Solar Grade Wafer
Product Carbon Footprint
Verification Report

Client: Jiangsu Shuangjing New Energy Technology Co., Ltd.

Verification Body: TÜV SÜD Certification and Testing (China) Co., Ltd.

Address of Verification Body: 3-13, No.151 Heng Tong Road, Jingan District Shanghai 200070 P.R. China

Report No.: 704062457301-00

Date of issue: 2024-09-10

Abstract of product carbon footprint verification

Name of the client	Jiangsu Shuangjing New Energy Technology Co., Ltd.
Name of responsible party	Jiangsu Shuangjing New Energy Technology Co., Ltd.
Address of responsible party	No.8, Lijiang Road, Yancheng Economic and Technological Development Zone, Yancheng City, Jiangsu Province PEOPLE'S REPUBLIC OF CHINA
Actual production address (if applicable)	N/A
Name of the verified product	Solar grade wafer
Type of the verified product	18XP 18XN 210XP 210XN 18XHN 210HN
Verification Time Boundary	2023-04-01 to 2024-03-31
System boundary	Cradle to gate
Declared unit	1 piece of silicon wafer
Verification criteria	☒ ISO 14067:2018 Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification ☐ PAS 2050:2011 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services ☒ ISO 14064-3:2019 Greenhouse gases – Part 3: Specification with guidance for the verification and validation of greenhouse gas statements ☐ ISO 14040:2006 Environmental management-Life cycle assessment- Principles and framework ☐ ISO 14044:2006: Environmental management-Life cycle assessment-Requirements and guidelines ☐ Others:
Verification objective	☒ To confirm the correctness and conformity of the claim from the responsible party according to verification criteria ☒ To provide an independent evaluation of relevant information through objectivev evidence, including whether the information in the GHG report meets the principles of relevance, completeness, consistency, accuracy and transparency; whether there are material

	errors and omissions in the reported data results; and whether the level of assurance provided is met. ☐ Others:
Operation rule	CCB_GHG_GR_001CS REV.05
Product carbon footprint claim	**Type** — **Carbon Emission (kg CO_2eq/p)** 18XP — 2.57 18XN — 2.41 210XP — 3.08 210XN — 2.64 18XHN — 1.24 210HN — 1.52
Product carbon footprint statement	**Type** — **Carbon Emission (kg CO_2eq/p)** 18XP — 2.57 18XN — 2.41 210XP — 3.08 210XN — 2.64 18XHN — 1.24 210HN — 1.52
Analysis of the difference between product carbon footprint claim and statement	The product carbon footprint statement is consistent with the product carbon footprint claim.
Related Industrial Category	B15 Storage batteries, primary batteries, primary battery packs, other batteries and its components
Materiality	Less than 5% of total carbon emissions in the system boundary
Level of assurance	☒ Reasonable assurance level ☐ Limited assurance level
Date of document review	2023.04.15
Date of on-site verification	2024.05.24
Verification team leader	Sun Chang Chang Sun
Verification team member	N/A
Other personnel (observers, interns/trainees, external auditors, etc.)	Li Yaohua Yaohua Li 、Li Junyu Junyu, Li
Address of the verification body	3-13, No.151 Heng Tong Road, Jingan District Shanghai 200070 P.R. China
Statement of responsibility	

1） The responsible party is responsible for the compliance of the Product Carbon Footprint claim with the ISO 14067:2018 standard, and the Responsible Party is responsible for the preparation and fair presentation of the Product Carbon Footprint Report in accordance with the standard. 2）The verifier is responsible for issuing a verification statement based on the verification of the product's carbon footprint claim, and the verification process and results are in accordance with ISO 14064-3:2019. 3） The procedure for collecting verification evidence for the assessment of GHG claim is: CCB_GHG_P_09ECS Greenhouse Gas Validation and Verification execution procedure.
Verification conclusion
The verification for the product carbon footprint claimed by the responsible party is conducted according to ISO 14064-3：2019. After verification, , it confirms that the claim of the responsible party:" The cradle-to-gate carbon footprint of wafer products 18XP and other five products produced by Jiangsu Shuangjing New Energy Technology Co., Ltd. from 2023-04-01 to 2024-03-31 is 2.57kg CO_2e，2.41kg CO_2e，3.08kg CO_2e，2.64kg CO_2e，1.24kg CO_2e，1.52kg CO_2e. the declared unit is 1 piece of silicon wafer" meets the requirements of ISO 14067 :2018.

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Abbreviations

TÜV	TÜV SÜD Certification and Testing (China) Co., Ltd.
PCR	Product Category Rules
IPCC	The Intergovernmental Panel on Climate Change
GWP	Global Warming Potentials
LCA	Life Cycle Assessment
DU	Declared unit

1 General description of verification

1.1 Verification Objectives

TÜV SÜD Certification and Testing (China) Co., Ltd. (hereinafter referred to as TÜV SÜD) was commissioned by Jiangsu Shuangjing New Energy Technology Co Ltd (hereinafter referred to as Shuangjing) to conduct a product life cycle carbon footprint verification of its solar grade wafer.

The verification objectives included:

1) to verify whether the product carbon emission information and data provided by Shuangjing and its evidential documents and sources are complete and credible.

2) to verify whether the product carbon emission data and calculation methods provided by Shuangjing comply with the requirements of ISO 14067:2018 standard.

3) According to the requirements of ISO14067:2018 standard, to conduct carbon emission calculation and evaluation by processing the product carbon emission data recorded and stored by Shuangjing and draw conclusions and explanations of carbon footprint verification for product life cycle.

1.2 Verification Criteria

The verification is mainly based on [ISO 14067:2018 Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification]. Other relevant standards and literature that were also referred to are listed in the [References] section of this verification report. According to the requirements of ISO 14067:2018, the Product Category Rule (PCR), if present, should be used by reference.

1.3 Verification evidence-gathering procedures

TÜV SÜD conducted document review and on-site verification of the responsible party on 2023-04-15 and 2024-05-24 respectively. The objects and contents include basic information of the enterprise, inventory of emission facilities, inventory of emission sources, inventory of monitoring equipment, information related to activity level and emission factors, etc. Through the strategic analysis of verification activities and risk assessment to identify the risks of verification activities in advance, a reasonable evidence-gathering plan was developed for:

1) Accounting boundaries, emission facilities and emission sources identification of the responsible party, etc.

2) Information flow management for the acquisition, recording, transmission and aggregation of activity level data and parameters related to emissions within the system boundary of responsible party.

3) Accounting methods and emission data calculation process.

4) Calibration and maintenance of measuring instruments and monitoring equipment.

5) Verification of quality assurance and documentation archiving.

The responsible party provided relevant supporting materials and evidentiary materials according to the evidence-gathering plan formulated by the verification team. Verification activity performed 100% of collection for data sources and 30% of sampling for data source for cross check.

1.4 Statement of responsibility

1) The responsible party is responsible for the compliance of the Product Carbon Footprint claim with the ISO 14067:2018 standard, and the responsible party is responsible for the preparation and fair presentation of the Product Carbon Footprint Report in accordance with the standard.

2) The verifier is responsible for issuing a verification statement based on the verification of the product's carbon footprint claim, and the verification process and results are in accordance with ISO 14064-3:2019.

3) The procedure for collecting verification evidence for the assessment of GHG claim is: CCB_GHG_P_09ECS GHG Validation and Verification Execution Procedures.

1.5 General information of responsible party and product

Jiangsu Shuangjing New Energy Technology Co., Ltd. was founded in 2022. The main business scope of the company includes general items: research and development of electronic special materials; manufacturing of electronic special materials; sales of electronic special materials; import and export of goods; import and export of technology.

The verified product of Shuangjing is solar grade wafer, and the product type is 18XP series, 18XN series , 210XP, 210XN, 18XHN, 210HN. The product information is shown in Table 1-1. The appearance of the product is shown in Figure 1-1.

Table 1-1 Dimension and yearly output information

Product	Product Model	Dimension (mm)	Output(pcs)
	18XP Series	182*182*0.15	109800122
		182.2*182.2*0.15	39635049
		182*183.75*0.15	58316848
		182.2*183.75*0.15	3916483
		182*182*0.13	32214610

Solar grade wafer	18XN Series	182.2*182.2*0.13	96220533
		182*183.75*0.15	657465
		182*183.75*0.13	31901978
		182.2*183.75*0.13	40701918
		182.2*182.2*0.12	657947
		182.2*183.75*0.12	1167281
		182.35*182.35*0.12	1164984
		182.2*191.6*0.13	31697577
		182.3*183.5*0.13	2919214
		182.35*182.35*0.13	2141079
		182.35*183.75*0.13	6994049
		182.2*186.7*0.13	42485576
	210P	210*210*0.14	73905332
	210N	210*210*0.13	14124353
	18XH	182*91*0.11	21935692
	210H	210.1*105.05*0.12	198744576

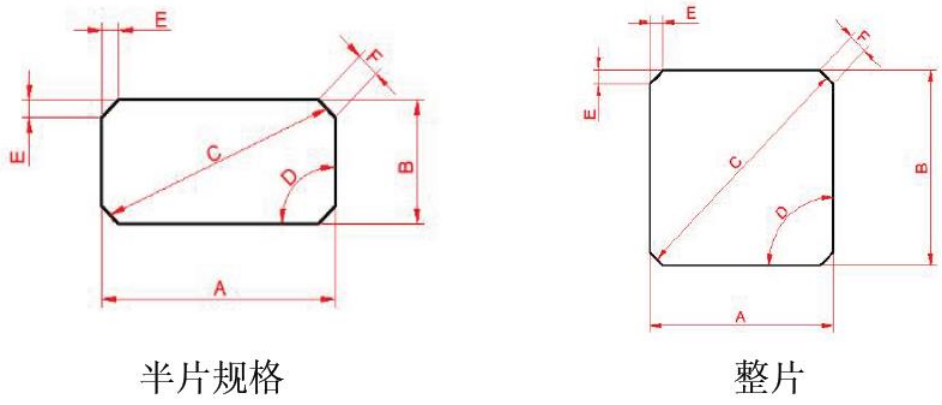


Figure 1-1 Photographs and specifications of solar grade wafer products (samples)

2 Scope of verification

2.1 Greenhouse gases categories

The scope of greenhouse gases in this verification of PCF is consistent with the scope of the IPCC Sixth Assessment Report, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and nitrogen trifluoride (NF_3).

2.2 Time boundary and location of verification data

The time boundary of carbon footprint data of the verified products covers from 2023-04-01 to 2024-03-31. The production address of the responsible party is No.8, Lijiang Road, Yancheng Economic and Technological Development Zone, Yancheng City, Jiangsu Province, PEOPLE'S REPUBLIC OF CHINA. The geographical boundary of the product production is shown in Figure 2-1.

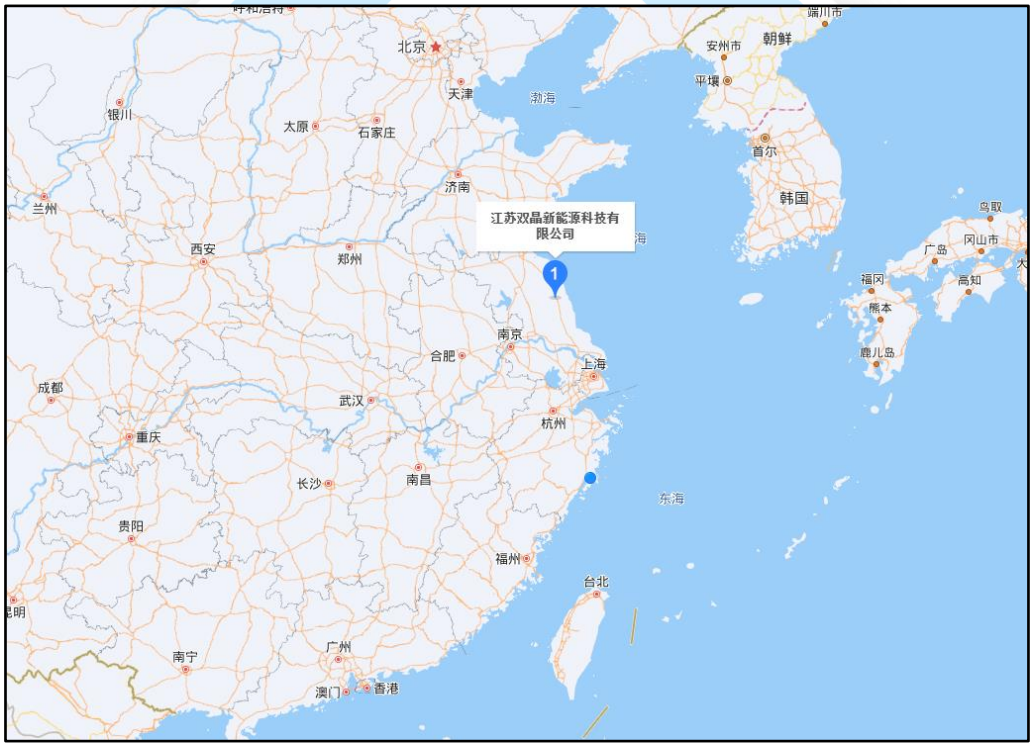


Figure 2-1 Production geographical boundary

2.3 Declared units

The declared unit of product carbon footprint for this verification is 1 piece of silicon wafer.

2.4 System boundary

The system boundary for this verification is cradle to gate. The process flow of the product lifecycle system boundary is shown in Figure 2-2.

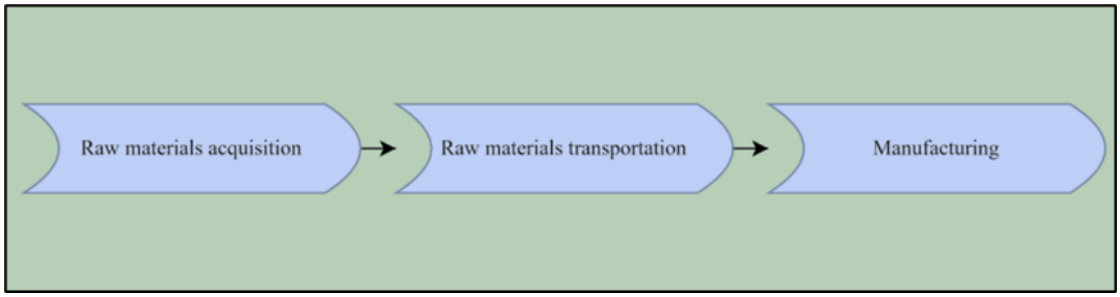


Figure 2-2 Process flow of the product lifecycle system boundary

2.5 Cut-off rules

A material flow that is less than 1% of the product mass or an energy flow that is less than 1% of the cumulative energy may be excluded. Sum of the flows excluded shall not exceed 5% of the product mass and whose environmental impact shall not greater than 5% of the total environmental impact. The cut-off principle was not used in this study.

2.6 Allocation principles

Allocation based on product yield was selected for this verification. In addition to raw materials , packaging materials, water consumption, energy consumption, and waste disposal are allocated according to this principle.

2.7 Software and Database

The Life cycle assessment software used in this study is Simapro 9.5.0.0 and uses 3.9.1 database. The GHG emission assessment method used is IPCC 2021 GWP100.

3 Verification of product carbon footprint data inventory

3.1 Data sources and quality assessment

The evaluation of data quality level is developed based on the guidelines outlined in section 6.3.8.3 in the BS EN 15804:2012+A2:2019 standard, and Guidance on Data Quality Assessment for Life Cycle Inventory Data.

Table 3-1 Data quality level and inventory

Quality level	Good	Fair	Poor
Geographical representativeness	The processes included in the data set are fully representative for the geography stated in the “location” indicated in the metadata	The processes included in the data set are sufficiently representative for the geography stated in the “location” indicated in the metadata	The processes included in the data set cannot properly represent the geography stated in the “location” indicated in the metadata
Technical representativeness	Technology aspects have been modelled as described, without significant need for improvement	Technology aspects are like what has been described but merits improvements	Technology aspects are different from what has been described. Substantial improvement is necessary
Time representativeness	Data are not older than 3 years as expressed in the ILCD field (“data set valid until” and the difference between the “valid until” and the “reference year” is not higher than 8 years)	Data are not older than 6 years as expressed in the ILCD field (“data set valid until” and the difference between the “valid until” and the “reference year” is not higher than 8 years)	Data are older than 6 years as expressed in the ILCD field (“data set valid until” and the difference between the “valid until” and the “reference year” is not higher than 8 years)
Precision	Data based on direct measurements and validation	Non-validated data based partly on measurements	Non-validated data based on assumptions
Completeness	All GHG emissions and removals that provide a significant contribution under study are included. The level of significance is	Most GHG emissions and removals that provide a significant contribution under study are considered. However, there may	The study fails to adequately include all relevant GHG emissions and removals that significantly impact the analysis

Quality level	Good	Fair	Poor
	determined by the cutoff criteria	be some minor limitations or areas for improvement	
Representativeness	The data set reflects the true population of involved interest, and fully covers different periods to balance out normal fluctuations	The data set reflects a degree of true population of involved interest, and covers different periods to involve partial fluctuations	The data set inadequately represents the true population of relevant interests, and lacks sufficient coverage of different periods to capture normal fluctuations
Consistency	Assumptions, methods, and data are consistently applied throughout the study in accordance with the goal and scope definition	Assumptions, methods, and data in the study are largely applied consistently. However, there may be some minor inconsistencies or incomplete mentions	Assumptions, methods, and data in the study are applied inconsistently or lack clear application
Reproducibility	The study provides comprehensive and detailed information about the methodology and data values used, enabling an independent practitioner to accurately reproduce the results	The study provides sufficient information about the methodology and data values, while there may be some gaps or ambiguities, which may affect the reproducibility to some extent	The study lacks essential information about the methodology and data values, making it difficult for an independent practitioner to reproduce the reported results
Sources of the data	The data is produced through reliable sources using	The data is collected from reliable sources	The data lack reliability and may come from

Quality level	Good	Fair	Poor
	accurate analytical or physical measurement procedures	using reliable measurement procedures with minimal bias and uncertainty	questionable sources
Uncertainty of the information	Appropriate models, methods, and parameters have been employed to minimize bias and uncertainty to the greatest extent practically possible. Uncertainty is accurately estimated when necessary	The models, methods, and parameters used in the study are reasonably suitable for reducing bias and uncertainty to the extent practically achievable. Uncertainty is appropriately estimated when required	The models, methods, and parameters used in the study are inadequate in reducing bias and uncertainty. The estimation of uncertainty may be inaccurate or lack sufficient information

According to data quality assessment, the data quality is in accordance with the requirements of section 6.3.5 of ISO 14067:2018 standard (Table 3-2).

Table 3-2 Data quality assessment

Data quality assessment	Data source	Quality
Time related coverage	Jiangsu Shuangjing New Energy Technology Co., Ltd. production inventory from 2023-04-01 to 2024-03-31.	Good
Geographical coverage	All specific data was collected from manufacturer in China. Other secondary data represent the level of rest of world (Row) unless otherwise specified.	Good
Technology coverage	The technology is from Jiangsu Shuangjing New Energy Technology Co., Ltd., and the data collected represents the current technology.	Good

Data quality assessment	Data source	Quality
Precision	All the data was collected through calculation and directly measurement.	Good
Completeness	All the flows were included with less than 1% cut off.	Good
Representativeness	See time related, geographical, technology coverage above.	Good
Consistency	The methodology is applied uniformly and consist with the goal and scope of the study.	Good
Reproducibility	The results can be reproduced basing on the same methodology.	Good
Sources of the data	The raw materials consumption, transport, and energy consumption of manufacturing is from specific data. The life cycle impacts of output and input flows are from secondary database Ecoinvent 3.9.1.	Good
Uncertainty of the information	All the data was confirmed with Jiangsu Shuangjing New Energy Technology Co., Ltd. with evidence provided.	Good

3.2 Assumptions

None.

3.3 List of product raw materials and packaging materials

By verifying the BOM, work orders and transportation records, confirmed the amounts of raw materials and packaging materials of 1 piece of silicon wafer product and the transportation information as Table 3-3 and Table 3-4.

Table 3-3 List of raw materials for 1 piece of silicon wafer

Raw materials	Unit	18XP	18XN	210XP	210XN	18XHN	210HN
Brick	kg	1.57E-02	1.46E-02	1.86E-02	1.56E-02	7.59E-03	9.19E-03
Diamond_wire	kg	5.49E-03	5.55E-03	7.29E-03	7.29E-03	2.74E-03	3.65E-03
Coolant	kg	8.25E-04	8.34E-04	1.09E-03	1.09E-03	4.11E-04	5.48E-04
Resin_board	kg	2.62E-04	2.65E-04	3.48E-04	3.48E-04	1.31E-04	1.74E-04
Epoxy_resin_glue	kg	5.06E-05	5.11E-05	6.71E-05	6.71E-05	2.52E-05	3.36E-05
Cleaning_liquid	kg	6.08E-04	6.14E-04	8.07E-04	8.07E-04	3.03E-04	4.04E-04
Lactic_acid	kg	5.78E-05	5.84E-05	1.18E-05	7.67E-05	2.88E-05	3.84E-05
Ethanol	kg	8.93E-06	9.02E-06	7.67E-05	1.18E-05	4.45E-06	5.93E-06
H_2O_2	kg	5.67E-04	5.73E-04	7.53E-04	7.53E-04	2.83E-04	3.77E-04
PAC	kg	2.21E-03	2.23E-03	2.93E-03	2.93E-03	1.10E-03	1.47E-03
PAM	kg	4.92E-06	4.97E-06	6.53E-06	6.53E-06	2.45E-06	3.27E-06
Citric_Acid	kg	6.53E-08	6.60E-08	8.67E-08	8.67E-08	3.26E-08	4.34E-08
Sodium_hydroxide_30%	kg	9.06E-04	9.15E-04	1.20E-03	1.20E-03	4.52E-04	6.02E-04
Potassium_dihydrogen_phosphate	kg	8.30E-06	8.38E-06	1.10E-05	1.10E-05	4.13E-06	5.51E-06
Organic	kg	6.22E-05	6.28E-05	8.25E-05	8.25E-05	3.10E-05	4.13E-05
Sodium_hydroxide_96%	kg	1.82E-06	1.83E-06	2.41E-06	2.41E-06	9.05E-07	1.21E-06
Sodium_Hypochlorite	kg	3.66E-06	3.70E-06	4.86E-06	4.86E-06	1.82E-06	2.43E-06
sodium_hydrogen_sulfite	kg	3.04E-06	3.07E-06	4.03E-06	4.03E-06	1.51E-06	2.02E-06
Kraft_paper	kg	2.83E-03	2.86E-03	3.75E-03	3.75E-03	1.41E-03	1.88E-03

Wooden_pallet	kg	5.05E-03	5.10E-03	6.70E-03	6.70E-03	2.51E-03	3.35E-03
PE	kg	1.53E-04	1.55E-04	2.04E-04	2.04E-04	7.64E-05	1.02E-04
PS	kg	9.18E-05	9.28E-05	1.22E-04	1.22E-04	4.58E-05	6.10E-05

Table 3-4 Transportation information of raw materials and packaging materials

Model type	Transportation mode	Unit (tkm)
18XP	Lorry	3.26E-02
18XN	Lorry	3.10E-02
210XP	Lorry	3.99E-02
210XN	Lorry	3.51E-02
18XHN	Lorry	1.59E-02
210HN	Lorry	1.97E-02

3.4 List of product manufacturing stages

3.4.1 Energy consumption list

The data of the manufacturing stage of the verified products are mainly electricity consumption and water (Table 3-5). By verifying energy consumption of Jiangsu Shuangjing New Energy Technology Co., Ltd., the electricity are from outsourced grid of Eastern China.

Table 3-5 List of energy consumption in manufacturing stage

Model type	Energy type	
	Electricity from the grid (kWh)	Water(kg)
18XP	8.19E-02	8.24E-01
18XN	8.27E-02	8.33E-01
210XP	1.09E-01	1.09E+00
210XN	1.09E-01	1.09E+00
18XHN	4.08E-02	4.11E-01
210HN	5.44E-02	5.47E-01

3.4.2 List of production auxiliary materials

No auxiliary material used in the production process.

3.4.3 List of waste disposal

The list of waste disposal in the manufacturing stage was confirmed by verifying the records of Jiangsu Shuangjing New Energy Technology Co., Ltd., The waste relevant to the manufacturing process was sent to an outsourced waste disposal site for incineration and recycling. The amounts of each category for 1 piece of silicon wafer are listed in Table 3-6.

Table 3-6 List of waste disposal data of manufacturing stage

Model type	Waste disposal	Weight(kg)	Transportation (tkm)
18XP	Waste for recycling	1.05E-02	3.17E-03
	Waste for incineration	3.44E-05	5.44E-06
18XN	Waste for recycling	1.06E-02	3.20E-03
	Waste for incineration	3.47E-05	5.50E-06
210XP	Waste for recycling	1.39E-02	4.20E-03
	Waste for incineration	4.56E-05	7.23E-06
210XN	Waste for recycling	1.39E-02	4.20E-03
	Waste for incineration	4.56E-05	7.23E-06
18XHN	Waste for recycling	5.21E-03	1.58E-03
	Waste for incineration	1.71E-05	2.71E-06
210HN	Waste for recycling	6.94E-03	2.10E-03
	Waste for incineration	2.28E-05	3.62E-06

3.5 List of product distribution and sales stages

Not applicable

3.6 Product use stage list

Not applicable

3.7 Product disposal or recycling stage list

Not applicable

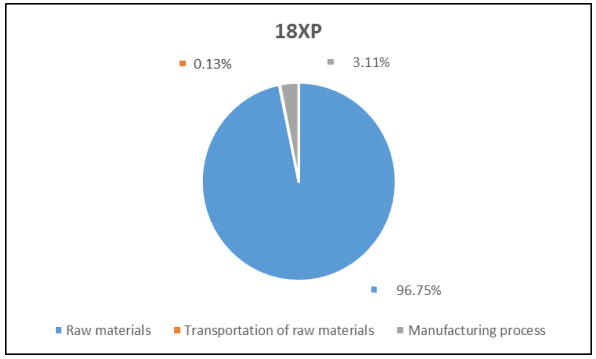
4 Product carbon footprint verification results and analysis

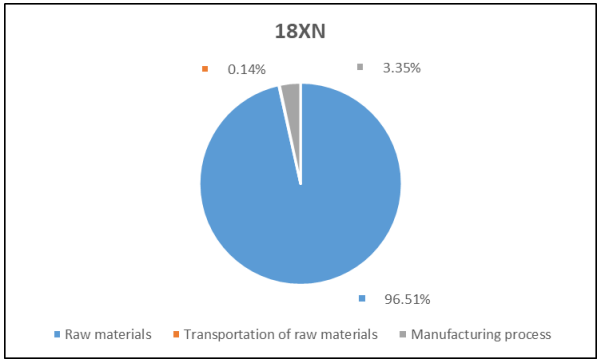
4.1 Product Carbon Footprint Verification Results

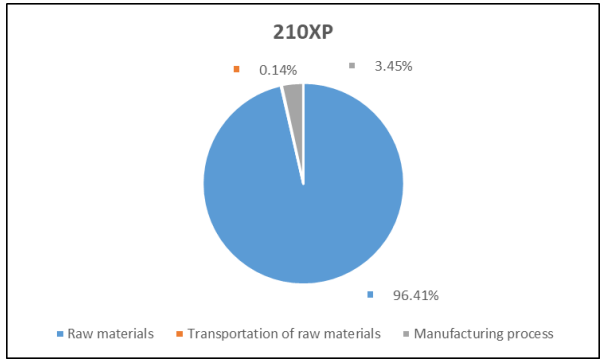
Based on the verified product carbon footprint data inventory, the carbon emissions of silicon wafer per declared unit at each life cycle stage are listed as Table 4-1. The carbon footprint proportion of each life stage is shown in Figure 4-1.
The carbon footprint proportion of each life cycle stage is shown in Figure 4-1.

Table 4-1 Carbon footprint information

Life stage	18XP	18XN	210XP	210XN	18XHN	210HN
Raw materials (kg CO_2e)	2.48E+00	2.32E+00	2.97E+00	2.53E+00	1.20E+00	1.47E+00
Transportation of raw materials (kg CO_2e)	3.44E-03	3.27E-03	4.21E-03	3.70E-03	1.68E-03	2.08E-03
Manufacturing process (kg CO_2e)	7.99E-02	8.07E-02	1.06E-01	1.06E-01	3.98E-02	5.31E-02
Total (kg CO_2e)	2.57	2.41	3.08	2.64	1.24	1.52







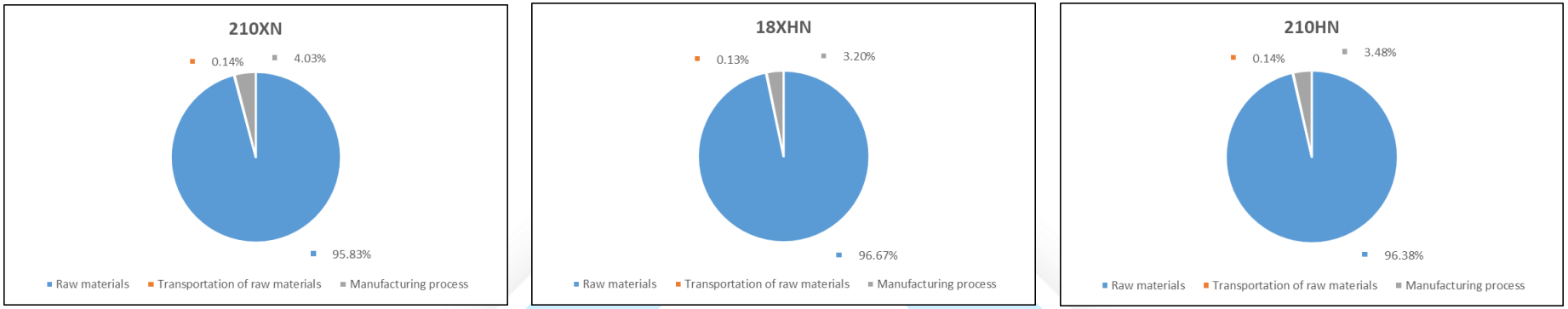


Figure 4-1 Life cycle stage contribution of model type 18XP, 18XN , 210XP , 210XN , 18XHN and 210HN, respectively.

4.2 Contribution of each life cycle stage

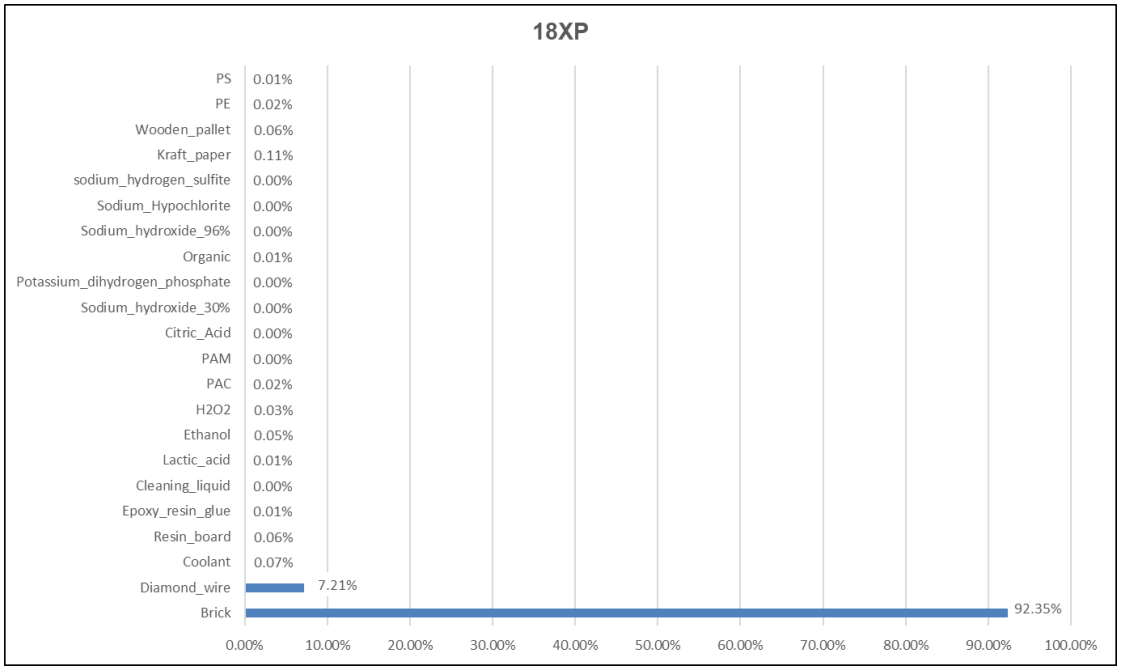
4.2.1 Raw material acquisition and processing stage

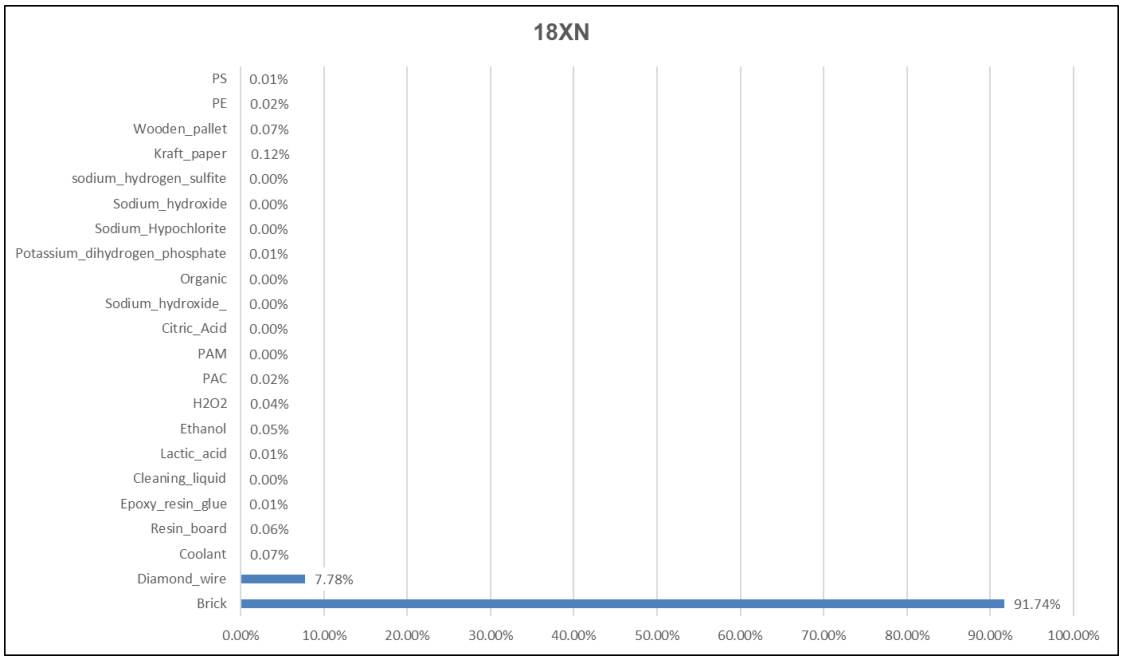
Based on the contribution analysis results, the most significant life cycle stage of silicon wafer is the raw materials acquisition stage. This stage accounts for more than 95% of the total carbon footprint for each product .Table 4-2 provides an overview of each material's contribution.

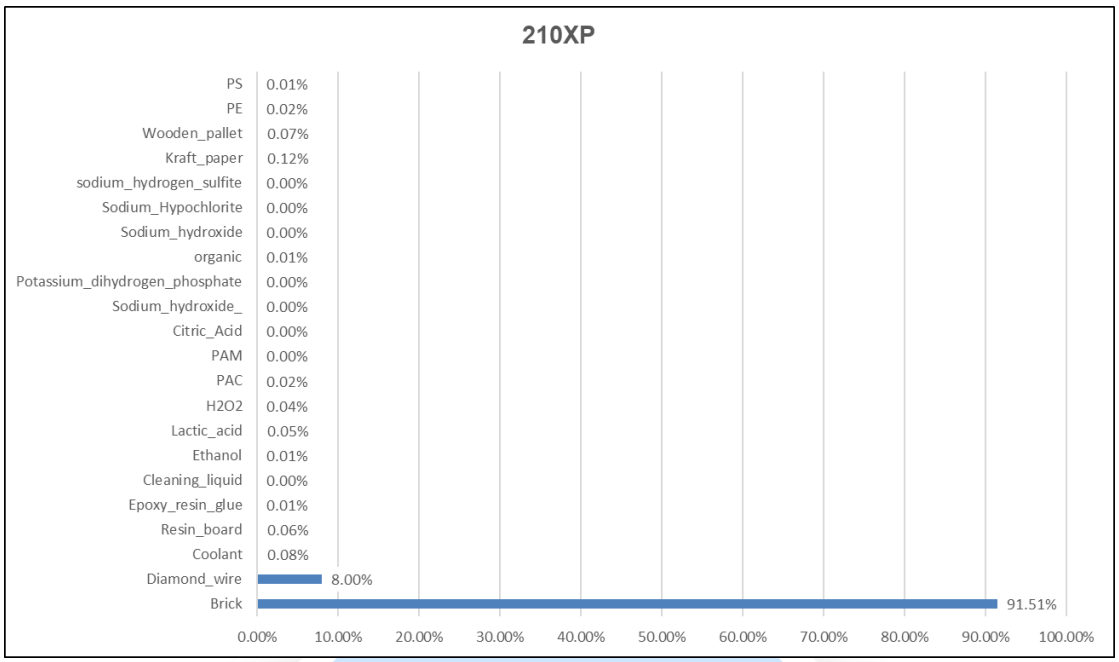
Table 4-2 Carbon emission of raw material (kg CO_2e)

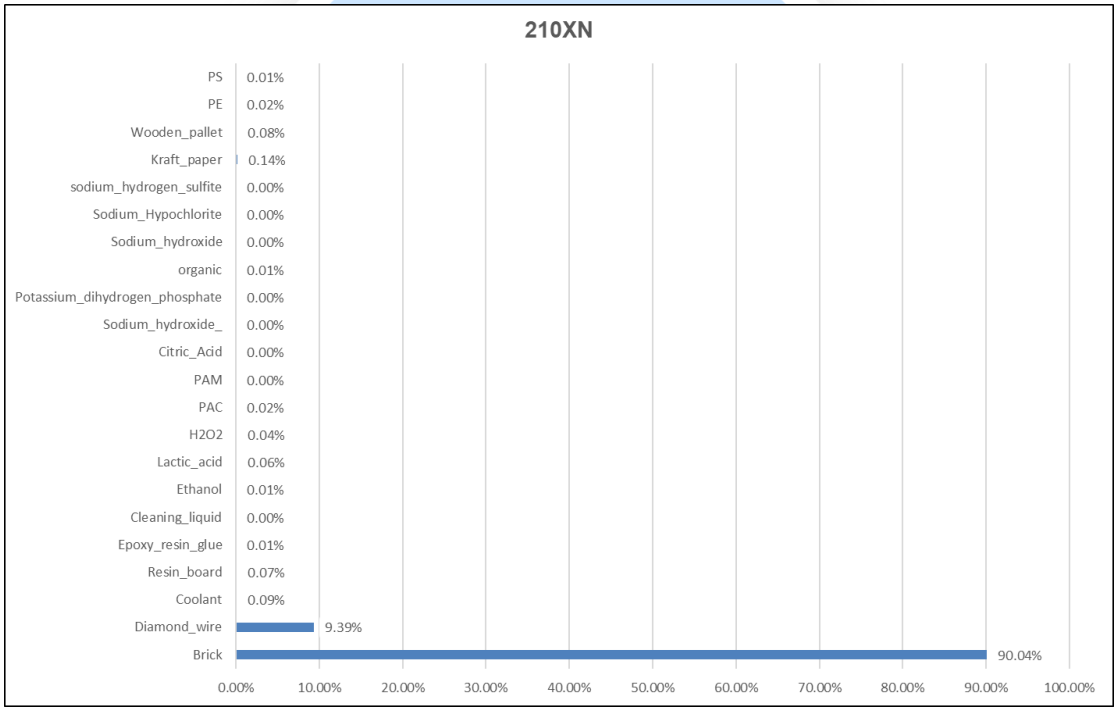
Raw material	18XP	18XN	210XP	210XN	18XHN	210HN
Brick	2.29E+00	2.13E+00	2.72E+00	2.28E+00	1.11E+00	1.34E+00
Diamond_wire	1.79E-01	1.81E-01	2.38E-01	2.38E-01	8.93E-02	1.19E-01
Coolant	1.69E-03	1.71E-03	2.23E-03	2.23E-03	8.42E-04	1.12E-03
Resin_board	1.38E-03	1.39E-03	1.83E-03	1.83E-03	6.88E-04	9.14E-04
Epoxy_resin_glue	2.59E-04	2.61E-04	3.43E-04	3.43E-04	1.29E-04	1.72E-04
Cleaning_liquid	1.19E-05	1.20E-05	1.57E-05	1.57E-05	5.91E-06	7.87E-06
Lactic_acid	2.56E-04	2.59E-04	3.40E-04	3.40E-04	1.28E-04	1.70E-04
Ethanol	1.13E-03	1.14E-03	1.50E-03	1.50E-03	5.62E-04	7.49E-04
H2O2	8.39E-04	8.48E-04	1.11E-03	1.11E-03	4.19E-04	5.58E-04
PAC	3.73E-04	3.76E-04	4.95E-04	4.95E-04	1.86E-04	2.48E-04
PAM	1.60E-05	1.62E-05	2.13E-05	2.13E-05	7.97E-06	1.06E-05
Citric_Acid	2.23E-08	2.26E-08	2.96E-08	2.96E-08	1.11E-08	1.48E-08
Sodium_hydroxide_30%	7.05E-07	7.09E-07	9.33E-07	9.33E-07	3.50E-07	4.68E-07
Potassium_dihydrogen_phosphate	2.26E-05	1.26E-04	3.00E-05	3.00E-05	1.13E-05	1.50E-05
Organic	1.25E-04	2.28E-05	1.65E-04	1.65E-04	6.22E-05	8.28E-05

Sodium_hydroxide_96%	2.25E-06	9.54E-07	2.99E-06	2.99E-06	1.12E-06	1.50E-06
Sodium_Hypochlorite	9.44E-07	2.27E-06	1.25E-06	1.25E-06	4.69E-07	6.27E-07
sodium_hydrogen_sulfite	3.98E-06	4.02E-06	5.27E-06	5.27E-06	1.98E-06	2.64E-06
Kraft_paper	2.67E-03	2.70E-03	3.54E-03	3.54E-03	1.33E-03	1.77E-03
Wooden_pallet	1.52E-03	1.53E-03	2.01E-03	2.01E-03	7.54E-04	1.01E-03
PE	4.72E-04	4.78E-04	6.30E-04	6.30E-04	2.36E-04	3.15E-04
PS	2.10E-04	2.12E-04	2.79E-04	2.79E-04	1.05E-04	1.39E-04


18XP
PS 0.01%
PE 0.02%
Wooden_pallet 0.06%
Kraft_paper 0.11%
sodium_hydrogen_sulfite 0.00%
Sodium_Hypochlorite 0.00%
Sodium_hydroxide_96% 0.00%
Organic 0.01%
Potassium_dihydrogen_phosphate 0.00%
Sodium_hydroxide_30% 0.00%
Citric_Acid 0.00%
PAM 0.00%
PAC 0.02%
H2O2 0.03%
Ethanol 0.05%
Lactic_acid 0.01%
Cleaning_liquid 0.00%
Epoxy_resin_glue 0.01%
Resin_board 0.06%
Coolant 0.07%
Diamond_wire 7.21%
Brick 92.35%
0.00% 10.00% 20.00% 30.00% 40.00% 50.00% 60.00% 70.00% 80.00% 90.00% 100.00%


18XN
PS 0.01%
PE 0.02%
Wooden_pallet 0.07%
Kraft_paper 0.12%
sodium_hydrogen_sulfite 0.00%
Sodium_hydroxide 0.00%
Sodium_Hypochlorite 0.00%
Potassium_dihydrogen_phosphate 0.01%
Organic 0.00%
Sodium_hydroxide_ 0.00%
Citric_Acid 0.00%
PAM 0.00%
PAC 0.02%
H2O2 0.04%
Ethanol 0.05%
Lactic_acid 0.01%
Cleaning_liquid 0.00%
Epoxy_resin_glue 0.01%
Resin_board 0.06%
Coolant 0.07%
Diamond_wire 7.78%
Brick 91.74%
0.00% 10.00% 20.00% 30.00% 40.00% 50.00% 60.00% 70.00% 80.00% 90.00% 100.00%


210XP
PS 0.01%
PE 0.02%
Wooden_pallet 0.07%
Kraft_paper 0.12%
sodium_hydrogen_sulfite 0.00%
Sodium_Hypochlorite 0.00%
Sodium_hydroxide 0.00%
organic 0.01%
Potassium_dihydrogen_phosphate 0.00%
Sodium_hydroxide_ 0.00%
Citric_Acid 0.00%
PAM 0.00%
PAC 0.02%
H2O2 0.04%
Lactic_acid 0.05%
Ethanol 0.01%
Cleaning_liquid 0.00%
Epoxy_resin_glue 0.01%
Resin_board 0.06%
Coolant 0.08%
Diamond_wire 8.00%
Brick 91.51%
0.00% 10.00% 20.00% 30.00% 40.00% 50.00% 60.00% 70.00% 80.00% 90.00% 100.00%


210XN
PS 0.01%
PE 0.02%
Wooden_pallet 0.08%
Kraft_paper 0.14%
sodium_hydrogen_sulfite 0.00%
Sodium_Hypochlorite 0.00%
Sodium_hydroxide 0.00%
organic 0.01%
Potassium_dihydrogen_phosphate 0.00%
Sodium_hydroxide_ 0.00%
Citric_Acid 0.00%
PAM 0.00%
PAC 0.02%
H2O2 0.04%
Lactic_acid 0.06%
Ethanol 0.01%
Cleaning_liquid 0.00%
Epoxy_resin_glue 0.01%
Resin_board 0.07%
Coolant 0.09%
Diamond_wire 9.39%
Brick 90.04%
0.00% 10.00% 20.00% 30.00% 40.00% 50.00% 60.00% 70.00% 80.00% 90.00% 100.00%

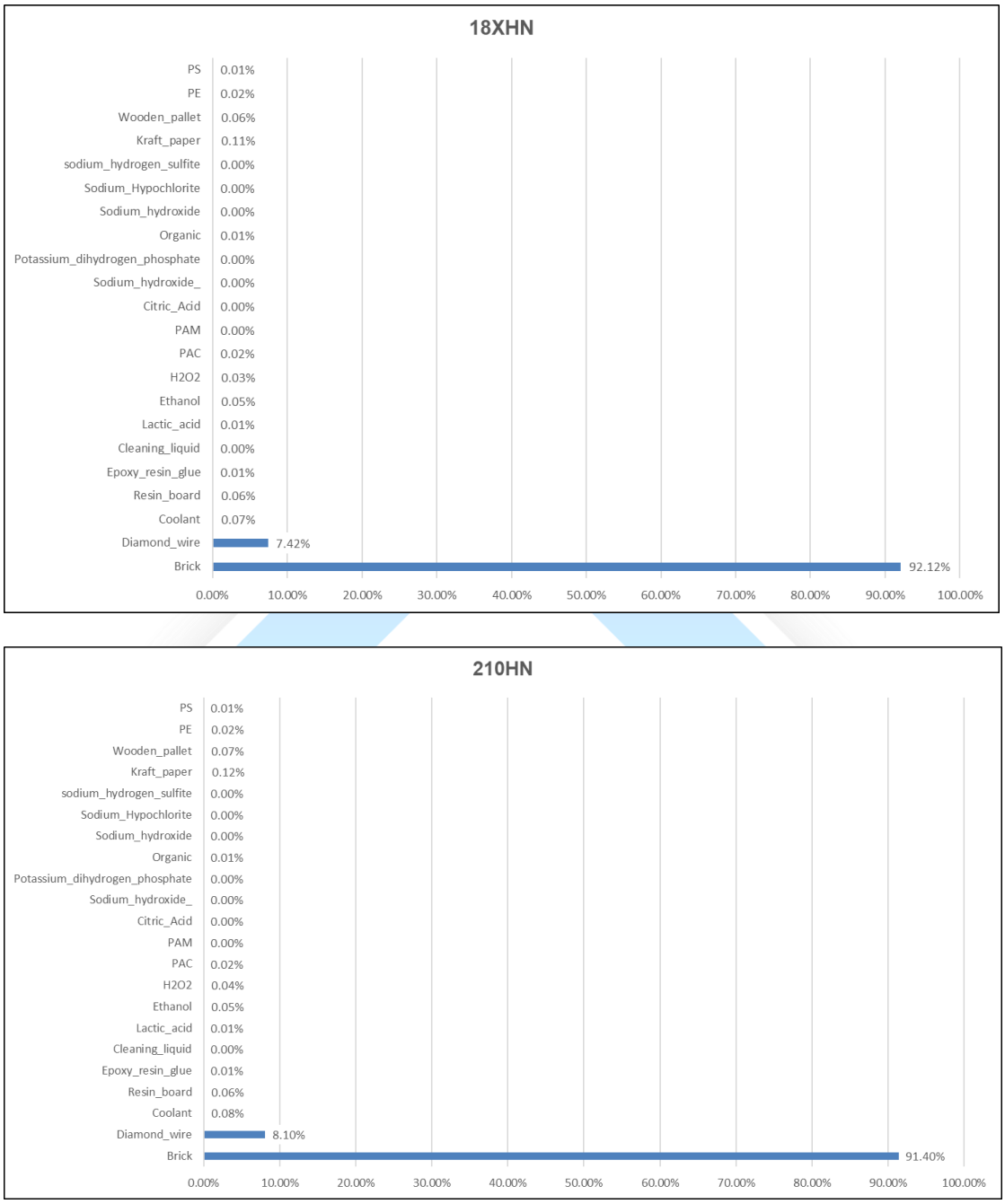


Figure 4-2 Raw material carbon emission contribution of model type 18XP, 18XN , 210XP , 210XN , 18XHN and 210HN, respectively.

In the raw material stage, brick is the main contributor, accounting for over 90% of the 18XP,18XN, 210XP, 210XN, 18XHN and 210HN carbon footprints. respectively. Figure 4-2 provides further details.

4.2.2 Manufacturing stage

In the manufacturing stage, the impacts on the carbon emissions of the product arise from water consumption, energy consumption and waste disposal, which includes transportation of waste from the factory to outsourced disposal sites. The detailed contributions are listed in Table 4-3.

For silicon wafer products, the carbon emissions of the six products at this stage accounted for 3.11%, 3.35%, 3.45%, 4.03%, 3.20% and 3.48 % of the total emissions, respectively. The primary impact in this stage is attributed to electricity consumption, which accounts for more than 97% respectively.

Table 4-3 List of carbon footprint contribution of manufacturing stage(kg CO_2e)

Manufacturing stages	18XP	18XN	210XP	210XN	18XHN	210HN
Water consumption	2.13E-04	2.15E-04	1.04E-01	1.04E-01	3.89E-02	5.19E-02
Energy consumption	7.81E-02	7.89E-02	2.82E-04	2.82E-04	1.06E-04	1.41E-04
Waste disposal transportation	3.35E-04	3.39E-04	4.44E-04	4.44E-04	1.67E-04	2.23E-04
Municipal solid waste treatment	1.00E-03	1.01E-03	2.66E-04	2.66E-04	1.00E-04	1.33E-04
Wastewater treatment	2.01E-04	2.03E-04	1.33E-03	1.33E-03	4.98E-04	6.66E-04
Hazardous waste treatment	8.52E-05	8.60E-05	1.13E-04	1.13E-04	4.24E-05	5.65E-05
Total	7.99E-02	8.07E-02	1.06E-01	1.06E-01	3.98E-02	5.31E-02

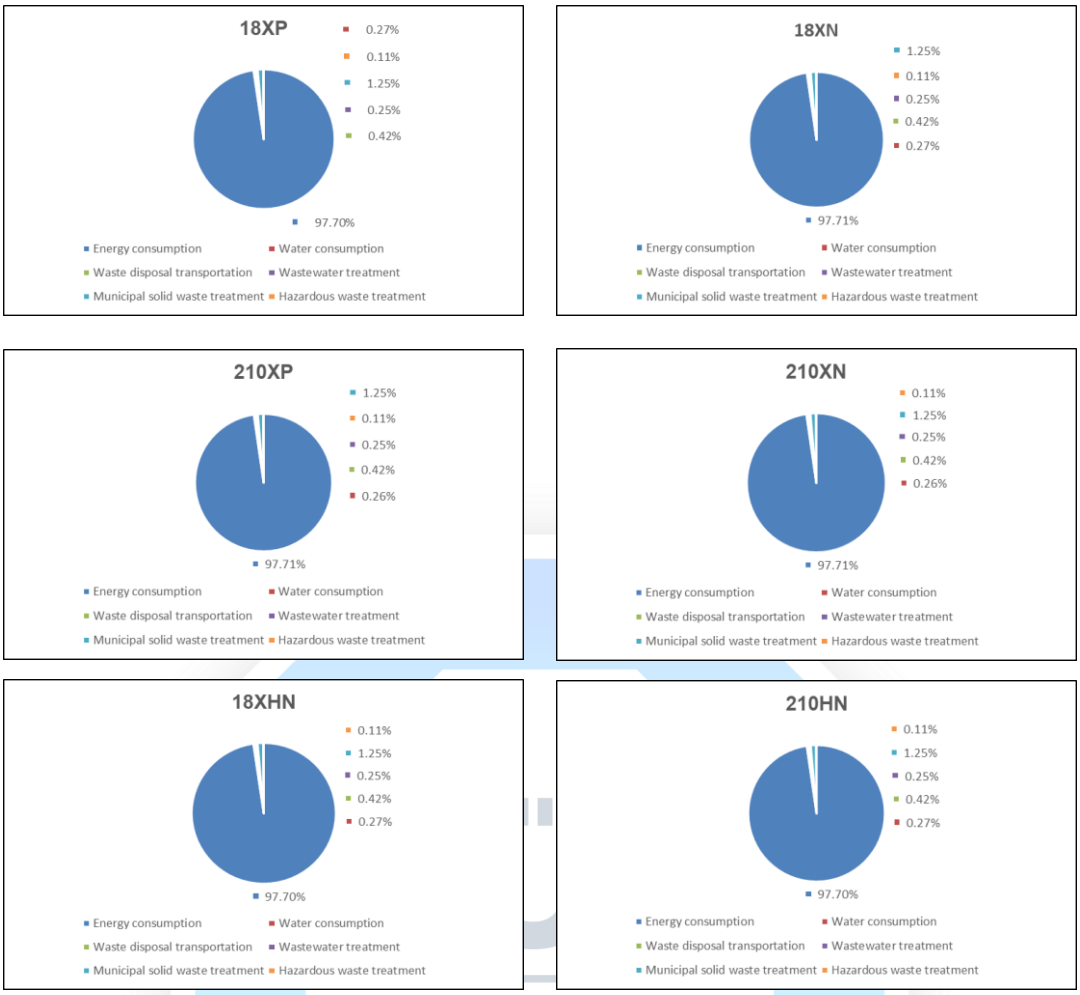


Figure 4-3 Carbon emission contribution of manufacturing stage of model type 18XP, 18XN , 210XP , 210XN , 18XHN and 210HN, respectively.

4.2.3 Product distribution and sales stage

Not applicable

4.2.4 Product use stage

Not applicable

4.2.5 Product disposal or recycling stage

Not applicable

4.3 Completeness and Consistency verification

The verification activity is conducted according to ISO 14064-3, each unit process and its input and output are confirmed. We confirmed that unit processes and their

input/output are complete. In terms of consistency verification, the study of this project is consistent with the original purpose and scope.

4.4 Sensitivity analysis

Not applicable

5 Conclusions and suggestions of product carbon footprint verification

Through analyzing the contribution of each life stage, the most significant impact is from raw materials. To optimize the carbon footprint of silicon wafer products, it is necessary to update procurement strategies, prioritize suppliers that meet environmental standards, and use more renewable and sustainable raw materials. The application of green logistics is an effective way to reduce the impact of the raw material acquisition stage. The impact of silicon rod data on the raw material acquisition stage mainly stems from the secondary database. Since the general data in the secondary database is usually conservative, conducting a life cycle assessment (LCA) of the silicon rod can help optimize the carbon footprint.

Through the analysis, we can get a conclusion that silicon rod contributes most significant impact, so another feasible way to further reduce the carbon footprint way is to conduct LCA study for this raw material. It also works for improving the environmental behavior from factories side, such as strengthening energy management, reducing energy consumption of manufacturing process, using more renewable energy and recycled materials.

6 References

1) ISO 14067:2018 Carbon footprint of products —Requirements and guidelines for quantification and communication
2) ISO 14064-3:2019 Greenhouse gases —Part 3: Specification with guidance for the verification and validation of greenhouse gas statements
3) ISO 14040:2006 Environmental management — Life cycle assessment — Principles and Framework
4) ISO 14044:2006 Environmental management — Life cycle assessment — Principles and guidelines
5) Ecoinvent database 3.9.1, http://www.ecoinvent.org

Annex: List of Carbon Emission Factors

Item	Dataset
Brick	Silicon, single crystal, Czochralski process, photovoltaics {RoW}| silicon production, single crystal, Czochralski process, photovoltaics | Cut-off, S
Diamond wire	Diamod wire
Coolant	Ethylene glycol {RoW}| ethylene glycol production | Cut-off, U
Resin board	Polyester resin, unsaturated {RoW}| polyester resin production, unsaturated | Cut-off, U
Epoxy resin glue	Epoxy resin, liquid {RoW}| epoxy resin production, liquid | Cut-off, U
Ethanol	Ethanol, without water, in 99.7% solution state, from ethylene {RoW}| ethylene hydration | Cut-off, U
Lactic acid	Lactic acid {RoW}| lactic acid production | Cut-off, U
Cleaning liquid	Chemical, inorganic {GLO}| chemical production, inorganic | Cut-off, U
H_2O_2	Hydrogen peroxide, without water, in 50% solution state {RoW}| hydrogen peroxide production, product in 50% solution state | Cut-off, U
PAC	Polyaluminium chloride {GLO}| polyaluminium chloride production | Cut-off, U
PAM	Polyacrylamide {GLO}| polyacrylamide production | Cut-off, U
Citric Acid	Hydrochloric acid, without water, in 30% solution state {RoW}| trichloroethylene production | Cut-off, U
Sodium hydroxide*0.3	Sodium hydroxide, without water, in 50% solution state {GLO}| market for sodium hydroxide, without water, in 50% solution state | Cut-off, U
Potassium dihydrogen phosphate	Potassium hydroxide {RoW}| potassium hydroxide production | Cut-off, U
organic	Chemical, organic {GLO}| chemical production, organic | Cut-off, U

Sodium hydroxide*0.96	Sodium hydroxide, without water, in 50% solution state {GLO}| market for sodium hydroxide, without water, in 50% solution state | Cut-off, U
Sodium Hypochlorite*0.1	Sodium hypochlorite, without water, in 15% solution state {RoW}| market for sodium hypochlorite, without water, in 15% solution state | Cut-off, U
Sodium hydrogen sulfite*0.98	Sodium hydrogen sulfite {RoW}| sodium hydrogen sulfite production | Cut-off, U
Kraft paper	Kraft paper {RoW}| kraft paper production | Cut-off, U
Wooden pallet	Glued laminated timber, average glue mix {RoW}| glued laminated timber production, average glue mix | Cut-off, U
PE	Packaging film, low density polyethylene {RoW}| packaging film production, low density polyethylene | Cut-off, U
PS	Polypropylene, granulate {RoW}| polypropylene production, granulate | Cut-off, U
Electricity	Electricity, medium voltage {CN}| market group for electricity, medium voltage | Cut-off, U
Water	Water, harvested from rainwater {GLO}| rainwater harvesting | Cut-off, U
Transportation	Transport, freight, lorry >32 metric ton, EURO5 {RoW}| transport, freight, lorry >32 metric ton, EURO5 | Cut-off, U
Wastewater	Wastewater, average {RoW}| market for wastewater, average | Cut-off, U
Municipal solid waste	Municipal solid waste {RoW}| treatment of municipal solid waste, sanitary landfill | Cut-off, U
Hazardous waste	Hazardous waste, for incineration {RoW}| treatment of hazardous waste, hazardous waste incineration | Cut-off, U