PCB (10 Layer)

Report for Product Carbon Footprint Assessment

(Based on ISO 14067:2018)

Reporting Enterprise: Dynamic Electronics (Huangshi) Co., Ltd.

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Table of Contents

List of Tables

List of Figures

1. Overview

1.1. About Dynamics

Dynamic Electronics (Huangshi) Co., Ltd. (hereinafter referred to as “The Company”) is a specialized PCB (printed circuit board) manufacturer and was established in 2015 at No.88, Daqi Avenue, Wangren Town, Economic and Technological Development Zone, Huangshi City, Hubei Province. It occupies an area of 600mus and received a total investment of CNY 4 billion. Now the company employs 2800 staff and realizes an output value of about CNY 2.12 billion.

The company mainly manufactures the products of high multi-layer, bent, high-frequency, thick-copper and high-density connection PCB boards. In 2022, the company manufactures different product forms including 63% for automotive, 18% for display panels, 8% for storage devices, 4% computer and peripherals, 4% for network communications and servers, and 3% for consumer electronics. Our products are sold globally and applied widely in fields such as automotive, opto-electronics, computers and peripherals, consumer electronics, communications, networks, IoT, aviation, energy, industry and medical, etc.

Our upstream customers mainly include NANYA, ITEQ, SHENGYI, TAIYO, EMC, etc. and some of our upstream material suppliers have established their production bases in Hubei province or even local development zones. Our downstream customers mainly include those well-known enterprises at home and abroad such as Tesla, Samsung, LGD, Continental AG, Valeo, Sharp, BOE, CSOT, HKC and CHOT, etc.

The company has been accredited with the system certification certificates such as ISO 9001, ISO14001, ISO13485, ISO27001, ISO45001, QC080000, UL2799, etc.

The company is rated as Hubei Healthy Enterprise and Hubei Water-saving Enterprise. In 2021, it is honored as China Green Factory and certified

as Authorized Economic Operator and Hubei Intelligent Manufacturing Demonstration Enterprise. In 2022, it passes the certification of China PCB industry specification and is continuously ranked as Top 5% best enterprises by China 8'th Enterprise Governance Assessment.

1.2. Introduction of target product

The target product for this carbon footprint assessment is PCB (10 Layer).

PCB (Printed Circuit Board) is a type of important electronic components and the support for electronic parts and components and also the electronically-interconnecting carriers for them.

The information of the target product is as shown in Table 11.

Table 1-1 Introduction of target product

Item	Information
Part number	****HATT0032C
Number of layers	10
Product dimensions	167Mm*185mm, 1PCB/Array, Thickness: 1.6mm+/-0.14mm
Weight	0.112Kg/PCB

The schematic appearance of the target product is as shown in Fig 11.

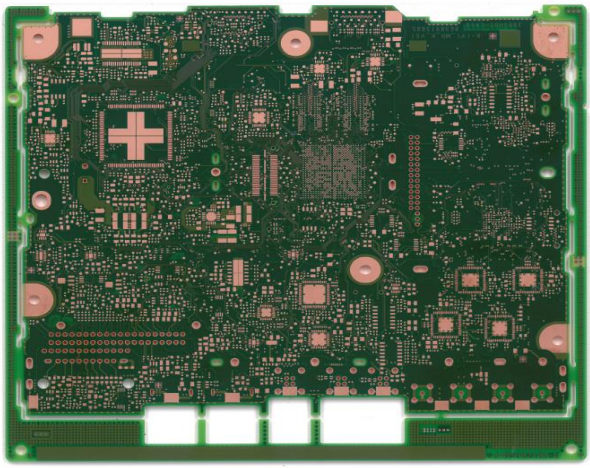

Fig 1-1 Schematic appearance of target product

Statistical period (Jan. 1, 2022 ~ Dec. 31, 2022): the output of target product is 39382.69sf (square feet).

1.3. Purposes for preparing report

The report aims to reveal the carbon footprint of PCB (10 Layer) across manufacturing the upstream raw and auxiliary materials to transportation until packaging of finished products (cradle-to-gate) from the perspective of life cycle. The detailed purposes include:

1) Obtaining the reliable carbon footprint data of target product.
2) Using the result of carbon footprint assessment as the basis to carry out green product design and advance green manufacturing.
3) As the upstream enterprise of supply chain, actively collaborating with the whole industry chain to carry out carbon peaking and carbon neutrality.
4) Actively implementing the disclosure of carbon information toward investors and the whole society.
5) Building a good corporate image of green and low carbon as well as improving product competitiveness.

1.4. Retention period of report

From the date of official issuance by the company, the report will be saved for 5 years and the contents to be saved include the “Product Carbon Footprint Assessment Report”, “Data Inventory of Product Carbon Footprint Activities” and “Exported Data of Product Carbon Footprint Model.”

1.5. Carbon footprint assessment working group

The company respects carbon management very much and specially sets up a working group whose members and member assignments are as follows:

Group leader: Wang Bo (Environment Safety Dept.)

Duty: overall arrangement of product carbon footprint certification across the company.

Deputy leader: Ke Yazhong (Environment Safety Dept.)

Duty: organize the relevant staffs from the relevant departments to implement, assist the certification process and undertake the interactions according to carbon footprint verification specification. Verify the authenticity and readiness of all the verification data and summarize all the collected data.

Group members:

Environment Safety Dept.: Be responsible for collection and summarization of the product data from the production and waste ends.

Purchase Dept.: be responsible for collecting the specifications, origins and mode of transport of raw materials.

Finance Dept.: provide and review the necessary annual financial data.

Production Management Dept.: be responsible for the production capacity data.

Public Utilities Dept.: Be responsible for providing the energy consumption data.

Industry Engineering Dept.: Be responsible for providing and analyzing production processes and unit consumption data of raw materials.

Production / Sales Material Control Dept.: Be responsible for providing raw materials data.

2. PCR and other supplementary requirements

According to the standard ISO 14067:2018, if there exists a product category rule (PCR), it should be referenced. By searching the web, it is found that the Chinese governments and industry associations have not issued a PCR for the PCB products. Thus, the product system boundary is defined in the report per the intended purpose (cradle-to-gate).

Moreover, according to ISO 14067, the supplementary requirements adopted in the report should also be introduced. All the supplementary requirements involved in the report are as shown in “Reference”

3. Scope of carbon footprint calculation

3.1. Greenhouse gases included

The case of the product carbon footprint assessment includes the greenhouse gases listed in the updated assessment report of IPCC as well as the substances as controlled by “MONTREAL PROTOCOL TREATY” as well as “MONTREAL PROTOCOL TREATY KIGALI AMENDMEN.T The specific greenhouse gases verified include: CO2, CH4, N2O, SF6, HFCs, PFCs and NF3. In the report, the GWP values of IPCC 2021 100a (AR6) are used as the method of greenhouse gas assessment.

For this project, in the live processes of production site, the enterprise has no emission and removal of biological carbon dioxide as well as greenhouse gases caused by land use change. The emission and removal of biological greenhouse gases from background processes as well as the greenhouse gases caused by land use change are calculated and described in Chapter V of the report.

3.2. Data collection period and location

The data collection period used to calculate the product carbon footprint in the report is from Jan. 1, 2022 to Dec. 31, 2022. The target product is actually under production in the period.

The actual production site of target product is the location verified in the report: No.88, Daqi Avenue, Wangren Town, Economic and Technological Development Zone, Huangshi City, Hubei Province. The geographical location and factory layout for data collection site are as shown as Fig. 31 and Fig. 32.

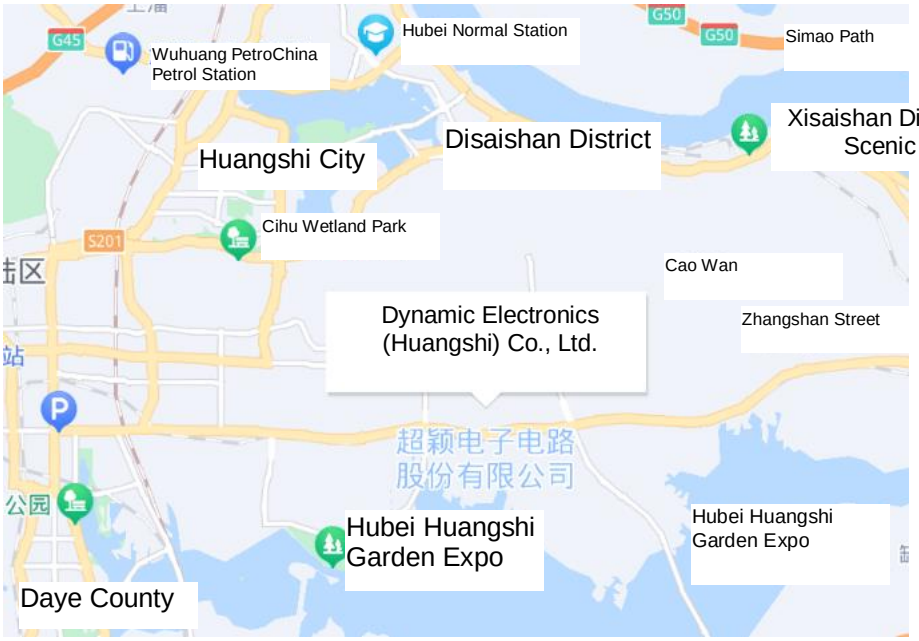

Fig. 3-1 Geographical location of the company

Fig. 3-2 Factory layout of the company

The areas related to producing the target product for this carbon footprint assessment include P1 workshop, WWTP1 workshop, boiler room and finished product warehouses. The living and office areas as well as production areas irrelevant to producing the target product are all excluded.

3.3. Declaration unit and reference flow

The declaration unit of carbon footprint assessment of target product in the report is 1sf (square feet).

The reference flow of carbon footprint assessment of target product is the 1sf PCB (10 Layer) manufactured between Jan.1, 2022 and Dec.31, 2022 by Dynamic Electronics (Huangshi) Co., Ltd..

3.4. System Boundary

The system boundary of the carbon footprint assessment of target product is “Cradle-to-gate” and the calculation of carbon footprint includes: manufacturing processes of upstream raw & auxiliary materials, manufacturing processes of upstream package materials, course of transport, manufacturing processes of target product as well as outsourced disposal process of production wastes.

The system boundary of target product is as shown in Fig. 33.

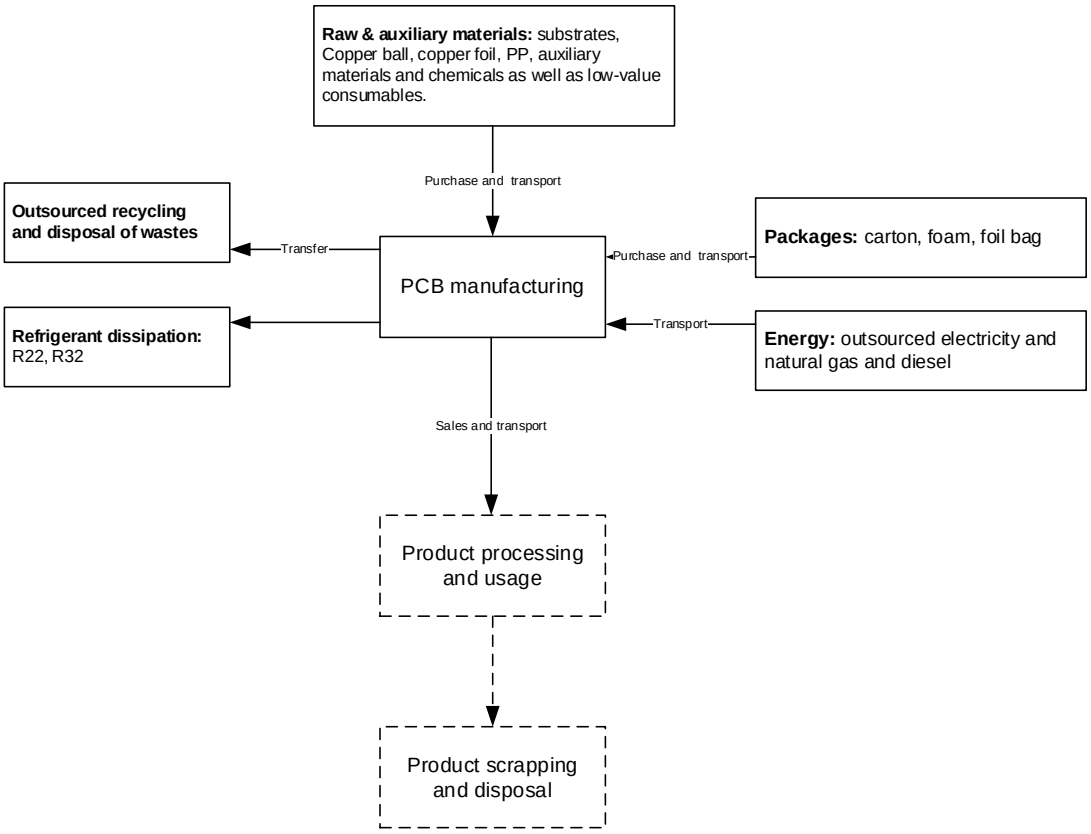

Fig. 3-3 System boundary of product carbon footprint assessment.

Various processes and covered contents in the scope of system boundary of target product are described as follows:

1) Manufacturing processes of upstream raw & auxiliary materials

Those processes cover the carbon footprints generated in the upstream manufacturing processes of raw and auxiliary materials. Those materials mainly include the raw materials of substrate, copper ball, PP, copper foil, the auxiliary and chemicals used for manufacturing PCB as well as treating production wastewater which include caustic soda liquid, hydrochloric acid, nitric acid, sulfuric acid, etc, the low-value consumables which include drill, slot cutter, pad, etc used for PCB machining.

2) Manufacturing processes of upstream package materials

The package materials include cartons, Al foil bag and foam.

3) Manufacturing processes of target product

The manufacturing processes of target product involve the consumption of energy and water resources, refrigerant dissipation as well as methane emission caused by COD removal by waste water anaerobic treatment.

The energy & power include: outsourced electricity, natural gas and diesel. The diesel is used in many ways including fixed combustion and non-road mobile combustion.

Water resource: tap water.

The refrigerant dissipation include R22 and R32 emitted from the air conditioning system.

The COD removal by waste water anaerobic treatment in the enterprise sewage treatment plant produces CH4 emission.

4) Course of transport

Those include the purchase and transport of raw & auxiliary materials, package materials and waste transfer. The transport methods include road, sea and air.

5) Outsourced disposal processes of production wastes

Those processes include the incineration and disposal of hazardous wastes.

3.5. Truncation

According to the requirements of ISO 14067:2018 and related LCA standard in combination with the actual production situation of target product, the truncation data and truncation basis in the report are as follows:

Table 3-1Truncation items and truncation basis

Truncation items	Truncation basis
Product quality inspection process	The contribution rate of carbon footprint in the process is estimated to be lower than 1% and thus is truncated.
Partial auxiliary and low-value consumables	The collection process of activity data for this product carbon footprint assessment includes all the main raw and auxiliary materials. The auxiliary and low-value consumable materials whose consumption is lower than 90% of the total consumption are truncated.

3.6. Allocation

The report uses the area ratio of target product output from the total product output as the allocation basis. The specific allocation result is as shown in Table 32.

Table 3-2Allocation data of the project

Allocation item	Allocation ratio
Allocation of P1 auxiliary, water, natural gas and wastewater anaerobic treatment	0.2007%
Allocation of P1 production power consumption	0.3337%
Allocation of factory public data (diesel, refrigerant emission, wastes)	0.1840%

4. Collection and calculation of life cycle inventory

4.1. Data collection and data quality management

In the report, the quality of the data collected to calculate the product carbon footprint conform to the requirements of Chapter 6.3.5 in ISO 14067:2018.

a) Time coverage: the collected activity data happened between Jan.1, 2022 and Dec.31, 2022.

b) Regional characteristics: for the background processes and parameters, the data from the material main origins or process sites are preferred and their order is from regional data, national data to international data.

c) About technical coverage: the data consistent with the processes and techniques of target product is preferred for the background processes and parameters.

d) About information accuracy: the most accurate data is selected.

e) Integrity: all the activity data is measured to eliminate the issues such as data missing or underrepresentation. No surrogate data is used in the background process and parameters.

f) Representation: the collection of all activity data covers all the POs of target product in the statistical period and can represent the average production level and corresponding emission of the product studied.

g) Consistency: all the parts of the data are collected and under statistics in a consistent quality requirements and data selection sequence.

h) Reproducibility: the data, methods and processes in the case all can be reproduced in LCA software (the Monte Carlo simulation for quantifying the uncertainty produces kinda different values each time

due to the operating principle) and the calculation result is exported separately as EXCEL file.

i) Data source: the activity data is sourced from BOM, workshop production report and utility invoices, etc. The background processes and parameters are from the updated Ecoinvent 3.9.1 database.

j) Uncertainty: the uncertainty analysis on the activity data information quality and calculation result is as shown in Chapter 5.5 of the report.

The work contents concerning the other data quality in the report are as follows:

a) Quality management of carbon footprint inventory in product life cycle: During the collection of activity data, the collection of each data is against the corresponding data quality and tries to use the original data having high data quality after being measured. Nevertheless, the product system inevitably needs allocation and thus will influence the final data quality.

b) Quality management personnel of carbon footprint inventory in product life cycle: the working group retains the contact information of every responsible person allocated to collect information and acquire data in each department.

The definition of data quality and activity data source for carbon footprint calculation are as shown in Table 41 and Table 42.

Table 4-1Definition of data quality

Data quality	Definition
High	Referencing primary activity data
Medium	Referencing secondary activity data
Low	Referencing estimated data

Table 4-2Carbon footprint assessment and identification and data quality

Data quality	Data category				Activity data source
High	Primary data	Specific site data	Inputs	Main raw materials	Actual input corresponding to target product output:
			Outputs	Product output	Actual output recorded during production:
				COD removal volume	Sewage on-line monitoring data
				Refrigerant dissipation volume	Actual annual filling volume is taken
Medium			Inputs	Auxiliary materials and chemicals	Use output to allocate actual total input data;
				Low-value consumables	
				Package materials	Use typical packing case to represent overall packing scene;
			Energy used	Outsourced electricity, natural gas and diesel	Per the bill for clearing, but the data is allocated by the output;
			Inputs	Water resource	
	Secondary data	LCA factor		Package materials	Ecoinvent 3.9.1database; PEF database; IPCC inventory guide;
				Manufacturing of upstream auxiliary materials and chemicals	
				Manufacturing of upstream package materials	
				Manufacturing of upstream low-	

Data quality	Data category			Activity data source
			value consumables	
			Production and combustion of fossil energy	
			Anaerobic removal of COD from sewage results in methane emission	
			Waste disposal	
			Transport factor	
			Outsourced electricity factor	
		Transport	Various transport distances	Map query to obtain transport distances based on transport origins and destinations;

4.2. Calculation method and assessment tool

The calculation logic and assessment tools used to calculate the product carbon footprint in the report are introduced below.

a) Establish the live processes in the life cycle assessment software, select the background processes and enter the activity data to produce the product life cycle inventory. The calculation result of the product carbon footprint is “Cradle-to-gate”.

b) Select the IPCC 2021 100a (AR6) as the assessment index to quantify the greenhouse gas emission for product life cycle inventory.

c) This assessment uses the open source life cycle assessment software developed by Germany GreenDelta company, OpenLCA (official version 2.0).

The main LCA databases used is Ecoinvent 3.9.1, as well as European Union PEF database.

4.3. Assumptions and estimation

The assumption and estimation below are used in the calculation processes involved in the report:

a) For the auxiliary materials whose chemical components cannot be elucidated, their properties are based to select other inorganic compounds, organic compounds or similar substance substitution factor.

b) The road transport vehicle types are assumed according to the material transport distance and weight.

4.4. Inventory of various process activities data

The inventory of reference flow activity data is as shown in Table 43.

Table 4-3Inventory of activity data

SN	Activity process	Data	unit
1	Main raw materials_pp	1.0985E-01	kg
2	Main raw materials_Substrate	3.6399E-01	kg
3	Main raw materials_Copper ball	8.8872E-02	kg
4	Main raw materials_Copper foil	7.4703E-02	kg
5	Auxiliary materials and chemicals_Chemical Ni	1.0087E-02	kg
6	Auxiliary materials and chemicals_Chemical Ni	1.3809E-02	kg
7	Auxiliary materials and chemicals_Chemical copper additive	1.3718E-02	kg
8	Auxiliary materials and chemicals_Hydrogen peroxide	6.2837E-02	kg
9	Auxiliary materials and chemicals_Dry film	1.7522E-02	kg
10	Auxiliary materials and chemicals_Ink	4.5655E-02	kg

SN	Activity process	Data	unit
11	Auxiliary materials and chemicals_Liquid caustic soda	9.6550E-01	kg
12	Auxiliary materials and chemicals_Hydrochloric acid	4.1356E-01	kg
13	Auxiliary materials and chemicals_Lime	4.1696E-02	kg
14	Auxiliary materials and chemicals_Nitric acid	4.3323E-02	kg
15	Auxiliary materials and chemicals_Sodium sulfide	1.6762E-02	kg
16	Auxiliary materials and chemicals_Sulfuric acid	3.9658E-01	kg
17	Auxiliary materials and chemicals_Alkaline etching solution	7.7811E-02	kg
18	Auxiliary materials and chemicals_Potassium carbonate	3.1434E-02	kg
19	Auxiliary materials and chemicals_Extra-coarse additives	1.9798E-02	kg
20	Auxiliary materials and chemicals_Sodium persulfate	3.0430E-02	kg
21	Auxiliary materials and chemicals_Acidic etching liquid	1.7024E-01	kg
22	Auxiliary materials and chemicals_Ferrous sulfate	4.0416E-02	kg
23	Low-value consumables_PP filter	6.7981E-04	kg
24	Low-value consumables_Single-sided Al clad	2.8221E-03	kg
25	Low-value consumables_Melamine pad	9.7530E-05	kg
26	Low-value consumables_Wound filter	2.1121E-03	kg

SN	Activity process	Data	unit
27	Low-value consumables_Film-covering Al sheet	1.1189E-03	kg
28	Low-value consumables_Phenolic pad	2.4524E-03	kg
29	Low-value consumables_Holing needle	4.3155E-04	kg
30	Low-value consumables_Al sheet	4.8849E-03	kg
31	Low-value consumables_Milling cutter	1.8345E-05	kg
32	Package material_EPE foam	1.2026E-02	kg
33	Package material_Vacuum bag	9.0198E-03	kg
34	Package material_Carton	8.2682E-02	kg
35	Energy_Outsourced electricity	1.0993E+01	kWh
36	Energy_Natural gas	1.8759E-01	m3
37	Energy_Diesel_No-road mobile source	6.8823E-04	kg
38	Energy_Diesel_Stationary combustion	3.6920E-04	kg
39	Water resource_Tap water	1.0571E-01	t
40	Refrigerant dissipation_R22	6.5228E-07	kg
41	Refrigerant dissipation_R32	1.0192E-07	kg
42	Anaerobic removal of COD from sewage	3.0904E-02	kg
43	Incineration of hazardous wastes	5.5940E-02	kg
44	Raw material purchase & transport_Lorry	2.7978E+00	t*km
45	Package material purchase and transport_Lorry	1.9689E-02	t*km
46	Waste transfer_Lorry	7.9949E-02	t*km

5. Result of carbon footprint assessment

5.1. Total carbon footprint

The modeling calculation shows the carbon footprint of reference flow of target product is 16.6347 kg CO_2e. The contribution of various processes on product carbon footprint is as shown in Table 51 and Fig. 51.

Table 5-1Carbon footprint of reference flow of target product

Item	Emission (kg CO_2e)	Ratio
Manufacturing processes of upstream raw & auxiliary materials	6.0373	36.29%
Manufacturing processes of upstream package materials	0.2249	1.35%
Manufacturing processes of target product	9.6756	58.17%
Course of transport	0.5583	3.36%
Outsourced disposal processes of production wastes	0.1385	0.83%
Total	16.6347	100%

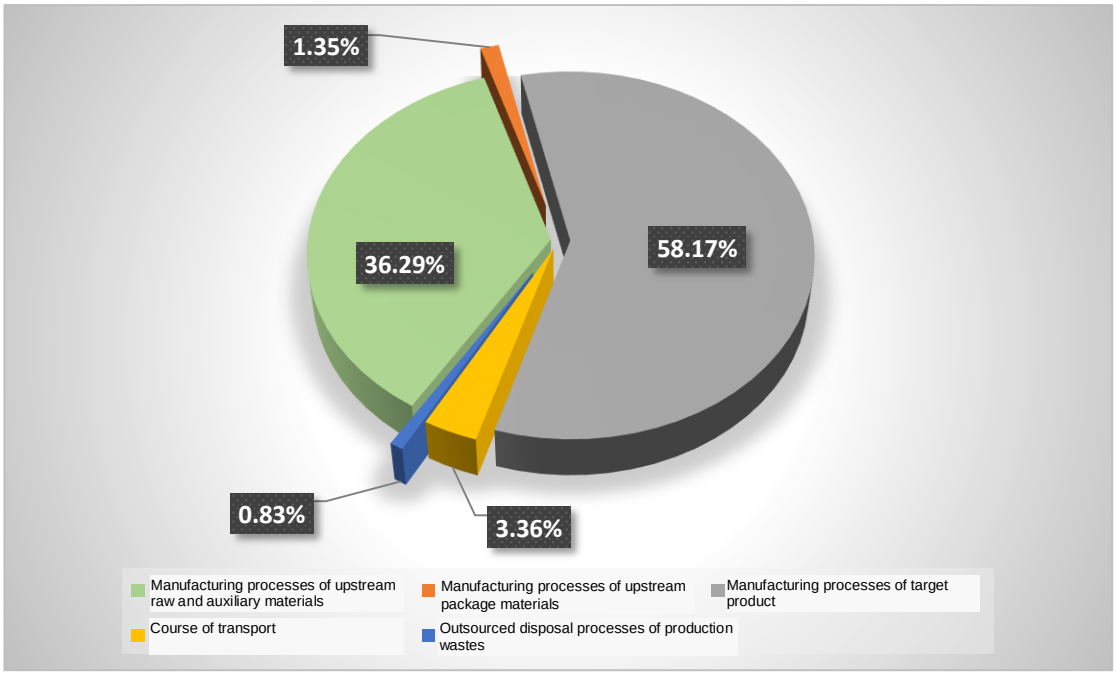

Fig. 5-1Carbon footprint of reference flow of target product

From the result of carbon footprint, the manufacturing processes of target product contributes the most to carbon footprint, which is 58.17%. The second is the upstream raw and auxiliary materials manufacturing processes, which is 36.29%; the contribution of various transport activities within the system boundary on carbon footprint is 3.36%. The manufacturing of the upstream package materials produces 1.35% of the total carbon footprint and the outsourced disposal processes of production wastes yields a contribution of 0.835 on carbon footprint.

By LCA calculation, in the carbon footprint of target product, the carbon footprints related to fossil carbon, biochar and land use change are as shown in Table 52. There is no emission of biomass CO2 and GHG caused by land use change in the live processes within the system boundary of target product.

Table 5-2 Carbon footprint structure (by main carbon source category)

Item	**Carbon footprint (kg CO_2e/kg)**
Fossil carbon	16.0528
Biochar	0.5808
Land use change	0.0011
Total carbon footprint	16.6347

5.2. Contribution of carbon footprint processes

5.2.1. Manufacturing processes of upstream raw & auxiliary materials

The manufacturing processes of the upstream raw & auxiliary materials of reference flow contribute 6.0373 kg CO_2e for the carbon footprint of target product, accounting for 36.39% of the total product carbon footprint.

The ratios of carbon footprint contributions from various activities in the process are as shown in Table 5-3 and Fig. 5-2.

Table 5-3 Structure of carbon footprint in upstream manufacturing processes of raw materials in the reference flow

Item	Emission (kg CO_2e)	Ratio
Main raw materials	2.9779	49.32%
Auxiliary materials and chemicals	2.9835	49.42%
Low-value consumables	0.0759	1.26%
Total	6.0373	100%

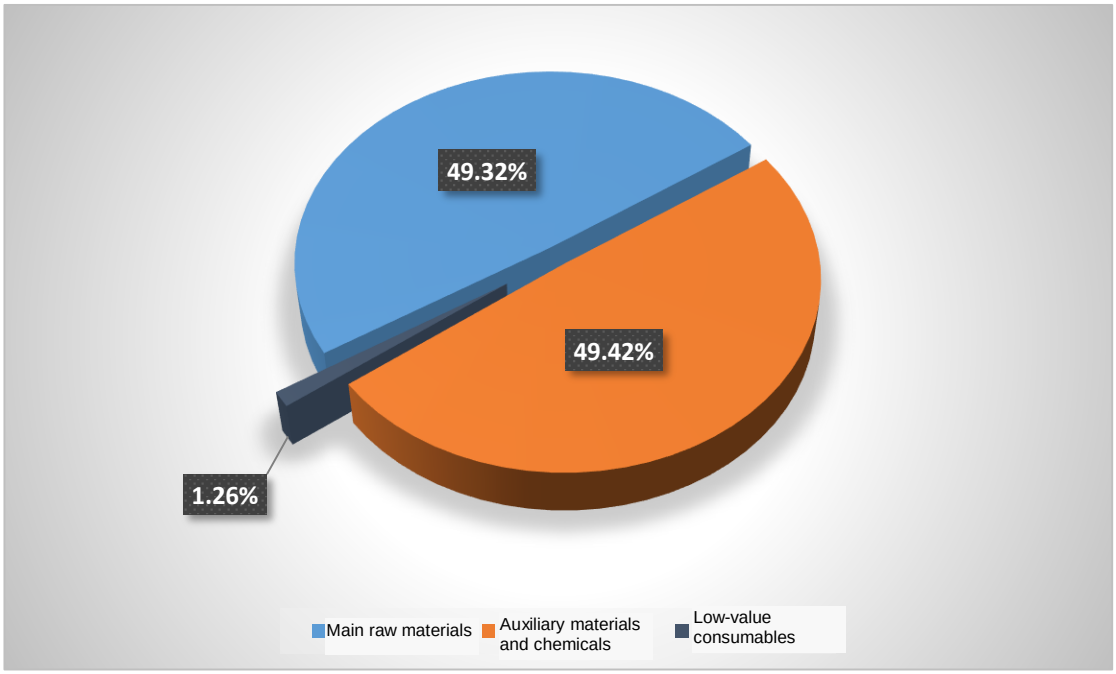

Fig. 5-2 Structure of carbon footprint in upstream manufacturing processes of raw materials in the reference flow

In the raw and auxiliary materials of target product, the auxiliary materials and chemicals produces the largest ratio of carbon footprint, which is 49.42%, the second is from the main raw materials, which is 49.32%, the low-cost consumables produce 1.26%.

5.2.2. Manufacturing processes of upstream package materials

The manufacturing processes of the upstream package materials of reference flow contribute 0.2249 kg CO_2e for the carbon footprint of target product, accounting for 1.35% of the total product carbon footprint.

The ratios of carbon footprint contributions from various activities in the process are as shown in Table 5-4 and Fig. 5-4.

Table 5-4 Structure of carbon footprint in upstream manufacturing processes of package materials in reference flow

Item	Emission (kg CO_2e)	Ratio
Package material_Carton	0.1531	68.07%
Package material_Foil bag	0.0416	18.47%
Package material_Foam	0.0303	13.45%
Total	0.2249	100%

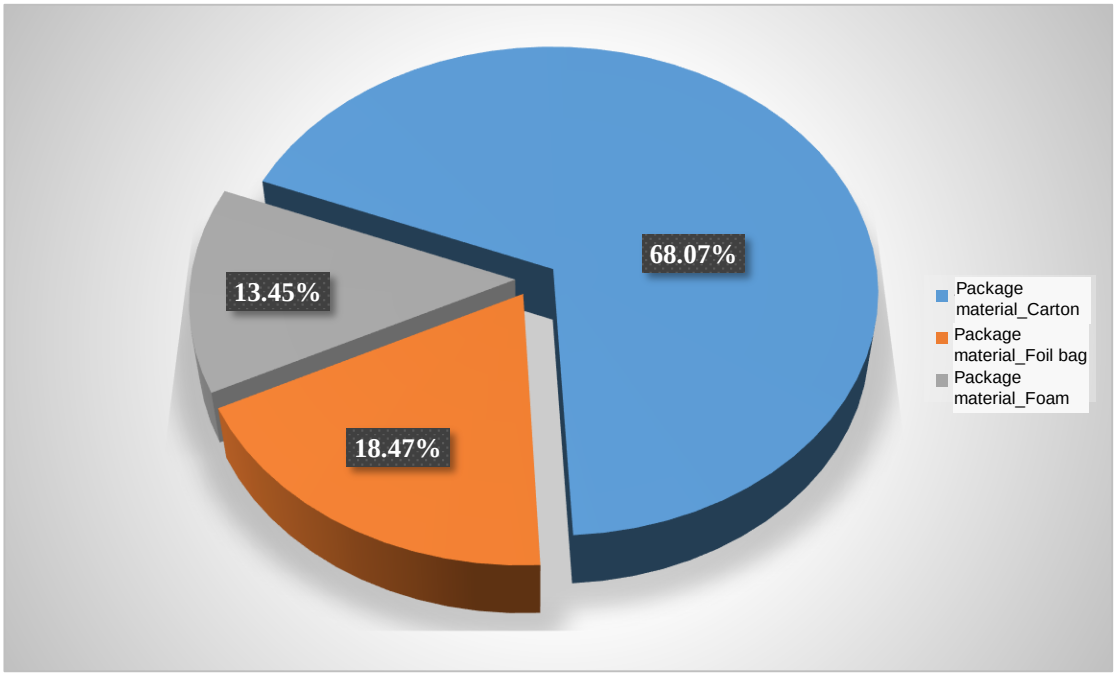

Fig. 5-3 Structure of carbon footprint in upstream manufacturing processes of package materials in the reference flow

5.2.3. Manufacturing processes of target product

The manufacturing processes of reference flow contribute 9.6756 kg CO2e for the carbon footprint of target product, making up 58.17% of total product carbon footprint. The contributions of various specific activities on the carbon footprints in the process are as shown in Table 5-5 and Fig. 5-4.

Table 5-5 Structure of carbon footprint in the reference flow

Item	Emission (kg CO_2e)	Ratio
Energy_Outsourced electricity	8.9795	92.81%
Energy_Natural gas	0.4722	4.88%

Item	Emission (kg CO_2e)	Ratio
Energy_Diesel	0.0043	0.04%
Water resource_Tap water	0.0457	0.47%
Refrigerant dissipation	0.0014	0.01%
Anaerobic removal of COD from sewage	0.1724	1.78%
Total	9.6756	100%

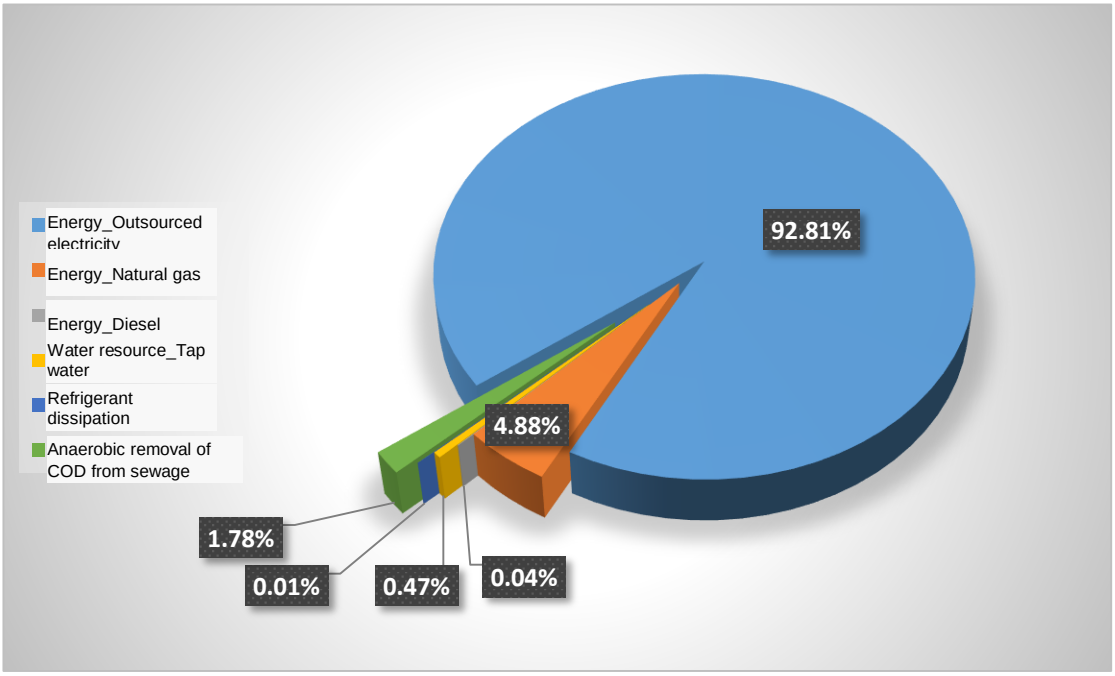

Fig. 5-4 Structure of carbon footprint in the reference flow

The outsourced electricity contributes the most on the carbon footprint of the process, accounting for 92.81% of the total amount. For the company, to carry out energy-saving and consumption-reduction as well as seek alternative renewable energy will be an effective means to reduce the product carbon footprint. In 2002, the company bought and consumed 10000MWh of green electricity via market transactions, accounting for 5.79% of total outsourced electricity of the factory.

5.2.4. Course of transport

The course of transport contributes 0.5583 kg CO_2e for the carbon footprint of reference flow of target product, accounting for 3.36% of the total carbon footprint of target product. The ratios of various transport activities within the system boundary in the process are as shown in Table 5-6 and Fig. 5-5.

Table 5-6 Structure of carbon footprint in the course of transport of reference flow

Item	Emission (kg CO_2e)	Ratio
Purchase & land transport of raw & auxiliary materials	0.5391	96.56%
Land transport of wastes	0.0154	2.76%
Purchase and land transport of package materials	0.0038	0.68%
Total	0.5583	100%

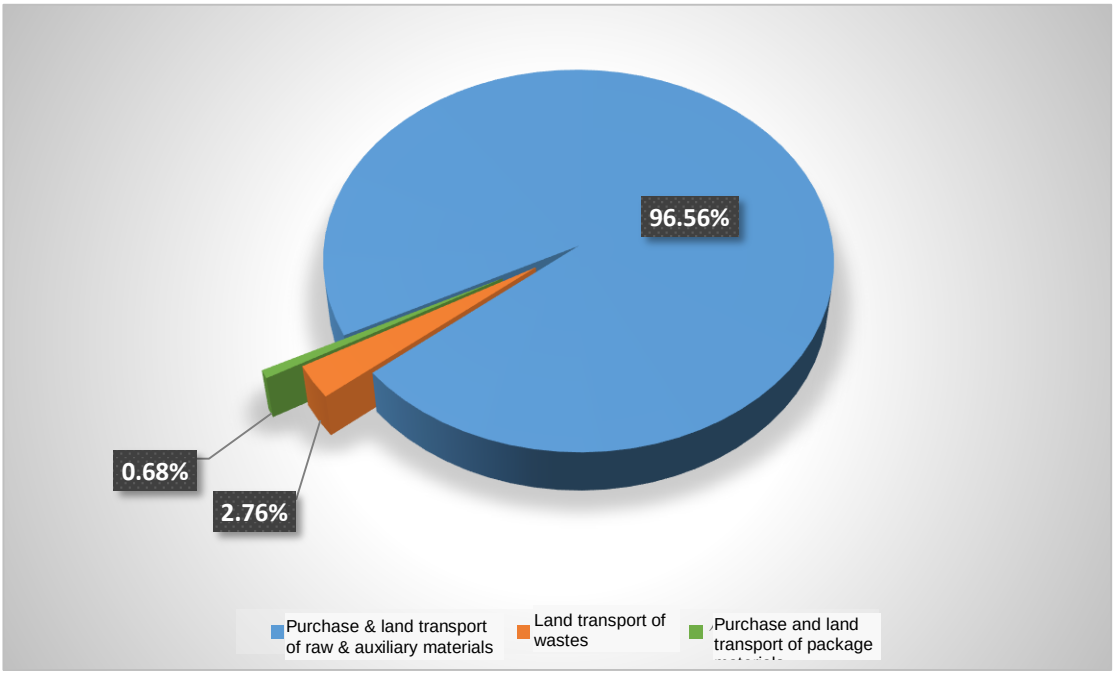

Fig. 5-5 Structure of carbon footprint in the course of transport of the reference flow

The transport activities are positively related to the cargo weights and transport distances. In the process, the purchase &transport activities of raw and auxiliary materials account for a large part up to 96.56%. No air transport is included in the transport activities in the reference flow.

5.2.5. Outsourced disposal processes of production wastes

The disposal processes of product wastes in the reference flow contribute 0.1385 kg CO_2e for the carbon footprint of target product, accounting for 0.83% of the total product carbon footprint. This process only includes the outsourced incineration disposal of hazardous wastes.

5.3. Check of integrity and consistency

In this report, the process of the carbon footprint assessment on the target product is checked for its integrity and consistency according to ISO 14044:2006.

The assessment process of carbon footprint of target product was carried out per the actual production situation of the company. The data of each process inventory filled is from the production report and the vouchers like purchase notes, etc of the company. Moreover, the questionnaires are sent to the main suppliers to collect all the data without missing. The truncations and allocation were also explained and met the requirements on integrity of life cycle assessment.

In the report, the checking result on the consistency also met the requirements and described as follows:

a) The data collection scope is consistent with the system boundary.

b) The selection of database parameters in the background processes is consistent with the manufacturing processes of the suppliers for energy and resources. The selection of transport parameters is consistent with the transport method.

c) The energy data in the background processes is accurate to a province level and the other parameters are also approximate to those in the local regions. Chronologically, all the data closest to those in the assessment year is selected.

d) The same allocation rule is used.

5.4. Sensitivity analysis

The carbon footprint assessment is a specific branch of life cycle assessment. The sensitivity analysis, i.e., sensibility test, aims to determine how the final results and conclusions are influenced by the uncertainty due to

data calculation and allocation methods or type parameter result, so as to evaluate their reliability.

The report employs the single-factor sensitivity analysis. The mathematical meaning of single-factor sensitivity analysis is when an independent variable of a function changes by any unit percentage, the function value will also change a percentage accordingly. The ratio between these two percentages is the sensitivity of function value against the independent variable. In LCA, the inventory data and their raw data in each unit process are the independent variables and the LCA result is the function value.

In the report, five process inventory data in the carbon footprint of target product is analyzed and calculated. It is found that the contribution of carbon footprint sensitivity of target product is larger than 3% and it can be used as the indicator of green design object. The relevant variables are increased by 10% to analyze the changes of carbon footprint result in the reference flow. The sensitivity result is as shown in Table 5-7, Fig.5-6 and Fig. 5-7.

Table 5-7 Result of sensitivity analysis

Process	**Sensitivity result**
Energy_Outsourced electricity	53.98%
Auxiliary materials and chemicals_Liquid caustic soda	8.50%
Main raw materials_Substrate	7.64%
Main raw materials_Copper ball	3.74%
Auxiliary materials and chemicals_Hydrochloric acid	3.65%
Purchase and land transport of raw materials	3.24%
Main raw materials_Copper foil	3.21%

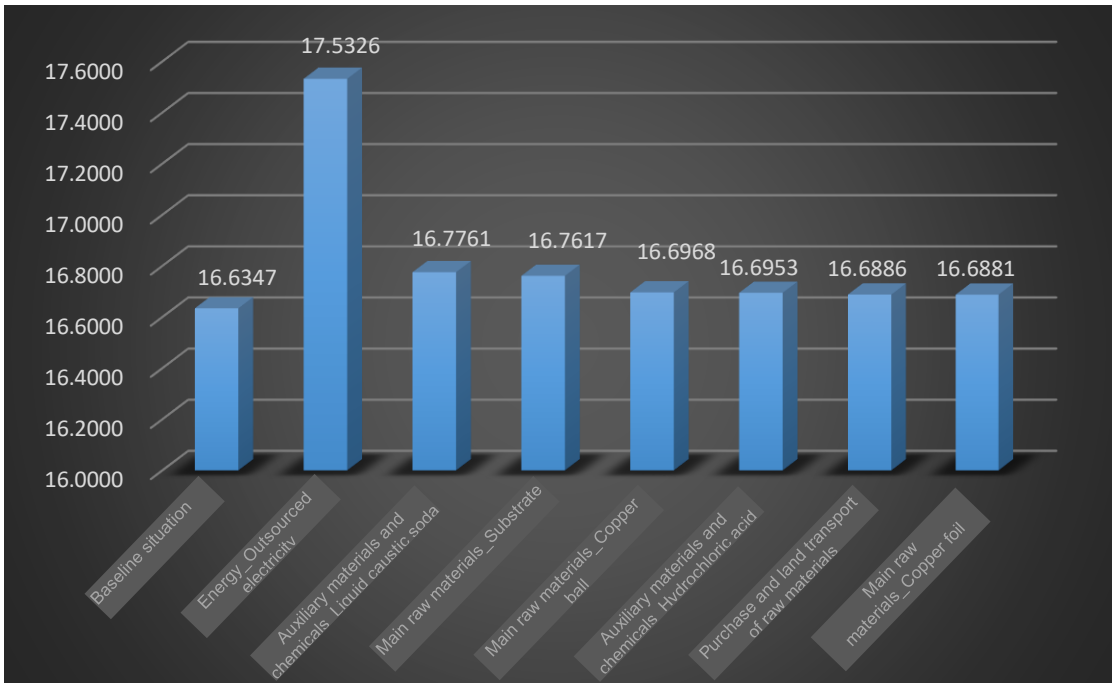

Fig. 5-6 Result of sensitivity analysis (changes of carbon footprint caused by 10% positive change of variables)

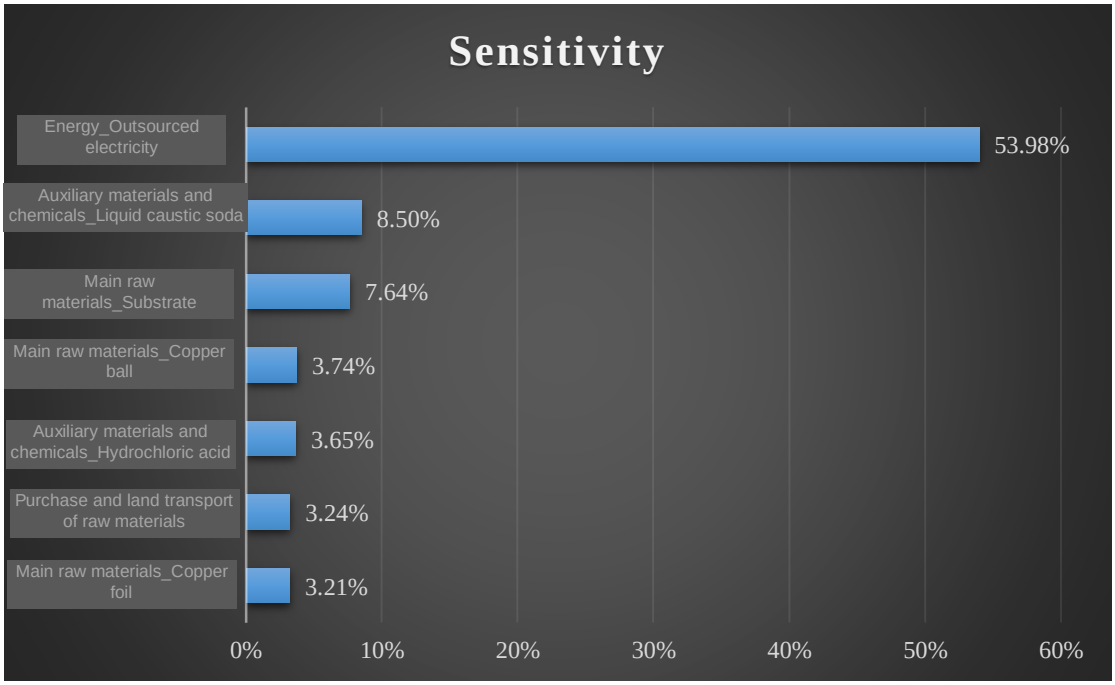

Fig. 5-7 Result of sensitivity analysis (sensitivities of various indexes)

As shown in the analysis result, the outsourced electricity contributes the most carbon footprint sensitivity up to 53.98%. Thus, to save power consumption and adopt green electricity is an effective. means for an enterprise to reduce the product carbon footprint.

5.5. Data quality and uncertainty calculation

5.5.1. Data quality

In the report, the data quality for the carbon footprint assessment is subject to a qualitative assessment method to qualitatively score various activity data in the live processes. The detailed situation is described below.

The uncertainty analysis on the factory activity data is divided into 4 types based on data quality level:

Table 5-8 Level of activity data quality

Quality level	Description
Very good	Measured value: the actual value measured such as the values actually used in the records of electric meter, water meter, receipt record and purchase documents or the allocated values on a basis.
Good	Estimated value by engineer: the values estimated by a reasonable means (for example, those estimated (calculated or allocated) by a person related to the data according to recorded data, however, such estimates have no explicit basis).
Fair	Theoretical values / empirical values: the values derived from theoretical deduction and calculation or the empirical values from site operation. For example, the weight of scraps per unit product.
Poor	References: information obtained from other literatures (such as academic literature and regulatory limit values) or the values from the verification by other factories.

The result of the activity data quality analysis is as shown in Table 5-9:

Table 5-9 Result of activity data quality analysis

Activity data category	Data quality level	Notes
Consumption of main raw materials	Very good	The data is from ERP system and is the actual production data.
Consumption of auxiliary materials and chemicals as well as low-value consumables.	Fair	The data is from ERP system and is the actual production data, but is allocated by output.

Activity data category	Data quality level	Notes
Consumption of package materials	Fair	The data uses the typical package method to represent the overall situation.
Energy and resource consumption	Fair	The data is from meter record but is allocated by output.
Refrigerant dissipation	Fair	The calculation method in the IPCC guide is used, which represents the overall average level in China.
CH4 emission from sewage anaerobic treatment	Fair	The COD removal volume is the on-line monitored data, but the discharge coefficient is an international one.
Waste generation and disposal	Fair	The data is from production statistics but is allocated by output.
Transport	Fair	The transport distances are obtained through map query and is indirect data. There are assumed distances.

5.5.2. Calculation of carbon footprint result uncertainty

In the report, the result uncertainty of the product carbon footprint assessment is quantified through using the “Monte Carlo Analysis” function in Open LCA and the analysis result is as shown in Table 5-10.

Table 5-10 Monte Carlo Analysis ($kgCO_2e$) of carbon footprint assessment result

Average value	Standard deviation	Minimum value	Maximum value	Median	90% confidence interval Lower limit	90% confidence interval Upper limit
16.6853	0.4645	15.3142	18.3183	16.6746	15.9319	17.4669

5.6. Notes on limitation of product carbon footprint study

According to the requirements in Annex A in ISO 14067:2018, the limitations of carbon footprint study on target product in the report are described as follows:

This carbon footprint assessment on target product aims to learn about and grasp the basic data. Thus, it will not lead to any negative change of any other environmental impact index because of focusing on product carbon footprint. In the future, the enterprise will carry out the carbon-reduction works centering on supply chain, which will be under the supervision of China environmental protection laws and regulations and be designed and implemented through adhering to the principle of not leading to increased emission of other environmental pollutants.

The system boundary, quantification method, principle of allocation and truncation, and assumption will all result in a limitation of the study result of the product carbon footprint assessment. The system boundary is set to meet the requirements of relevance and integrity as much as possible with the premise of the truth. The quantification method also follows the principle of relevance with also taking into account the requirements of feasibility and improved precision to the utmost. Through following the standard, the data necessary to be allocated is allocated by physical method and the auxiliary & raw materials, low-value consumables, public auxiliary system materials, energy and water resources are allocated by output which will cause limitations on the data. The product carbon footprint assessment conducts a cautious assessment on all the truncated items in order not to pose any substantial influence on the assessment result. The assumed scenarios used in the report follow the principle of relevance and take into account the actual situations in China and the specific industry. Also the experiences of the front-line staffs are also referenced. respectively.

6. Interpretation of carbon footprint assessment result

The data collection and modeling calculation of life cycle showed that the 1sf (10 Layer) products manufactured between Jan.1, 2022 and Dec.31, 2022 by Dynamic Electronics (Huangshi) Co., Ltd. produce a carbon footprint of 16.6347 kgCO_2e. From the result of carbon footprint, the manufacturing processes of target product contributes the most to carbon footprint, which is 58.17%. The second is the upstream raw and auxiliary materials manufacturing processes, which is 36.29%; the contribution of various transport activities within the system boundary on carbon footprint is 3.36%. The manufacturing of the upstream package materials produces 1.35% of the total carbon footprint and the outsourced disposal processes of production wastes yields a contribution of 0.835 on carbon footprint.

The report suggests the enterprise to exploit the potentials of carbon reduction from the following aspects.

1) Increasing the investments on R&D, taking green design as acting point, optimizing the production processes and improve the production efficiency, thus reducing the emission of greenhouse gases and other environmental impacts from the source.
2) Advancing the establishment and implementation of energy management system continuously and deeply. Working for improvement to save energy and power consumption.
3) Expanding the utilization scale of green electricity.
4) Carrying out carbon management throughout supply chain and stepwise requiring the upstream suppliers to provide the carbon footprint reports for their products.

7. External check

Dynamic Electronics (Huangshi) Co.,Ltd. will entrust a third party to carry out an independent verification on the carbon footprint assessment result of target product and obtain a verification statement having a reasonable assurance level.

References

1. *Climate Change 2021 The Physical Science Basis*
2. *ISO 14067:2018 Carbon footprint of products — Requirements and guidelines for quantification and communication*
3. *ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework*
4. *ISO 14044:2006 Environmental management — Life cycle assessment — Requirements and guidelines*
5. 2006 IPCC Guidelines for National Greenhouse Gas Inventories
6. 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol
7. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
8. IPCC 6th Assessment Report
9. Ecoinvent 3.9.1 [DB].
10. Product Environmental Footprints (PEF) [DB].

Annex 1: Background processes

SN	Substances / Energy / Activities	Background processes	Region
1	SiO_2	activated silica production | activated silica | APOS, S	GLO
2	Liquid oxygen	air separation, cryogenic | oxygen, liquid | APOS, S	RoW
3	Al alloy	aluminum alloy production, AlMg3 | aluminum alloy, AlMg3 | APOS, S	RoW
4	Al alloy	aluminum production, primary, ingot | aluminum, primary, ingot | APOS, S	CN
5	Ammonia	ammonia production, partial oxidation, liquid | ammonia, anhydrous, liquid | APOS, S	CN
6	ammonium bicarbonate	ammonium bicarbonate production | ammonium bicarbonate | APOS, S	RoW
7	ammonium chloride	ammonium chloride production | ammonium chloride | APOS, S	GLO
8	Organic compounds	chemical production, organic | chemical, organic | APOS, S	GLO
9	sodium hydroxide	chlor-alkali electrolysis, diaphragm cell | sodium hydroxide, without water, in 50% solution state | APOS, S	RoW
10	corrugated board	containerboard production, fluting medium, semichemical | containerboard, fluting medium | APOS, S	RoW
11	Copper	copper production, cathode, solvent extraction and electrowinning process | copper, cathode | APOS, S	GLO
12	copper sulfate	copper sulfate production | copper sulfate | APOS, S	GLO

SN	Substances / Energy / Activities	Background processes	Region
13	Production of corrugated board box	corrugated board box production | corrugated board box | APOS, S	RoW
14	diesel	diesel production, low-sulfur, petroleum refinery operation | diesel, low-sulfur | APOS, S	RoW
15	Medium-voltage power - Central China power grid	electricity voltage transformation from high to medium voltage | electricity, medium voltage | APOS, S	CN-CCG
16	Medium-voltage power - East China Power Grid	electricity voltage transformation from high to medium voltage | electricity, medium voltage | APOS, S	CN-ECGC
17	Medium-voltage power - North China Power Grid	electricity voltage transformation from high to medium voltage | electricity, medium voltage | APOS, S	CN-NCGC
18	High-voltage power - Central China power grid	electricity, high voltage, production mix | electricity, high voltage | APOS, S	CN-CCG
19	Epoxy resin	epoxy resin production, liquid | epoxy resin, liquid | APOS, S	RoW
20	Formic acid	formic acid production, methyl formate route | formic acid | APOS, S	RoW

SN	Substances / Energy / Activities	Background processes	Region
21	Glass fiber	glass fiber production | glass fiber | APOS, S	RoW
22	hydrochloric acid	hydrochloric acid production, from the reaction of hydrogen with chlorine | hydrochloric acid, without water, in 30% solution state | APOS, S	RoW
23	hydrogen peroxide	hydrogen peroxide production, product in 50% solution state | hydrogen peroxide, without water, in 50% solution state | APOS, S	RoW
24	iron(III) sulfate	iron (III) sulfate production, without water, in 12.5% iron solution state | iron (III) sulfate, without water, in 12.5% iron solution state | APOS, S	RoW
25	lime	lime production, hydrated, packed | lime, hydrated, packed | APOS, S	RoW
26	melamine formaldehyde resin	melamine formaldehyde resin production | melamine formaldehyde resin | APOS, S	RoW
27	methanol	methanol production | methanol | APOS, S	GLO
28	methyl acrylate	methyl acrylate production | methyl acrylate | APOS, S	GLO
29	nickel sulfate	nickel sulfate production | nickel sulfate | APOS, S	GLO
30	nitric acid	nitric acid production, product in 50% solution state | nitric acid, without water, in 50% solution state | APOS, S	CN
31	Formaldehyde	oxidation of methanol | formaldehyde | APOS, S	RoW
32	Natural gas	petroleum and gas production, onshore | natural gas, high pressure | APOS, S	CN

SN	Substances / Energy / Activities	Background processes	Region
33	phenolic resin	phenolic resin production | phenolic resin | APOS, S	RoW
34	Low-density polyethylene	polyethylene production, low density, granulate | polyethylene, low density, granulate | APOS, S	RoW
35	PET	polyethylene terephthalate production, granulate, amorphous | polyethylene terephthalate, granulate, amorphous | APOS, S	RoW
36	High-density polyethylene	polyethylene, high density, granulate, recycled to generic market for high density PE granulate | polyethylene, high density, granulate | APOS, S	RoW
37	polypropylene	polypropylene production, granulate | polypropylene, granulate | APOS, S	RoW
38	polyurethane	polyurethane adhesive production | polyurethane adhesive | APOS, S	GLO
39	potassium carbonate	potassium carbonate production, from potassium hydroxide | potassium carbonate | APOS, S	GLO
40	printing ink	printing ink production, offset, product in 47.5% solution state | printing ink, offset, without solvent, in 47.5% solution state | APOS, S	RoW
41	sodium chloride	sodium chloride production, powder | sodium chloride, powder | APOS, S	RoW
42	sodium persulfate	sodium persulfate production | sodium persulfate | APOS, S	GLO
43	sodium sulfide	sodium sulfide production | sodium sulfide | APOS, S	GLO
44	steel	steel production, low-alloyed, hot rolled | steel, low-alloyed, hot rolled | APOS, S	RoW
45	sulfuric acid	sulfuric acid production | sulfuric acid | APOS, S	RoW

SN	Substances / Energy / Activities	Background processes	Region
46	Tap water	tap water production, conventional treatment | tap water | APOS, S	RoW
47	Non-woven textile	textile production, nonwoven polypropylene, spunbond | textile, non-woven polypropylene | APOS, S	RoW
48	Transport by lorry	transport, freight, lorry 16-32 metric tons, EURO5 | transport, freight, lorry 16-32 metric tons, EURO5 | APOS, S	RoW
49	treatment of hazardous waste	treatment of hazardous waste, hazardous waste incineration, with energy recovery | hazardous waste, for incineration | APOS, S	RoW
50	De-ionised water	water production, de-ionised | water, de-ionised | APOS, S	RoW
51	photovoltaic power	electricity production, solar thermal parabolic trough, 50 MW | electricity, high voltage | APOS, S	RoW