Action Guide for Green Supply Chain Management of Photovoltaic Equipment

Contents

I. Introduction of Green Supply Chain Theory

1. Basic concepts

Green Supply Chain. Green supply chain, also known as environmentally conscious supply chain (ECSC) or environmental supply chain (ESC), is a management mechanism that comprehensively considers environmental hazards and resource efficiency modernization throughout the entire supply chain. GB/T 33635-2017 defines green supply chain as: The concept of environmental protection and resource conservation runs through the entire process of the company from product design to raw material purchase, production, transportation, storage, sales, use and scrapping, so that the company's economic activities are coordinated with environmental protection.

Green supply chain is based on green manufacturing theory and supply chain management technology, and integrates the concepts of green manufacturing, product life cycle management and extended producer responsibility into company business processes, involving suppliers, manufacturers, sellers and end users in the industrial chain. Its purpose is to minimize the impact of the whole product life cycle on the environment and maximize resource efficiency. Implementing green supply chain management is an effective way to enhance the competitiveness and realize the sustainable development of companies.

Life Cycle Assessment (LCA). It refers to the entire process of a product (or service) from obtaining raw materials, production, use to disposal, that is, from cradle to grave.

Regarding LCA, ISO14040 is defined as a method used to assess environmental factors and potential impacts related to a certain product (or service). It is carried out by compiling the stock records of related inputs and outputs of a certain system, evaluating the potential environmental impacts related to these inputs and outputs, and interpreting the stock records and the analysis results of environmental impacts according to the objectives of LCA research. GB/T 24040-2008 defines LCA as the compilation and assessment of the inputs, outputs and their potential environmental impacts in the life cycle of a product system.

Carbon Footprint. The concept of "carbon footprint" is derived from "ecological footprint", which mainly uses carbon dioxide emission equivalent (CO_2 equivalent, abbreviated as CO_{2eq}) to represent the total greenhouse gas emissions emitted during human production and consumption activities. Since many countries or organizations have developed and issued carbon footprint accounting standards for different system levels, there are currently many types of carbon footprint standards.

Product carbon footprint refers to the total direct and indirect emissions of CO_2 and other greenhouse gases (expressed in the form of CO_2 emission equivalents) caused by a product during its life cycle. The accounting of product carbon footprint usually uses LCA as an assessment tool to evaluate and account for the whole life cycle process of products or services, that is, the energy consumption and environmental impact from cradle to grave.

Carbon Efficiency Rating Assessment. Carbon efficiency rating assessment is to compare the carbon emissions per unit of added value of product in a certain cycle with the average carbon emissions per unit of added value of the industry in the same period, and to obtain the carbon efficiency value. According to the size of the carbon efficiency value, it is divided into several levels, and "labels" are set according to different levels to effectively evaluate the carbon efficiency level of the company or product in the industry. The carbon efficiency value is the average carbon emissions per unit of added value of company or product in a certain cycle/the carbon emissions per unit of added value of the industry in the same period.

2. Scope of application

This guide is applicable to the green and low-carbon quantitative assessment of the entire life cycle process of photovoltaic equipment from product design, material acquisition, purchase, production, transportation, storage, packaging, application, recycling, and scrap treatment, as well as the selection, cultivation, incentives, assessment and information disclosure of photovoltaic equipment suppliers.

3. Working principles

Systematic layout. Grasp the new development trend, based on the actual foundation of the province's new energy industry, strengthen systematic deployment, implement it in stages, and build an industrial chain policy system that adapts to the long-term development of the region.

Technology leadership. Focus on key weak links in the green supply chain, make breakthroughs, support key technology breakthroughs, accelerate the deployment of green supply chain applications, and drive the overall upgrade of the industrial chain.

Open collaboration. Give full play to the guiding role of policies, promote the integration of government, industry, academia, research and application, support chain-leading companies to strengthen collaboration with upstream and downstream companies, and promote the open sharing of green supply chain technology and information. Improve the development environment and build a good industrial ecology.

LCA perspective on lifecycle. Consider the entire lifecycle of a product, from the acquisition of raw materials, production of energy and materials, manufacturing and use of the product, to end-of-life processing and final disposal. Through this systematic perspective, it is possible to identify and potentially avoid the transfer of potential environmental loads at various stages or stages of the entire lifecycle.

Focus on the environment. LCA focuses on environmental factors and impacts in product systems, usually without considering economic and social factors and their impacts. Other tools can be combined with LCA for a broader evaluation.

Relative methods and functional units. LCA is a relative method built around functional units. The functional unit defines the object of study. All subsequent analyses, as well as the input-output and LCIA results in LCl, correspond to the functional units.

Repeated methods. LCA is a repetitive technique. Each stage of LCA uses the results of other stages. Applying this iterative approach in each stage and between stages will ensure comprehensiveness and consistency in research work and reported results.

Transparency. Due to the inherent complexity of LCA, transparency is an important guiding principle in implementing LCA to ensure appropriate interpretation of results.

Comprehensiveness. LCA considers all attributes or factors of natural environment, human health, and resources. By considering all attributes and factors in a study from a comprehensive perspective, it is possible to identify and evaluate issues that require trade-offs.

The priority of scientific methods. Decisions in LCA are more suitable to be based on natural sciences. If it is not possible, other scientific methods (such as social and economic sciences) or reference to international conventions can be applied. If there is no scientific basis, no justification based on other scientific methods, and no international conventions to follow, then the decisions made can be based on value choices.

II. Research on LCA Carbon Emission Assessment and Carbon Efficiency Level Assessment Methods of Photovoltaic Equipment

1. Analysis of photovoltaic equipment industry chain

Photovoltaic power generation system is mainly composed of three parts: solar panels (components), controllers and inverters. They are mainly composed of electronic components and do not involve mechanical components.

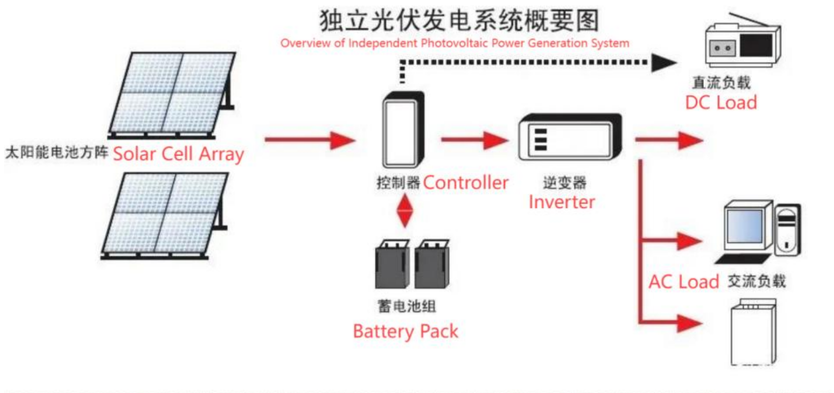

Figure 2-1 Outline diagram of photovoltaic power generation system

The photovoltaic equipment industry chain includes: high-purity polysilicon, silicon rods/silicon ingots/silicon wafers, photovoltaic cells, photovoltaic modules, photovoltaic power generation systems and other links. Among them, the upstream is the production of high-purity polysilicon, the midstream is polycrystalline ingot casting/monocrystalline rod drawing, slicing, photovoltaic cell production, photovoltaic power generation component packaging and other links, and the downstream includes photovoltaic power generation systems such as centralized photovoltaic power stations and distributed photovoltaic power stations.

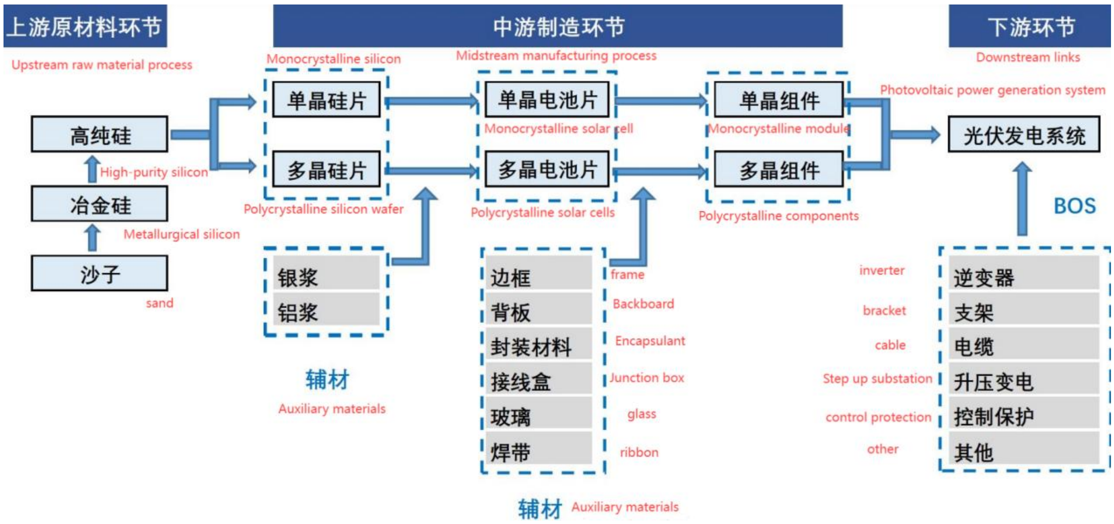

Figure 2-2 Schematic diagram of photovoltaic equipment industry chain

2. Carbon footprint accounting of the whole life cycle of photovoltaic equipment

(1) Determine accounting boundaries

According to the definition of ISO 14067, the quantification of product carbon footprint (CFP) considers the entire lifecycle of a product, including raw material procurement, design, production, transportation/delivery, use, and end-of-life treatment.

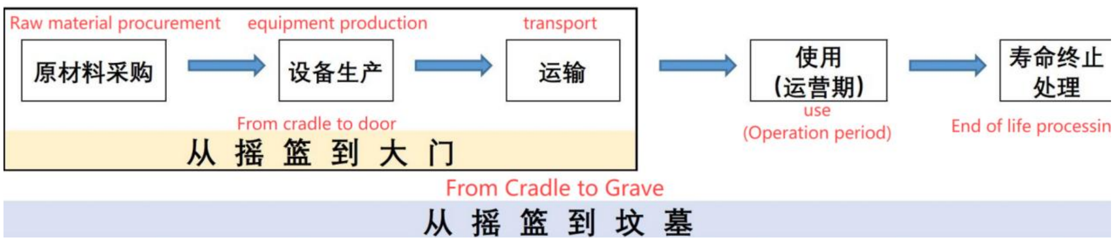

Figure 2-3 Schematic diagram of life cycle accounting boundaries

According to the actual situation of photovoltaic power generation equipments, this report sets the carbon emission accounting boundary as follows:

① All equipments need to calculate the carbon emission intensity level per unit product from cradle to gate.

Description: From cradle to gate, there are three stages: raw material procurement, production, and transportation/delivery.

② The main equipments used in the terminal need to calculate the carbon emission intensity level of unit power generation from cradle to grave.

Description: From cradle to grave includes five stages: raw material procurement, production transportation/delivery, use, and end-of-life treatment.

(2) Assessment index and functional unit

This standard comprehensively considers the specific characteristics of each major power generation product. According to the accounting boundary determined above, the functional units of each assessment index are set as follows:

Table 2-1 Functional units of each assessment index

Category	Equipment	Assessment index	Functional unit
Photovoltaic power generation products	(1) Photovoltaic modules	①Carbon emission intensity per unit product	tCO_2e/MW
		②Carbon emission intensity per unit of power generation	tCO_2e/MWh
	Upstream products of photovoltaic modules: High purity silicon material Single/polycrystalline silicon wafer Mono/polycrystalline cells	①Carbon emission intensity per unit product	tCO_2e/t
	(2) Bracket	①Carbon emission intensity per unit product	tCO_2e/t scaffold

	(3) Inverter	①Carbon emission intensity per unit product	tCO_2e/MW
		②Carbon emission intensity per unit of power generation	tCO_2e/MWh

(3) Calculation method of carbon footprint of photovoltaic products

For the purposes of this section, the following definitions will be used:

- Monitoring Value: The emission factor value obtained by the enterprise manufacturer through actual measurement methods;
- Default Value: When monitoring values cannot be obtained, publicly recognized data from both domestic and international sources shall be used;
- AD refers to “usage amount”
- EF refers to “emission factor”

① Calculation of total carbon emissions of products

Calculate the total carbon emissions of products by quantifying all significant greenhouse gas emissions throughout the product's life cycle or selected processes.

$E_{\text{Cradle to Gate}} = E_{\text{Raw Material Purchase}} + E_{\text{Production}} + E_{\text{Transportation}}$

$E_{\text{Cradle to Grave}} = E_{\text{Raw Material Purchase}} + E_{\text{Production}} + E_{\text{Transportation}} + E_{\text{Use}} + E_{\text{End of Life Processing}}$

② Calculation of carbon emissions during raw material purchase process

$$E_{Raw-material\ Procurement} = \sum_{r=1}^{n}(AD_r \times EF_r)$$

Wherein:

AD_r——the usage of the r-th raw material/auxiliary material/upstream non-end-use product. According to the specific statistics, the unit can be tons (t), cubic meters (m3) or pieces, etc.;

EF_r——the emission factor of the r-th raw material/upstream non-end-use product according to specific statistics, the unit can be tCO_2e/t, $tCO_2e/m3$ or $tCO_2e/piece$, etc.;

r——the type of raw materials entering the production boundary of the product, and the type of upstream non-end-use products;

Table 2-2 Instructions for obtaining photovoltaic product usage and emission factor data

Product name	Raw material acquisition	Amount	Carbon emission factor
High purity silicon material	Industrial silicon	Monitor value	Default value
	Sodium hydroxide	Monitor value	Default value
Single/polycrystalline silicon wafer	High purity silicon material	Monitor value	Monitor value or default value
Mono/polycrystalline cells	Single/polycrystalline silicon wafer	Monitor value	Monitor value or default value
	Silver paste	Monitor value	Default value
	Aluminum paste	Monitor value	Default value
	Mono/polycrystalline cells	Monitor value	Monitor value or default value
	Border	Monitor value	Default value
	Glass	Monitor value	Default value
	Backplane	Monitor value	Default value

Photovoltaic modules	Encapsulation material	Monitor value	Default value
	Junction box	Monitor value	Default value
	Welding ribbon	Monitor value	Default value
Inverter	/	Monitor value	Monitor value or default value
Support	/	Monitor value	Monitor value or default value

③ Calculation of carbon emissions in the production process

$$E_{production} = AD_{production\ electricity} \times EF_{electricity} + AD_{production\ heat} \times EF_{heat}$$

where:

$AD_{production\ electricity\ consumption}$——the net purchase of electricity consumption of production products, in MWh;

$EF_{electricity}$——CO_2 emission factor of electricity supply in tCO_{2e}/MWh;

$AD_{production\ heat}$——net purchased heat consumption of production products, in GJ (million kilojoules);

EF_{heat}——carbon dioxide emission factor of heat supply in tCO_{2e}/GJ;

Table 2-3 Instructions for data acquisition of electricity and heat usage and emission factors

Parameter name	Source description	Amount	Carbon emission factor
Production electricity	Only the annual power purchase from the grid and the power supply from fossil fuel captive power plants that produce the corresponding products are counted, and waste heat power generation and direct power supply from renewable energy are not counted.	Monitor value	Default value

Production heat	Only the annual purchased heat and fossil fuel self-owned power plant heating are counted for the production of corresponding products, and waste heat heating and renewable energy heating are not counted.	Monitor value	Default value

④ Calculation of carbon emissions during transportation

$E_{transportation} = \Sigma p\ (n) = 1\ ADp\ (t) \times EF_{transportation}$

Wherein:

$AD_{p(t)}$——the transportation volume of the r-th product (product) in tons kilometers (t km). Other units such as cubic meters, pieces, kW, etc. should be converted to tons;

p——type of product;

$EF_{Transportation}$-emission factor from the transportation process in tonnes of carbon dioxide equivalent/(tonnes · kilometers) ($tCO_2e/(t \cdot km)$);

Table 2-4 Explanation table for data acquisition of transportation volume and emission factor

Parameter name	Transportation weight	Transportation distance	Carbon emission factor
Transportation volume	Monitor value	Monitor value	Default value

⑤ Calculation of carbon emissions during operation

$E_{operation} = (E_{raw\ material\ purchase} + E_{production} + E_{transportation}) \times r_{replacement\ rate} + AD\ oil \times EF_{oil}$

where:

$r_{Replacement\ rate}$——the average replacement rate of accessories, in%;

Table 2-5 Explanation Table for Obtaining Operating Volume and Emission Factor Data

Parameter name	Transportation weight	Oil quantity	Carbon emission factor
Operating volume	Monitor value	Monitor value	Default value

⑥ Calculation of carbon emissions from the recycling process

$$E_{\text{Recovery Process}} = AD_{w\,(t)} \times EF_{\text{Transportation}} + AD_{\text{Recovery (t)}} \times EF_{\text{Recovery}}$$

Wherein:

$AD_{w(t)}$——the transportation volume of end-of-life products and building materials, in tons · kilometers (t·km), and other units such as cubic meters, pieces, kW, etc. need to be converted to tons;

$EF_{\text{Transportation}}$——emission factor from the transportation process in tonnes of carbon dioxide equivalent/(tonnes · kilometers) ($tCO_2e/(t \cdot km)$);

$AD_{\text{recycling (t)}}$——the amount of recycling and reuse of end-of-life products and building materials, in tons (t), and other units such as cubic meters, pieces, kW, etc. need to be converted to tons;

$EF_{\text{recycling}}$——the emission factor of recycling and reuse in tonnes of carbon dioxide equivalent/(tonnes) (tCO_2e/t);

Table 2-6 Explanation Table for Obtaining Consumption and Emission Factor Data in the Recycling Process

Parameter name	Amount	Transportation volume	Carbon emission factor
Recycling and transportation	Monitor value	Monitor value	Default value
Recycling and reusing	Monitor value	/	Default value

⑦ Software support

This standard study is intended to be based on the support of Gabi software. Gabi software is a professional software for LCA jointly developed by the LBP Institute of the Universität Stuttgart and PE-INTERNATIONAL. It has been updated to Gabi version 9 and will be updated continuously. Companies can use GaBi for quantitative analysis of LCA, and it also helps companies evaluate the grade of supply chain products with the highest standards; Analyze the drivers of energy consumption, carbon footprint, waste emissions, etc. of products. As the most trusted product sustainability solution for LCA, GaBi has more than 10,000 users worldwide, including Fortune 500 companies, leading industry associations and innovative small and medium-sized companies. Customers involve many famous domestic universities such as Tsinghua University, Peking University, Zhejiang University, Beijing University of Technology, Nankai University, etc. There are also testing and consulting institutions such as German TiV, and companies include well-known companies such as Baowu Group, Ningde Times, and SAIC Motor. Some research institutions such as the China Institute of Standardization are using GaBi.

Gabi has the characteristics of the world's largest data set content, flexible and transparent graphical interface, etc. It provides methods, interpretation, disadvantage analysis and sensitivity analysis for systematic assessment or distributed assessment according to each project stage of LCA and life cycle engineering. It can be applied to industry, research fields and environmental consulting fields, and can provide a strong data quality foundation for the study of this assessment standard.

3. Accounting of carbon emission intensity throughout the life cycle of photovoltaic equipment

Based on the carbon emission calculation methods for different stages of the entire lifecycle mentioned above, the carbon emission intensity level of each product in the photovoltaic power generation industry chain can be calculated from cradle to gate; For terminal products in the photovoltaic industry chain, it is possible to calculate the carbon emission intensity level of unit power generation from cradle to grave.

(1) Calculation of carbon emission intensity index per unit product

$$S_{\text{unit product strength, product p}} = E_{\text{cradle to gate, product p}} / AD_{\text{product p}}$$

$S_{\text{unit product strength, product p}}$——$CO_2e$ emissions per unit product P in the photovoltaic industry chain. According to the product type, the unit can be power (MW), mass (ton), volume (m^3), or quantity.

$E_{\text{Cradle to gate, product p}}$——the carbon emissions from cradle to gate in the lifecycle of product p, measured in tCO_2e;

$AD_{\text{product p}}$——the output of product p. For photovoltaic modules, inverters and other products, the unit should be MW. For other products, the unit can be determined according to the specific characteristics of the product;

(2) Calculation of carbon emission intensity index per megawatt hour

① Calculation of power generation during operation period

The specific performance data of the power generation products to be used, as well as the information of the renewable energy power plants to be put into operation, including the total power generation during the operation period estimated in the feasibility study report, the average total power generation level of local power stations of the same type, etc., to estimate the total power generation during the operation period.

② Calculation method of electrical strength

$$S_{\text{degree electrical strength, product p}} = E_{\text{cradle to grave, product p}}/Wfd,p$$

$S_{\text{degree electrical strength, product p}}$——The CO_2e emitted per unit of electricity generated during the entire lifecycle of product P is measured in MWh.

$E_{\text{Cradle to grave, product p}}$——carbon emissions throughout the life cycle of the product, in tCO_2e;

wfd, p——the power generation of product p during the operation period, in MWh;

4. Evaluation index system for photovoltaic green supply chain management

The Green Supply Chain Index aims to evaluate the sustainable development performance of enterprises in the supply chain of solar power generation systems by evaluating various aspects related to green management and low-carbon policies. The purpose of green supply chain management is to play the main role of core enterprises in the supply chain, on the one hand, to do a good job in energy conservation, emission reduction and environmental protection, continuously expand effective supply to society, and on the other hand, to lead and drive upstream and downstream enterprises in the supply chain to continuously improve resource and energy utilization efficiency, improve environmental performance, and achieve green development. Its management scope is based on the requirements of the product life cycle, managing business processes such as design, procurement, production, logistics, and recycling, which involves cooperation between suppliers, manufacturing enterprises, logistics providers, distributors, end-users, and recycling and dismantling enterprises.

The method for evaluating green supply chain management of photovoltaic equipment is to construct a green supply chain management evaluation index system, which mainly includes six aspects: green supply chain management strategic indicators, green supplier management indicators, green production indicators, green recycling indicators, green information platform construction indicators, and green information disclosure indicators. The specific evaluation indicators and calculation methods are disclosed in Appendix 1.

Composition of assessment index system for photovoltaic equipment suppliers

① Company green supply chain management strategy and system

Incorporate the concept of green supply chain management into the development strategic planning, clarify the goals of green supply chain management, establish management departments, and promote the green supply chain management work of the enterprise.

② Company green purchase and green supplier management

Establish the concept of green procurement, continuously improve and perfect procurement standards and systems, and integrate green procurement throughout the entire process of raw material, product, and service procurement.

③ Green production

Establish a green design concept based on the entire product lifecycle, integrate environmental data resources, establish a basic process and product database, build an evaluation model, and conduct a full lifecycle (LCA) evaluation during the research and development design phase.

④ Green recycling and reuse

Establish an extended producer responsibility system and proactively assume responsibility for the recycling and resource utilization of discarded products.

⑤ Green information platform construction and information disclosure

Establish an online monitoring system for energy consumption and an emission reduction monitoring database.

⑥ Green information disclosure

Regularly release corporate social responsibility reports, disclosing information on the completion of energy conservation and emission reduction targets, pollutant emissions, violations, and other related matters.

5. Data quality requirements

Data quality control is carried out by adopting the actual data of the company (primary data) or selecting a more representative database (secondary data) until the specified data quality requirements are met. The requirements of this guideline for data quality control are as follows:

(1) Production process data shall be reviewed by designated institutions;

(2) Production process data should give priority to primary data, and secondary data (including activity level data and emission factors) should not use more than 50% of carbon emissions;

(3) Analyze the contribution of various material consumption and energy consumption to the whole life cycle of the product. If the contribution rate exceeds 10%, the material balance and energy balance should be made, and the material consumption and energy consumption should be measured according to the national standard. If conditions are not met, you can select supplier data > data from the same raw material or fuel from the same origin > average data from the same raw material or fuel from the same origin > regional average data from similar regions with the same main energy consumption types of raw materials with the same action > China average data and world average data;

(4) Quality requirements for database data: The quality of data covering 70% of carbon emissions should come from the average data of regions with the same raw materials or main energy consumption types in similar regions that are not lower than those from similar regions.

Appendix 1: Assessment Index System of Green Supply Chain Management Companies

(20 year)

Primary indexes	No.	Secondary indexes	Unit	Highest score	Index type

Green supply chain management strategy X1	1	Incorporated into the development plan X11	-	8	Qualitative
	2	Setting green supply chain management objectives X12	-	6	Qualitative
	3	Set up a special management agency X13	-	6	Qualitative
Implementing green supplier management X2	4	Improvement of green purchase standard system X21	-	4	Qualitative
	5	Improved supplier certification system X22	-	3	Qualitative
	6	Periodic audits of suppliers X23	-	3	Qualitative
	7	Improved supplier performance assessment system X24	-	3	Qualitative
	8	Training suppliers on a regular basis X25	-	3	Qualitative
	9	Proportion of low-risk suppliers X26	%	4	Quantitative
Green production X3	10	Energy saving, emission reduction and environmental protection compliance X31	-	10	Qualitative
	11	Comply with the administrative measures for restricted use of hazardous substances X32	-	10	Qualitative
Green recycling X4	12	Product recovery X41	%	5	Quantitative
	13	Packaging recovery X42	%	5	Quantitative
	14	Complete recycling system (including self-built and joint recycling with third parties) X43	-	5	Qualitative

	15	Guide downstream companies to recycle and dismantle X44	-	5	Qualitative
Green information platform construction X5	16	Improvement of green supply chain management information platform X51	-	10	Qualitative
Green information disclosure X6	17	Disclosure of corporate energy conservation, emission reduction and carbon reduction information X61	-	2.5	Qualitative
	18	Disclosure of the audit rate of high and medium-risk suppliers and the proportion of low-risk suppliers X62	-	2.5	Qualitative
	19	Disclosure of supplier energy conservation and emission reduction information X63	-	2.5	Qualitative
	20	Release of corporate social responsibility report (including green purchase information) X64	-	2.5	Qualitative

Note: To facilitate the assessment of green supply chain management, the green supply chain management index formula in the "Green Supply Chain Management Assessment Requirements" (Announcement 3 of the General Office of the Ministry of Industry and Information Technology on the Development of Green Manufacturing System, Ministry of Industry and Information Technology [2016] No. 586) is simplified. The specific calculation formula is simplified to:

$GSCI=X_{11}+X_{12}+X_{13}+X_{21}+X_{22}+X_{23}+X_{24}+X_{25}+X_{26}+X_{31}+X_{32}+X_{41}+X_{42}+X_{43}+X_{44}+X_{51}+X_{61}+X_{62}+X_{63}+X_{64}$