阳光电源
SUNGROW

Sungrow Power Supply Co., Ltd.

ENVIRONMENTAL PRODUCT DECLARATION

Product Name: ST5015UX Battery module of energy storage system
P1044AL-ACA/P1044AL-AHA

Site Plant: Hefei, Anhui Province, China

in accordance with ISO 14025:2006 and EN50693:2019

Program Operator	EPDItaly
Publisher	EPDItaly
Declaration Number	*SG-EPD03*
Registration Number	EPDITALY0945
Issue Date	26/03/2025
Date of revision	26/11/2025
Valid to	26/03/2030

1. GENERAL INFORMATION

EPD Owner:	Sungrow Power Supply Co., Ltd. Address: No.1699, Xiyou Road, New & High Technology Industrial Development Zone, Hefei City, Anhui Province, P.R.China
Product Name:	ST5015UX Battery module of energy storage system P1044AL-AHA/P1044AL-ACA
Production site:	No.788, Mingchuan Road, High-tech Industry Development Zone, Hefei City, Anhui Province, China
Field of application:	Energy storage, B2B or B2C application
Program Operator:	EPDITALY (www.epditaly.it) Add: via Gaetano De Castillia n° 10 - 20124 Milano, Italy
CPC Code:	464 "Accumulators, primary cells and primary batteries, and parts thereof"
Company Contact:	Yadan Chen Email: chenyadan@sungrowpower.com
External Audit:	This declaration has been developed referring to EPDItaly, following the General Program Instruction; further information and the document itself are available at: www.epditaly.it. Independent verification of the declaration and data, according to EN ISO 14025:2006 and EN 50693. ☐ INTERNAL ☒ EXTERNAL Third party verifier: ICMQ SpA - Via Gaetano De Castillia, 10 - 20124 – Milano/Italy
LCA Consultant:	This life cycle assessment was conducted in accordance with ISO 14044 and the reference PCR by: Tian Hongyu, TÜV SÜD Certification and Testing (China) Co., Ltd. Shanghai Branch
Reference PCR and version number:	Core PCR: EPDItaly007 – PCR for Electronic and Electrical Products and Systems, Rev. 3.1 Sub PCR: PCR EPDItaly021 – Energy storage systems, Rev. 5
Other reference documents:	Regulations of the EPDItaly Program rev. 6.0. EN 50693:2019 - Product category rules for life cycle assessments of electronic and electrical products and systems.
Comparability:	EPDs relating to the same category of products but belonging to different programmes may not be comparable. Full conformance with a PCR allows EPD comparability only when all stages of a life cycle have been considered. However, variations and deviations are possible. Example of variations: Different LCA software and background LCI datasets may lead to differences results for upstream or downstream of the life cycle stages declared.
Liability:	The owner of the declaration will be responsible for the information and supporting evidence. EPDItaly disclaims any liability regarding the manufacturer's information data.
Reference document:	This declaration is based on the EPDItaly regulation, available on the website www.epditaly.com

2. COMPANY INTRODUCTION

As a key high-tech enterprise in China, Sungrow Power Supply Co., Ltd. (Stock code: 300274) specializes in R&D, production, sales and services of new energy equipment, such as solar energy, wind energy, energy storage, hydrogen energy, electric vehicles, mainly provides photovoltaic inverters, wind energy converters, energy storage system, floating PV system, new energy automotive driving system, EV charging station, renewable hydrogen production system, smart operation and maintenance, and commits itself to providing first-class life cycle solutions of clean energy.

Since the establishment in 1997, the Company has been concentrating on the field of new energy power generation, adhering to market demand orientation, and taking technological innovation as the propellant for development. The Company has cultivated a professional R&D team with solid R&D experiences and strong capabilities of independent innovation. Sungrow has successively undertaken more than 20 national key science and technology programs, led the drafting of multiple national standards, and is one of the few companies in the industry that have mastered a number of independent core technologies.

Photovoltaic inverters, Sungrow's core products, have been accredited by TÜV, CSA, SGS, and other international authorities, and sold to more than 180 countries and regions in the world. Sungrow's cumulative installed capacity of power electronic converters across the world has been above 605GW by the end of June 2024.

The Company has successively won the awards of China Grand Awards for Industry, National Manufacturing Single Champion Demonstration Enterprise, Top 50 Innovative Chinese Companies, National Intellectual Property Demonstration Enterprise, Global Top 500 New Energy Enterprises, and Best Companies to Work for in Asia. Sungrow is a company with state-level post-doctoral research workstation, a national high-tech industrialization demonstration base, a national enterprise technology center, a national industrial design center, a national green factory, and ranks among the best in the global new energy power generation industry in terms of comprehensive strength.

In the future, Sungrow will adhere to its mission of "Clean power for all", accelerate the development of clean energy power generation system integration based on the new energy equipment business, innovate and expand new business in the field of clean power conversion technology, keep in close contact with the customers, actively participate in global competition, and strive to build itself into a trusted world-class company.

3. SCOPE AND TYPE OF EPD

3.1. Scope of EPD

The system boundary of this study on Sungrow's battery module of energy storage system encompasses the entire life cycle of the product, from cradle to grave, including the manufacturing, distribution, installation, use, and end-of-life stage, as defined in the PCR.

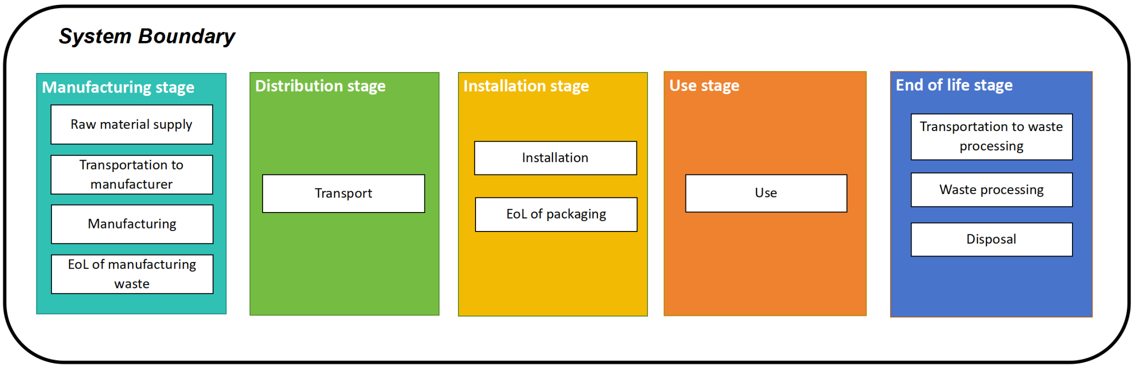

Figure 3-1 System boundary

3.2. Type of EPD

This EPD is a product specific EPD. The declaration covers in total 2 models of ST5015UX battery module of energy storage system, including P1044AL-ACA and P1044AL-AHA.

3.3. Geographical scope

The geographical boundary for this LCA study is defined with manufacturing of the systems taking place in mainland China, while use phase and end-of-life treatment stage will be modelled with a case study taken place in Europe. It is noted that the systems can be installed and operated worldwide. Therefore, when interpreting the LCA results, the location where the products is installed and operated shall be considered.

3.4. Time representativeness

All manufacturing data has been collected by Sungrow based on their production inventory in the reference period from July, 2023 to June, 2024. Datasets have been selected according to the actual processes used by the manufacturer. For generic products where no upstream data was available, such as packaging, manufacturing has been modelled according to current industry practices.

3.5. Database and LCA software used

In this study, generic data for materials, energy as well as waste disposal and transportation were taken from the database Ecoinvent 3.10. LCA-software SimaPro 9.6.0.1 was used for the modeling and calculation.

4. DETAILED PRODUCT DESCRIPTION

4.1. Description of the Product

A battery module of energy storage system stores energy from power source. Sungrow offers a wide range of products for residential, commercial, and utility-scale applications. The products that are under study are ST5015UX battery module of energy storage system, including P1044AL-ACA and P1044AL-AHA.

4.2. Technical parameters

The type of coupling and application of two modules are DC and industrial/commercial.

Table 4-1 General information of the battery module

LFP battery module	Parameter	Value
	Model	P1044AL-ACA
	Size (W*H*D (without terminals, spigots))*	(790 ± 3) mm * (240 ± 3) mm * (2214 ± 5) mm
	Multiplying power	≤0.5 C
	Cell type	Prismatic aluminum shell LFP
	Combination	1P104S
	Rated capacity	314 Ah
	Weight (without coolant)*	(650 ± 15) kg

LFP battery module	Parameter	Value
	Model	P1044AL-AHA
	Size (W*H*D (without terminals, spigots))*	(790 ± 3) mm * (240 ± 3) mm * (2214 ± 5) mm
	Multiplying power	≤0.5 C
	Cell type	Prismatic aluminum shell LFP
	Combination	1P104S
	Rated capacity	314 Ah
	Weight (without coolant)*	(660 ± 9) kg

*Indicates that the parameter values are for reference only, please refer to the actual project!

4.3. Materials compositions

Table 4-2 Materials compositions

IEC62474 Classname	IEC62474 ID	P1044AL-ACA		P1044AL-AHA	
		Mass (g)	Percentage	Mass (g)	Percentage
Stainless steel	M-100	5634.90	0.85%	5634.90	0.85%
Other ferrous alloys, non-stainless steels	M-119	3372.67	0.51%	3372.67	0.51%
Aluminium and its alloys	M-120	91153.70	13.68%	90743.09	13.71%
Copper and its alloys	M-121	95126.80	14.28%	94445.95	14.27%
Nickel and its alloys	M-123	2.59	0.00%	2.59	0.00%
Zinc and its alloys	M-124	0.02	0.00%	0.02	0.00%
Lead and its alloys (including Pb solders)	M-125	0.31	0.00%	0.31	0.00%
Tin and its alloys (including Pb-free solders)	M-126	3.89	0.00%	3.89	0.00%
Other non-ferrous metals and alloys	M-149	3.83	0.00%	3.83	0.00%
Gold	M-150	0.02	0.00%	0.02	0.00%
Palladium	M-152	0.02	0.00%	0.02	0.00%
Other precious metals	M-159	0.32	0.00%	0.32	0.00%
Glass	M-161	32.40	0.00%	32.40	0.00%
Other inorganic materials	M-199	302443.14	45.40%	300236.36	45.36%
PolyVinylChloride (PVC)	M-200	246.13	0.04%	246.13	0.04%
PolyEthylene (PE)	M-201	9918.78	1.49%	9855.67	1.49%
PolyPropylene (PP)	M-202	759.80	0.11%	755.35	0.11%
PolyCarbonate (PC)	M-204	936.56	0.14%	936.66	0.14%
PolyAmide (PA)	M-208	73.62	0.01%	73.62	0.01%
PolyEthyleneTerephthalate (PET)	M-209	4604.22	0.69%	4591.68	0.69%
Polyphenylenesulfide (PPS)	M-213	12479.59	1.88%	12479.59	1.89%
Polymethylmethacrylate (PMMA)	M-220	0.07	0.00%	0.07	0.00%
Other unfilled thermoplastics	M-249	0.37	0.00%	0.37	0.00%
PolyAmide (PA) filled	M-258	1.57	0.00%	1.57	0.00%
Polyurethane (PUR)	M-300	9357.40	1.41%	9357.40	1.42%
Epoxy resin (EP)	M-302	2.71	0.00%	2.71	0.00%
Silicone	M-321	7965.68	1.20%	7965.68	1.21%
Ethylene-Propylene-Diene-Rubber (EPDM)	M-324	20.80	0.00%	20.80	0.00%
Other organic materials	M-399	121986.84	18.31%	121090.78	18.30%

4.4. Description of the production process

The production process of battery module starts from the battery cell loading, then a performance test of the cells will be conducted to ensure their quality. After that, adhesive is applied to the surface of the cells and cell polarity detection is carried out. Next, insulation pads are pasted to enhance the safety of the module. The cells are then strapped in place. Subsequently, the module will be generated. The module undergoes safety testing. By utilizing Charge Coupled Device (CCD) pole addressing technology, pole positions are determined and cleaned for welding quality assurance. Cells contact system (CCS) are installed and laser welding takes place after that. After completing welding, cleaning and post-weld warping inspection are conducted to ensure defect-free welds. Post-weld inspection further confirms welding quality. Then, functional tests such as voltage resistance measurement for key parameters are carried out on the module. Finally, upper cover is installed to complete the assembly of the battery module.

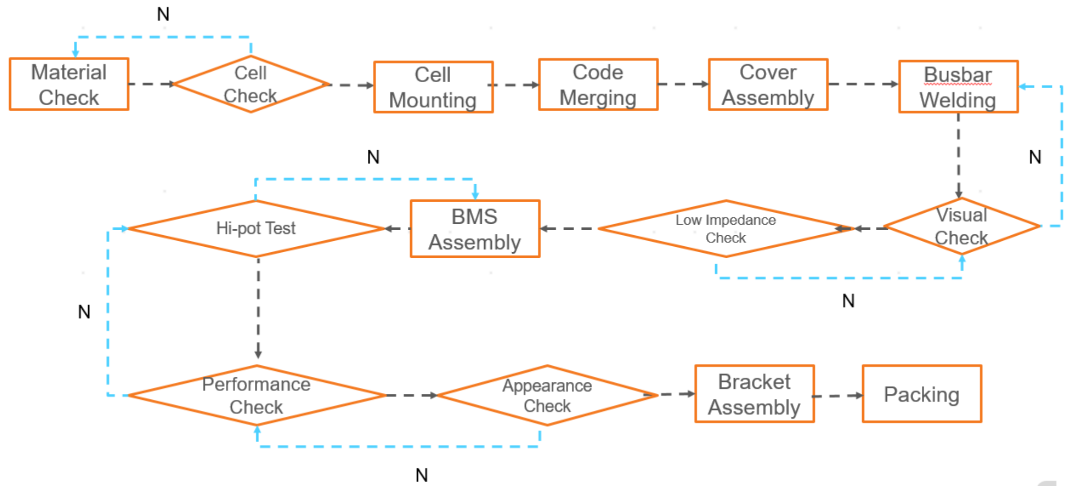

Figure 4-1 Manufacturing process flow diagram of systems

5. LCA RESULTS

The LCA results show the environmental impacts and resource input and output flows calculated according to EN 15804: 2012+A2:2019/AC:2021 reference package based on EF3.1. The results are shown per functional unit (1kWh stored by a single energy storage module). The LCA results have been calculated using the LCA software SimaPro 9.6.0.1 and the data from ecoinvent v3.10.

Table 5-1 System boundaries and life cycle stages within this study

System boundaries (X=included, MND=module not declared, MNR=module not relevant)					
Module	Manufacturing	Distribution	Installation	Use & Maintenance	End-of-life
Modules declared	X	X	X	X	X

5.1. Environmental impacts

Table 5-2 Environmental impacts

Battery module	Impact category	Unit	Manufacturing stage		Distribution	Installation	Use&Maintenance	EoL
			Upstream	Core				
P1044AL-ACA	GWP-total	kg CO2 eq	6.04E+01	1.37E-01	2.08E+00	4.60E-05	1.36E+02	2.60E+00
	GWP-fossil	kg CO2 eq	6.01E+01	1.35E-01	2.08E+00	4.60E-05	1.34E+02	9.41E-01
	GWP-biogenic	kg CO2 eq	2.27E-01	1.93E-03	3.64E-04	5.43E-09	1.90E+00	1.65E+00
	GWP-luluc	kg CO2 eq	8.33E-02	6.59E-05	5.80E-05	1.34E-09	3.89E-03	4.23E-04
	ODP	kg CFC11 eq	1.29E-06	4.55E-10	3.31E-08	6.17E-13	2.83E-06	3.77E-09
	AP	mol H+ eq	1.48E+00	6.33E-04	3.91E-02	1.25E-07	3.34E-01	2.11E-03
	EP-Freshwater	kg P eq	5.36E-03	2.61E-06	2.41E-06	1.14E-10	2.01E-03	3.50E-05
	EP-Marine	kg N eq	1.05E-01	1.32E-04	1.02E-02	4.53E-08	6.14E-02	1.95E-03
	EP-Terrestrial	mol N eq	3.53E+00	1.45E-03	1.13E-01	4.98E-07	6.83E-01	5.75E-03
	POCP	kg NMVOC eq	2.89E-01	1.02E-02	3.13E-02	1.86E-07	3.23E-01	1.98E-03
	ADP- M&M	kg Sb eq	7.32E-03	5.03E-09	5.45E-08	2.73E-12	1.10E-06	2.41E-08
	ADP-fossil	MJ	7.83E+02	1.41E+00	2.66E+01	6.14E-04	1.99E+03	5.26E+00
	WDP	m3 depriv.	2.36E+01	1.66E-02	1.35E-02	5.66E-07	3.30E+01	-2.18E-01
P1044AL-AHA	GWP-total	kg CO2 eq	5.96E+01	1.37E-01	2.07E+00	4.60E-05	1.36E+02	2.58E+00
	GWP-fossil	kg CO2 eq	5.93E+01	1.35E-01	2.07E+00	4.60E-05	1.34E+02	9.35E-01
	GWP-biogenic	kg CO2 eq	2.26E-01	1.93E-03	3.61E-04	5.43E-09	1.90E+00	1.64E+00
	GWP-luluc	kg CO2 eq	8.29E-02	6.59E-05	5.76E-05	1.34E-09	3.89E-03	4.21E-04
	ODP	kg CFC11 eq	1.27E-06	4.55E-10	3.29E-08	6.17E-13	2.83E-06	3.75E-09
	AP	mol H+ eq	1.46E+00	6.33E-04	3.89E-02	1.25E-07	3.34E-01	2.10E-03
	EP-Freshwater	kg P eq	5.32E-03	2.61E-06	2.39E-06	1.14E-10	2.01E-03	3.47E-05
	EP-Marine	kg N eq	1.04E-01	1.32E-04	1.01E-02	4.53E-08	6.14E-02	1.93E-03
	EP-Terrestrial	mol N eq	3.50E+00	1.45E-03	1.12E-01	4.98E-07	6.83E-01	5.71E-03
	POCP	kg NMVOC eq	2.86E-01	1.02E-02	3.11E-02	1.86E-07	3.23E-01	1.96E-03
	ADP- M&M	kg Sb eq	7.27E-03	5.03E-09	5.41E-08	2.73E-12	1.10E-06	2.40E-08
	ADP-fossil	MJ	7.72E+02	1.41E+00	2.64E+01	6.14E-04	1.99E+03	5.23E+00
	WDP	m3 depriv.	2.35E+01	1.66E-02	1.34E-02	5.66E-07	3.30E+01	-2.17E-01

Disclaimer: The results of the environmental impact indicators of ADPminerals and metals, ADPfossil and WDP shall be used with care as the uncertainties on these results are high or as there is limited experience with the indicator. The additional environmental impact indicators have been calculated for all the products, but not reported in the EPD.

Caption:

1E+01 is equal to 1 x 10^1

GWP-total: Global Warming Potential; **GWP-fossil**: Global Warming Potential fossil fuels; **GWP-biogenic**: Global Warming Potential biogenic; **GWP-luluc**: Global Warming Potential land use and land use change; **ODP**: Depletion potential of the stratospheric ozone layer; **AP**: Acidification potential, Accumulated Exceedance; **EP-Freshwater**: Eutrophication potential, fraction of nutrients reaching freshwater and compartment; See "additional Norwegian requirements" for indicator given as PO4 eq. **EP-Marine**: Eutrophication potential, fraction of nutrients reaching freshwater end compartment; **EP-Terrestrial**: Eutrophication potential, Accumulated Exceedance; **POCP**: Formation potential of tropospheric ozone; **ADP-M&M**: Abiotic depletion potential for non-fossil resources (minerals and metals); **ADP-fossil**: Abiotic depletion potential for fossil resources; **WDP**: Water deprivation potential, deprivation weighted water consumption

5.2. Resource use, end-of-life-waste, and output flows

Table 5-3 Resource use, end-of-life-Waste, and output flows

Battery module	Impact category	Unit	Manufacturing stage		Distribution	Installation	Use&Maintenance	EoL
			Upstream	Core				
P1044AL-ACA	PERE	MJ	6.65E+01	6.28E-02	6.04E-02	1.00E-06	1.15E+02	4.71E-01
	PERM	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	PERT	MJ	6.65E+01	6.28E-02	6.04E-02	1.00E-06	1.15E+02	4.71E-01

	PENRE	MJ	3.15E+02	1.16E+00	3.64E-01	1.64E-05	3.93E+02	2.76E+00
	PENRM	MJ	1.18E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	PENRT	MJ	3.27E+02	1.16E+00	3.64E-01	1.64E-05	3.93E+02	2.76E+00
	SM	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	RSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	FW	m3	6.44E-01	3.96E-04	6.37E-04	2.06E-08	9.84E-01	-4.25E-03
	HWD	kg	3.15E-02	2.24E-06	1.52E-04	4.20E-09	7.54E-03	1.57E-05
	NHWD	kg	7.29E+00	1.51E-03	6.59E-04	2.55E-08	3.81E-01	1.85E+00
	RWD	kg	9.02E-04	3.23E-06	1.46E-06	2.21E-11	1.27E-03	1.05E-05
	CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MFR	kg	0.00E+00	7.57E-02	0.00E+00	1.24E-02	0.00E+00	3.66E+00
	MER	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	ETE	MJ	0.00E+00	7.82E-02	0.00E+00	0.00E+00	0.00E+00	2.54E+00
	EEE	MJ	0.00E+00	9.00E-03	0.00E+00	0.00E+00	0.00E+00	1.24E+00
P1044AL-AHA	PERE	MJ	6.61E+01	6.28E-02	6.00E-02	1.00E-06	1.15E+02	4.68E-01
	PERM	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	PERT	MJ	6.61E+01	6.28E-02	6.00E-02	1.00E-06	1.15E+02	4.68E-01
	PENRE	MJ	3.13E+02	1.16E+00	3.61E-01	1.64E-05	3.93E+02	2.75E+00
	PENRM	MJ	1.18E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	PENRT	MJ	3.24E+02	1.16E+00	3.61E-01	1.64E-05	3.93E+02	2.75E+00
	SM	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	RSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	FW	m3	6.40E-01	3.96E-04	6.33E-04	2.06E-08	9.84E-01	-4.23E-03
	HWD	kg	3.13E-02	2.24E-06	1.51E-04	4.20E-09	7.54E-03	1.56E-05
	NHWD	kg	7.24E+00	1.51E-03	6.55E-04	2.55E-08	3.81E-01	1.84E+00
	RWD	kg	8.96E-04	3.23E-06	1.45E-06	2.21E-11	1.27E-03	1.05E-05
	CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MFR	kg	0.00E+00	7.57E-02	0.00E+00	1.24E-02	0.00E+00	3.63E+00
	MER	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	ETE	MJ	0.00E+00	7.82E-02	0.00E+00	0.00E+00	0.00E+00	2.52E+00
	EEE	MJ	0.00E+00	9.00E-03	0.00E+00	0.00E+00	0.00E+00	1.24E+00

Caption:

1E+01 is equal to 1 x 10^1

PENRE: Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; **PERE**: Use of renewable primary energy excluding renewable primary energy resources used as raw materials; **PENRM**: Use of non-renewable primary energy resources used as raw materials; **PERM**: Use of renewable primary energy resources used as raw materials; **PERT**: Total use of renewable primary energy resources; **PENRT**: Total use of non-renewable primary energy resources; **SM**: Use of secondary materials; **RSF**: Use of renewable secondary fuels**;** **NRSF**: Use of non-renewable secondary fuels; **FW**: Use of net fresh water; **HWD** = Hazardous waste disposed; **NHWD** = Non-hazardous waste disposed; **RWD** = Radioactive waste disposed; **CRU** = Components for re-use; **MFR** = Materials for recycling; **MER** = Materials for energy recovery; **EEE** = Exported electrical energy; **ETE** = Exported thermal energy

6. Calculation rules

6.1. Declared or functional unit

The functional unit has been defined as 1kWh stored by a single battery module. And other necessary information is listed below.

- Rated capacity: 314Ah, 104.49kWh.
- Type of coupling: DC
- Type of cell technology: Prismatic aluminum shell $LiFePO_4$
- Type of application: Industrial or commercial

The geographical boundary for this LCA study is defined with manufacturing of battery module taking place in mainland China, while use phase and end-of-life treatment stage will be modelled with a case study taken place in Europe.

6.2. Reference Service Life

The reference service life of the studied product is 10 years.

6.3. Assumptions

Table 6-1 List of assumptions

Life cycle stages	Items	Assumptions
Manufacturing stage	Material of the plug and cable	PVC and copper share 50% of the total weight respectively.
	Material of the FFC/FPC	PET and copper share 50% of the total weight respectively.
	Transportation vehicle type	For the vehicle used for raw material transportation and transportation of solid and hazardous wastes, EURO 5 lorry with 16-32ton capacity is assumed for modelling
	Waste disposal	Treatments includes physicochemical treatment, washing and others are replaced by incineration, due to lack of data from the manufacturer and appropriate data in the database for modelling, and the quantity is relatively small.
Distribution stage	Transportation vehicle type	For the vehicle used for product distribution, EURO 5 lorry with 3.5-7.5 ton (for transport in-plant), EURO 5 16-32 ton (plant to inland port) and EURO 4 16-32 ton (overseas port to customer) is assumed.
Installation stage	Electricity and materials use	No electricity and materials used for installation as it can be done manually
	Waste transportation	The vehicle used is assumed as EURO 5 lorry with 16-32 ton capacity.
Use & Maintenance	Replacement	No replacement for the module as the module has RSL>10 years
End-of-life	De-construction	The de-construction is assumed to be done manually, no electricity and materials use in this stage
	Waste transportation	Waste transportation distance from the de-installation plant to the waste treatment facilities is assumed to be 50 km for simplification purposes. The vehicle used is assumed as EURO 4 lorry with 16-32 ton capacity.
	Waste processing	Waste electric and electronic equipment treatment, shredding
	Disposal	The disposal scenario follows PEF EoL default values in Europe and IEC/TR 62635 guidelines

6.4. Cut-off rules

For the processes within the system boundary, all available energy and material flow data have been included in the model. The cut-off criteria were set to 2% in this study according to PCR.

Table 6-2 Cut-off flows

Flow name	Process stage	Mass %	Criteria to cut-off
Fuse, label, multiplexer etc.	Raw material	0.0002	<2%
Devices external to the systems itself required for installation	Installation stage	N/A	Cut-off due to small impact according to PCR
Any extraordinary maintenance done on the switch	Use & Maintenance	N/A	Specified in PCR
Total cut-off mass % estimated			<2%

6.5. Data quality

Primary data system (such materials or energy flows that enter the production system) is from Sungrow manufacturing facilities in a reference period from July, 2023 to June, 2024 (annual average). Generic data related to the life cycle impacts of the material or energy flows that enter the production system is sourced from Ecoinvent 3.10 "allocation, cut-off by classification - unit" database.

6.6. Excluded processes

The following steps/stages are not included in the system boundary due to the reason that the elements below are considered irrelevant or not within the boundary to the LCA study:

- Impacts related to the production, transportation and installation of capital goods (buildings, infrastructure, machinery, internal transport packaging) and general operations (staff travel, marketing and communication actions) that cannot be directly allocated to products are excluded from the LCA study.
- Emissions during the installation and operation due to no obvious emission observable.
- Storage phases and sales of products due to no observable impact. Product losses due to abnormal damage such as natural disasters or fire accidents. These losses would mostly be accidental.
- Handling operations at the distribution center and retail outlet due to small contribution and negligible impact.
- Research and development activities.
- Long-term emissions.
- The recycling process of defective products is reused internally for the manufacturing process.

6.7. Allocations

The allocation is made in accordance with the provisions of EN 50693 and Core PCR. Allocation refers to the partitioning of input or output flows of a process or a product system between the product systems under study and one or more other product systems. In this study, there are three types of allocation procedures considered:

Multi-input allocation

For data sets in this study, raw materials as well as packaging materials are based on the BOM from Sungrow, no allocation is used at the stage. As for the manufacturing process, the energy consumption and emission are allocated based on working hours of different product, i.e., the electricity consumption and the emissions are calculated based on the amount of time spent producing each energy storage system.

Multi-output allocation

No other by-products are produced from the production, hence there is no production of by-products that need to be used to allocate the situation.

End-of-life allocation

For end-of-life allocation of background data (energy and materials), the model "allocation cut-off by classification" (ISO standard) is used. The underlying philosophy of this approach is that primary (first) production of materials is always allocated to the primary user of a material. If material is recycled, the primary producer does not receive any credit for the provision of any recyclable materials. Consequently, recyclable materials are available burden-free for recycling processes, and secondary (recycled) materials bear only the impacts of the recycling processes.

For end-of-life stage of the energy storage systems, the polluter pays principle (PPP) is followed in this report. This means that the waste transportation to the treatment site and the waste processing (mainly shredding) is considered in this report, while the benefit, the load from waste treatment for recycling purposes such as de-pollution and crushing, etc., is allocated to the next life cycle of substituted products, but not the primary producers, hence no burden or benefit will be allocated to the primary producer of the electric products (cut-off approach).

In addition, the principle of "modularity" is followed.

6.8. Electricity mix

The manufacturing stage of the battery module takes place in Anhui, China. Therefore, the eastern China grid market average electricity mix is used in this study. The operation of product, as well as the end-of-life stage, are assumed taken place in Europe as a case study. Charge/discharge consumption is modelled using residual mix electricity in Italy, Europe.

Table 6-3 Electricity mix used for modelling

Consumption type	Electricity process type	GWP (kg CO2eq./kWh)
Electricity use in manufacturing stage (from grid)	Electricity, medium voltage {CN-ECGC}| market for electricity, medium voltage | Cut-off, U	8.41E-01
Electricity use in use stage (charge/discharge consumption)	Electricity, low voltage {IT}| electricity, low voltage, residual mix | Cut-off, U	5.98E-01

7. LCA calculation scenarios

7.1. Installation

In the installation stage, the energy use is negligible since the installation process is mainly done manually. According to the product category rules (PCR), end of life of the packaging materials, scrap and general waste generated are considered in this stage. In this case, 2 plastic bags of the battery module for transport within the factory are recycled after installation.

7.2. Use & Maintenance

The electricity consumption during the use stage of the systems includes two different parts, which are the energy required by the battery to operate, and the energy loss due to charge and discharge cycles.

$$E_{tot}[kWh] = E_{use} + E_{loss}$$

According to PCR, the following formula shall be used to calculate the electricity used during the product's service life to keep the battery active:

$$E_{use}[kWh] = \frac{P_{use} \times 8760 \times RSL}{1000}$$

where:

E_{use} (kWh) is the power losses during the operation of system;

P_{use} (W) is the power of the system to keep active during the reference service life;

As the product under study is just a battery module, but not a complete energy storage system, E_{use} =0

RSL is the service life of the product, 10 years;

While the energy loss due to charge and discharge cycles can be calculated by:

$$E_{loss}\ [kWh] = \sum_{i=0}^{RSL} \frac{E_{useful\ i} \times N_{cycles} \times 365}{DC\ RTEi} \times (1 - DC\ RTEi)$$

where E_{loss}(kWh) is the electricity dissipation occurring whenever the battery is charged and discharged,

$E_{useful\ i}$ (kWh) is the max energy dischargeable from the battery system.

N_{cycles} is the number of full charge/discharge cycles per day, 1 time;

$DC\ RTEi$ is DC round trip efficiency in the year i.

The electricity consumption during use stage is listed in Table 7-2.

Table 7-2 Electricity consumption of systems during use stage

Year i	Max energy dischargeable	SOH	Eusefuli	DC RTEi	Eloss
1	104.49	100%	104.49	94%	2.43E+03
2	104.49	96.77%	101.11	93.88%	2.41E+03
3	104.49	94.97%	99.23	93.76%	2.41E+03
4	104.49	93.20%	97.38	93.64%	2.41E+03
5	104.49	91.45%	95.56	93.52%	2.42E+03
6	104.49	89.72%	93.75	93.40%	2.42E+03
7	104.49	88.01%	91.96	93.28%	2.42E+03
8	104.49	86.32%	90.20	93.16%	2.42E+03
9	104.49	84.66%	88.46	93.04%	2.42E+03
10	104.49	83.01%	86.74	93.92%	2.05E+03
Ps: Unit of energy in this table is kWh				**E_{loss} total**	**2.38E+04**

The battery module is designed to be free of maintenance during its service life. Therefore, no inputs and outputs are taken place in the maintenance stage in this study.

7.3. End-of-life

For end-of-life (EoL) stage, assumptions are made due to a lack of data. De-installation stage of the system is assumed to be manually done with no energy use. Transportation distance from the plant site to the waste treatment site is assumed to be 50km according to PCR. For waste processing, the system is shredded and post-processed.

The systems disposal and recycling stage involves removing hazardous valuable materials, metal scraps. The most recyclable materials constitute the metal components, printed circuit board (PCBs), and cables. In this study, both PEF EoL default values in Europe and IEC/TR 62635 guidelines are referred to.

8. REFERENCES

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