Shanghai Sieyuan High Voltage Switchgear Co., LTD.

ENVIRONMENTAL PRODUCT DECLARATION

ZF28A-145 Gas insulated metal-enclosed switchgear

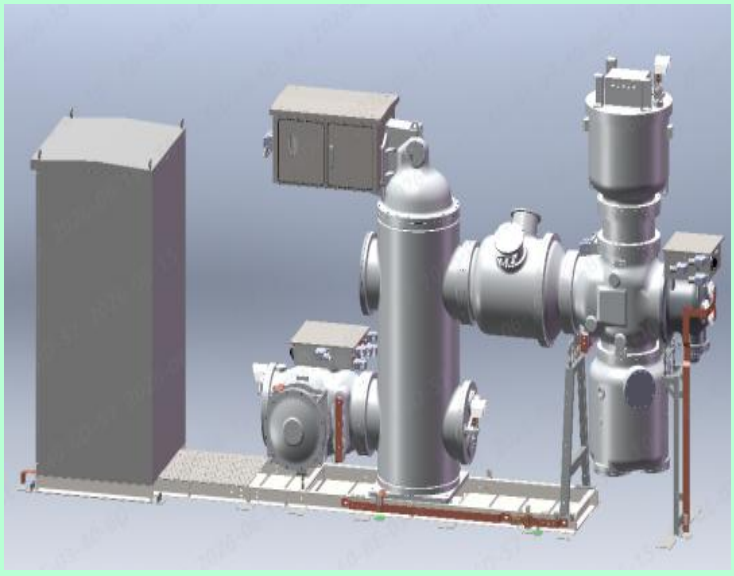
No.3399, Huaning Road, Minhang District, Shanghai

In accordance with ISO 14025:2006 and EN 50693:2019

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GENERAL INFORMATION

EPD OWNER

Name of the company	Shanghai Sieyuan High Voltage Switchgear Co., Ltd.
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PROGRAM OPERATOR

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INFORMATION ON THE EPD

Product name (s)	ZF28A-145 Gas insulated metal-enclosed switchgear
Site (s)	No.3399, Huaning Road, Minhang District, Shanghai
Short description and technical information of the product (s)	ZF28A-145 Gas insulated metal-enclosed switchgear, ENEL Code: GSCH006/1103
Field of application of the product (s)	The ZF28A-145 GIS equipment organically combines circuit breakers, disconnectors, earthing switches, current transformers, voltage transformers, lightning arresters, busbars, cable terminations, incoming and outgoing line bushings, etc., through modular design. All relevant modules are enclosed in a sealed metal casing, filled with sulfur hexafluoride (SF_6) as an insulating and arc-extinguishing medium. It is equipped with a pointer-type density relay to monitor gas pressure and density in real time.
Product (s) reference standards (if any)	EN 50693:2019 – Product category rules for life cycle assessment of electronic and electrical products and systems
CPC Code (number) https://unstats.un.org/unsd/classifications/Econ	46211 – "Electrical apparatus for switching or protecting electrical circuits, or for making connections to or in electrical circuits, for a voltage exceeding 1000 V"

VERIFICATION INFORMATION

PCR (title, version, date of publication or update)	EPDItaly007 – PCR for Electronic and electrical products and systems, Rev. 3.2, 2025/12/20 reviewed by Ing. Ugo Pannuti, ICMQ Spa (Moderator), Eng. Elena Neri, Indaco (Committee) EPDItaly012 – Electronic and electrical products and systems – Switches, Rev. 1, 2024/06/28 reviewed by NA – Implementation of the Core-PCR EPDItaly 007 Rev.3 (Moderator), NA – Implementation of the Core-PCR EPDItaly 007 Rev.3 (Committee)

EPDItaly Regulation (version, date of publication or update)	REGULATIONS OF THE EPDItaly PROGRAMME VER. 6.0, ISSUED ON 2023/10 /30
Project Report LCA	SHANGHAI SIEYUAN ZF28A-145 Gas insulated metal-enclosed switchgear LCA Report 4.0 15.06.2026
Independent Verification Statement	The PCR 007 review was performed by Ing. Balazs Sarà, Arch. Michele Paleari, Ing. Luca Giacomello. The sub-PCR 012 review was performed by Ing. Daniele Pace, Arch. Michele Paleari, Ing. Sara Toniolo - info@epditaly.it' Independent verification of the declaration and data, carried out according to ISO 14025: 2010. ☐ Internal ☑ External Third party verification carried out by: ICMQ S.p.A., via Gaetano De Castillia n ° 10 - 20124 Milan, Italy. Accredited by Accredia.
Comparability Statement	Environmental statements published within the same product category, but from different programs, may not be comparable. In particular, EPDs of construction products may not be comparable if they do not comply with EN50693:2019.
Liability Statement	The EPD Owner releases EPDItaly from any non-compliance with environmental legislation. The holder of the declaration will be responsible for the information and supporting evidence. EPDItaly disclaims any responsibility for the information, data and results provided by the EPD Owner for life cycle assessment.

OTHER INFORMATION **The reference production year of the product is 2023**

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1. Company information

Shanghai Sieyuan High Voltage Switchgear Co., Ltd. currently employs over 1,600 people and boasts two production bases that are domestically leading and internationally first-class: the Shanghai Production Base and the Rugao Production Base in Jiangsu. The company spans a total area of 300,000 square meters, with a factory area exceeding 100,000 square meters. It possesses a professional system for development, design, production, testing, logistics, and service.

The company independently develops and produces 72.5~800kV GIS/HGIS, GIL, and tank circuit breaker products. The company boasts a 500kV and 1000kV fully shielded high voltage testing hall, equipped with 1500kV and 3000kV impulse voltage generators and automated measurement systems. Its main production equipment, conditions, and manufacturing technology have reached the international advanced level. The company's business covers domestic and overseas industries such as power, 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. Product Information

This is a specific EPD for the ZF28A-145 gas-insulated metal enclosed switchgear, with an ENEL code of GSCH006/1103.

The ZF28A-145 GIS equipment organically combines circuit breakers, disconnectors, earthing switches, current transformers, voltage transformers, lightning arresters, busbars, cable terminations, and incoming and outgoing line bushings into a unified whole through modular design. All relevant modules are enclosed within a sealed metal casing, filled with sulfur hexafluoride (SF_6) as an insulating and arc-extinguishing medium. A pointer-type density relay is equipped to monitor gas pressure and density in real time.

Specifications:

- Nominal Voltage: 145kV

- Rated Frequency: 50/60Hz

- Nominal Current: 3150A

- Number of poles of the switch:3

- Nominal short-circuit breaking current: 40kA

The calculation report contains product configurations that match GSCH006/1103 and are applicable to these numbers and products of the same type.

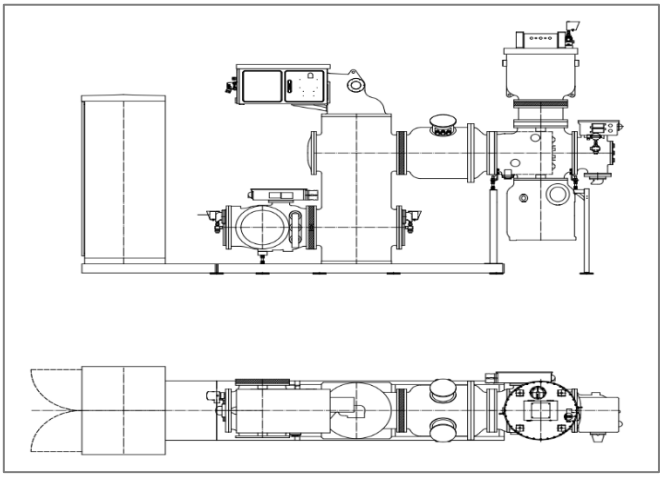


Figure 2.1 - Gas insulated metal-enclosed switchgear ZF28A-145

Table 2.1 – Total weight of the ZF28A-145 Gas insulated metal-enclosed switchgear

Module Weight（kg/Model	ZF28A-145 Single-bay CB+2*DES+CT+VT+CSE+FES+BUS （GSCH006/1103）
CB (Circuit Breaker)	846
DES (Digital Elevation System)	754

FES (Fault Making Earth Switch)	109
BUS (Busbar)	33
CT (Current Transformer)	300
CSE (Cable Sealing End)	168
Steel support	310
Secondary circuit	294
LCP (Local Control Panel) cabinets	370
Accessories	224
PT (Potential Transformer)	315
Packaging	808
Total	4533

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

Figure 2.2 - Gas insulated metal-enclosed switchgear ZF28A-145

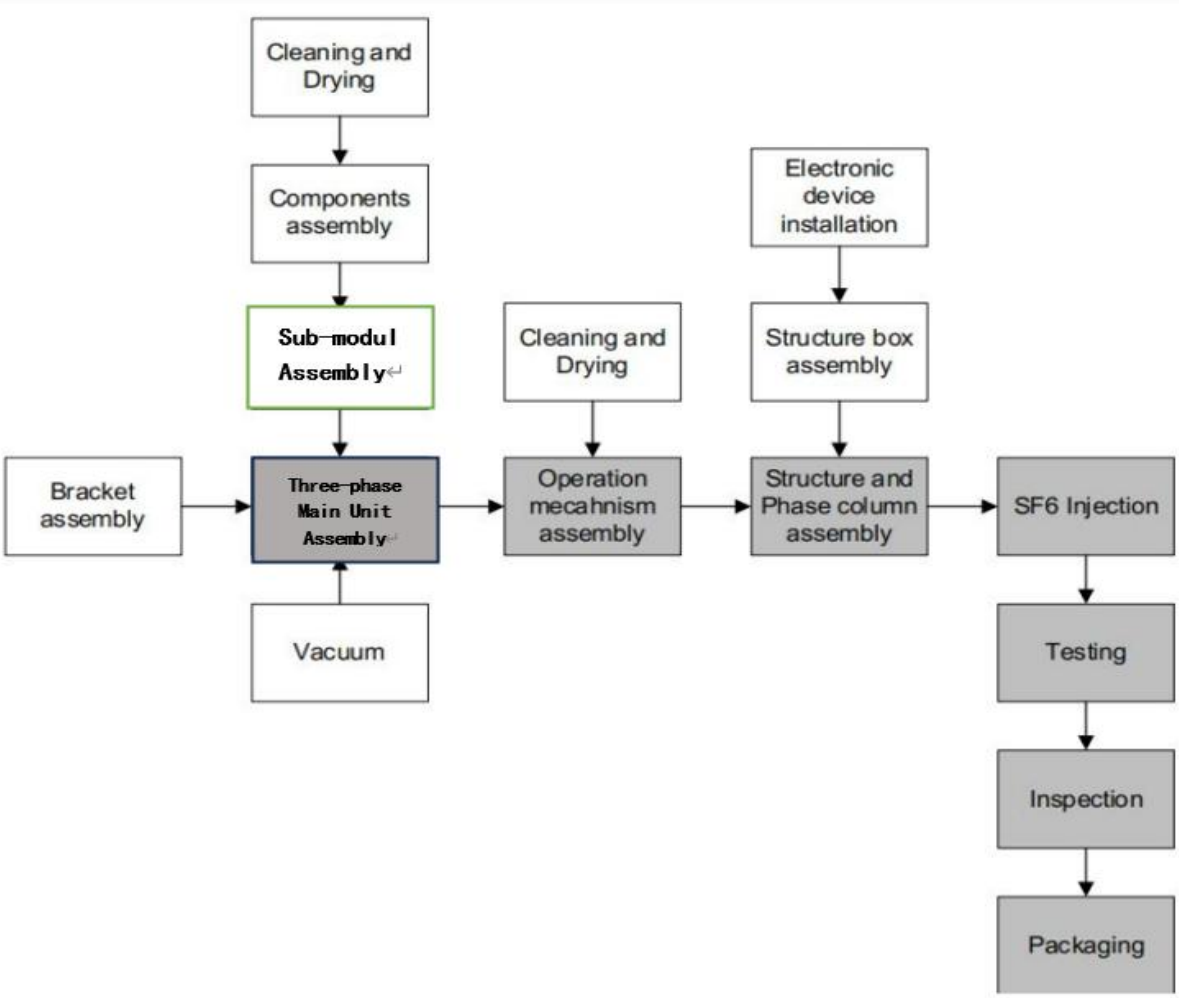


Table 2.2 Material composition of the products (in accordance with EN IEC 62474)

Product Identification Code	Gas insulated metal-enclosed switchgear ZF28A-145(GSCH006/1103)		
Country of installation	Colombia		
Total product mass, without packaging	4533.82		
Material content	**ID**	**Kg**	**%**
Stainless steel	M-100	50.67	1.12%
Other ferrous alloys, non-stainless steels	M-119	1292.49	28.51%
Aluminium and its alloys	M-120	1644.32	36.27%
Copper and its alloys	M-121	169.42	3.74%
Acrylonitrile-Butadiene-Styrene (ABS)	M-206	1.18	0.03%
Thermoplastic Elastomeres (TPE)	M-327	20	0.44%

Other unfilled thermoplastics	M-249	11	0.24%
Glass	M-161	0	0.00%
Other material（cable，BVR，etc）		1344.49	29.65%

Note: No substance in the product greater than 0.10% by weight is present on the "List of Potentially Hazardous Substances" candidates for authorization under the REACH legislat

3. Life Cycle Assessment Information

A Life Cycle Assessment (LCA) is a methodology for assessing the environmental impacts associated with the entire life cycle of a particular product or process. LCA consists of 4 stages (Goal and Scope, Inventory Analysis, Impact Assessment, and review/presentation) which must follow similar procedures to a PCR (Product Category Rules) and helps to evaluate the carbon footprint and natural resources of a product or process. In this EPD, LCA is conducted specially to obtain environmental impact information.

3.1. Declared unit

According to PCR EPDItaly012 – Electronic and electrical products and systems – Switchs, Rev. 1, 2024/06/28, 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 ZF28A-145 Gas insulated metal-enclosed switchgear operating for 20 years. Reference flow is one single unit of ZF28A-145 Gas insulated metal-enclosed switchgear.

Specifications of the product:

- Nominal Voltage: 145kV
- Nominal Current: 3150A
- Number of poles of the switch:3
- Nominal short-circuit breaking current: 40kA

3.2. System, temporal, and geographical boundaries

The system boundary includes the whole life cycle of the analyzed product, according to a “from cradle to grave” application, covering the following life cycle stages:

PHASES	MANUFACTURING STAGE	DISTRIBUTION STAGE	INSTALLATION STAGE	USE & Maintenance STAGE	END-OF-LIFE STAGE De-installation	BENEFITS & LOADS BEYOND THE SYSTEM BOUNDARIES*
	IN ACCORDANCE TO EN 50693					
Phases declared	X	X	X	X	X	Opt.
Data quality indicator[11]	%	-				

Figure 3.2.1: System boundary (Life cycle modules)

The manufacturing stage covers 70.18% of the emissions factors assessed for data quality

Manufacturing stage. This phase includes the upstream and core modules described previously (raw material transformation, transportation of raw materials and semi-finished products, production of the finished product packaging, generation of process waste including its transportation to the disposal sire, energy and material consumption associated with plant operations);

Distribution stage. This module includes the impacts related to the distribution of the product at the installation site.

Installation stage. This module includes the end of life of packaging, the energy consumption associated to installation and setup, scrap and waste generated during the installation stage.

Use & Maintenance Stage. This module includes the energy consumed by the product to operate during its entire reference service life, ordinary scheduled maintenance and extraordinary scheduled maintenance.

In this module，Energy used during the product service life is calculated using the formula below.

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

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 *I*n. The P_{use} of Gas insulated metal-enclosed switchgear is calculated and listed in table 4.5.1.

$$P_{\text{use}} = I_{\text{r}}^2 \times R \times 3$$

Table 3.2.1 – Power consumption of Gas insulated metal-enclosed switchgear

Gas insulated metal-enclosed switchgear	Nominal current, I_n / A	Single phase resistance, $R / \mu\Omega$	P_{use} / W
ZF28A-145	3150	119.8	35.66

For the maintenance of the electric products, the Shanghai Sieyuan high-voltage electric equipment are designed to be free of maintenance during its service life. Meanwhile, though the Gas insulated metal-enclosed switchgear has reliable sealing performance, a yearly leakage of SF6 during its 20 service life is supposed to be. Therefore, an output of 0.4988 kg SF6 should have taken place in maintenance stage in this study.

End of Life Stage. This module includes the transportation of the GIS to the collection site, disassembly operations, distribution and destination of the various material flows to be sent for recycling or disposal. Treatment of SF6 is assumed to be treated before recycled in accordance with literature (Shiojiri et al. 2006).

Table 3.2.2– EoI treatment inventory（GSCH006/1103）

Material		Weight of material to be disposal（kg）	Material recycling rate	Weight of material being recycled（kg）	Weight of material being treated（kg）	Treatment method for rest of material
Metals	Steel	1343.16	80%	1074.528	268.632	Landfilled
	Aluminum	1644.32	70%	1151.024	493.296	Landfilled
	Copper	169.42	60%	101.652	67.768	Landfilled
Plstic/Rubber	Rubber	4.25	0%	0	4.25	Incineration
	Plastics	223.05	20%	44.61	178.44	Incineration
Others	Cables	253.26	50%	126.63	126.63	Incineration
	Electronics	41	50%	20.5	20.5	Landfilled
	SF6	99.5	100%	99.5	0	Recycled

Table 3.2.3 –Life cycle stages of SF6 (100 kg)

Nr.	Life cycle processes of SF6	Calculation methode according to the formula in the literature	Energy consumption required for recycling pro kg SF6	Unit	SF6 amount to be treated/ leckage	Energy consumption required for recycling for 100 kg SF6	Unit
1	**Aqusition of SF6**						
	Compression for SF6	8901/1300*5.78/3.6/1000	0.010993115	kWh/kg	100	1.099311538	kWh
	Transportation of SF6	already calculation in Upstream					
2	**Recovery from the device**						
	Vakuum Pump	1.5*480/60/1300	0.009230769	kWh/kg	99.5011	0.918471692	kWh
3	**Purification process**						
	Heating	8901/1300*2.77/3.6/1000	0.005268327	kWh/kg	99.5011	0.524204324	kWh
	Pressurizing	8901/1300*10.75/3.6/1000	0.020445673	kWh/kg	99.5011	2.034366961	kWh
4	**Decomposition process**						
	Low-temperature plasma	8901/1300*403.2/3.6/1000	0.766855385	kWh/kg	99.2523	76.11216069	kWh
	Evacuation	8901/1300*13.3/3.6/1000	0.025295577	kWh/kg	99.2523	2.510644189	kWh
5	**Leakage of SF6 During Recycling Processes**						
	Leakage of SF6 During the Recovery and Separation Processes (0.25% Offgas)	100*99.5011%*0.25%	/	/	0.24875275	/	kg
	Leakage of SF6 During the Decomposition Processes(2.3% release)	100*99.5011%*(1-0.25%)*(1-98.7%)	/	/	1.290280514	/	kg

It should be noted that the construction, maintenance, and decommissioning of infrastructure, i.e. buildings and machinery, as well as the occupation of industrial land have not been considered, as their contribution to the environmental impact of the declared unit is considered negligible.

For the study, reference was made to the data deriving from the BOMs of specific products, whose production began in 2023 (reference year). For plant consumption, reference was made to the data related to the Sieyuan production plant and referred to the year 2023 (January – December), considered representative (at the time of conducting the study, this is the last complete calendar year for which the data are available).

The suppliers of raw materials and semifinished products are located in China. Where possible, the specific origin of the raw material has been investigated and characterized accordingly. The product is to be used in Colombia (GSCH006/1103). For the downstream phases, an worst case scenario was considered.

3.3. Impact categories

The methodology chosen to evaluate the potential environmental impacts of the product subject of this study includes all the impact categories required by the Standard EN 50693:2019. The models used are those shown in EN 15804 + A2: 2019, as implemented in the SimaPro software. The categories analyzed are therefore:

Indicator name and abbrevation (EN)	Unit (EN)
Global Warming Potential - total (GWP-total)	kg CO2 eq.
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.
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.
Formation potential of tropospheric ozone (POCP)	kg NMVOC eq.
Abiotic Depletion for non-fossil resources potential - (ADP-minerals&metals)	kg Sb eq.
Abiotic Depletion for non-fossil resources potential (ADP-fossil)	MJ, net calorific value
Water deprivation potentail, deprivation-weighted water consumption (WDP)	m3 eq.

*Please also note that the EN 15804+A2 method is based on the EF 3.11 version for this study.

3.4. Cut-off

According to EPD Italy Regulations and PCR EPDItaly007-PCR for Electronic and electrical products and systems, Rev.3.2, 2025/12/20, the following flows and operations are cut-offed:

- Production, use and disposal of the packaging of components and the packaging of semi-finished intermediates.
- Material and energy flows related to dismantling phase which is performed by adopting manual tools (e.g. screwdrivers, hammers, etc.).
- Manufacture of equipment used in production, buildings or any other capital goods;
- The transportation of personnel to the plant.
- Transportation of personnel within the plant.
- Research and development activities.
- Long-term emissions.

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

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.

3.5. Allocation Principles

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 Gas insulated metal-enclosed 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.

The principle of "modularity" is followed in the study. 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).

3.6. Limitation and Assumption

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 manufacturing conditions change. The following assumptions are used in this assessment:

Table 3.6.1 – 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. • The raw material used for SF6 is recycled SF6, so the emissions from the raw material can be neglected.
	Core Module	• In the context of China, a market-based approach is not applicable due to the absence of a Guarantee of Origin system. Therefore, a location-based approach is employed to assess the environmental impact of electricity in this EPD. Regional production mix from medium voltage (production of transmission lines, in addition to direct emissions and losses in grid) of applied electricity for the manufacturing process (A3). China consumption electricity mix from East Centre China Grid was used in the core module. For 1kWh electricity used, upstream CO_2 emission is 0.78kgCO2e • Assume same amount of energy and resource consumption were used to produce each unit of rated power of ZF28A-145 Gas insulated metal-enclosed switchgear（0107-0106） in the manufacturing phase. • Assume the heat released during natural gas combustion is 33.4 MJ/m³ • Assume same amount of waste were produced to produce each unit of ZF28A-145 Gas insulated metal-enclosed switchgear in the manufacturing phase. • The distance from the Shanghai Sieyuan plant to the downstream waste disposal site is assumed to be 200 km.
DISTRIBUTION STAGE	Downstream Module	• The product is to be used in Colombia (GSCH006/1103). Downstream distribution distances are estimated from the GAODE map and SEARATE website for shipment distances (Shanghai to Colombia), inland transport is by truck freight and sea transport is by ship. •The distance from Shanghai Sieyuan to Shanghai port is 300 km and port in Columbia to the client is assumed to be 500km.
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 ZF28A-145 Gas insulated metal-enclosed switchgear. • The distance from the user installation site to the downstream waste disposal site is also assumed to be 200 km • In this stage, packaging of the ZF28A-145 Gas insulated metal-enclosed switchgear was disposed, of which 100% of waste wood packaging and 100% of waste stretch film are assumed to be incinerated.
USE & Maintenance STAGE		• Energy used during the product service life is provided by Shanghai Sieyuan in accordance with PCR EPDItaly012 – Electronic and electrical products and systems – Switchs, Rev. 1, 2024/06/28, it is assumed the same amount of energy were used to install each unit of ZF28A-145 Gas insulated metal-enclosed 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 ZF28A-145 Gas insulated metal-enclosed switchgear SF6 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 dismantled into components and then sorted for further processing. Some metals like steel, copper and aluminum are recycled according to IEC-TR 62635 standards, while the remaining materials are either landfilled or incinerated.

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4. Inventory analysis

In this EPD, where available, reference was made to primary data. Where access to this type of data was not possible, datasets from the Ecoinvent v3.11 database were used as reference.

Data collection was carried out by preparing a sheet that collected input and output data, in terms of mass, energy consumption was obtained within production site. The data collection sheet was verified and checked and reported any inconsistencies that were clarified and resolved.

In the study, SimaPro 10.2.0.0 software was used to establish the model for the life cycle of products and calculate LCA results.

According to EN 50693:2019 4.2.7 data quality for ZF28A-145 Gas insulated metal-enclosed switch gear will be estimated. Conclusion: The use of datasets for manufacturing stage and end-of-life stage accounts for 40.20% and 43.31% of the GWP impact respectively. Use and maintenance stage accounts for 13.97% of the rest GWP impact.

Table 4.1: Data quality evaluation for ZF28A-145 Gas insulated metal-enclosed switch gear

Data collection	1/1/2023-31/12/2023
Sites used	1 site owned by Shanghai Sieyuan High Voltage Switchgear Co.,Ltd
Geography	Shanghai Sieyuan High Voltage Switchgear Co.,Ltd. produces 100% of its GIS in Shanghai. The GIS is sold to Columbia. The EPD is modelled for use and disposal in Columbia.
Technology	ZF28A-145 Gas insulated metal-enclosed switchgear is composed of multiple unit components, including CB module, DES module, FES module, CT module, etc. These modules are all self-made, and the raw materials for these modules are outsourced components
Averaging	Production weighted average covering 100% of production by Sieyuan
LCI/LCA database	Ecoinvent 3.11
EPD used	Sieyuan EPD Program, EPD for ZF28A-145 Gas insulated metal-enclosed switch gear
Data Quality Scheme	EN 50693:2019 4.2.7
Use of Fair data with more than 30% of a core impact	The use of datasets for manufacturing stage and the end-of-life stage of GIS account for 40.20% (fair emission factor 70.18%) and 43.31% (fair emission factor 19.30%) of the GWP impact respectively. Use and maintenance stage accounts only for 13.86% of the rest GWP impact.
Use of Poor relevant data	Data quality for manufacturing stage and use and maintenance stage is both geographically relatively average, because they summaries a big area of data sources. They account for 75.04% and 24.09% of Climate change - Land use and LU change impact.
Use of Very Poor relevant data	No very poor data used.

5. Environmental Impact Assessment

Potential Environmental impact of each lifecycle stage are shown below.

Table 5.1.1 – Environmental impact descriptive parameters

Impact category	Unit	Total	Manufacturing Stage	Distribution Stage	Installation Stage	Use & Maintenance Stage	End of Life Stage
Climate change -total	kg CO2 eq	9.23E+04	3.71E+04	1.14E+03	1.29E+03	1.28E+04	4.00E+04
Climate change - Fossil	kg CO2 eq	9.20E+04	3.80E+04	1.14E+03	1.89E+02	1.27E+04	4.00E+04
Climate change - Biogenic	kg CO2 eq	1.38E+02	-9.97E+02	2.43E-02	1.10E+03	3.76E+01	6.63E-01
Climate change - Land use and LU change	kg CO2 eq	1.09E+02	8.15E+01	5.85E-01	1.94E-02	2.64E+01	1.19E-01
Ozone depletion	kg CFC11 eq	2.75E-02	2.75E-02	1.63E-05	3.85E-07	8.21E-07	3.20E-06
Acidification	mol H+ eq	4.16E+02	3.87E+02	2.30E+01	1.93E+00	1.14E+00	2.52E+00
Eutrophication, freshwater	kg P eq	2.90E+01	2.89E+01	6.97E-02	9.11E-03	3.90E-02	4.81E-02
Eutrophication, marine	kg N eq	5.63E+01	4.85E+01	5.74E+00	8.93E-01	1.30E-01	1.08E+00
Eutrophication, terrestrial	mol N eq	6.21E+02	5.35E+02	6.36E+01	9.67E+00	1.39E+00	1.15E+01
Photochemical ozone formation	kg NMVOC eq	1.87E+02	1.63E+02	1.80E+01	2.71E+00	4.64E-01	3.42E+00
Depletion of abiotic resources – minerals and metals	kg Sb eq	4.40E+00	4.40E+00	1.86E-03	1.29E-04	5.92E-05	5.19E-04
Depletion of abiotic resources – fossil fuels	MJ	4.58E+05	4.34E+05	1.49E+04	2.17E+03	1.99E+03	4.86E+03
Water use	m3 depriv.	2.28E+04	2.25E+04	5.07E+01	9.09E+00	2.25E+01	1.36E+02

Note: The negative value upstream and distribution stage of Climate change -Biogenic indicator is due to the use of container board as packaging material and plywood as auxiliary material that will be used in the main material of the upstream and container for sea transportation in the distribution stage. Container board, plywood and container for sea transportation will be seen as CO2e absorbed, since they are from biogenic material.

Parameters describing resource use are shown below.

Table 5.1.2 – 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	4.53E+05	4.19E+05	1.49E+04	2.47E+03	1.99E+03	1.45E+04
Use of renewable primary energy excluding renewable primary energy resources used as raw material (PERE)	MJ, net calorific value	8.11E+04	6.65E+04	1.45E+02	1.05E+04	3.80E+03	9.15E+01
Use of non-renewable primary energy resources used as raw material (PENRM)	MJ, net calorific value	4.53E+03	1.44E+04	0.00E+00	-3.03E+02	0.00E+00	-9.61E+03
Use of renewable primary energy resources used as raw material (PERM)	MJ, net calorific value	9.20E-04	1.05E+04	0.00E+00	-1.05E+04	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	4.58E+05	4.34E+05	1.49E+04	2.17E+03	1.99E+03	4.86E+03
Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials) (PERT)	MJ, net calorific value	8.11E+04	7.70E+04	1.45E+02	1.17E+01	3.80E+03	9.15E+01
Net use of fresh water (FW)	m3	7.30E+02	7.18E+02	1.55E+00	2.98E-01	3.96E+00	6.22E+00
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

Descriptive waste production parameters are shown below.

Table 5.1.3 – Waste production descriptive parameters

Parameter	Unit	Total	Manufacturing Stage	Distribution Stage	Installation Stage	Use & Maintenance Stage	End of Life Stage
Hazardous waste disposed (HWD)	kg	7.84E+01	5.74E+01	2.71E-01	6.35E+00	3.60E-02	1.43E+01
Non-hazardous waste disposed (NHWD)	kg	4.59E+03	3.12E+03	4.90E+02	2.88E+01	3.11E+01	9.21E+02
Radioactive waste disposed (RWD)	kg	5.31E-01	5.28E-01	2.18E-03	1.93E-04	1.02E-04	1.39E-03
Materials for energy recovery (MER)	kg	1.07E+03	9.60E-03	0.00E+00	7.59E+02	0.00E+00	3.09E+02
Material for recycling (MFR)	kg	2.52E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.52E+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	5.10E+03	4.02E-02	0.00E+00	2.70E+03	0.00E+00	2.40E+03
Exported electricity energy (EEE)	MJ	2.53E+03	2.02E-02	0.00E+00	1.34E+03	0.00E+00	1.19E+03

6. 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 show that the end-of-life stage is the stage with the greatest potential environmental impact throughout the life cycle of the product due to the release of SF6 gas during the recycling. In response to the LCA results, the following recommendations 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. Searching for alternatives with insulation strength comparable to SF6 but lower greenhouse effect than SF6, including perfluoroisobutyronitrile (C4F7N) mixed gas. This is currently one of the most promising alternatives. The insulation strength of C4F7N is about 2.2 times that of SF6, but its global warming potential (GWP) is significantly lower than that of SF6. Perfluoroketone (such as C5F10O) mixed gas, represented by 3M's Novec™ 5110, has an extremely low GWP value (<1) and an insulation strength about twice that of SF6. Perfluoromethyl vinyl ether (PMVE, also known as K6 gas) is a newer candidate gas with an extremely low GWP value (only 0.004) and insulation performance comparable to SF6.

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.

7. References

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