reflects the average technological level in China.

### ( 4 ) Boundary

The system boundary for lithium manganese oxide (LMO) production is illustrated in Figure 24.

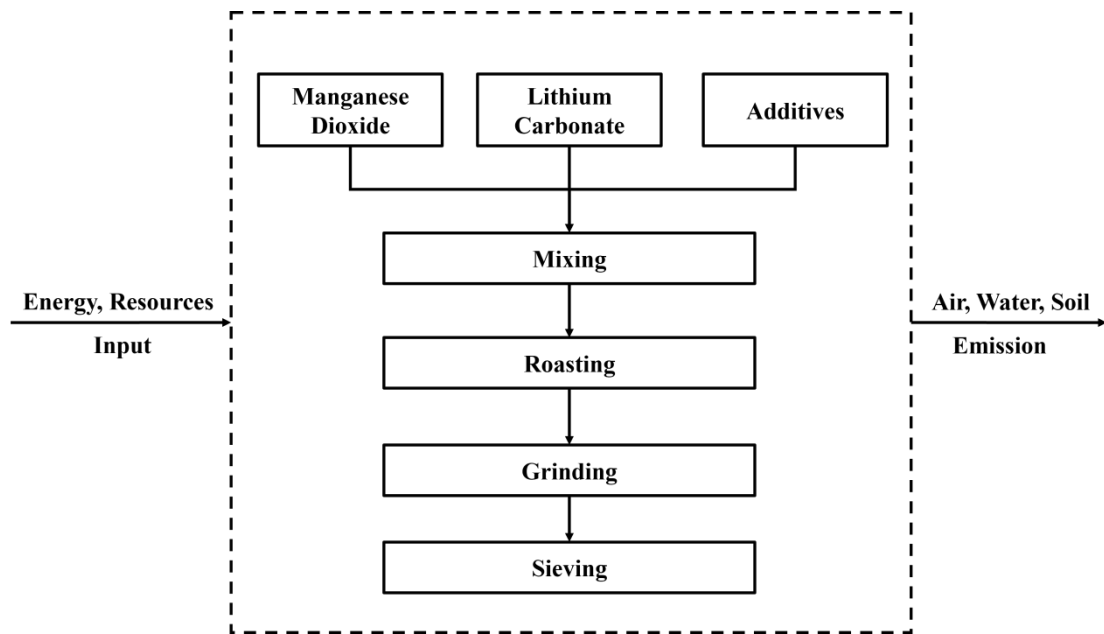


Figure 24 System Boundary of Lithium Manganese Oxide (LMO) Production

### ( 5 ) Computational models and other conventions

A hybrid inventory approach was adopted, combining an energy input-output model with a process-based material flow balance linkage method.

## 5.1.18 Graphite

### ( 1 ) Functional Unit

The functional unit of graphite refers to 1 kg of graphite product produced at the factory.

### ( 2 ) Process Step Description

Natural graphite production includes mining, beneficiation, chemical purification, and spheroidization modification stages. Artificial graphite is produced using petroleum coke or coal tar pitch from refineries as raw

materials. The manufacturing of production equipment and the construction of facilities are not included within the system boundary.

### ( 3 ) Data Description

#### ■ Data Sources Representative

In December 2020, a data survey was conducted at BTR (Beiterui), focusing on the production process, regional distribution, and industry status of graphite materials. The information provided supports the validity and scientific robustness of the graphite carbon emission factor data.

#### □ Geographical Representative

The geographical scope of graphite production is limited to China.

#### ■ □ Time Representative

The data covers the period from 2020 to 2023.

#### ■ □ Technical Representative

Natural graphite accounts for 49.5% and artificial graphite for 50.5%, reflecting the average technological level in China.

### ( 4 ) Boundary

The system boundary of graphite production is shown in Figure 25.

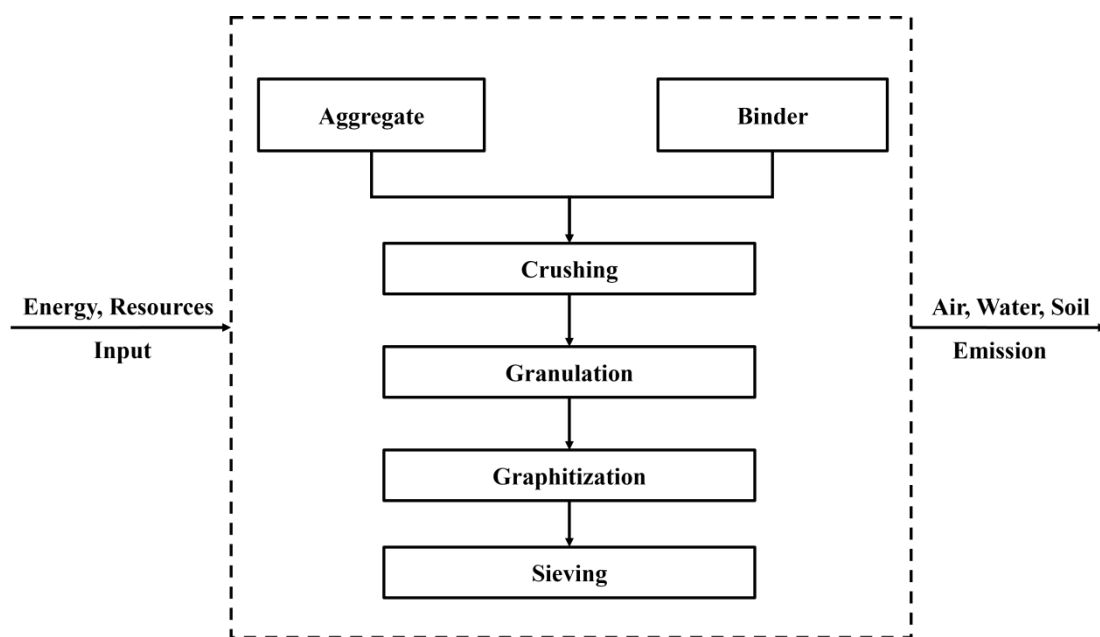


Figure 25 System Boundary of Graphite Production

### ( 5 ) Computational Models and Other Conventions

A process-based material flow balance linkage method was adopted. In the hybrid inventory approach, natural graphite and artificial graphite each account for 50%.

## 5.1.19 Lithium Hexafluorophosphate

### ( 1 ) Functional Unit

The functional unit of lithium hexafluorophosphate is 1 kg of lithium hexafluorophosphate product produced at the factory.

### ( 2 ) Process Step Description

The process includes dissolution, lithium hexafluorophosphate crystallization, separation, drying, and other steps. The manufacturing of production equipment and the construction of facilities are not included

within the system boundary.

### ( 3 ) Data Description

#### ■ Data Sources Representative

In June 2022, a data survey was conducted at Tianqi Materials, focusing on the production process and equipment energy consumption of lithium hexafluorophosphate, which provided evidence for the accuracy of the data.

In August 2023, a data survey was conducted at DoFluoride, focusing on the production process and energy consumption of lithium hexafluorophosphate, which further supported the validity and accuracy of the data.

#### ■ Geographical Representative

The geographical scope of lithium hexafluorophosphate production is limited to China.

#### ■ Time Representative

The data covers the period from 2021 to 2023

#### ■ Technical Representative

The data reflects the average technological level in China.

### ( 4 ) Boundary

The system boundary of lithium hexafluorophosphate production is shown in Figure 26.

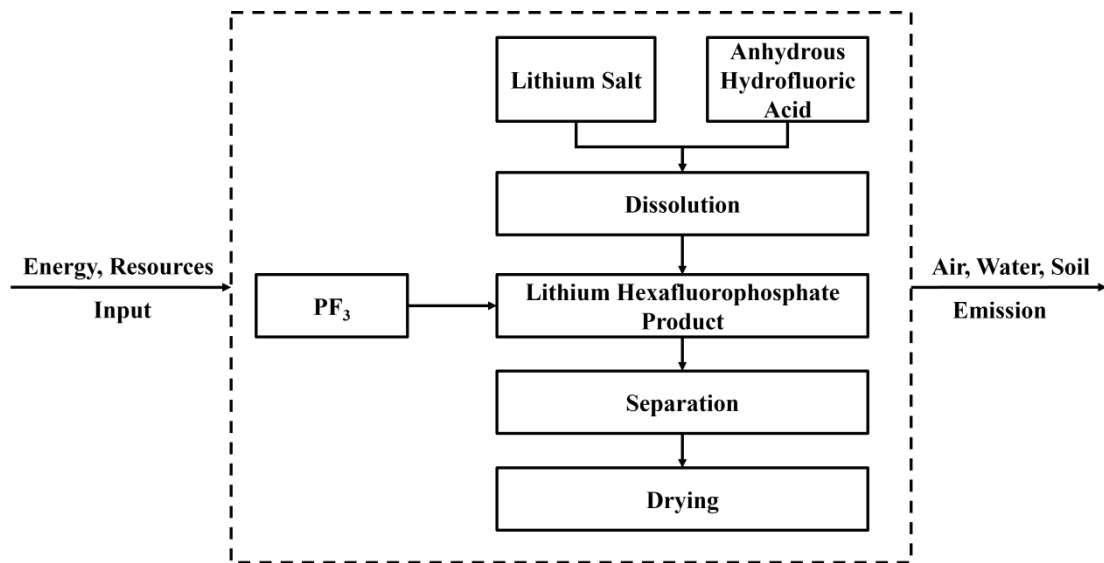


Figure 26 System Boundary of Lithium Hexafluorophosphate Production

### ( 5 ) Computational Models and Other Conventions

A hybrid inventory approach was adopted, based on an energy input-output model and a process-based material flow balance linkage method.

## 5.1.20 Refrigerants

### ( 1 ) Functional Unit

The functional unit of refrigerants refers to 1 kg of refrigerant product produced at the factory.

### ( 2 ) Process Step Description

The process includes fluorination and other steps. The manufacturing of production equipment and the construction of facilities are not included within the system boundary.

### ( 3 ) Data Description

#### ■ Data Sources Representative

The carbon emission data for refrigerants primarily comes from a survey of major refrigerant producers and suppliers in China. It is supplemented and refined by referencing data reserves and industry experience from the China Petroleum and Chemical Industry Federation, with data corrections performed.

■ □ Geographical Representative

The geographical scope of refrigerant production is limited to China.

■ □ Time Representative

The data covers the period from 2020 to 2023.

■ □ Technical Representative

The data reflects the average technological level in China.

( 4 ) Boundary

The system boundary for refrigerant production is shown in Figure 27.

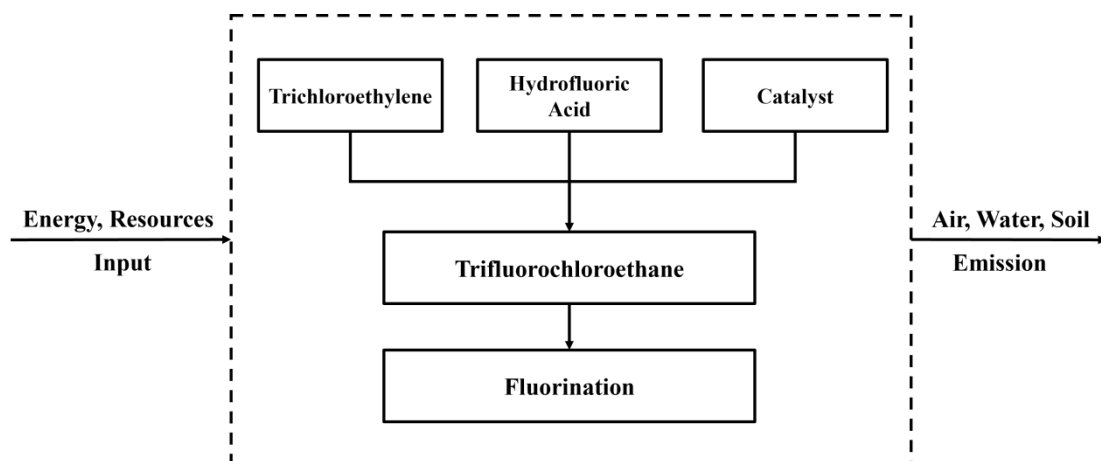


Figure 27 System Boundary of Refrigerant Production

( 5 ) Computational Models and Other Conventions

A hybrid inventory approach was adopted, based on an energy input-

output model and a process-based material flow balance linkage method.

## 6 Data Review

### 6.1 Reviewers

The external reviewer for the CALCD database is Professor Gong Xianzheng from the National Engineering Laboratory for Industrial Big Data Application Technologies.

### 6.2 Types and Scope of Review

The CALCD database review is an external review. The scope of the review includes:

- (1) Objectives and scope of the dataset
- (2) Raw data
- (3) LCI methodology
- (4) Applicability of the life cycle impact assessment methodology
- (5) Unit process inventory
- (6) Integrated process inventory
- (7) Dataset documentation

### 6.3 Review Results

The CALCD database passed the external review. The review results are shown in Table 7.

Table 7 Review Results Explanation Table

Review Category	External Review
Review Content	Definition of objectives and scope
	Raw data
	Unit process inventory data
	Integrated process inventory
	Life cycle inventory data
	Applicability of life cycle impact assessment methodology
	Dataset documentation
	Data quality indicator checks
Review Conclusion	All checks performed have passed
Reviewer and Institution Name	Gong Xianzheng, National Engineering Laboratory for Industrial Big Data Application Technologies