SHANGHAI SIEYUAN ZHW58A-145 Hybrid Gas-Insulated Switchgear LCA Report

Shanghai Sieyuan High Voltage Switchgear Co.,Ltd.

Organization Name:	Shanghai Sieyuan High Voltage Switchgear Co.,Ltd.
Organization Address:	E Zone, Building 2, No. 999 Zhuanxing Road, Minhang District, Shanghai
Production address:	No. 1,Dengyuan Road,Rugao City,Jiangsu,China
Products:	ZHW58A-145 Hybrid Gas-Insulated Switchgear
Declare unit:	a single unit of ZHW58A-145 Hybrid Gas-Insulated Switchgear operating for 20 years
Product Description:	The design of ZHW58A-145 Hybrid Gas-Insulated Switchgear including circuit breakers, disconnectors, earthing switches,bushings, operating mechanism and all other components as in service.It is of three-phase binning structure and designed for outdoor application, each of which is equipped with a spring operating mechanism that can realize a three-phase mechanical linkage. It applies SF6 gas as insulation and arc extinguishing media and is applied with pointer-type density relay for monitoring its pressure and density.
Product Model:	ZHW58A-145（0107-0106/150020/150033/150798）
Primary data collection period:	January 2023–December 2023
Age of data:	Primary data: 1 year. Secondary data: Maximal 10 years
Reference documents:	ISO 14040:2006 Life cycle assessment – Principles and framework ISO 14044:2006 Life cycle assessment – Requirements and guidance EN 50693:2019 – Product category rules for life cycle assessment of electronic and electrical products and systems EPDItaly007 – PCR for Electronic and electrical products and systems, Rev. 3, 2023/01/13 EPDItaly012 – Electronic and electrical products and systems – Switchs, Rev. 0, 2020/03/16

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Content

1. Purpose of the study

In recent years, the degradation of ecological systems has become a pressing global issue, with human industrial activities playing a significant role in exacerbating environmental pollution and degradation. As the world grapples with the consequences of climate change, deforestation, pollution, and loss of biodiversity, there has been a growing realization among businesses of the need to address their environmental footprint.

Enterprises nowadays are increasingly recognizing the importance of assessing the entire lifecycle of their products to identify areas where environmental impacts can be reduced or mitigated. Lifecycle assessment, a methodology that evaluates the environmental impacts of a product from extraction of raw materials to its disposal, has emerged as a valuable tool in this endeavor. Understanding the environmental impact of products across their lifecycle allows companies to make informed decisions regarding product design, sourcing of materials, manufacturing processes, distribution methods, and end-of-life management. By incorporating sustainability principles into their operations, businesses can not only minimize negative environmental impacts but also enhance their reputation, meet regulatory requirements, and appeal to environmentally conscious consumers.

In alignment with the principles of sustainable development and environmental stewardship, Shanghai Sieyuan High Voltage Switchgear Co.,Ltd has embarked on a comprehensive lifecycle assessment of its product. This initiative aims to assess the product's environmental performance, identify areas for improvement, and ultimately contribute to the company's commitment to producing environmentally responsible products as well as complying with requirement of type III Environmental Product Declaration.

In this report, Shanghai Sieyuan High Voltage Switchgear Co.,Ltd. conducted a cradle-to-grave life cycle assessment of its Hybrid Gas-Insulated Switchgear.

2. Company and Product Information

2.1 Company Introduction

Shanghai Siyuan High Voltage Switchgear Co., Ltd. has more than 1200 employees and has two major production bases that are advanced in China and world-class in the world, covering an area of 110kV GIS equipment production base in Shanghai and 252kV to 550kV GIS production base in Rugao City, Nantong, Jiangsu. The total area is 300000 square meters, and the production plant and office area is more than 100000 square meters. It has professional production, logistics, development, design A professional system of testing and services. The company independently develops and produces 72.5kV to 550kV high-voltage and ultra-high-voltage GIS, HGIS, GIL, and tank circuit breaker products. With an annual production capacity of over 4800 intervals for 110kV voltage grade GIS/DTCB products, over 3600 intervals for 252kVGIS/DTCB products, and over 800 intervals for 420kV/550kVGIS/DTCB products, the company can achieve sales of 4 billion yuan. The company has four high-voltage test halls with full shielding of 500kV and 1000kV, and is equipped with 1500kV and 3000kV impulse voltage generators and automatic measurement systems. The main production equipment is imported from abroad, and the production conditions and manufacturing technology have reached the international advanced level. The company's business covers domestic and overseas industries such as electricity, metallurgy, mining, transportation, and public utilities.

Figure 2.1.1 – Shanghai Sieyuan High Voltage Switchgear Co.,Ltd.

The company has also obtained ISO9001, ISO14001 and ISO45001 management system certifications.

2.2 Product Description

The design of ZHW58A-145 Hybrid Gas-Insulated Switchgear including circuit breakers, disconnectors, earthing switches,bushings, operating mechanism and all other components as in service.It is of three-phase binning structure and designed for outdoor application, each of which is equipped with a spring operating mechanism that can realize a three-phase mechanical linkage. It applies SF6 gas as insulation and arc extinguishing media and is applied with pointer-type density relay for monitoring its pressure and density..

Specifications:

- Rated Voltage: 145kV
- Rated Frequency: 50/60Hz
- Rated Current: 2500A
- Rated Short-time Withstand Current: 40kA

The calculation report contains product configurations that match GSCH002 code 0107-0106, 150020, 150033, 150798, and are applicable to these numbers and products of the same type.

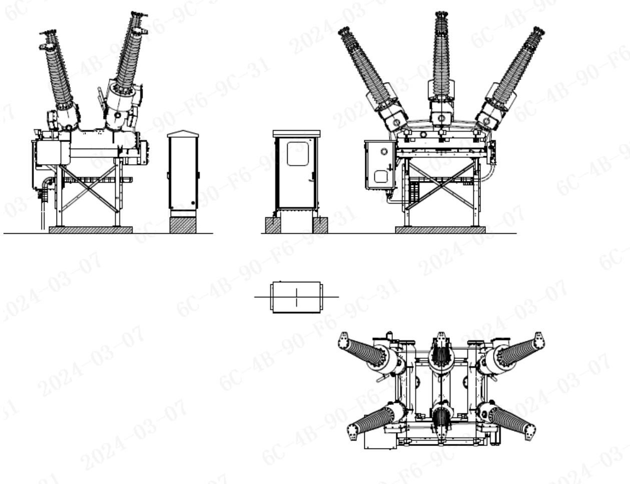

Figure 2.2.1 Hybrid Gas-Insulated Switchgear ZHW58A-145, Product code 0107-0106

The product manufacturing process is as follows:

Step 1: Main Assembly

This process focuses on assembling the arc extinguishing unit, isolation switch, and grounding switch within the product.

Step 2: Actuator Mechanism Assembly

This process involves assembling the circuit breaker mechanism, as well as the mechanisms for the isolation switch and grounding switch.

Step 3: Integration of Actuator Mechanism with Main Assembly

This process involves assembling the main body with the support frame, connecting the support frame with the mechanism, and connecting the mechanism with the main body's bending arm.

Step 4: SF6 Gas Filling

This process involves injecting SF6 gas into the product's interior to reach the specified pressure.

Step 5: Testing

This process focuses on testing the product's mechanical characteristics and confirming whether its insulation performance meets design requirements.

Step 6: Inspection

This process involves conducting a visual inspection of the product before packaging, in accordance with specified requirements.

Step 7: Packaging

The finished products are packaged in specified quantities for transportation and sale.

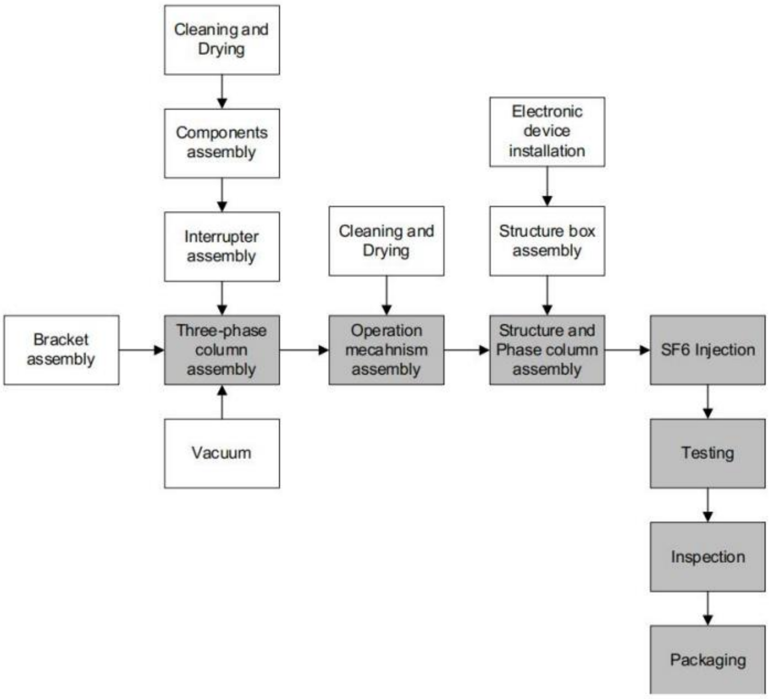

Chart 2.2.1 - Manufacturing flow chart

The product can be divided into the following main parts, weights are as follows.

Table 2.2.1 – Total weight of the ZHW58A-145 Hybrid Gas-Insulated Switchgear

Module Weight （kg） /Model	**ZHW58A-145 Single-bay CB+DS+DES+VD+CT+2 *BSG （0107-0106）**	**ZHW58A-145 Single-bay CB+DS+DES+CT+2* BSG （150020）**	**ZHW58A-145 Single-bay CB+DES+VD+CT+2* BSG （150033）**	**ZHW58A-145 Single-bay CB+DS+DES+VD+CT+2 *BSG （150798）**
CB	926	926	926	926
DS	262	262	0	262
DES	266	266	266	266
VD	4	0	4	4
CT	346	378	403	622
BSG	386	386	694	386
Steel bracket	407	407	407	407
Secondary components	351	351	351	351

LCP cabinets	176	176	176	176
Accessories	65	65	65	65
Packaging	1155	1155	1155	1155
Total	4344	4373	4446	4620

3. Goal and Scope Definition

3.1 Goal of Study

The reason for this LCA study is to conduct life cycle assessment in accordance with EPDItaly007 – PCR for Electronic and electrical products and systems, and EPDItaly012 – Electronic and electrical products and systems - Switches.
The intended audience is the head of Shanghai Sieyuan High Voltage Switchgear Co.,Ltd. and the business partners, the communication is focused on the above-mentioned audience.
According to the PCR the declared unit related to the functional unit is a single switch which establishes or interrupts the electrical continuity of the circuit to which it is applied, during a service life of 20 years. The type of EPD is "from cradle to grave".

The system boundaries include the following processes classified in life cycle phases according to EN 50693:2019 (Manufacturing, Distribution, Installation, Use and maintenance, End of life) and the Regulations of the EPD Italy (Upstream, Core, Downstream).

3.2 Scope of Study

The life cycle assessment in this study is conducted according to international standards and PCRs as follows:

- ISO 14040:2006 Environmental management — Life cycle assessment — Requirements and guidelines
- ISO 14044:2006 Environmental management — Life cycle assessment — Principles and framework
- EPDItaly007 – PCR for Electronic and electrical products and systems, Rev. 3, 2023/01/13
- EPDItaly012 – Electronic and electrical products and systems – Switchs, Rev. 0, 2020/03/16
- EN 50693:2019 Product category rules for life cycle assessments of electronic and electrical products and systems

3.2.1 Product System, Declared Unit and Reference Flow

According to PCR EPDItaly012, a single switch is adopted as the declared unit which establishes or interrupts the electrical continuity of the circuit to which it is applied, during a service life of 20 years.

The declared unit is therefore defined as a single unit of ZHW58A-145 Hybrid Gas-Insulated Switchgear operating for 20 years. Reference flow is one single unit of ZHW58A-145 Hybrid Gas-Insulated Switchgear.

3.2.2 System Boundary

The system boundary covers the entire life cycle stage from cradle to grave in accordance with PCR EPDItaly012:

Table 3.2.1 - Life cycle modules

<table>
<tr><th colspan="2">MANUFACTURING STAGE</th><th>DISTRIBUTION STAGE</th><th>INSTALLATION STAGE</th><th>USE & Maintenance STAGE</th><th>END-OF-LIFE STAGE

De-installation</th></tr>
<tr><th>UPSTREAM MODULE</th><th>CORE MODULE</th><th colspan="4">DOWNSTREAM MODULE</th></tr>
<tr><td>extraction of raw materials, including waste recycling processes and the production of semi-finished, packaging and ancillary products</td><td>manufacturing of the product constituents, including all the stages</td><td colspan="4" rowspan="4">IN ACCORDANCE WITH EN 50693</td></tr>
<tr><td>transportation of raw materials to the manufacturing company</td><td>product assembly</td></tr>
<tr><td></td><td>packaging</td></tr>
<tr><td></td><td>waste handling processes</td></tr>
</table>

The system boundary of the Product life cycle is shown in Figure blow:

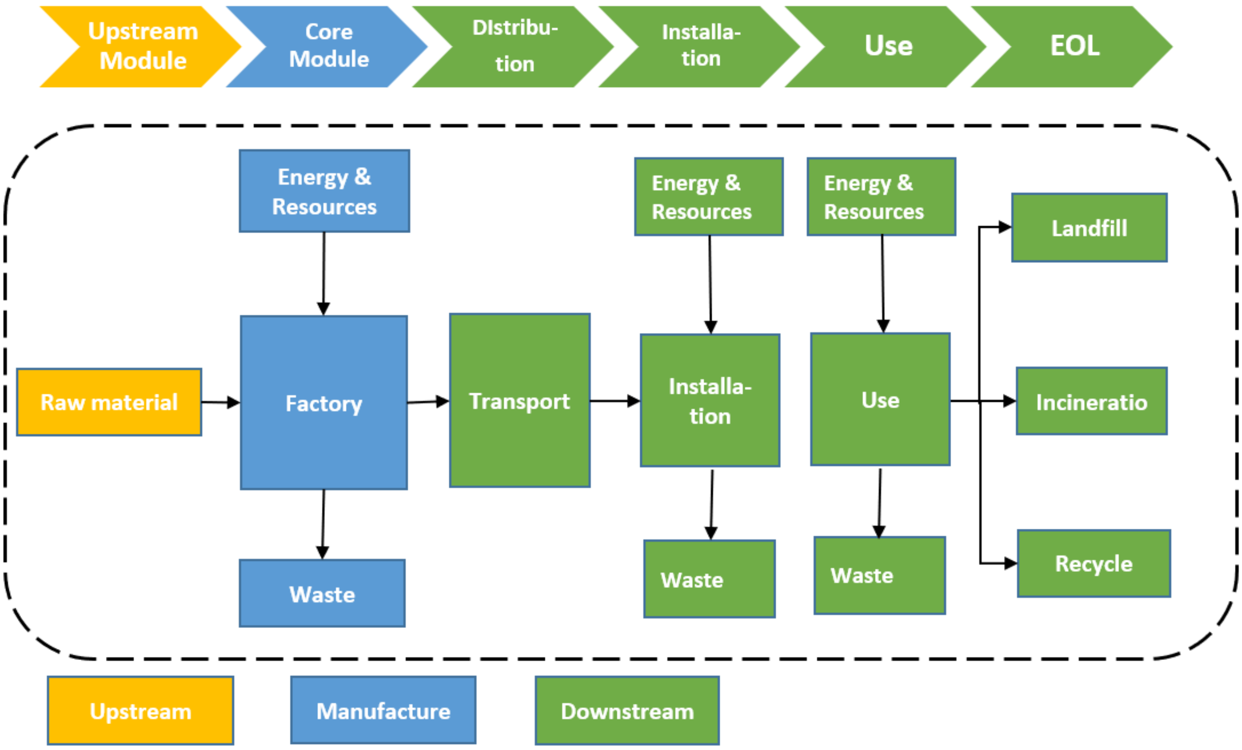

Figure 3.2.1: Lifecycle Flow chart

3.2.3 Allocation Rules

The energy and resources usage per functional unit in the production stage of the product is calculated by dividing the annual energy or resource consumption by the total output of the company's product, In detail, the allocation of energy resources for plant processing use is calculated using the units of Hybrid Gas-Insulated Switchgear produced to the total energy and resources consumption in the Shanghai Sieyuan plant during the reference period. That is, the physical allocation method is used for allocation.

In addition, the default distribution rule for the environmental impacts and benefits of reuse, recovery and/or recycling is based on the polluter pays principle (PPP), which means that the recovery or reuse beneficiary bears the environmental impacts and benefits associated with the recovery or reuse treatment, and the original product manufacturer does not have to bear this part of the impact burden. It also does not participate in the sharing of benefits (environmental impact of the production of the same product avoided by recycling and reuse).

3.2.4 Cut-off Criteria

According to EPD Italy Regulations and PCR EPDItaly007, the following flows and operations are cut-offed:

- Production, use and disposal of the packaging of components and the packaging of semi-finished intermediates.

- Materials making up the ZHW58A-145 Hybrid Gas-Insulated Switchgear itself whose total mass does not exceed 1% of the total weight of the device.
- Material and energy flows related to dismantling phase which is performed by adopting manual tools (e.g. screwdrivers, hammers, etc.).

During the production process, auxiliary materials such as alcohol (used for cleaning agents), machine oil, and cutting oil are utilized. However, due to their minimal consumption and the resulting waste generation being less than 1% of the weight of the raw materials per unit of product produced, they have negligible impact on the overall results of the life cycle assessment (LCA) and are therefore cut-offed in accordance with cut-off principle from the calculation.

3.2.5 Relevant Assumptions

The following assumptions are used in this assessment:

Table 3.2.2 - Assumptions for each stage of the life cycle

Life cycle module	Life cycle stage	Assumption
MANUFACTURING STAGE	Upstream Module	• Raw material information is provided by SHANGHAI SIEYUAN according to product's bill of material. • The density of wood package is assumed to be 768kg/m3 as plywood is used.
	Core Module	• China consumption electricity mix was used in the core module as residual mix is not available. • Assume same amount of energy and resource consumption were used to produce each unit of rated power of ZHW58A-145 Hybrid Gas-Insulated Switchgear（0107-0106） in the manufacturing phase. • Assume same amount of waste were produced to produce each unit of ZHW58A-145 Hybrid Gas-Insulated Switchgear in the manufacturing phase. • The distance from the SHANGHAI SIEYUAN plant to the downstream waste disposal site is assumed to be 1000km.
DISTRIBUTION STAGE	Downstream Module	• The product is to be used in Argentina(0107-0106), Romania (150020), Colombia(150033), Rio(150798). Downstream distribution distances are estimated from the GAODE map and SEARATE website for shipment distances, inland transport is by truck freight and sea transport is by ship. • The distance from port of Colombia to the client is assumed to be 1000km.
INSTALLATION STAGE		• Energy and resources needed during installation are provided by SHANGHAI SIEYUAN, it is assumed the same amount were used to install each unit of ZHW58A-145 Hybrid Gas-Insulated Switchgear. • The distance from the user installation site to the downstream waste disposal site is also assumed to be 1000km • In this stage, package of the ZHW58A-145 Hybrid Gas-Insulated Switchgearwere disposed, of which 80% of steel and 0% of wood is assumed to be recycled in accordance with en50693 annex G table G.4, 20% of steel is assumed to be landfilled and 100% of waste wood package is assumed to be incinerated.
USE & Maintenance STAGE		• Energy used during the product service life is provided by SHANGHAI SIEYUAN in accordance with PCR EPDItaly018, it is assumed the same amount of energy were used to install each unit of ZHW58A-145 Hybrid Gas-Insulated Switchgear. • According to expert judgement and from various users provided by SHANGHAI SIEYUAN, inspection and maintenance do not require replacement parts during the service life, and ZHW58A-145 Hybrid Gas-Insulated SwitchgearSF6 changes are not necessary or foreseen, therefore are not considered in the study.

END-OF-LIFE STAGE De-installation		• During the end-of-life disposal stage, the product is transported and then manually dismantled into components and then sorted for further processing. Some metals or plastics are recycled according to EN50693 standards, while the remaining materials are either landfilled or incinerated.

3.2.6 Impact Category and Assessment Method

Based on the definition of the goal of study, the LCIA methodology for indicators/impact category used in this study is choose in accordance with EN 15804:2012+A2:2019. Detailed impact categories are shown below.

Table 3.2.3 - Category of environmental impacts and assessment models

Indicator name and abbrevation (EN)	Unit (EN)
Global Warming Potential - fossil fuels (GWP-fossil)	kg CO2 eq.
Global Warming Potential - biogenic (GWP-biogenic)	kg CO2 eq.
Global Warming Potential - land use and land use change (GWP-luluc)	kg CO2 eq.
Global Warming Potential - total (GWP-total)	kg CO2 eq.
Depletion potential of the stratospheric ozone layer (ODP)	kg CFC-11 eq.
Acidifcation potential, Accumulated Exceedance (AP)	mol H+ eq.
Eutrophication potential - freshwater (EP-freshwater)	kg P eq.
Eutrophication potential - marine (EP-marine)	kg N eq.
Eutrophication potential - terrestrial (EP-terrestrial)	mol N eq.
Photochemical Ozone Creation Potential (POCP)	kg NMVOC eq.
Abiotic depletion potential - non-fossil resources (ADPE)	kg Sb eq.
Abiotic depletion potential - fossil resources (ADPF)	MJ, net calorific value
Water Use	m3 eq.

Note: eq is short for equivalent, meaning equivalent. For example, the indicator of climate change is CO_2 as reference material, other greenhouse gases have their own CO_2 equivalent factors according to the strength of the greenhouse effect, so the product life cycle of all kinds of greenhouse gas emissions can be multiplied by the equivalent factor, cumulative climate change index total, unit is kg CO2 eq. For details, see Appendix a.

3.2.7 Software and Database

In the study, SimaPro 9.5 software was used to establish the model for the life cycle of products and calculate LCA results. SimaPro is a specialized LCA program developed by the Dutch company PRé Consultants. It supports analysis on LCA stages with built-in databases including Swiss Ecoinvent Dataset, European Reference Life Cycle Reference Database (ELCD), Agri-footprint, USLCI and etc. In this study, datasets from the Ecoinvent v3.9 were used.

In terms of the choice of background data, the system model chosen in this study is cut-off by classification, as required by EPD.

3.2.8 Data Quality Requirement

As far as possible, the entire calculation is based primarily on primary data, and secondary data is obtained based on life-cycle databases or literature, among them, energy consumption is mainly geographical, that is, refer to local data.

Data quality represents the difference between LCA study target representation and the actual data representation, and four dimensions of data was used to evaluate the data quality in this report. The consumption and emission inventory data in the model were evaluated from four aspects: inventory data source and algorithm, representative of time, geography and technical. The consumption of the associated background database was also evaluated to assess the uncertainty by matching with the upstream background process.

Shows data quality requirements in the following table:

Table 3.2.4 - Data quality requirements of LCA

Parameter	Describe	Requirements
Time Representation	Priority is given to the year of the data and the minimum time span for data collection, as well as time data for specific evaluated carton	Primary data were collected from SHANGHAI SIEYUAN as average production data from January to December 2023. While the secondary data were mainly acquired from database and cover a relatively broad period, generally within 10 years.
Geographical Representation	Priority is given to the geographical area where the data is located (e.g., city, province, country, region), as well as specific data for geographically specific products	The primary data are the manufacturing data provided by SHANGHAI SIEYUAN. Electricity data from the China region of the Ecoinvent database was used for the upstream electricity data. For other secondary data, priority is given to data from the China region of the database, followed by data from the global region,

		and in the absence of data from both China and the global region, data from the remaining regions are then used.
Technical Representation	Priority should be given to whether the data is targeted at a specific technology or a set of mixed technologies, as well as product specific technical data	The primary data are all the manufacturing data provided by SHANGHAI SIEYUAN. Secondary data are mainly used based on global average technology levels.
Data algorithms (calculation accuracy, precision, completeness, consistency and reproducibility)	Priority should be given to representative data. A range of variability (e.g., variance) for each type of data as well as more accurate data (e.g., with the lowest statistical variance) should be given priority; Prioritize the percentage of the measured data and the representativeness of the data (e.g., allows independent practitioners to repeat report results in sampling range, the periodicity of the measurements, etc.); Data selection should be considered in a uniform manner in each part of the analysis; Information about methodology and data should allow independent practitioners to replicate reported results to the greatest extent possible.	Allow independent practitioners to reproduce report results.

To fulfil above requirements and ensure the reliability of the calculated results, priority was given to the site-specific data provided by the manufacturers and suppliers during the data collection process. Secondary data was used from the Ecoinvent database, which has been strictly reviewed and widely applied in LCA studies internationally.

4. Life Cycle Inventory Analysis

The life cycle data for this study includes both primary data and secondary data.

Primary data - collected and provided by SHANGHAI SIEYUAN from January to December 2023.

Secondary data - Ecoinvent v3.9 database.

4.1 Upstream module

Raw material consumption and transportation data are shown in the table 4.1.1 and table 4.1.2 below.

Table 4.1.1 – Raw material inventory(0107-0106 as example)

Module	Material	Weight（kg）
CB	steel	96.62
	copper	9.27
	ABS	0.21
	plastics	1.60
	adsorbent	3.00
	rubber	0.82
	epoxy resin	50.46
	stainless steel	354.89
	silastic	0.68
	Unalloyed steels	103.44
	Polytetrafluoroethylene	3.87
	Aluminum alloy	278.60
	Zinc alloy	3.75
	Electromagnets	0.46
	Cold-rolled steel	8.47
	Copper alloys	1.59
	Nitrile rubber	0.00
	toughened glass	0.48
	aluminium	0.08
	Polyvinylidene Fluoride	0.15
	Chemicals	0.57
	Motor	7.43
DS	steel	35.68
	stainless steel	22.09
	epoxy resin	5.49
	Unalloyed steels	22.38
	Polytetrafluoroethylene	0.04
	Motor	3.38
	resistance	0.36
	PET	0.00
	Aluminum alloy	169.02
	copper	1.27
	rubber	0.35
	ABS	0.24
	plastics	1.31
	PC	0.12
	nylon	0.18
DES	steel	35.68
	stainless steel	22.09

	epoxy resin	5.49
	Unalloyed steels	21.96
	Polytetrafluoroethylene	0.04
	Motor	3.38
	resistance	0.36
	PET	0.00
	Aluminum alloy	173.64
	rubber	0.35
	ABS	0.24
	plastics	1.31
	copper	0.73
	PC	0.12
	nylon	0.18
VD	plastics	3.60
CT	steel	231.19
	rubber	0.75
	Aluminum alloy	65.79
	Polytetrafluoroethylene	1.80
	stainless steel	0.27
	plastics	0.06
	Aluminum alloy	45.87
BSG	Aluminum alloy	116.40
	FRP:16.5kg HTV：14.2kg Aluminum alloy: 12.8kg	261.00
	rubber	0.55
	steel	8.53
Steel support	Unalloyed steels	390.59
	steel	11.51
	stainless steel	0.78
	copper	3.82
Secondary circuit	button	0.03
	Relays	2.53
	Contactors	0.18
	plastics	0.50
	Terminal	7.82
	lamp	0.52
	copper	13.34
	switch	1.89
	heater	1.25
	receptacle	0.19
	steel	71.08
	aluminium	0.25
	connector	14.67
	cable	236.82
LCP	steel	1.44
	stainless steel	157.30
	copper	1.12
	Unalloyed steels	16.32
Accessories	Unalloyed steels	1.34
	steel	1.47
	stainless steel	8.40
	adsorbent	3.00
	Aluminum alloy	1.14
	rubber	0.05
	SF6	50.00
Packing	wood	850.60
	steel	35.60
	rubber	0.77
	Unalloyed steels	267.80
	Polytetrafluoroethylene	0.12

Table 4.1.2 – Upstream transport distance of major components

Module	Ton·km transport
CB	108.57
DS	25.56
DES	26.42
VD	0.29
CT	51.87
BSG	28.72
Steel bracket	69.05
Secondary components	54.65
LCP cabinets	2.12
Accessories	101.13
Packaging	23.55
Total	491.93

4.2 Core Module

In this stage, inputs are the energy used during production in SHANGHAI SIEYUAN while outputs are the waste generated.

The product consumes electricity and water during the manufacturing phase, of which all were being supplied externally. All of SHANGHAI SIEYUAN's electricity consumption comes from grid electricity and no additional green power or green certificates are purchased. According to the China Energy Yearbook, grid electricity is supplied from all major power plants in China, with a mix of fossil, natural gas, wind, solar, and nuclear energy sources.

The energy and resources usage per functional unit in the production stage of the product is calculated by dividing the annual energy or resource consumption by the total output of the company's product, In detail, 226712.5kWh electricity and 59145t of water were used during 2023 and 633 units of products in total, thus the electricity and water used per unit of product is:

Table 4.2.1 – Core Module inventory

Lifecycle stage	Activity	Usage per functional unit	Unit
Energy and resource consumption during manufacturing	Grid Power	358.16	kWh
	Water	93.44	t
Waste produced during manufacturing	Waste water	93.44	t

During the production process, auxiliary materials such as alcohol (used for cleaning agents), machine oil, and cutting oil are utilized. However, due to their minimal consumption and the resulting w aste generation being less than 1% of the weight of the raw materials per unit of product produced , they have negligible impact on the overall results of the life cycle assessment (LCA) and are therefore cut-offed in accordance with cut-off principle from the calculation.

4.3 Distribution

The product is manufactured in China and to be used in Argentina. Downstream distribution distances are estimated from the GAODE map and SEARATE website for shipment distances, inland transport is by truck freight and sea transport is by ship. The weight of single piece of ZHW58A-145 Hybrid Gas-Insulated Switchgear（0107-0106）(including package and oil tank) is approximately 4.4t.

Table 4.3.1 – Downstream transportation inventory

Lifecycle stage	Activity	Distance	Usage per functional unit(ton•km)
Downstream transportation	Freight by truck（lorry 16-32 metric ton, EURO4）	SHANGHAI SIEYUAN to port:190km Port to Client：1000km	5236
	Freight by ship（container ship）	Shanghai port to Argentina port:20640km	90816

4.4 Installation

Hybrid Gas-Insulated Switchgear（0107-0106）is hoisted with a 5T crane with an engine power of 85kW, and the service time is 4.8h. According to the calculation, the lower value of diesel is 43MJ/kg, and 34kg diesel is needed during installation.

At this stage, as the installation was completed, the product packaging (850.60kg wood) and steel (303.40kg steel)was discarded, of which 80% of steel and 0% of wood is assumed to be recycled in accordance with en50693 annex G table G.4, 20% of steel is assumed to be landfilled as inert material and 100% of waste wood package is assumed to be incinerated to achieve a biogenic carbon balance. Other packaging material such as waste rubber and plastic are treated in mix treatment method.

Table 4.4.1 – Installation inventory

Lifecycle stage	Activity	Usage per functional unit	Unit
Installation	Diesel consumed by crane	34	kg
	SF6	50	kg
Waste Packaging	Wood packaging to be incinerated	850.60	kg
	Steel to be landfilled	303.40	kg
	Waste Plastics(mix treatment)	0.89	kg
Transportation of waste to waste management	Waste Packaging	1154.89	ton*km

4.5 USE & Maintenance

Energy used during the product service life is1208 kWh.

$$E_{use}[\text{kWh}] = \frac{P_{use} * 8760 * RSL * \alpha}{1000}$$

where: (P_{use} is the power consumed by the switch at a given value of current;RSL is the service life of the product, assumed to be 20 years; 8760 is the number of hours in a year; α is a coefficient describing the amount of time in which the switch is requested to operate its function, according to PCR, 30% is selected for high voltage equipment; 1000 is the conversion factor that allows the energy consumed in kWh over the product's service life to be expressed. (P_{use} can be calculated by the following formula. The referenced current specified in PCR is 50% of the nominal current, while according to Shanghai Sieyuan, the real testing current normally is only 10% of the nominal current.Thus, in this study the reference current Ir is calculated as 10% of the nominal current In.

The P_{use} of hybrid gas-insulated switchgear is calculated and listed in table 4.5.1.

$$P_{use} = I_r^2 \times R \times 3$$

Table 4.5.1 – Power consumption of hybrid gas-insulated switchgear

Hybrid gas-insulated switchgear	Nominal current, I_n/A	Single phase resistance, $R/\mu\Omega$	P_{use}/W
ZHW58A-145	2500	122.61	27.79

For the maintenance of the electric products, the Shanghai Sieyuan high-voltage electric equipments are designed to be free of maintenance during its service life. Meanwhile, the hybrid gas-insulated switchgear has reliable sealing performance, thus requires no additional recharge of SF6 during its service life. Therefore, no inputs and outputs are taken place in maintenance stage in this study.

4.6 End of life

According to EN50693, the inputs and outputs associated with all relevant steps from deinstallation to the disposal or the point of substitution, shall be included in the end-of-life stage. In this study, it is assumed that same as installation, a 5T crane with an engine power of 85kW, and the service time is 4.8h. According to the calculation, the lower value of diesel is 43MJ/kg, and 34kg diesel is needed during deinstallation.

After disassembling, it is assumed that the disposal components will be transported to corresponding waste management factory, the distance is assumed to be 1000km by truck. The weight of the waste ZHW58A-145 Hybrid Gas-Insulated Switchgear（0107-0106）is approximately 3.2ton.

Table 4.6.1 – Eol transportation inventory

Lifecycle stage	Activity	Usage per functional unit	Unit
Disassemble	Diesel used by crabe	34	kg
Eol transportation	Transportation by truck	3200	ton•km

During the end-of-life disposal stage, the product is manually dismantled into components and then sorted for further processing. Some metals or plastics are recycled according to EN50693 standards, while the remaining materials are either landfilled or incinerated. The details of the disposal methods and their respective weights are as follows:

Table 4.6.2 – Eol treatment inventory

Material		Weight of material to be disposal（kg）	Material recovery rate	Weight of material being recycled（kg）	Weight of material being treated（kg）	Treatment method
Metals	Steel	1623.54	80%	1298.83	324.71	Landfilled
	Other ferrous metals	0.46	80%	0.37	0.09	Landfilled
	Aluminum	850.79	70%	595.55	255.24	Incineration
	Copper	31.14	60%	18.68	12.46	Incineration
	Other non-ferrous metals	3.75	60%	2.25	1.50	Incineration
Plastics	ABS	0.68	20%	0.14	0.54	Treatment mix
	Rubber	64.98	0%	0.00	64.98	Treatment mix
	Other Plastics	14.90	0%	0.00	14.90	Treatment mix
Minerals	Glass	0.48	60%	0.29	0.19	Incineration
Others	Cables	236.82	0%	0.00	236.82	Open burnings
	Electronics	304.97	0%	0.00	304.97	Incineration
	SF6	50.00	100%	50.00	0.00	Recycled

4.6 Additional data collected

Table below listed the primary energy resources used as raw material and secondary fuels during product lifecycle.

Table 4.6.1 –Primary energy resources used as raw material

	Upstream Module	Core	Downstream					
Material	Manufacturing		Distribution	Installation	Use	End of Life	Unit	LHV
Plastic	81.44	0	0	0	0	0	kg	43MJ/kg
Wood	850.60	0	0	0	0	0	kg	18MJ/kg

5. Impact Assessment

Potential Environmental impact of each lifecycle stage are shown below.

Table 5.1 – Environmental impact descriptive parameters

Impact Category	Unit	Total	Manufacturing Stage	Distribution Stage	Installation Stage	Use & Maintenance Stage	End of Life Stage
Climate change	kg CO2 eq	3.17E+04	1.96E+04	1.92E+03	8.45E+03	4.82E+02	1.19E+03
Climate change - Fossil	kg CO2 eq	3.15E+04	2.08E+04	1.92E+03	7.20E+03	4.64E+02	1.19E+03
Climate change - Biogenic	kg CO2 eq	9.43E+01	-1.16E+03	1.58E-01	1.25E+03	6.87E+00	2.74E+00
Climate change - Land use and LU change	kg CO2 eq	4.65E+01	3.29E+01	1.23E+00	1.15E+00	1.11E+01	1.45E-02
Ozone depletion	kg CFC11 eq	1.19E-01	1.19E-01	2.98E-05	1.10E-05	1.71E-05	6.63E-07
Acidification	mol H+ eq	2.79E+02	2.39E+02	3.19E+01	7.06E+00	7.75E-01	5.58E-01
Eutrophication, freshwater	kg P eq	1.82E+01	1.78E+01	1.12E-01	2.68E-01	1.34E-02	1.13E-02
Eutrophication, marine	kg N eq	3.99E+01	2.91E+01	8.47E+00	1.81E+00	2.00E-01	2.98E-01
Eutrophication, terrestrial	mol N eq	4.28E+02	3.10E+02	9.32E+01	1.93E+01	2.12E+00	2.76E+00
Photochemical ozone formation	kg NMVOC eq	1.38E+02	1.03E+02	2.64E+01	5.76E+00	1.11E+00	1.63E+00
Resource use, minerals and metals	kg Sb eq	2.31E+00	2.29E+00	4.10E-03	1.01E-02	2.75E-04	5.00E-05
Resource use, fossils	MJ	2.79E+05	2.33E+05	2.54E+04	1.14E+04	8.29E+03	3.06E+02
Water use	m3 depriv.	3.30E+03	2.38E+03	8.77E+01	1.50E+02	6.67E+02	1.65E+01

Parameters describing resource use are shown below.

Table 5.2 – Parameters describing resource use

Parameter	Unit	Total	Manufacturing Stage	Distribution Stage	Installation Stage	Use&Maintenance Stage	End of Life Stage
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw material (PENRE)	MJ, net calorific value	2.75E+05	2.30E+05	2.54E+04	1.14E+04	8.29E+03	3.06E+02
Use of renewable primary energy excluding renewable primary energy resources used as raw material (PERE)	MJ, net calorific value	4.62E+04	4.35E+04	2.60E+02	7.91E+02	1.68E+03	6.21E+00
Use of non-renewable primary energy resources used as raw material (PENRM)	MJ, net calorific value	3.50E+03	3.50E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Use of renewable primary energy resources used as raw material (PERM)	MJ, net calorific value	1.53E+04	1.53E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials) (PENRT)	MJ, net calorific value	2.79E+05	2.34E+05	2.54E+04	1.14E+04	8.29E+03	3.06E+02
Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials) (PERT)	MJ, net calorific value	6.15E+04	5.88E+04	2.60E+02	7.91E+02	1.68E+03	6.21E+00
Net use of fresh water (FW)	m^3	1.27E+02	1.04E+02	2.92E+00	4.70E+00	1.46E+01	5.51E-01
Use of secondary raw materials (MS)	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Use of renewable secondary fuels (RSF)	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Use of non-renewable secondary fuels (NRSF)	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Waste production descriptive parameters are shown below.

Table 5.3 – Waste production descriptive parameters

Parameter	Unit of measurement	Total	Manufacturing Stage	Distribution Stage	Installation Stage	Use&Maintenance Stage	End of Life Stage
Hazardous waste disposed (HWD)	kg	1.05E+01	1.02E+01	1.47E-01	5.10E-02	3.32E-02	1.80E-03
Non-hazardous waste disposed (NHWD)	kg	9.16E+03	7.52E+03	7.15E+02	2.74E+02	2.04E+01	6.25E+02
Radioactive waste disposed (RWD)	kg	3.59E-01	3.06E-01	4.09E-03	1.29E-02	3.62E-02	7.96E-05
Materials for energy recovery (MER)	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Material for recycling (MFR)	kg	2.21E+03	0.00E+00	0.00E+00	2.43E+02	0.00E+00	1.97E+03
Components for reuse (CRU)	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Exported thermal energy (ETE)	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Exported electricity energy (EEE)	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

6. Result Interpretation

6.1 Identification of Significant Issues

The percentage of potential environmental impacts at each life cycle stage is shown in the figure below. As can be seen from the diagram, the raw material acquisition stage accounts for most of the potential environmental impact in each impact category due to consumption of material such as steel, aluminum, plastic and electronic components.

Furthermore, depending on the category of impact, the installation and distribution transportation stages also bring a certain proportion of influence.

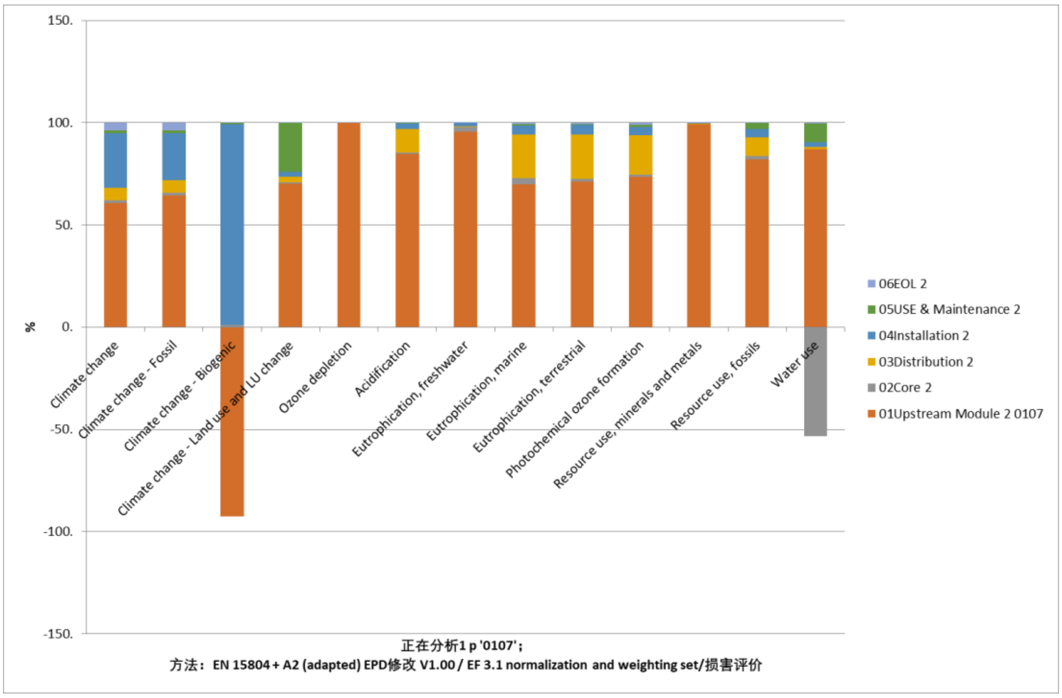

Figure 6.1.1 – Potentiel environnemental impact per life stage

Moreover, raw material with significant impact were identified in figure 6.1.2 below.

As seen from the graph, for climate change, the sub component CB and BSG contribute to the main carbon emissions of the ZHW58A-145 Hybrid Gas-Insulated Switchgear（0107-0106）, however, for the impact categories such as acidification, eutrophication and abiotic depletion, the potential environmental impact of secondary component is much higher in percentage due to consumption of cable(copper).

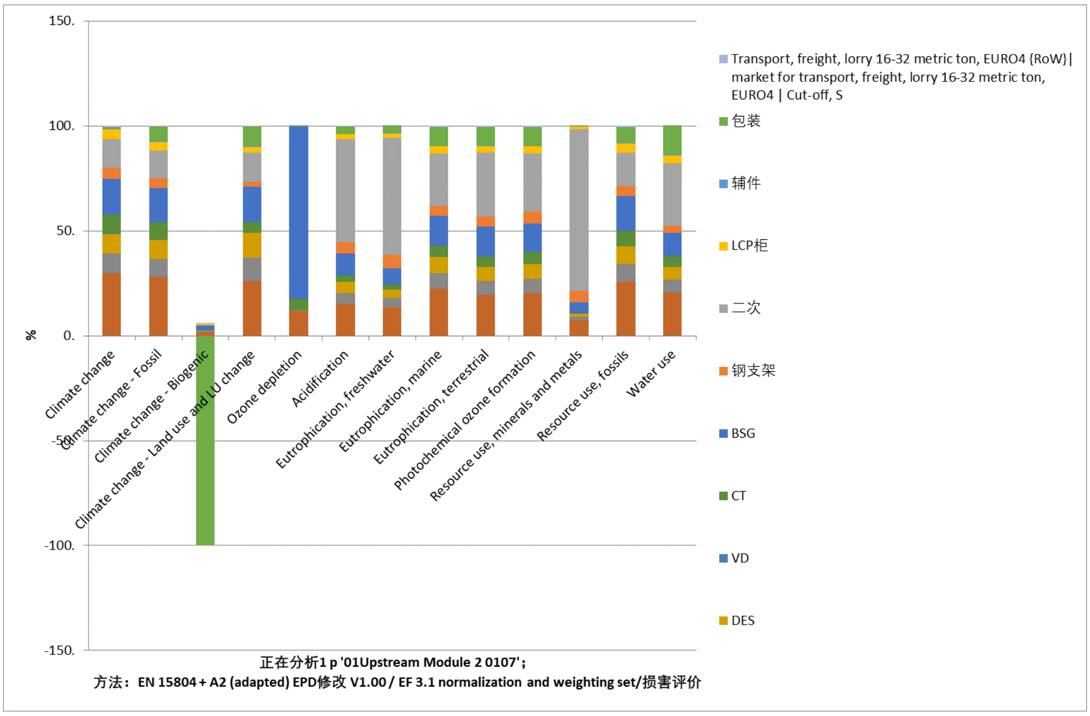

Figure 6.1 .2– Potential environmental impact of major component

6.2 Completeness, Sensitivity, Uncertainty and Consistency Evaluation

6.2.1 Completeness

According to the requirements in ISO 14040, completeness was evaluated within the life cycle, including,

- The completeness of processes in the life cycle of the product.

  The system boundary of this study was set from "cradle-to-grave". The system boundary includes the raw material acquisition stage, the production stage, the distribution stage, the use stage and the end-of-life stage in accordance with PCR. The primary data of the study includes material consumption and transportation. Secondary data was defined from "cradle-to-gate". The life cycle model and assessment methodology are appropriate for the system boundary as defined in the goal and scope of the study.

- The inclusion of raw material and energy input for the product.

Primary data was collected for the raw materials required for the production, energy information and material transportation. Primary data collection has been completed.

The evaluation of completeness reflects that the life cycle impact assessment of this study is consistent with the goal of this study. Primary and secondary data collection has been completed.

6.2.2 Sensitivity Analysis

The aim of the sensitivity analysis was to assess the reliability of ISO 14044:2006 by determining the impact of uncertainty in the calculation of data, allocation methods, and parameters on the final results and conclusions. As the study was performed in strict compliance with the PCR requirements, no additional checks for sensitivity were performed.

6.2.3 Uncertainty Analysis

This LCA study is designed to assess the potential environmental impact of Shanghai Sieyuan High Voltage Switchgear Co.,Ltd. ZHW58A-145 Hybrid Gas-Insulated Switchgear（0107-0106）during its life cycle, and the calculation result is subject to the data collected. The use of secondary emission factors is justified within the cradle-to-grave boundary.

Data gaps, data representativeness, and temporal variables can lead to uncertainties. Therefore, based on a balance through level of detail and reasonable evaluation costs, the data applied in this report is the most suitable at the time of the research, while sources of primary and secondary data are subject to uncertainty.

To minimize uncertainty, the following approach were used in the modeling and calculation:

1. Completing correct data collection (close mass and energy balances).
2. Choosing representative LCA data for the upstream and background data, which represent the actual technology.
3. Understanding the technical processes and defining parameters that are uncertain.
4. Completeness of the system (no unjustified cut-offs).

The consistency in the data collected and background data reduces uncertainty. In addition, the analysis of the different scenarios, some sensitivity calculations performed and the technical understanding of the LCA modeler (as well as the reviewer) ensure minimum uncertainty.

A common rule estimates that the best achievable uncertainty in LCA to be around 10%. For this EPD LCA study, the use of the most appropriate datasets available and the most representative technology route reduces the level of uncertainty.

6.2.4 Consistency Evaluation

Consistency evaluation is to ensure that assumptions, methods, and data are applied in the same way throughout the LCA study in accordance with the goal and scope definition.

All assumptions, methods and data are consistent with each other and with the study's goal and scope. Differences in background data quality were minimized by exclusively using LCI data from the Ecoinvent 3.9 databases. System boundaries, allocation rules, and impact assessment methods have been applied consistently throughout the study. Moreover, the elements of impact assessment have been consistently applied. The impact evaluation models applied in this study is in accordance with EN 15804 +A2 Method.

6.3 Limit

The results are only valid for the situation defined by the assumptions described in the present report, and they are subject to change if these conditions change. The relevance and reliability of the report and its conclusions for use by third parties, or for purposes other than those specifically mentioned in this report cannot be guaranteed. Secondary data used for the study mainly come from Ecoinvent 3.9, which is a Swiss database. Even if this one is the most widely used in the world, data precision for Chinese situation might be improved by using local data.

LCIA only covers environmental issues which identified within the evaluation purpose and scope. Product LCA is still a field for further development. At LCA current level in the global, there is no universally accepted approach to establish a consistent and accurate link between inventory data and specific potential environmental impacts. Models for various impact category are at different development stages currently.

7. Conclusion and Recommendation

The LCA result per functional unit of this product has been calculated and shown in the report. The calculation is based on the data collected from cradle to grave from January 2023 to December 2023. Results shown that the use stage is the stage with the greatest potential environmental impact throughout the life cycle of the product due to large electricity consumption.

In response to the LCA results, the following recommendation are made as future improvement directions:

1. In addition to the use phase, the impact from raw material acquisition of the product has the largest potential environmental impact. To reduce the potential impact of raw materials, in addition to reducing the loss of raw materials in the production process, the manufacturer can encourage suppliers to take the lead in assessing the lifecycle impact of their products and carry out research on sustainable product design.

2. Environmental impact from the core manufacture stage are mainly from the use of electricity. In future, it is recommended to concentrate on reviewing the use of electricity, breaking down electricity consumption by process, keeping track of energy consumption, considering energy saving methods such as energy audits and energy efficiency assessments, identifying areas for improvement, identifying systems that can be optimized or equipment that can be upgraded. Improving energy efficiency and reducing energy consumption will inevitably lead to cost savings in the short and long term.

3. Strengthen awareness training for internal staff and promote the need to save energy and reduce loss of raw materials.

4. Strengthen awareness of data recording and enhance the reliability of recorded data. In conjunction with the results of this product carbon footprint assessment, data should be recorded and tracked for the sources of emissions that contribute substantially to the reduction, so that when the product carbon footprint is calculated again, more accurate and complete data will be available, and more effort can be spent on effectively reducing product environmental impact.

Appendix Additional Information

Impact Category	Unit	Total	Manufacturing Stage	Distribution Stage	Installation Stage	Use&Maintenance Stage	End of Life Stage
Ecotoxicity, freshwater	CTUe	4.07E+05	3.75E+05	1.33E+04	5.06E+03	6.12E+02	1.30E+04
Particulate matter	disease inc.	6.25E-03	2.24E-03	1.09E-04	5.65E-05	4.51E-06	3.84E-03
Human toxicity, cancer	CTUh	1.49E-04	8.33E-05	8.53E-07	3.93E-07	8.05E-08	6.48E-05
Human toxicity, non-cancer	CTUh	2.12E-03	2.06E-03	1.34E-05	1.63E-05	9.07E-07	3.03E-05
Ionising radiation	kBq U-235 eq	1.31E+03	1.12E+03	1.74E+01	5.33E+01	1.15E+02	3.23E-01
Land use	Pt	2.52E+05	2.40E+05	9.26E+03	3.42E+03	-3.78E+02	2.60E+02

References

i. ISO 14040:2006 Environmental management — Life cycle assessment — Requirements and guidelines

ii. ISO 14044:2006 Environmental management — Life cycle assessment — Principles and framework

iii. EPDItaly007 – PCR for Electronic and electrical products and systems,Rev. 3, 2023/01/13

iv. EPDItaly012 – Electronic and electrical products and systems – Switchs, Rev. 0, 2020/03/16

v. EN 50693:2019 Product category rules for life cycle assessments of electronic and electrical products and systems