Sustainability Consulting

Report

Life cycle assessment (LCA) of four types of bamboo products

Prepared for Dasso

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EXECUTIVE SUMMARY

Founded in 1993, headquartered in Hangzhou, China, the Dasso Group has been committed for over two decades to the development and production of innovative bamboo products, including bamboo flooring, decking, siding, and furnishings.

Dasso has now 8 manufacturing facilities and over 1000 employees, in addition to owning over 2,700 acres of productive, sustainable bamboo forest in China. Besides, Dasso has also established an independent R&D team with 50 people for product optimization and innovation. Up until now, 65 authorized patents, 24 innovative patents and 13 international patents have been acquired by Dasso.

Through continuous innovation, Dasso has by far produced five generation products available for both indoor and outdoor applications, namely dasso traditional bamboo the First generation; dasso strand woven bamboo the second generation; dasso Ecosolid the third generation; dassoXTR the fourth generation; and dassoCTECH the fifth generation. These five generation of products are all included in the LCA study within this report.

Life cycle assessment (LCA) is defined by ISO as the "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" (ISO 14040). In other words, LCA identifies the materials, energy, emissions and waste flows of a product, process or service over its entire life cycle in order to determine its environmental impacts.

This life cycle stages within this report includes raw materials extraction and processing (A1), transport to the manufacturing (A2), manufacturing (A3), and transport of product (A4), end of life (C) and benefit beyond boundary(D).

For certain aspects of bamboo flooring studied, the following assumptions were made:

1) For missing background data, substitution of missing data using similar background data approach was taken to shorten the gap.
2) Transport assumptions were made where it was not possible to obtain the specific data, for instance from distribution center to outlet and from outlet to consumer. When this occurred, it was clearly stated in the report.
3) Electricity consumption data was not obtained for certain processes so assumptions were made for these. When this occurred, it was clearly stated in the report.
4) In line with the requirement from EN 15804, the lifecycle stage in this report include cradle to gate with option of considering end of life treatment and benefit beyond boundary. For the simplicity of modeling, waste to energy was modeled in stage C3 (treatment of waste product) and system expansion approach was used to include the benefit of avoided electricity production;
5) Biogenic carbon dioxide storage and uptake from the air was not included in the modeling, and emission of CO2 was not considered in the incineration of the waste bamboo product either, to follow a so-called carbon-neutral approach for calculation of the global warming potentials of the product. The reason to exclude biogenic carbon is to follow the requirement set in the newest version of EN 15804 and PCR 2019: 14 of construction product.

Modification of the global background database was done in case of necessary by replacing all the energy data, especially electricity production data, with Chinese energy data, and the study used the modified background data to get better indication of the potential environmental impact results by using more localized dataset of energy supply.

The LCA results show that the stage of raw material stage A1, manufacturing stage A3, and product transportation stage A4 contribute to the main environment impact with different shares for each environment impacts categories. For product dasso traditional bamboo and dasso Ecosolid bamboo, the A3 manufacturing stage account for the largest impact. For product dasso strand woven bamboo, dassoXTR, and dassoCTECH, the A1 raw materials stage accounts for the largest impact.

In the stage of end of life, for the product sold in China and oversea, the impact of global warming potential becomes positive due to the benefit of burning used bamboo product for energy especially electricity generation, hence avoided potential CO2 emission, however since electricity generation is powered from various sources in China and oversea, in China most electricity was generated from coal and other non-renewable materials, meanwhile in Europe and many other developed countries, electricity is generated from largely non-coal based sources such as nuclear or water (hydropower), which means the level of reduction of CO2 emission and impact is different in China and in other countries, burning bamboo for electricity brings more environmental credit in China than burning in other developed countries, same results applies to impact category of Marine aquatic ecotoxicity, the impact becomes positive in both China and oversea market. But the patten does not apply to the rest 9 environment impacts categories, some impact categories become positive but others become worse off. (see table 23 and report for more detail)

Besides stage contribution, from the study four findings are worth highlighted below:

1) In the manufacturing stage A3, some processes are more energy intensive than the rest processes, including heat treatment, profiling, drying, sanding etc. Measures should be taken to lower the level of energy consumption.
2) In the raw material stage A1, packaging materials account for a large share of the environment impacts. Measures to develop green package by eco-design or manufacturing is suggested approach for next step.
3) In addition, transport has a significant environmental impact, how to reduce the environment burden through optimization of transportation is a key issue for bamboo products.
4) Attention should also be paid to waste bamboo floor; proper disposal management can bring more environmental benefit. End of life treatment approach could be investigated to find a most economic and environmental friendly one to replace existing incineration approach, which could potentially extend the lifecycle as well as improve environmental impact of dasso products

Critical Review Statement

This LCA has been critically reviewed to the ISO 14040:2006, ISO 14044:2006 standards as well as EN 15804 and PCR 2019:14 of construction product from IVL, Sweden by Ecovane Environmental Co. Ltd (www.1mi1.org) in Shanghai. According to the verification report, the report achieved a good level of representativeness and transparency and is compliant with the requirements of LCA, PCR and EN 15804 standard.

Disclaimer

The results presented in this study are based on a few realistic models of typical bamboo product life cycles. As with any model, different assumptions will lead to different outcomes. It is important to understand the working of the model, the scope and the limitations before applying these results to support decisions or other applications.

Acknowldegments

The author wants to send acknowledgement to the following organizations for their support during the LCA study and report:

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1. Introduction

1.1 Company introduction

Founded in 1993, headquartered in Hangzhou, China, the Dasso Group has been committed for over two decades to the development and production of innovative bamboo products, including bamboo flooring, decking, siding, and furnishings.

Dasso has now 8 manufacturing facilities and over 1000 employees, in addition to owning over 2,700 acres of productive, sustainable bamboo forest in China. Besides, Dasso has also established an independent R&D team with 50 people for product optimization and innovation. Up until now, 65 authorized patents, 24 innovative patents and 13 international patents have been acquired by Dasso.

Figure 1 Dasso factory in Jiangxi, China

1.2 Product description

Bamboos are one of the fastest-growing plants in the world. They are renewable and versatile resource with multi-purpose usage. Bamboos are of notable economic and cultural significance in South Asia, Southeast Asia and East Asia where the climate is best suitable for its cultivation.

The material may be cut and laminated into sheets and planks, and may be curved or flattened by the application of heat and pressure. It is an ideal construction material as it is durable, sustainable, and environmentally friendly. Bamboo used for construction purposes must be harvested when the culms reach their greatest strength and when sugar level in the sap is at its lowest (usually when the bamboo culm is 3 to 5 years old), and afterwards it should be cured and dried properly for further treatment and manufacturing purpose. Harvesting is best taking place at the end of the dry season, and a few months prior to the start of the rainy season.

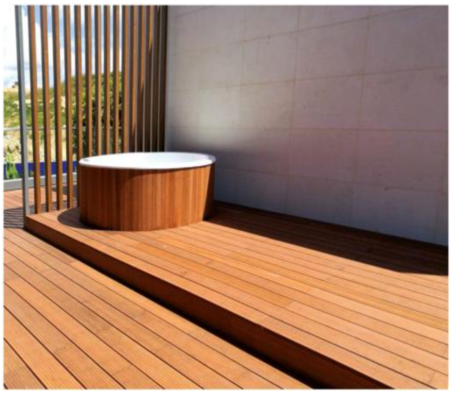


Figure 2 Bamboo products and example of applications

This LCA report serves as the background report for Environmental Product Declarations (EPD) for product portfolio of Dasso Group as bellows:

- dassoXTR and dassoCTECH
- dasso traditional bamboo

- dasso strand woven bamboo

Figure 3 Bamboo products and example of applications

dassoXTR and dassoCTECH

dassoXTR and dassoCTECH products are used for both commercial and residential outdoor applications, including decking, cladding, soffit and so on. They are produced using a patented fusion treatment and have a solid fused bamboo fiber construction.

dassoXTR products are composed of 87% bamboo and 13% phenolic resin. And dassoCTECH products are composed of 84% bamboo, 3% CeramiX® nano particle and 13% phenolic resin.

dassoXTR is manufactured using Dasso's patented process, which combines two stages of heat treatment to first carbonize the bamboo in order to remove the starch and sugar from the bamboo fiber, and then restructure the bamboo to reinforce its natural strength characteristics. The modified bamboo strands are then fused together using phenolic resin. The result is an extremely dense, durable exterior-use product. dassoXTR has a relative flawless appearance and resistance to shrinkage. This consistent grain structure also allows dassoXTR to distribute weight very dassoXTR evenly, adding to its durability.

Unlike dassoXTR, during the production of dassoCTECH, the bamboo fibers are crystalized with CeramiX® particles, and impregnated with phenolic resin, then compressed to form Fused Bamboo® that is hard, dense and durable and can prevent itself from the attack from bacteria, fungus and other microorganisms in outdoor environment.

dasso traditional bamboo

dasso traditional bamboo is made from bamboo strips that are cut from the bamboo stems. The production procedure is quite traditional and classical. Bamboo poles with suitable diameter are selected and cut into shorter lengths. The poles are pushed through a metal "splitter" until the entire stem is cut into slats. After carbonizing and drying, bamboo strips with glue are pressed together through the panel press machine to realize horizontal or vertical structure which show rather rustic structure of the bamboo material. These traditional bamboo panels can be used for various interior applications.

dasso strand woven bamboo

The density of dasso strand woven bamboo is much higher than that of dasso traditional bamboo. During the manufacturing, the carbonized bamboo strips are crushed into rough fibrous bamboo strands. After glue impregnation, the strands are compressed with high pressure to make the final intensive bamboo planks.

dasso Ecosolid bamboo

dasso Ecosolid Bamboo flooring offers a unique style to residential or commercial interior spaces. The patented manufacturing process is revolutionary. Bamboo poles with required diameter are selected and cut into shorter lengths. The entire piece of bamboo is unfolded and flattened into panels to give the final product a natural look with unique bamboo cross knuckle, which would allow the users to feel exactly the original appearance of bamboo surface. The product is quite durable because the outer skin layer of the bamboo, which is the hardest part of the bamboo, has been preserved.

2. Introducing life cycle assessment

Life cycle assessment (LCA) is a standardised method for measuring and comparing the environmental impacts of producing, using and disposing of a product. LCA consists of several interrelated stages: definition of goal and scope, inventory analysis, impact assessment and interpretation of results, as shown in Figure 4.

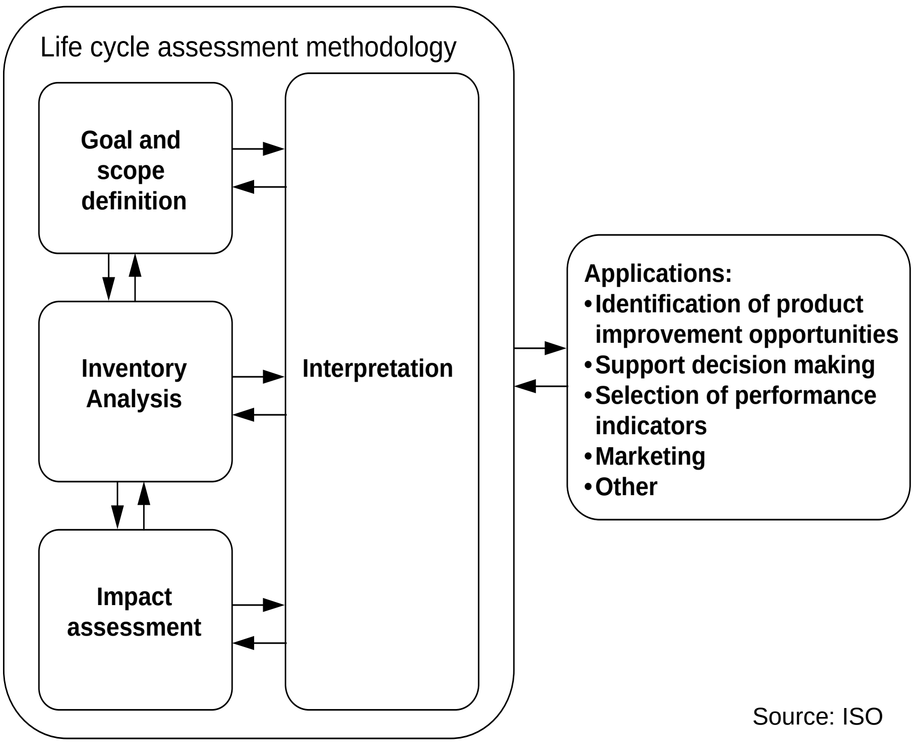


Figure 4 Life cycle assessment

Life cycle assessment (LCA) is defined by ISO as the “compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle” (ISO 14040). In other words, LCA identifies the materials, energy, emissions and waste flows of a product, process or service over its entire life cycle in order for its environmental impacts to be determined.

LCA is an internationally standardised analytical framework for identifying and quantifying the impact of resource use and emissions (e.g. greenhouse gases) from the “cradle” to the “grave” of a system. The general impacts to be considered include resource depletion, human health, and ecological consequences. For example:

- Emissions of greenhouse gases affecting human health and causing loss of ecosystem services through the effects of global warming and climate change;
- Depletion or pollution of scarce freshwater resources necessary for human consumption, food production systems and to sustain eco-systems;
- Use of finite resources such as fossil fuels that are limiting the available pool for future generations, etc.

The study followed the ISO 14040 and ISO 14044 guidelines, it:

- Identified the goal and scope of products and life cycle to be reviewed;
- Identified the energy, water and materials used, pollution emitted and waste generated through the life cycle, by life cycle stages;
- Assessed the potential resource use, human and ecological impacts of those uses and emissions, acknowledging the uncertainties and assumptions used;
- Compared those impacts for the selected bamboo products;

- Highlighted any significant results and implications.

The study has also followed the requirement of EN 15804 and PCR 2019:14 Construction products (EN 15804:A2).

To complete compliance, the study should be critically reviewed before public disclosure.

A full LCA of a product can be a time- and cost-consuming exercise. This has proved a great obstacle to the uptake of LCA in industry. As a response, the concept of the streamlined LCA has evolved. The streamlining primarily involves using generic industry data instead of collecting system specific data.

This study followed a complete LCA approach rather than streamlined version, other than using generic data, the team collected as many specific data as possible in order to get more accurate LCA results.

Companies undertake LCAs for a variety of reasons. Companies often strive to improve the environmental performance of their products due to environmental legislation and pressures along the supply chain. Another reason is the increasing number of environmentally conscious customers who are demanding better performing products and seeking products that combine the benefits of high performance and low cost with good environmental performance.

The life cycle principle is also the main foundation for many information tools. For example, the life cycle principle lies behind the criteria for environmental labels such as the EU Product Environmental Footprint Scheme (PEF), environmental product declaration (EPD), Eco-labels such as the German Blue Angel and the Nordic Swan. It also forms the basis of analysing product carbon footprinting and water footprinting.

While LCA is a valuable tool, it should be emphasised that it is one of many factors that need to be considered by companies during decision-making, among others, costs, consumer acceptance, production feasibility and so on. And it should be noted that the estimated impact results are only relative statements which do not indicate the end points of the impact categories, exceeding threshold values, safety margins or risks.

3. Goal of study

With over 26 years' history of bamboo products production, Dasso is always thinking of new ways to use bamboo. Dasso concentrates on developing high quality products, following customer needs and providing outstanding value-added service.

As part of Dasso's continuous innovation activities and fulfillment of social responsibility, Dasso intends to report the environmental aspects of the products with transparency by means of Environmental Product Declaration (EPD). The goal of this LCA study is to generate the LCA results for a portfolio of Dasso products (dassoXTR and dassoCTECH, dasso traditional bamboo, dasso strand woven bamboo, dasso Ecosolid bamboo) for EPD application, and also identify the hotspot of the products' environmental impact, based on which Dasso may seek ways in the future to continuously improve its environmental footprint through better recycling system or improvement in e.g. manufacturing processes and so on.

The LCA study is intended to be used for application of product environmental declaration (EPD). The main purpose of EPDs is for business-to-business communication about the environmentally relevant information of the products.

4. Scope of study

4.1 Functional unit

In order to assess the environmental impacts of different products, it is important that the functional units of these products are equivalent so that the results may be interpreted clearly.

In this report, the functional unit is the 1kg of bamboo flooring.

4.2 Product systems and system boundaries

4.2.1 Product systems studied

Up to now, dasso has five generation products. The First generation is dasso traditional bamboo; the second generation is dasso strand woven bamboo; the third generation is dasso Ecosolid; the fourth generation is dassoXTR; and the fifth generation is dassoCTECH. These five kinds of products are all included in this report. The information is shown in Table 1.

Table 1 Information of products

Name	Density	Thickness
dasso traditional bamboo	680 kg/m^3	20mm
dasso Ecosolid bamboo	750 kg/m^3	18mm
dasso strand woven bamboo	1050 kg/m^3	20mm
dassoXTR	1150 kg/m^3	20mm
dassoCTECH	1250 kg/m^3	20mm

4.2.2 System boundaries

The study of dasso bamboo flooring products includes all life cycle stages and processes. All energy and material inputs have been traced back to the extraction of resources. Emissions from the whole system have been quantified.

Figure 5 illustrates the system boundary for the study of five products. Transport is represented in the figure with the letter 'T'. The processes in dashed box were not included in the system as selling and using stage (stage B) was irrelevant to the purpose of study, and end-of-life benefits (stage D) were included in this study. Therefore, this report includes A1 raw materials extraction and processing, A2 transport to the manufacturing, A3 manufacturing, A4 transport of product, C end of life and D.

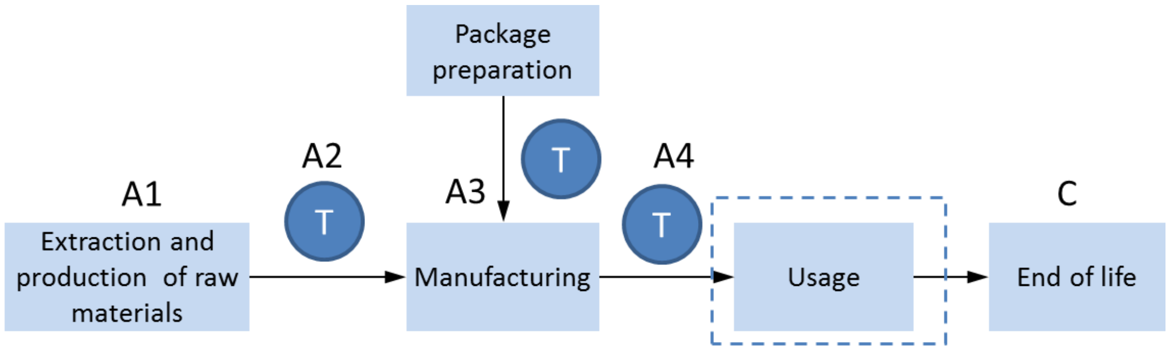


Figure 5 System boundaries

Within this report, the scenarios included are currently in use and are representative for one of the most likely scenario alternatives, more detailed description of each included life cycle stage is shown below.

Extraction and production of raw material

The extraction and production of the raw materials, such as original bamboo, synthetic latex, wax, vegetable oil and auxiliary packaging materials were included in the study. All packaging materials used for flooring packaging were included in the raw material modeling (A1 stage). Packaging materials includes corrugated board, wrapping film, pallet, and packing belt.

Table 2 Life cycle stages

Included modules in the life cycle assessment	Product Stage	X	A1 Raw material supply
		X	A2 Transport to the manufacturer
		X	A3 Manufacturing
	Construction process stage	X	A4 Transport to the site
		MND	A5 Assembly/Install
		MND	B1 Use
		MND	B2 Maintenance
		MND	B3 Repair
		MND	B4 Replacement
		MND	B5 Refurbishment
		MND	B6 Operational energy use
		MND	B7 Operational water use
	End of Life Stage	X	C1 Deconstruction
		X	C2 Transport to waste processing
		X	C3 Waste processing for reuse, recovery and/or recycling
		X	C4 Disposal;
	Benefits and loads beyond the product system boundary	X	D Reuse, recovery and/or recycling potentials,
Note: X=Declared Module, MND=Module not Declared in this LCA study			

Transport of raw materials

The transport of the raw materials to the flooring manufacturer has been included. Where it was not possible to define specific distances, justified estimates and web-based map service was used to the best of our knowledge. For all transportation vehicles, if not specified, 10-tonne-truck scenario was used for LCA modelling for simplification purpose.

Packaging Production

The manufacturing of packaging from raw materials and associated energy, additives and wastes were included.

Transport of packaging materials

The transport of the packaging materials to the flooring manufacturing site has been included. Where it was not possible to define specific distances, justified estimates were used.

Manufacturing

The manufacturing process of the five kinds of products was included. The process of dasso traditional bamboo, dasso Ecosolid bamboo, dasso strand woven bamboo, dassoXTR, and dassoCTECH are different from each other, see Section 5 for more explanation for manufacturing stage.

Transport of bamboo products to regional market

The transport of the bamboo product from the manufacturing site to the distribution centre located in various regions in China and other countries was included. Where it was not possible to define specific distances, justified estimates were used.

Consumer

Environment impacts associated with the transport of the product from market to the consumers were considered minor and not included.

Environmental impact associated with the energy and material used for cleaning and maintenance of the bamboo product was considered minor and not included.

Deconstruction

Demounting and demolition were assumed manually, no industrial process was considered

Transport to waste management

Waste collection of used bamboo product from consumer households to waste management facilities was included and estimated to be 100km in average.

Waste processing

The current EU 25 waste management scenario of landfill, incineration and recycling was used as there is not a readily available waste management scenario to follow. As waste scenario after the demolition stage, incineration for energy production was assumed as scenario following default values for division between incineration (95%) and landfill (5%) for bamboo flooring.

Allocation of benefit during waste management

Where materials are reused or recycled or if energy is recovered, the system boundaries could be expanded to include the environment benefits resulting from these waste management activities. In this study, 95 % of waste bamboo flooring was assumed to be incineration and 5% to be landfill.

The end of life bamboo flooring is burned as calorific values for electricity generation. Therefore, environment impact of electricity from waste is considered. For benefit of incineration with electricity generation, “avoided” production of electricity was included. Two scenarios are set. The first is the CN scenario (C-CN), the other is the EU scenario (C-EU). CN scenario means the electricity from waste bamboo flooring replace electricity mix in China. This electricity is the average electricity supply in China. EU scenario means the electricity from waste bamboo flooring replace electricity mix in European.

Benefits and loads beyond the system boundary

It is assumed that there is no recovery, reuse, and recycling of bamboo flooring. The avoided energy use as a result from the incineration of bamboo flooring is not considered as benefit beyond the system boundary, but is calculated in the waste processing (C3-C4).

4.2.3 Excluded processes

The following are the secondary processes that have been excluded from the system and have not formed part of the study:

- Handling operations such as during usage at the consumer household
- Transit packaging such as pallets
- Transport from retailer / outlet to consumer household
- Capital equipment
- General infrastructure

4.3 Key assumptions and limitations

For certain aspects of bamboo flooring studied, the following assumptions were made:

- For missing background data, substitution of missing data using similar background data approach was taken to shorten the gap.
- For instance, synthetic latex used in the study was replaced by latex. When the contribution from replaced material was more than 5%, modification or further quality enhancement approach such as supplier data collection was adopted to enhance data accuracy and modelling quality;

- Transport assumptions were made where it was not possible to obtain the specific data, for instance from distribution center to outlet and from outlet to consumer. When this occurred, it was clearly stated in the report;
- Electricity consumption data was not obtained for certain processes so assumptions were made for these. When this occurred, it was clearly stated in the report;
- A modification of the global background database was done by replacing all the energy data, especially electricity production data, by Chinese energy data, and the study used the modified background data to get better indication of the potential environmental impact results by using more localized dataset of energy supply.
- In this report, the benefit of incineration of waste bamboo flooring is considered. It is assumed that there is no recovery, reuse, and recycling of bamboo flooring. During the end of life stage, bamboo flooring is burned to generate calorific values. The heat value of bamboo is 18.87MJ/kg. Calorific value recovery replaces coal-fired power generation. The efficiency of thermal power is assumed 42%, therefore, 2.2 kWh electricity can be generated by 1kg waste bamboo flooring.

  And it is also assumed that there is no difference among five kinds of Dasso products during end of life stage treatment.

4.4 Allocation

Allocation refers to partitioning of input or output flows of a process or a product system between the product systems under study and one or more other product systems. In the production of bamboo flooring, special production is used because all the inputs and outputs are clearly corresponding to the products, there is no production of by products that need to be used to allocate the situation.

4.5 Carbon emission

This section will introduce the carbon emission of product, including carbon emissions in different life cycle stages, carbon emissions calculation method, assumptions and limitations.

4.5.1 Carbon emission from transportation

Carbon emission by burning of fossil fuel from transportation was mostly for raw material and product transportation purpose. The harvested bamboo was transported from nearby forest to the manufacturing plant located in Zixi and Shunchang. And other raw materials including mainly the additive materials were sourced and transported from domestic and overseas market. The related transportation data are shown in section 5.4.

4.5.2 Carbon emission from production

Producing bamboo flooring needs up to 20 processing procedures. To calculate the direct carbon emission from consumed electric energy during each processing procedure, we measured the involved machine's power, operation, and idle time to calculate the power consumption and then carbon emission was derived.

4.5.3 Carbon emission from additive materials

Weights of the additive materials were derived by weighting the products before and after the processing or packaging. The corresponding carbon emission of the unit additive materials was collected from the database of Ecoinvent.

4.5.4 Carbon stock

When a product contains biomass carbon that is stored in product for more than one year, this biomass carbon can be accounted in assessment of carbon emissions of the product. The calculation method will be shown in section 6.6. Carbon stock can be included in an LCA if the bamboo is burned for electricity or heat. The scenario of end of life of bamboo flooring is not clear during the reporting period and assumption was made based on 95% incineration and 5% landfill scenario. In this report, the carbon stock of dasso products was considered during end of life stage. See more explanation in section 6.5.

In the manufacturing stage, the steam which is generated from bamboo waste is used during some processes. The emissions during steam generation did not include carbon emissions considering the carbon stock in the biomass counter act the emission.

4.5.5 Carbon emissions from end of life

In the stage of end of life, carbon emission from electricity based on waste was ignored and not included because of counteracting effect of biomass carbon stock.

4.6 Electricity power mix

In this LCA, the grid mix data on electricity of for the site in Fujian and Jiangxi Province is based on grid mixes of China. The electricity inventory is based on the year of 2015 for Chinese electricity generation (China Energy Statistics). In Chinese map of electricity generation, thermal power is the principal part of total national installed capacity and electricity generation in China. Develop of hydropower is slower than the speed of thermal power development, and nuclear power is still in its initial step of development in China. Power generation from renewable energy resources, such as wind, solar energy and tide, is usually not included due to the small share in electricity generation in China, however the renewable energy was also considered in this study by taking into account the small ratio of wind, solar and other renewable energy generation in China. In 2015, the content of power supply is 73.3% thermal power, 19.4% hydropower and 2.9% nuclear power. The transmission of electricity in all cases is taken from the power station via a high voltage electricity grid to low voltage electricity suitable for domestic use, with a loss factor of 7.52% of the electricity produced at the power station, and a loss of 6.15% by the electricity consumption at the power plants.

4.7 Initial data quality requirements

Steps were taken to ensure that the life cycle inventory data were reliable and representative. The type of data that was used is clearly stated in the Inventory Analysis, be it measured or calculated from primary sources or whether data are from the life cycle inventory databases. In this streamlined study, generic data for certain processes were sourced from these databases in SimaPro 9.

SimaPro is the world’s most widely used LCA software and the data in it comes predominantly from Ecoinvent, the world’s most complete and widely used set of data on industrial processes, material production, packaging production, transport and so on.

The data quality requirements for this study were as follows:

- Existing LCI data were, at most, 10 years old. Newly collected LCI data were current or up to 3 years old;
- The LCI data related to the geographical locations where the processes occurred;
- The technology represented the average technologies at the time of data collection.

5. Inventory Analysis

5.1 System description

The system boundary has been described in section 4.2. Same system boundary is considered for five kinds of products. The main differences are manufacturing stage and transportation. The transportation of raw materials and products mainly depends on the raw material production site and market. Transportation will be described in 5.4. In this part, the manufacturing stage will be shown.

5.1.1 dassoXTR, dassoCTECH, and dasso strand woven bamboo

The following scheme represents different steps of the manufacturing of dassoXTR, dassoCTECH, and dasso strand woven bamboo (SWB) considered in this study.

These three products have same processes crushing process and after glue impregnation. The specific processes for dassoXTR are bamboo fiber, drying, and heat treated. The key processes for dassoCTECH are ceramic and drying, which is also the same for dasso SWB.

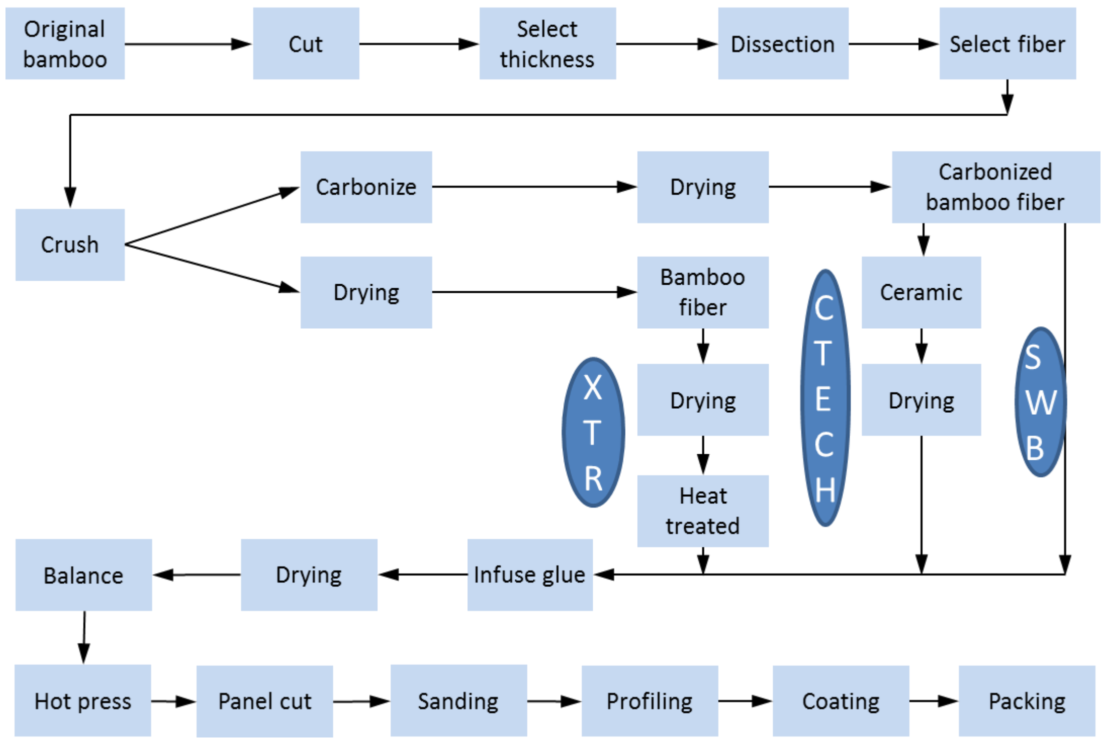


Figure 6 Manufacturing process of the dasso SWB, dassoXTR & dassoCTECH

5.1.2 dasso traditional bamboo

The following scheme represents manufacturing steps of dasso traditional bamboo considered in this study.

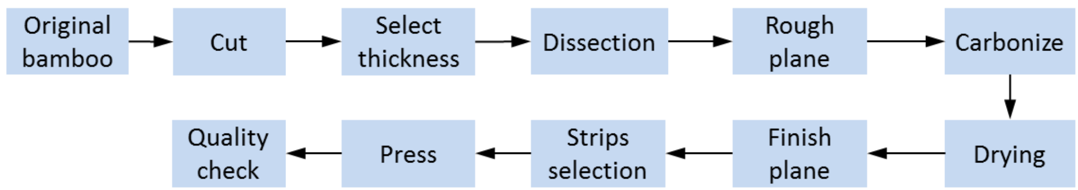


Figure 7 Manufacturing process of the dasso traditional bamboo

5.1.3 dasso Ecosolid bamboo

The following scheme represents manufacturing steps of dasso Ecosolid bamboo considered in this study.

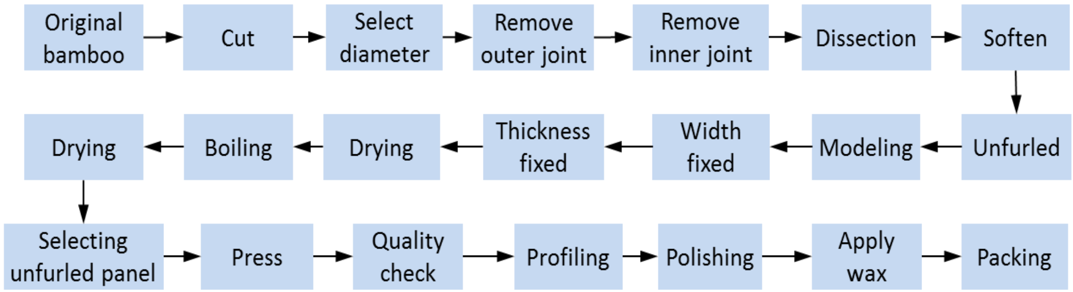


Figure 8 Manufacturing process of the Dasso Ecosolid bamboo

5.2 Raw material acquisition

The materials required for products include raw material and packaging materials for transportation. The raw materials include original bamboo, synthetic latex, wax and vegetable oil. The packaging materials include corrugated board, tray, wrapping film, and packing belt. The main material original bamboo is mainly from the bamboo plant not far from the manufacturing plant. The original bamboo for dasso traditional bamboo and dasso Ecosolid are from Shunchang, Fujian province. The original bamboo for dasso strand woven bamboo, dassoXTR, and dassoCTECH are from Zixi, Jiangxi province.

The details of raw materials for five kinds of products are shown in table 3.

5.3 Manufacturing

The manufacturing process of five kinds of bamboo flooring mainly includes drying, profiling, and polishing, press and etc., which involves raw materials, energy, and emissions. The inputs and outputs for manufacturing of different kinds of bamboo flooring are different.

Table 3 Raw materials of products

Raw materials		Units	dasso traditional	dasso Ecosolid	dasso strand woven bamboo	dassoXTR	dassoCTECH
Raw materials	Original bamboo	kg/kg	1.2125	3.3333	4.0000	4.0000	4.0000
	Synthetic latex	kg/kg	0.0300	0.0293	0.1278	0.1278	0.1278
	Wax	kg/kg	-	0.0007	-	-	-
	Vegetable oil	kg/kg	-		0.0022	0.0022	0.0022
Packing materials	Corrugated board	kg/kg	-		0.0125	0.0113	0.0105
	Wrapping film	kg/kg	-		0.0008	0.0007	0.0006
	Pallet	kg/kg	0.0227	0.0196	0.0352	0.0322	0.0296
	Packing belt	kg/kg	0.0021	0.0018	0.0010	0.0009	0.0008

Since the raw materials are already considered in “raw material acquisition” step above, the model will mainly deal with auxiliary materials, energy consumption and emissions. The life cycle inventory data including input and output data of energy, water, steam, other materials and emissions is calculated using weighted average method. All the life cycle inventory data of manufacturing was calculated and submitted by dasso.

The energy steam is used during manufacturing. The steam is generated by using bamboo waste as the fuel. Therefore, a steam production model was created, the related data are shown in table 5.

Table 4 Inputs for manufacturing

Name	Electricity: kWh/kg	Steam: kg/kg
dasso traditional bamboo	0.68	1.57
dasso Ecosolid bamboo	0.83	1.58
dasso strand woven bamboo	0.25	3.33
dassoXTR	0.28	1.74
dassoCTECH	0.26	2.80

Table 5 Inputs for steam generation

Data	Items	Values	Units
Input	Transport of bamboo	6.38E-02	tkm
	Biomass-bamboo	6.38E-01	t/t
	Electricity	4.86E-05	kWh/t
Output	Particulate	5.10E-03	kg/t
	SO2	5.08E-07	kg/t

5.4 Transportation

5.4.1 Raw material transportation

The transportation mainly takes place on the upstream of raw material supply and downstream of product delivery. According to the production site in Zixi, Jiangxi province and Shunchang, Fujian province, the raw materials besides bamboo are sourced from Shanghai, Zhejiang, and Guangdong province, and delivered by lorry. As it was not possible to define specific distances, justified estimates and web map service were used to the best of our knowledge. For all transportation vehicles, if not specified, 10-tonne-truck scenario was used for LCA modelling for simplification purpose.

Products are transported to both domestic and foreign markets, the mode of transportation involves land transportation and sea transportation.

The information related to raw materials transportation including distance, vehicle is shown in the table below.

Table 6 Transportation of raw material

Name	Original bamboo			Synthetic latex			Wax		
	Distance :km	sources	vehicles	Distance :km	sources	vehicles	Distance: km	sources	vehicles
dasso traditional bamboo	30	Shunchang	Lorry	800	Shanghai	Lorry	-	-	-
dasso Ecosolid	30	Shunchang	Lorry	800	Shanghai	Lorry	800	Shanghai	Lorry
Name	**Original bamboo**			**Synthetic latex**			**Plant oil**		
	Distance: km	**sources**	**vehicles**	**Distance: km**	**sources**	**vehicles**	**Distance :km**	**sources**	**vehicles**
dasso strand woven bamboo	30	Zixi	Lorry	900	Guangdong	Lorry	700	Shanghai	Lorry
dassoXTR	30	Zixi	Lorry	900	Guangdong	Lorry	700	Shanghai	Lorry
dassoCTECH	30	Zixi	Lorry	900	Guangdong	Lorry	700	Shanghai	Lorry

5.4.2 Product transportation

According to dasso, products are consumed both in China and oversea, and transportation distance for product delivery was estimated with reference to external resources. The volume of the goods is given in table below.

Table 7 Transportation of products for domestic-dasso traditional bamboo

Market	Value	Unit
Anhui	0.45568	m^3
Beijing	3.89365	m^3
Fujian	1.8267	m^3
Gansu	2.52721	m^3
Guangdong	13.0143	m^3
Guangxi	7.57056	m^3
Guizhou	0.56172	m^3
Henan	1.10085	m^3
Hebei	9.5039	m^3
Henan	0.86674	m^3
Hubei	0.94134	m^3
Hunan	1.50095	m^3
Jiangsu	42.8969	m^3
Inner mongolia	2.10507	m^3
Shandong	17.6998	m^3
Shanghai	5.90543	m^3
Sichuan	67.9502	m^3
Yunnan	2.68034	m^3
Zhejiang	44.0822	m^3
Chongqing	2.5201	m^3

Table 8 Transportation of products for domestic-dasso Ecosolid bamboo

Market	**Value**	**Unit**
Gansu	0.52863	m^3
Guangdong	0.03499	m^3
Guangxi	0.32398	m^3
Hebei	2.11747	m^3
Jiangsu	0.05204	m^3
Jiangxi	0.00135	m^3
Shandong	1.43748	m^3
Shaanxi	0.00338	m^3
Shanghai	0.10545	m^3
Zhejiang	2.81896	m^3

Table 9 Transportation of products for domestic-dasso SWB

Market	Value	Unit
Anhui	35.5558	m^3
Beijing	47.1072	m^3
Fujian	80.4077	m^3
Gansu	0.44768	m^3
Guangdong	889.991	m^3
Guizhou	2.30009	m^3
Hainan	306.546	m^3
Hebei	24.4886	m^3
Henan	101.998	m^3
Heilongjiang	9.56078	m^3
Hubei	4.45151	m^3
Hunan	102.473	m^3
Jilin	51.3281	m^3
Jiangsu	275.889	m^3
Jiangxi	21.2158	m^3
Inner Mongolia	200.925	m^3
Shandong	291.849	m^3
Shanxi	29.8093	m^3
Shaanxi	67.5489	m^3
Shanghai	24.065	m^3
Sichuan	528.919	m^3
Tianjin	49.229	m^3
Xinjiang	1.18975	m^3
Yunnan	20.8657	m^3
Zhejiang	521.58	m^3
Chongqing	151.761	m^3

Table 10 Transportation of products for domestic-dassoXTR

Market	Value	Unit
Anhui	51.9038	m^3
Beijing	185.353	m^3
Fujian	209.436	m^3
Gansu	3.38673	m^3
Guangdong	395.394	m^3
Guangxi	33.4785	m^3
Guizhou	52.7916	m^3
Hainan	118.129	m^3
Hebei	71.9472	m^3
Henan	17.45	m^3

Heilongjiang	14.938	m^3
Hubei	32.0308	m^3
Hunan	96.7195	m^3
Jilin	0.78821	m^3
Jiangsu	129.745	m^3
Jiangxi	28.9171	m^3
Liaoning	4.79021	m^3
Inner Mongolia	1.0949	m^3
Ningxia	0.00357	m^3
Qinghai	0.05475	m^3
Shangdong	153.649	m^3
Shanxi	18.1912	m^3
Shaanxi	352.746	m^3
Shanghai	16.713	m^3
Sichuan	810.88	m^3
Tianjin	31.1779	m^3
Yunnan	24.0938	m^3
Zhejiang	882.405	m^3
Chongqing	296.041	m^3

Table 11 Transportation of products for domestic-dassoCTECH

Market	Value	Unit
Anhui	51.9038	m^3
Beijing	185.353	m^3
Fujian	209.436	m^3
Gansu	3.38673	m^3
Guangdong	395.394	m^3
Guangxi	33.4785	m^3
Guizhou	52.7916	m^3
Hainan	118.129	m^3
Hebei	71.9472	m^3
Henan	17.45	m^3
Heilongjiang	14.938	m^3
Hubei	32.0308	m^3
Hunan	96.7195	m^3
Jilin	0.78821	m^3
Jiangsu	129.745	m^3
Jiangxi	28.9171	m^3
Liaoning	4.79021	m^3
Inner Mongolia	1.0949	m^3
Ningxia	0.00357	m^3

Qinghai	0.05475	m^3
Shandong	153.649	m^3
Shanxi	18.1912	m^3
Shaanxi	352.746	m^3
Shanghai	16.713	m^3
Sichuan	810.88	m^3
Tianjin	31.1779	m^3
Yunnan	24.0938	m^3
Zhejiang	882.405	m^3
Chongqing	296.041	m^3

Table 12 Transportation of products for oversea-dasso traditional

Market	Value	Unit
Germany	67.69	m^3
Netherland	49.11	m^3
Japan	43.48	m^3
Mexicanos	1.88	m^3
England	0.39	m^3

Table 13 Transportation of products for oversea-dasso Ecosolid bamboo

Market	Value	Unit
Germany	78.51	m3
Belgien	31.28	m3
Netherland	58.81	m3
France	47.92	m3
Japan	3.65	m3
Taiwan	1.86	m3
Vietnam	1.57	m3

Table 14 Transportation of products for oversea-dassoXTR and dassoCTECH

Market	dassoXTR (m^2)	dassoXTR (m^3)	dassoCTECH (m^2)	dasoCTECH (m^3)
Germany	36,850.59	737.01	29221.05	584.42
England	2,445.96	48.92	1423.37	28.47
Belgien	2,335.79	46.72	291.97	5.84
Netherlands	1,313.88	26.28	875.92	17.52
Lithuania	431.72	8.63	681.14	13.62
Spain	6,222.30	124.45	2896.32	57.93
France	3,065.72	61.31	2181.02	43.62
Portuguesa	2,204.87	44.1	452.76	9.06

Danmark	420.27	8.41	420.27	8.41
Italia	855.60	17.11	20.28	0.41
Japan	888.82	17.78	221.77	4.44
Taiwan	1,724.55	34.49	426.97	8.54
Korea	370.53	7.41	2.12	0.04
Malaysia	8,750.00	175	986.22	19.72
Thailand	2,844.20	56.88	1795.76	35.92
Singapore	0.00	0	202.12	4.04
HongKong	1,081.64	21.63	263.14	5.26
India	200.23	4	0	0
Pilipinas	218.99	4.38	670.6	13.41
Australia	4,775.42	95.51	2928.57	58.57
American	19,783.57	395.67	18237.29	364.7s5
Mexicanos	2,255.32	45.11	2789.92	55.8
Vietnam	594.55	11.89	8220.16	164.4
Pakistan	290.96	5.82	401.54	8.03
Dubai	12.17	0.24	280.55	5.61
Israel	6,869.54	137.39	7994.94	159.9
Caribbean sea	0.00	0	3856.07	77.12

5.5 End of life

Demounting and demolition of assumed was conducted manually, so there is no energy and material input involved. The transport distance from installation site to final waste processing site was assumed to be 100 km. For waste processing, three sets of background data were used. The first set is electricity generation from waste incineration; the second is the electricity generation in China/EU; the last one is the landfill of waste bamboo flooring. These data are all adapted from the ecoinvent 3.5 database.

6. Environment Impact Assessment

To compare life cycle inventory results, “CML” impact category methods were used.

6.1 Environmental impact assessments (CML IA)

CML-IA (baseline) is a LCA methodology developed by the center of Environmental Science (CML) of Leiden University in the Netherlands. This method is an update of the CML 2 baseline 2000 and released by CML in April 2013 (version 4.2). The CML-IA (baseline) method elaborates on the problem – oriented (midpoint) approach. The impact categories presented in this CML baseline method are the recommended methods according to the Handbook on Life Cycle Assessment (table 4.2.2, page 534). Table 15 illustrates the categories from CML -IA baseline method.

Table 15 Impact categories in CML method

Name of the impact category	Expression in equivalent unit
Abiotic depletion	Abiotic Depletion Factor (ADF), in kg antimony equivalents / kg extraction
Global warming (GWP100a)	Global Warming Potential for time horizon 100 years (GWP100), in kg carbon dioxide/kg emission
Ozone layer depletion	kg CFC-11 equivalent/ kg emission
Human toxicity	Human Toxicity Potentials (HTP) expressed as 1,4-dichlorobenzene equivalents/ kg emission
Fresh-water aquatic eco-toxicity	Eco-toxicity Potential (FAETP) expressed as 1,4-dichlorobenzene equivalents/kg emission
Marine eco-toxicity	Same above
Terrestrial ecotoxicity	Same above
Photochemical oxidation	*Photo-oxidant formation* Potential (POCP) expressed in kg ethylene equivalents/kg emission
Acidification	Acidification Potentials (AP) expressed as kg SO2 equivalents/ kg emission
Eutrophication	Nutrification potential (NP) expressed as kg PO4 equivalents/ kg emission

6.2 LCA results

This section showed the LCA results of five kinds of bamboo flooring. The results of life cycle environment impact are shown in table 16 and 17.

Table 16 Life cycle environment impacts of production stage (A1-A4)

Impact category	Unit	Traditional	Ecosolid	SWB	XTR	CTECH
Abiotic depletion	kg Sb eq	1.2E-06	1.0E-06	2.0E-06	1.8E-06	1.8E-06
Abiotic depletion (fossil fuels)	MJ	1.5E+01	1.6E+01	2.4E+01	2.4E+01	2.3E+01
Global warming (GWP100a)	kg CO2 eq	1.0E+00	1.1E+00	1.2E+00	1.3E+00	1.2E+00
Ozone layer depletion (ODP)	kg CFC-11 eq	6.0E-08	6.8E-08	6.3E-08	6.6E-08	6.8E-08
Human toxicity	kg 1,4-DB eq	5.3E-01	5.5E-01	6.0E-01	5.9E-01	5.6E-01
Fresh water aquatic ecotox.	kg 1,4-DB eq	2.5E-01	2.9E-01	1.9E-01	2.0E-01	1.9E-01
Marine aquatic ecotoxicity	kg 1,4-DB eq	1.0E+03	1.2E+03	7.7E+02	8.0E+02	7.6E+02
Terrestrial ecotoxicity	kg 1,4-DB eq	2.2E-03	2.4E-03	3.5E-03	3.5E-03	3.5E-03
Photochemical oxidation	kg C2H4 eq	3.9E-04	4.2E-04	4.5E-04	4.7E-04	4.4E-04
Acidification	kg SO2 eq	7.9E-03	9.3E-03	7.4E-03	8.7E-03	8.1E-03
Eutrophication	kg PO4--- eq	1.3E-03	1.5E-03	1.3E-03	1.4E-03	1.4E-03

Table 17 Life cycle environment impacts of products (A1-A4, C-CN,D)

Impact category	Unit	Traditional	Ecosolid	SWB	XTR	CTECH
Abiotic depletion	kg Sb eq	2.6E-05	2.6E-05	2.7E-05	2.6E-05	2.6E-05
Abiotic depletion (fossil fuels)	MJ	6.5E+00	7.4E+00	1.6E+01	1.6E+01	1.5E+01

Global warming (GWP100a)	kg CO2 eq	-1.2E+00	-1.1E+00	-9.5E-01	-9.4E-01	-9.7E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	5.5E-07	5.5E-07	5.5E-07	5.5E-07	5.5E-07
Human toxicity	kg 1,4-DB eq	8.3E-01	8.5E-01	9.0E-01	8.9E-01	8.6E-01
Fresh water aquatic ecotox.	kg 1,4-DB eq	8.4E-01	8.8E-01	7.7E-01	7.8E-01	7.8E-01
Marine aquatic ecotoxicity	kg 1,4-DB eq	-7.1E+01	8.0E+01	-3.3E+02	-3.0E+02	-3.4E+02
Terrestrial ecotoxicity	kg 1,4-DB eq	1.1E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01
Photochemical oxidation	kg C2H4 eq	-1.7E-04	-1.4E-04	-1.1E-04	-8.5E-05	-1.2E-04
Acidification	kg SO2 eq	-9.9E-03	-8.5E-03	-1.0E-02	-9.0E-03	-9.7E-03
Eutrophication	kg PO4--- eq	1.8E-03	2.0E-03	1.8E-03	2.0E-03	1.9E-03

6.3 Contribution of life cycle stages

6.3.1 dasso traditional bamboo

To produce dasso traditional bamboo, the main contributors for environment impacts are A1 raw materials and A3 manufacturing. Each environment impact has a different characteristic of life cycle stage contribution. When considering the stage of end of life, the impact of marine aquatic ecotoxicity, acidification, global warming potential, and photochemical oxidation is negative.

(1) Abiotic depletion

In the impact category of abiotic depletion, to produce traditional product, A1 dominates the contribution with 68.9% of impact, the stage A3 contributes to 17.3%, the stage A4 contributes to 12.4%. Regarding A1, the packaging materials contribute to 97.2%. For the stage of A3, rough plane stage is the main contributor, which account for 22.4%. For the stage of A4, the transport of domestic market accounts for 63.5%.

When considering the stage of end of life, abiotic depletion is positive. The eutrophication from end of life accounts for 95.5% of the total.

(2) Abiotic depletion (fossil fuels)

In the impact category of abiotic depletion (fossil fuels), to produce traditional product, A1 dominates the contribution with 48.5% of impact, the stage A3 contributes to 31.8%, the stage A4 contributes to 18.3%. Regarding A1, the packaging materials contribute to 63.0%. For the stage of A3, rough plane stage is the main contributor, which account for 22.4%. For the stage of A4, the transport of domestic market accounts for 19.7%.

When considering the stage of end of life, abiotic depletion (fossil fuels) in this stage is negative. However, the total abiotic depletion (fossil fuels) is still positive. The environmental benefit of bamboo flooring waste-based power generation cannot compensates the environmental impacts of the production process (A1-A4).

(3) Global warming potential (GWP100)

In the impact category of global warming potential, to produce traditional product, A3 dominates the contribution with 43.4% of impact, the stage A1 contributes to 38.4%, the stage A4 contributes to 17.0%. Regarding A1, the packaging materials contribute to 79.1 %. For the stage of A3, rough plane stage is the main contributor, which account for 22.4%. For the stage of A4, the transport of domestic market accounts for 18.7%.

When considering the stage of end of life, global warming potential in this stage is negative. The total global warming potential become negative.

The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(4) Ozone layer depletion (ODP)

In the impact category of ozone layer depletion, to produce traditional product, A4 dominates the contribution with 48.5% of impact, the stage A3 contributes to 31.6%, the stage A1 contributes to 16.4%. Regarding A1, the packaging materials contribute to 98.0%. For the stage of A3, rough plane stage is the main contributor, which account for 22.4%. For the stage of A4, the transport of domestic market accounts for 20.7%.

When considering the stage of end of life, ozone layer depletion is positive. The ozone layer depletion from end of life accounts for 89.0% of the total.

(5) Human toxicity

In the impact category of human toxicity, to produce traditional product, A1 dominates the contribution with 54.2 % of impact, the stage A3 contributes to 31.5%, the stage A4 contributes to 13.4%. Regarding A1, the packaging materials contribute to 98.3%. For the stage of A3, rough plane stage is the main contributor, which account for 22.4%. For the stage of A4, the transport of domestic market accounts for 15.2%.

When considering the stage of end of life, human toxicity is positive. The human toxicity from end of life accounts for 36.3% of the total.

(6) Fresh water aquatic ecotox.

In the impact category of fresh water aquatic ecotox., to produce traditional product, A3 dominates the contribution with 64.0% of impact, the stage A1 contributes to 24.1%, the stage A4 contributes to 11.0%. Regarding A1, the packaging materials contribute to 96.3%. For the stage of A3, rough plane stage is the main contributor, which account for 22.4%. For the stage of A4, the transport of domestic market accounts for 10.3%.

When considering the stage of end of life, fresh water aquatic ecotox. is positive. The fresh water aquatic ecotox. from end of life accounts for 69.6% of the total.

(7) Marine aquatic ecotoxicity

In the impact category of marine aquatic ecotoxicity, to produce traditional product, A3 dominates the contribution with 65.1% of impact, the stage A1 contributes to 25.7%, the stage A4 contributes to 8.5%. Regarding A1, the packaging materials contribute to 98.0 %. For the stage of A3, rough plane stage is the main contributor, which account for 22.4%. For the stage of A4, the transport of domestic market accounts for 10.2%.

When considering the stage of end of life, marine aquatic ecotoxicity in this stage is negative. The total marine aquatic ecotoxicity become negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(8) Terrestrial ecotoxicity

In the impact category of terrestrial ecotoxicity, to produce traditional product, A1 dominates the contribution with 47.9% of impact, the stage A3 contributes to 39.8%, the stage A4 contributes to 11.5%. Regarding A1, the packaging materials contribute to 58.1 %. For the stage of A3, rough plane stage is the main contributor, which account for 22.4%. For the stage of A4, the transport of domestic market accounts for 17.2 %.

When considering the stage of end of life, terrestrial ecotoxicity is positive. The terrestrial ecotoxicity from end of life accounts for 98.0% of the total.

(9) Photochemical oxidation

In the impact category of photochemical oxidation, to produce traditional product, A1 dominates the contribution with 54.9% of impact, the stage A4 contributes to 26.4%, the stage A3 contributes to 18.2%. Regarding A1, the packaging materials contribute to 92.5 %. For the stage of A3, rough plane stage is the main contributor, which account for 22.4%. For the stage of A4, the transport of domestic market accounts for 5.2%.

When considering the stage of end of life, photochemical oxidation become negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(10) Acidification

In the impact category of acidification, to produce traditional product, A4 dominates the contribution with 39.9% of impact, the stage A1 contributes to 36.6%, the stage A3 contributes to 22.9%. Regarding A1, the packaging materials contribute to 83.7%. For the stage of A3, rough plane stage is the main contributor, which account for 22.4%. For the stage of A4, the transport of domestic market accounts for 4.0%.

When considering the stage of end of life, acidification become negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(11) Eutrophication

In the impact category of eutrophication, to produce traditional product, A1 dominates the contribution with 34.8% of impact, the stage A3 contributes to 34.5%, the stage A4 contributes to 29.5%. Regarding A1, the packaging materials contribute to 88.4%. For the stage of A3, rough plane stage is the main contributor, which account for 22.4%. For the stage of A4, the transport of domestic market accounts for 7.7%.

When considering the stage of end of life, eutrophication is positive. The eutrophication from end of life accounts for 28.5% of the total.

Table 18 Environment impacts of dasso traditional bamboo

Impact category	Unit	A1 Raw materials	A2 Transport materials	A3Manufacturing	A4Transport-product	C End of life-CN	D Benefits
Abiotic depletion	kg Sb eq	8.0E-07	1.7E-08	2.0E-07	1.4E-07	2.5E-05	0.0E+00
Abiotic depletion (fossil fuels)	MJ	7.1E+00	2.0E-01	4.7E+00	2.7E+00	-8.2E+00	0.0E+00
Global warming (GWP100a)	kg CO2 eq	3.9E-01	1.2E-02	4.5E-01	1.7E-01	-2.2E+00	0.0E+00
Ozone layer depletion (ODP)	kg CFC-11 eq	9.8E-09	2.1E-09	1.9E-08	2.9E-08	4.9E-07	0.0E+00
Human toxicity	kg 1,4-DB eq	2.9E-01	4.8E-03	1.7E-01	7.1E-02	3.0E-01	0.0E+00
Fresh water aquatic ecotox.	kg 1,4-DB eq	6.2E-02	2.0E-03	1.6E-01	2.8E-02	5.8E-01	0.0E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.6E+02	6.2E+00	6.7E+02	8.7E+01	-1.1E+03	0.0E+00
Terrestrial ecotoxicity	kg 1,4-DB eq	1.1E-03	1.7E-05	8.8E-04	2.6E-04	1.1E-01	0.0E+00
Photochemical oxidation	kg C2H4 eq	2.1E-04	2.1E-06	7.1E-05	1.0E-04	-5.6E-04	0.0E+00
Acidification	kg SO2 eq	2.9E-03	4.8E-05	1.8E-03	3.1E-03	-1.8E-02	0.0E+00
Eutrophication	kg PO4--- eq	4.6E-04	1.6E-05	4.5E-04	3.9E-04	5.2E-04	0.0E+00

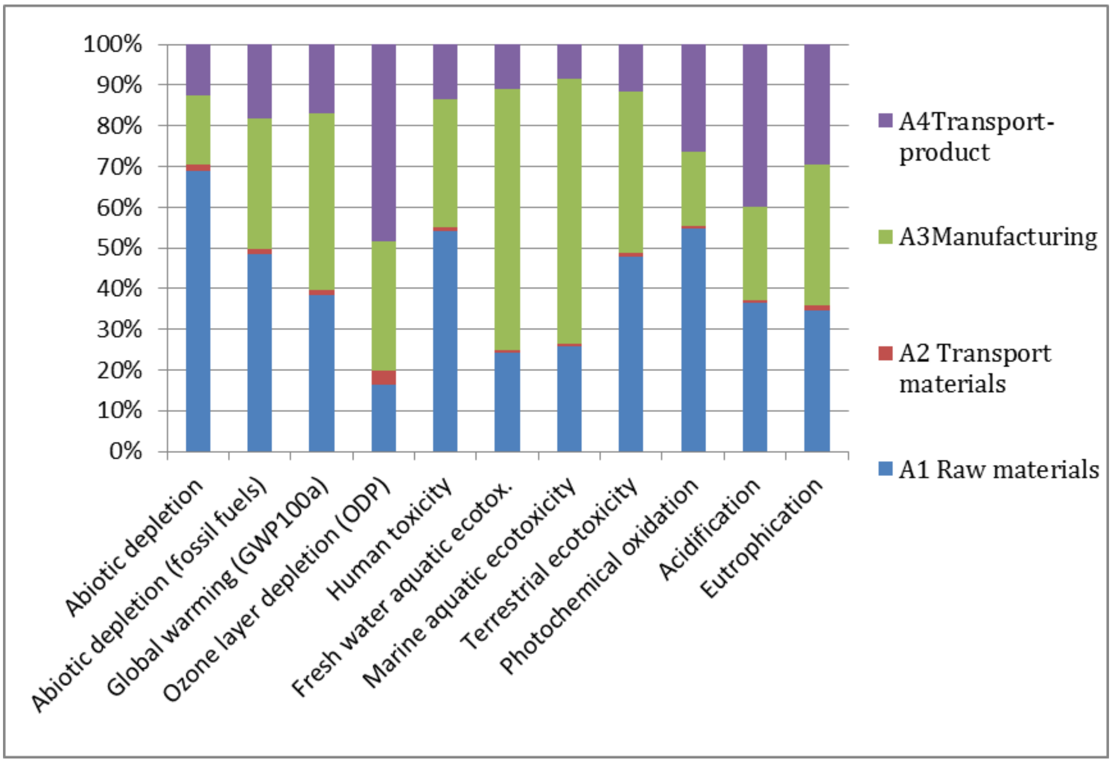


Figure 9 Life cycle contributions of dasso traditional producttion

6.3.2 dasso Ecosolid

For the product of dasso Ecosolid, the main contributors for environment impacts are A1 raw materials and A3 manufacturing. Each environment impact has a different characteristic of life cycle stage contribution. When considering the stage of end of life, global warming potential, acidification, and photochemical oxidation are negative.

(1) Abiotic depletion

In the impact category of abiotic depletion, A1 dominates the contribution with 67.1% of impact, the stage A3 contributes to 23.9%, the stage A4 contributes to 7.6%. Regarding A1, the packaging materials contribute to 96.5 %. For the stage of A3, profiling stage is the main contributor, which account for 28.8%. For the stage of A4, the transport of overseas market accounts for 98.2%.

When considering the stage of end of life, abiotic depletion is positive. The eutrophication from end of life accounts for 96.0% of the total.

(2) Abiotic depletion (fossil fuels)

In the impact category of abiotic depletion (fossil fuels), to produce traditional product, A1 dominates the contribution with 41.5% of impact, the stage A3 contributes to 37.0%, the stage A4 contributes to 20.4%. Regarding A1, the packaging materials contribute to 59.8%. For the stage of A3, rough plane stage is the main contributor, which account for 22.4%. For the stage of A4, the transport of overseas market accounts for 99.7%.

When considering the stage of end of life, abiotic depletion (fossil fuels) in this stage is negative. However, the total abiotic depletion (fossil fuels) is still positive. The environmental benefit of bamboo flooring waste-based power generation cannot compensates the environmental impacts of the production process (A1-A4).

(3) Global warming potential (GWP100)

In the impact category of global warming potential, A3 dominates the contribution with 49.0% of impact, the stage A1 contributes to 31.2%, the stage A4 contributes to 18.8%. Regarding A1, the packaging materials contribute to 76.9 %. For the stage of A3, profiling stage is the main contributor, which account for 28.8%. For the stage of A4, the transport of overseas market accounts for 99.8%.

When considering the stage of end of life, global warming potential become negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(4) Ozone layer depletion (ODP)

In the impact category of ozone layer depletion, A4 dominates the contribution with 50.6% of impact, the stage A3 contributes to 34.7%, the stage A3 contributes to 12.6%. Regarding A1, the packaging materials contribute to 97.4 %. For the stage of A3, profiling stage is the main contributor, which account for 28.8%. For the stage of A4, the transport of overseas market accounts for 99.7%.

When considering the stage of end of life, ozone layer depletion is positive. The ozone layer depletion from end of life accounts for 87.8% of the total.

(5) Human toxicity

In the impact category of human toxicity, A1 dominates the contribution with 45.4% of impact, the stage A3 contributes to 37.6%, the stage A4 contributes to 16.3%. Regarding A1, the packaging materials contribute to 97.9 %. For the stage of A3, profiling stage is the main contributor, which account for 28.8%. For the stage of A4, the transport of overseas market accounts for 99.8 %.

When considering the stage of end of life, human toxicity is positive. The human toxicity from end of life accounts for 35.5% of the total.

(6) Fresh water aquatic ecotox.

In the impact category of fresh water aquatic ecotox., A3 dominates the contribution with 68.5% of impact, the stage A1 contributes to 18.2%, the stage A4 contributes to 12.7%. Regarding A1, the packaging materials contribute to 95.5%. For the stage of A3, profiling stage is the main contributor, which account for 28.8%. For the stage of A4, the transport of overseas market accounts for 99.9%.

When considering the stage of end of life, fresh water aquatic ecotox. is positive. The fresh water aquatic ecotox. from end of life accounts for 66.5% of the total.

(7) Marine aquatic ecotoxicity

In the impact category of marine aquatic ecotoxicity, A3 dominates the contribution with 70.1% of impact, the stage A1 contributes to 19.5%, the stage A4 contributes to 9.9%. Regarding A1, the packaging materials contribute to 97.4 %. For the stage of A3, profiling stage is the main contributor, which account for 28.8%. For the stage of A4, the transport of overseas market accounts for 99.9 %.

When considering the stage of end of life, marine aquatic ecotoxicity in this stage is negative. The total marine aquatic ecotoxicity become negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(8) Terrestrial ecotoxicity

In the impact category of terrestrial ecotoxicity, A3 dominates the contribution with 45.7% of impact, the stage A1 contributes to 40.5%, the stage A4 contributes to 13.1%. Regarding A1, the packaging materials contribute to 55.1 %. For the stage of A3, profiling stage is the main contributor, which account for 28.8%. For the stage of A4, the transport of overseas market accounts for 99.8%.

When considering the stage of end of life, terrestrial ecotoxicity is positive. The terrestrial ecotoxicity from end of life accounts for 97.8% of the total.

(9) Photochemical oxidation

In the impact category of photochemical oxidation, A1 dominates the contribution with 44.4% of impact, the stage A4 contributes to 34.3%, the stage A3 contributes to 20.8%. Regarding A1, the packaging materials contribute to 91.6 %. For the stage of A3, profiling stage is the main contributor, which account for 28.8%. For the stage of A4, the transport of overseas market accounts for 99.9%.

When considering the stage of end of life, photochemical oxidation becomes negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(10) Acidification

In the impact category of acidification, A4 dominates the contribution with 48.1% of impact, the stage A1 contributes to 27.4%, the stage A3 contributes to 24.0%. Regarding A1, the packaging materials contribute to 81.9 %. For the stage of A3, profiling stage is the main contributor, which account for 28.8%. For the stage of A4, the transport of overseas market accounts for 99.9%.

When considering the stage of end of life, acidification becomes negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(11) Eutrophication

In the impact category of eutrophication, A3 dominates the contribution with 37.3% of impact, the stage A4 contributes to 35.1%, the stage A1 contributes to 26.7%. Regarding A1, the packaging materials contribute to 86.8 %. For the stage of A3, profiling stage is the main contributor, which account for 28.8%. For the stage of A4, the transport of overseas market accounts for 99.9%.

When considering the stage of end of life, eutrophication is positive. The eutrophication from end of life accounts for 25.8% of the total.

Table 19 Environment impacts of dasso Ecosolid

Impact category	Unit	A1Raw materials	A2Trans port-material	A3Manu facturing	A4Trans port-product	C End of life-CN	D Benefits
Abiotic depletion	kg Sb eq	7.0E-07	1.5E-08	2.5E-07	7.9E-08	2.5E-05	0.0E+00
Abiotic depletion (fossil fuels)	MJ	6.5E+00	1.7E-01	5.8E+00	3.2E+00	-8.2E+00	0.0E+00
Global warming (GWP100a)	kg CO2 eq	3.5E-01	1.1E-02	5.5E-01	2.1E-01	-2.2E+00	0.0E+00
Ozone layer depletion (ODP)	kg CFC-11 eq	8.5E-09	1.4E-09	2.3E-08	3.4E-08	4.9E-07	0.0E+00
Human toxicity	kg 1,4-DB eq	2.5E-01	3.6E-03	2.1E-01	9.0E-02	3.0E-01	0.0E+00
Fresh water aquatic ecotox.	kg 1,4-DB eq	5.4E-02	1.8E-03	2.0E-01	3.7E-02	5.8E-01	0.0E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.3E+02	5.8E+00	8.2E+02	1.2E+02	-1.1E+03	0.0E+00
Terrestrial ecotoxicity	kg 1,4-DB eq	9.7E-04	1.4E-05	1.1E-03	3.1E-04	1.1E-01	0.0E+00
Photochemical oxidation	kg C2H4 eq	1.9E-04	1.9E-06	8.8E-05	1.4E-04	-5.6E-04	0.0E+00
Acidification	kg SO2 eq	2.5E-03	4.6E-05	2.2E-03	4.5E-03	-1.8E-02	0.0E+00
Eutrophication	kg PO4--- eq	4.0E-04	1.4E-05	5.6E-04	5.3E-04	5.2E-04	0.0E+00

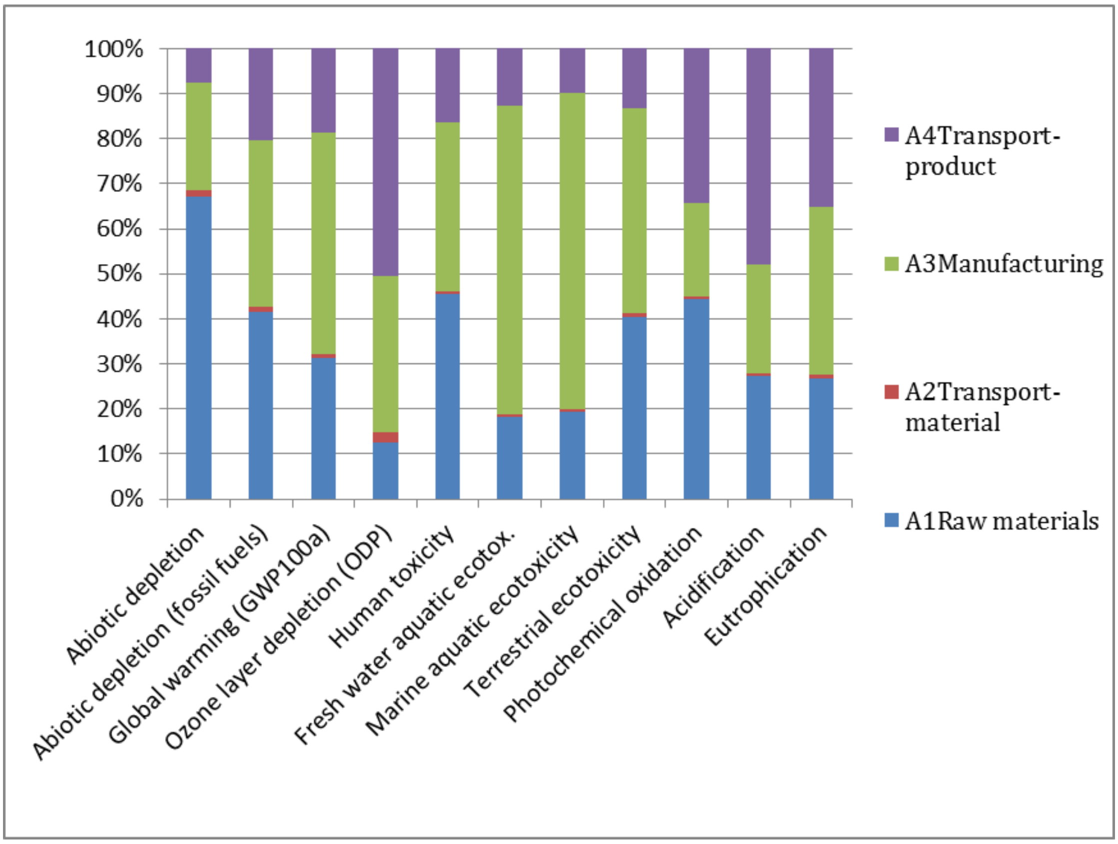


Figure 10 Life cycle contributions of dasso Ecosolid production

6.3.3 dasso strand woven bamboo

For the product of dasso strand woven bamboo, the main contributors for environment impacts are A1 raw materials and A4 transport of product. Each environment impact has a different characteristic of life cycle stage contribution. When considering the stage of end of life, global warming potential, marine aquatic ecotoxicity, acidification, and photochemical oxidation are negative.

(1) Abiotic depletion

In the impact category of abiotic depletion, A1 dominates the contribution with 67.8% of impact, the stage A4 contributes to 25.1%, the stage A3 contributes to 3.7%. Regarding A1, the packaging materials contribute to

92.1 %. For the stage of A3, drying stage is the main contributor, which account for 30.9 %. For the stage of A4, the transport of domestic market accounts for 100%.

When considering the stage of end of life, abiotic depletion is positive. The eutrophication from end of life accounts for 92.5% of the total.

(2) Abiotic depletion (fossil fuels)

In the impact category of abiotic depletion (fossil fuels), to produce traditional product, A1 dominates the contribution with 77.3% of impact, the stage A4 contributes to 12.2%, the stage A3 contributes to 7.3%. Regarding A1, the packaging materials contribute to 38.6%. For the stage of A3, rough plane stage is the main contributor, which account for 22.4%. For the stage of A4, the transport of overseas market accounts for 100%.

When considering the stage of end of life, abiotic depletion (fossil fuels) in this stage is negative. However, the total abiotic depletion (fossil fuels) is still positive. The environmental benefit of bamboo flooring waste-based power generation cannot compensates the environmental impacts of the production process (A1-A4).

(3) Global warming potential (GWP100)

In the impact category of global warming potential, A1 dominates the contribution with 68.5% of impact, the stage A4 contributes to 14.4%, the stage A3 contributes to 13.2%. Regarding A1, the packaging materials contribute to 58.1 %. For the stage of A3, drying stage is the main contributor, which account for 30.9 %. For the stage of A4, the transport of domestic market accounts for 100 %.

When considering the stage of end of life, global warming potential become negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(4) Ozone layer depletion (ODP)

In the impact category of ozone layer depletion, A4 dominates the contribution with 52.3% of impact, the stage A1 contributes to 27.5%, the stage A3 contributes to 11.1%. Regarding A1, the packaging materials contribute to 94.5 %. For the stage of A3, drying stage is the main contributor, which account for 30.9 %. For the stage of A4, the transport of domestic market accounts for 100 %.

When considering the stage of end of life, ozone layer depletion is positive. The ozone layer depletion from end of life accounts for 88.5% of the total.

(5) Human toxicity

In the impact category of human toxicity, A1 dominates the contribution with 77.3% of impact, the stage A3 contributes to 10.3%, the stage A4 contributes to 9.9%. Regarding A1, the packaging materials contribute to 95.2 %. For the stage of A3, drying stage is the main contributor, which account for 30.9 %. For the stage of A4, the transport of domestic market accounts for 100%.

When considering the stage of end of life, human toxicity is positive. The human toxicity from end of life accounts for 33.4% of the total.

(6) Fresh water aquatic ecotox.

In the impact category of fresh water aquatic ecotox., A1 dominates the contribution with 55.8% of impact, the stage A3 contributes to 31.9%, the stage A4 contributes to 8.4%. Regarding A1, the packaging materials contribute to 90.1%. F For the stage of A3, drying stage is the main contributor, which account for 30.9 %. For the stage of A4, the transport of domestic market accounts for 100%.

When considering the stage of end of life, fresh water aquatic ecotox. is positive. The fresh water aquatic ecotox. from end of life accounts for 75.5% of the total.

(7) Marine aquatic ecotoxicity

In the impact category of marine aquatic ecotoxicity, A1 dominates the contribution with 58.3% of impact, the stage A3 contributes to 32.2%, the stage A4 contributes to 6.4%. Regarding A1, the packaging materials contribute to 94.5 %. For the stage of A3, drying stage is the main contributor, which account for 30.9 %. For the stage of A4, the transport of domestic market accounts for 100 %.

When considering the stage of end of life, marine aquatic ecotoxicity become negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(8) Terrestrial ecotoxicity

In the impact category of terrestrial ecotoxicity, A1 dominates the contribution with 82.1% of impact, the stage A3 contributes to 9.3%, the stage A4 contributes to 6.9%. Regarding A1, the packaging materials contribute to 34.5 %. For the stage of A3, drying stage is the main contributor, which account for 30.9 %. For the stage of A4, the transport of domestic market accounts for 100 %.

When considering the stage of end of life, terrestrial ecotoxicity is positive. The terrestrial ecotoxicity from end of life accounts for 96.8% of the total.

(9) Photochemical oxidation

In the impact category of photochemical oxidation, A1 dominates the contribution with 85.8% of impact, the stage A4 contributes to 6.5%, the stage A3 contributes to 5.9%. Regarding A1, the packaging materials contribute to 81.1 %. For the stage of A3, drying stage is the main contributor, which account for 30.9 %. For the stage of A4, the transport of domestic market accounts for 100%.

When considering the stage of end of life, photochemical oxidation become negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(10) Acidification

In the impact category of acidification, A1 dominates the contribution with 78.8% of impact, the stage A4 contributes to 9.4%, the stage A3 contributes to 9.0%. With regard to A1, the packaging materials contribute to 65.4 %. For the stage of A3, drying stage is the main contributor, which account for 30.9 %. For the stage of A4, the transport of domestic market accounts for 100%.

When considering the stage of end of life, acidification becomes negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(11) Eutrophication

In the impact category of eutrophication, A1 dominates the contribution with 70.1% of impact, the stage A3 contributes to 12.8%, the stage A4 contributes to 12.5%. Regarding A1, the packaging materials contribute to 71.5 %. For the stage of A3, drying stage is the main contributor, which account for 30.9 %. For the stage of A4, the transport of domestic market accounts for 100 %.

When considering the stage of end of life, eutrophication is positive. The eutrophication from end of life accounts for 28.6% of the total.

Table 20 Environment impacts of dasso strand woven bamboo

Impact category	Unit	A1Raw materials	A2Transport-material	A3Manufacturing	A4Transport-product	C End of life-CN	D Benefits
Abiotic depletion	kg Sb eq	1.4E-06	7.0E-08	7.4E-08	5.0E-07	2.5E-05	0.0E+00
Abiotic depletion (fossil fuels)	MJ	1.8E+01	7.5E-01	1.7E+00	2.9E+00	-8.2E+00	0.0E+00
Global warming (GWP100a)	kg CO2 eq	8.6E-01	4.9E-02	1.6E-01	1.8E-01	-2.2E+00	0.0E+00
Ozone layer depletion (ODP)	kg CFC-11 eq	1.7E-08	5.8E-09	7.0E-09	3.3E-08	4.9E-07	0.0E+00
Human toxicity	kg 1,4-DB eq	4.6E-01	1.5E-02	6.2E-02	5.9E-02	3.0E-01	0.0E+00
Fresh water aquatic ecotox.	kg 1,4-DB eq	1.1E-01	7.4E-03	6.0E-02	1.6E-02	5.8E-01	0.0E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	4.5E+02	2.4E+01	2.5E+02	4.9E+01	-1.1E+03	0.0E+00
Terrestrial ecotoxicity	kg 1,4-DB eq	2.9E-03	6.2E-05	3.3E-04	2.4E-04	1.1E-01	0.0E+00
Photochemical oxidation	kg C2H4 eq	3.9E-04	8.1E-06	2.6E-05	2.9E-05	-5.6E-04	0.0E+00
Acidification	kg SO2 eq	5.8E-03	2.0E-04	6.7E-04	7.0E-04	-1.8E-02	0.0E+00
Eutrophication	kg PO4--- eq	9.2E-04	5.9E-05	1.7E-04	1.6E-04	5.2E-04	0.0E+00

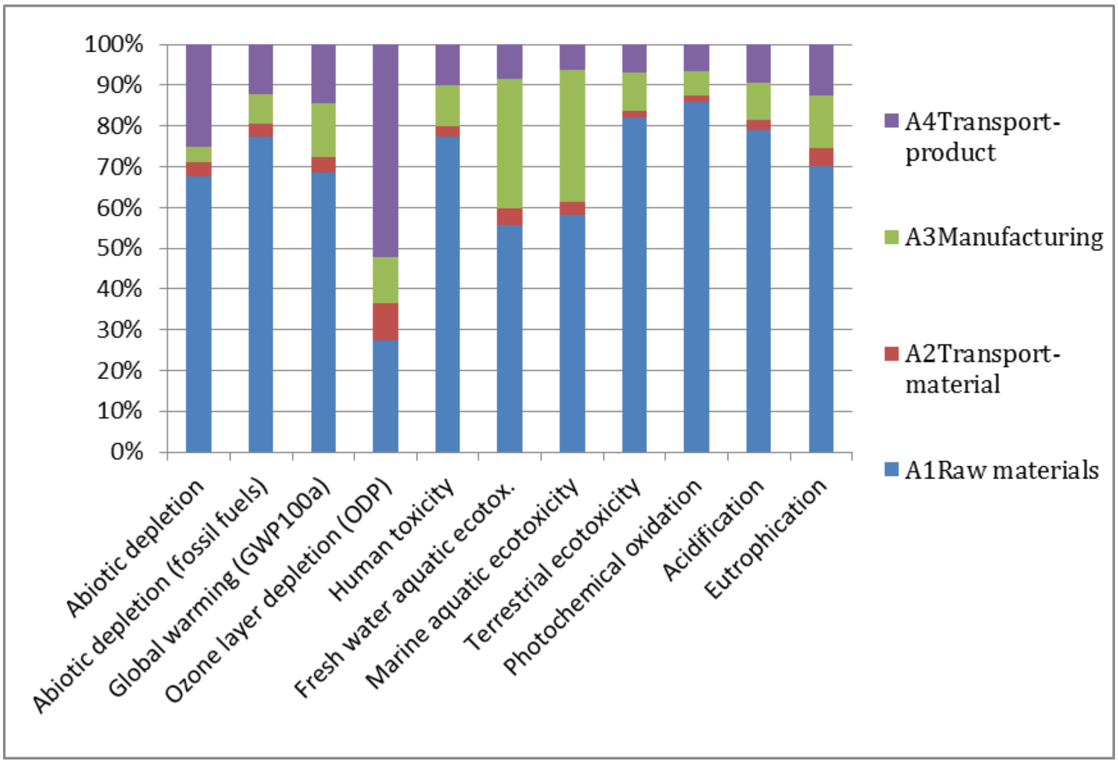


Figure 11 Life cycle contributions of dasso strand woven bamboo producition

6.3.4 dassoXTR

For the product of dassoXTR, the main contributors for environment impacts are A1 raw materials and A3 manufacturing. Each environment impact has a different characteristic of life cycle stage contribution. When considering the stage of end of life, marine aquatic ecotoxicity, acidification, global warming potential, and photochemical oxidation are negative.

(1) Abiotic depletion

In the impact category of abiotic depletion, A1 dominates the contribution with 70.0% of impact, the stage A4 contributes to 21.4%, the stage A3 contributes to 4.7%. Regarding A1, the packaging materials contribute to 91.5%. For the stage of A3, heat treated stage is the main contributor, which account for 23.7 %. For the stage of A4, the transport of domestic market accounts for 92.1%.

When considering the stage of end of life, abiotic depletion is positive. The eutrophication from end of life accounts for 93.2% of the total.

(2) Abiotic depletion (fossil fuels)

In the impact category of abiotic depletion (fossil fuels), to produce traditional product, A1 dominates the contribution with 74.7% of impact, the stage A4 contributes to 13.8%, the stage A3 contributes to 8.3%. Regarding A1, the packaging materials contribute to 36.5%. For the stage of A3, rough plane stage is the main contributor, which account for 23.7%. For the stage of A4, the transport of overseas market accounts for 62.1%.

When considering the stage of end of life, abiotic depletion (fossil fuels) in this stage is negative. However, the total abiotic depletion (fossil fuels) is still positive. The environmental benefit of bamboo flooring waste-based power generation cannot compensates the environmental impacts of the production process (A1-A4).

(3) Global warming potential (GWP100)

In the impact category of global warming potential, A1 dominates the contribution with 64.7% of impact, the stage A4 contributes to 16.5%, the stage A3 contributes to 14.9%. Regarding A1, the packaging materials contribute to 56.0 %. For the stage of A3, heat treated stage is the main contributor, which account for 23.7 %. For the stage of A4, the transport of domestic market accounts for 60.6%.

When considering the stage of end of life, global warming potential become negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(4) Ozone layer depletion (ODP)

In the impact category of ozone layer depletion, A4 dominates the contribution with 55.0% of impact, the stage A1 contributes to 24.2%, the stage A3 contributes to 12.1%. Regarding A1, the packaging materials contribute to 94.0 %. For the stage of A3, heat treated stage is the main contributor, which account for 23.7 %. For the stage of A4, the transport of domestic market accounts for 63.6%.

When considering the stage of end of life, ozone layer depletion is positive. The ozone layer depletion from end of life accounts for 88.0% of the total.

(5) Human toxicity

In the impact category of human toxicity, A1 dominates the contribution with 72.5% of impact, the stage A4 contributes to 13.0%, the stage A3 contributes to 12.0%. Regarding A1, the packaging materials contribute to 94.8 %. For the stage of A3, heat treated stage is the main contributor, which account for 23.7 %. For the stage of A4, the transport of domestic market accounts for 54.5%.

When considering the stage of end of life, human toxicity is positive. The human toxicity from end of life accounts for 33.9% of the total.

(6) Fresh water aquatic ecotox.

In the impact category of fresh water aquatic ecotox., A1 dominates the contribution with 48.9% of impact, the stage A3 contributes to 34.5%, the stage A4 contributes to 12.9%. Regarding A1, the packaging materials contribute to 89.2%. For the stage of A3, heat treated stage is the main contributor, which account for 23.7 %. For the stage of A4, the transport of domestic market accounts for 43.6 %.

When considering the stage of end of life, fresh water aquatic ecotox. is positive. The fresh water aquatic ecotox. from end of life accounts for 74.6% of the total.

(7) Marine aquatic ecotoxicity

In the impact category of marine aquatic ecotoxicity, A1 dominates the contribution with 51.6% of impact, the stage A3 contributes to 35.3%, the stage A4 contributes to 10.0%. Regarding A1, the packaging materials contribute to 94.0 %. For the stage of A3, heat treated stage is the main contributor, which account for 23.7 %. For the stage of A4, the transport of domestic market accounts for 43.2%.

When considering the stage of end of life, marine aquatic ecotoxicity become negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(8) Terrestrial ecotoxicity

In the impact category of terrestrial ecotoxicity, A1 dominates the contribution with 79.5% of impact, the stage A3 contributes to 10.5%, the stage A4 contributes to 8.2%. Regarding A1, the packaging materials contribute to 32.5 %. For the stage of A3, heat treated stage is the main contributor, which account for 23.7 %. For the stage of A4, the transport of domestic market accounts for 58.2%.

When considering the stage of end of life, terrestrial ecotoxicity b is positive. The terrestrial ecotoxicity from end of life accounts for 96.8% of the total.

(9) Photochemical oxidation

In the impact category of photochemical oxidation, A1 dominates the contribution with 75.8% of impact, the stage A3 contributes to 16.2%, the stage A4 contributes to 6.3%. Regarding A1, the packaging materials contribute to 79.6%. For the stage of A3, heat treated stage is the main contributor, which account for 23.7 %. For the stage of A4, the transport of domestic market accounts for 26.7%.

When considering the stage of end of life, photochemical oxidation become negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(10) Acidification

In the impact category of acidification, A1 dominates the contribution with 63.4% of impact, the stage A4 contributes to 25.5%, the stage A3 contributes to 8.7%. Regarding A1, the packaging materials contribute to 63.4 %. For the stage of A3, heat treated stage is the main contributor, which account for 23.7 %. For the stage of A4, the transport of domestic market accounts for 22.0 %.

When considering the stage of end of life, acidification becomes negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(11) Eutrophication

In the impact category of eutrophication, A1 dominates the contribution with 60.2% of impact, the stage A4 contributes to 22.3%, the stage A3 contributes to 13.3%. Regarding A1, the packaging materials contribute to 69.7 %. For the stage of A3, heat treated stage is the main contributor, which account for 23.7 %. For the stage of A4, the transport of domestic market accounts for 35.8%.

When considering the stage of end of life, eutrophication is positive. The eutrophication from end of life accounts for 26.8% of the total.

Table 21 Environment impacts of dassoXTR

Impact category	Unit	A1Raw materials	A2Transport-material	A3Manufacturing	A4Transport-product	C End of life-CN	D Benefits
Abiotic depletion	kg Sb eq	1.3E-06	7.0E-08	8.5E-08	3.8E-07	2.5E-05	0.0E+00
Abiotic depletion (fossil fuels)	MJ	1.8E+01	7.5E-01	2.0E+00	3.3E+00	-8.2E+00	0.0E+00
Global warming (GWP100a)	kg CO2 eq	8.1E-01	4.9E-02	1.9E-01	2.1E-01	-2.2E+00	0.0E+00
Ozone layer depletion (ODP)	kg CFC-11 eq	1.6E-08	5.8E-09	8.0E-09	3.6E-08	4.9E-07	0.0E+00
Human toxicity	kg 1,4-DB eq	4.3E-01	1.5E-02	7.0E-02	7.6E-02	3.0E-01	0.0E+00
Fresh water aquatic ecotox.	kg 1,4-DB eq	9.8E-02	7.4E-03	6.9E-02	2.6E-02	5.8E-01	0.0E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	4.1E+02	2.4E+01	2.8E+02	7.9E+01	-1.1E+03	0.0E+00
Terrestrial ecotoxicity	kg 1,4-DB eq	2.8E-03	6.2E-05	3.7E-04	2.9E-04	1.1E-01	0.0E+00
Photochemical oxidation	kg C2H4 eq	3.6E-04	8.1E-06	3.0E-05	7.7E-05	-5.6E-04	0.0E+00
Acidification	kg SO2 eq	5.5E-03	2.0E-04	7.6E-04	2.2E-03	-1.8E-02	0.0E+00
Eutrophication	kg PO4--- eq	8.6E-04	5.9E-05	1.9E-04	3.2E-04	5.2E-04	0.0E+00

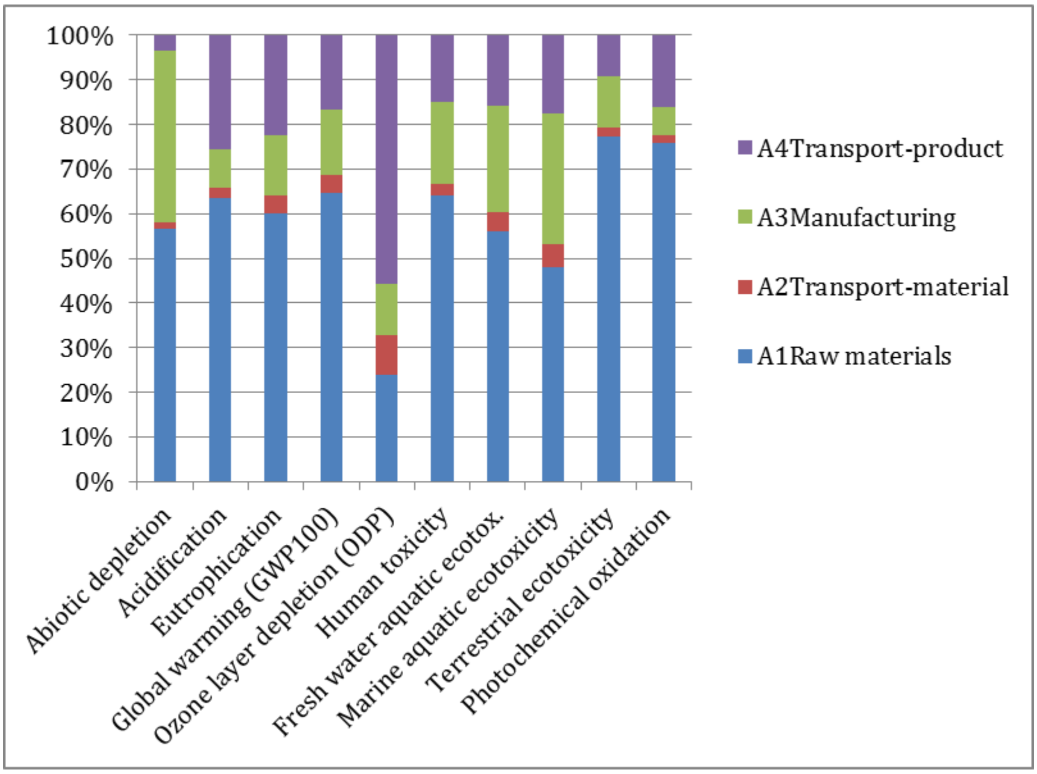


Figure 12 Life cycle contributions of dassoXRD production

6.3.5 dassoCTECH

For the product of dassoCTECH, the main contributors for environment impacts are A1 raw materials and A3 manufacturing. Each environment impact has a different characteristic of life cycle stage contribution. When considering the stage of end of life, the impact of acidification, global warming potential, marine aquatic ecotoxicity and photochemical oxidation is negative.

(1) Abiotic depletion

In the impact category of abiotic depletion, A1 dominates the contribution with 65.0% of impact, the stage A4 contributes to 26.4%, the stage A3 contributes to 4.7%. Regarding A1, the packaging materials contribute to 90.8 %. For the stage of A3, drying stage is the main contributor, which account for 24.8 %. For the stage of A4, the transport of domestic market accounts for 95.4 %.

When considering the stage of end of life, abiotic depletion is positive. The eutrophication from end of life accounts for 93.2% of the total.

(2) Abiotic depletion (fossil fuels)

In the impact category of abiotic depletion (fossil fuels), to produce traditional product, A1 dominates the contribution with 73.5% of impact, the stage A4 contributes to 14.9%, the stage A3 contributes to 8.3%. Regarding A1, the packaging materials contribute to 34.6%. For the stage of A3, rough plane stage is the main contributor, which account for 24.8%. For the stage of A4, the transport of overseas market accounts for 74.4%.

When considering the stage of end of life, abiotic depletion (fossil fuels) in this stage is negative. However, the total abiotic depletion (fossil fuels) is still positive. The environmental benefit of bamboo flooring waste-based power generation cannot compensates the environmental impacts of the production process (A1-A4).

(3) Global warming potential (GWP100)

In the impact category of global warming potential, A1 dominates the contribution with 63.1% of impact, the stage A4 contributes to 17.9%, the stage A3 contributes to 15.1%. Regarding A1, the packaging materials contribute to 53.9%. For the stage of A3, drying stage is the main contributor, which account for 24.8 %. For the stage of A4, the transport of domestic market accounts for 73.2%.

When considering the stage of end of life, global warming potential become negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(4) Ozone layer depletion (ODP)

In the impact category of ozone layer depletion, A4 dominates the contribution with 57.9% of impact, the stage A1 contributes to 21.8%, the stage A3 contributes to 11.7%. Regarding A1, the packaging materials contribute to 93.5%. For the stage of A3, drying stage is the main contributor, which account for 24.8 %. For the stage of A4, the transport of domestic market accounts for 75.7%.

When considering the stage of end of life, ozone layer depletion is positive. The ozone layer depletion from end of life accounts for 87.8% of the total.

(5) Human toxicity

In the impact category of human toxicity, A1 dominates the contribution with 70.7% of impact, the stage A4 contributes to 14.1%, the stage A3 contributes to 12.5%. Regarding A1, the packaging materials contribute to 94.3%. For the stage of A3, drying stage is the main contributor, which account for 24.8 %. For the stage of A4, the transport of domestic market accounts for 68.0%.

When considering the stage of end of life, human toxicity is positive. The human toxicity from end of life accounts for 35.1% of the total.

(6) Fresh water aquatic ecotox.

In the impact category of fresh water aquatic ecotox., A1 dominates the contribution with 47.4% of impact, the stage A3 contributes to 35.7%, the stage A4 contributes to 13.0%. Regarding A1, the packaging materials contribute to 88.4 %. For the stage of A3, drying stage is the main contributor, which account for 24.8 %. For the stage of A4, the transport of domestic market accounts for 57.8 %.

When considering the stage of end of life, fresh water aquatic ecotox. is positive. The fresh water aquatic ecotox. from end of life accounts for 75.4% of the total.

(7) Marine aquatic ecotoxicity

In the impact category of marine aquatic ecotoxicity, A1 dominates the contribution with 50.1% of impact, the stage A3 contributes to 36.7%, the stage A4 contributes to 10.1%. Regarding A1, the packaging materials contribute to 93.5%. For the stage of A3, drying stage is the main contributor, which account for 24.8 %. For the stage of A4, the transport of domestic market accounts for 57.4%.

When considering the stage of end of life, marine aquatic ecotoxicity become negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(8) Terrestrial ecotoxicity

In the impact category of terrestrial ecotoxicity, A1 dominates the contribution with 78.8% of impact, the stage A3 contributes to 10.6%, the stage A4 contributes to 8.8%. Regarding A1, the packaging materials contribute to 30.7 %. For the stage of A3, drying stage is the main contributor, which account for 24.8 %. For the stage of A4, the transport of domestic market accounts for 71.3%.

When considering the stage of end of life, terrestrial ecotoxicity is positive. The terrestrial ecotoxicity from end of life accounts for 96.9% of the total.

(9) Photochemical oxidation

In the impact category of photochemical oxidation, A1 dominates the contribution with 76.3% of impact, the stage A4 contributes to 15.1%, the stage A3 contributes to 6.7%. Regarding A1, the packaging materials contribute to 78.2 %. For the stage of A3, drying stage is the main contributor, which account for 24.8 %. For the stage of A4, the transport of domestic market accounts for 39.3%.

When considering the stage of end of life, photochemical oxidation become negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(10) Acidification

In the impact category of acidification, A1 dominates the contribution with 64.9% of impact, the stage A4 contributes to 23.2%, the stage A3 contributes to 9.3%. Regarding A1, the packaging materials contribute to 61.4 %. For the stage of A3, drying stage is the main contributor, which account for 24.8 %. For the stage of A4, the transport of domestic market accounts for 33.4%.

When considering the stage of end of life, acidification becomes negative. The environmental benefit of bamboo flooring waste-based power generation compensates the environmental impacts of the production process (A1-A4).

(11) Eutrophication

In the impact category of eutrophication, A1 dominates the contribution with 60.6% of impact, the stage A4 contributes to 21.7%, the stage A3 contributes to 13.9%. Regarding A1, the packaging materials contribute to 67.9%. For the stage of A3, drying stage is the main contributor, which account for 24.8 %. For the stage of A4, the transport of domestic market accounts for 49.8%.

When considering the stage of end of life, eutrophication is positive. The eutrophication from end of life accounts for 27.9% of the total.

Table 22 Environment impacts of dassoCTECH

Impact category	Unit	A1Raw materials	A2Trans port-material	A3Manufa cturing	A4Transpor t-product	C End of life-CN	D Benefits
Abiotic depletion	kg Sb eq	1.2E-06	7.0E-08	8.4E-08	4.7E-07	2.5E-05	0.0E+00
Abiotic depletion (fossil fuels)	MJ	1.7E+01	7.5E-01	1.9E+00	3.5E+00	-8.2E+00	0.0E+00
Global warming (GWP100a)	kg CO2 eq	7.8E-01	4.9E-02	1.9E-01	2.2E-01	-2.2E+00	0.0E+00
Ozone layer depletion (ODP)	kg CFC-11 eq	1.5E-08	5.8E-09	7.9E-09	3.9E-08	4.9E-07	0.0E+00
Human toxicity	kg 1,4-DB eq	3.9E-01	1.5E-02	7.0E-02	7.8E-02	3.0E-01	0.0E+00
Fresh water aquatic ecotox.	kg 1,4-DB eq	9.1E-02	7.4E-03	6.8E-02	2.5E-02	5.8E-01	0.0E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	3.8E+02	2.4E+01	2.8E+02	7.6E+01	-1.1E+03	0.0E+00
Terrestrial ecotoxicity	kg 1,4-DB eq	2.7E-03	6.2E-05	3.7E-04	3.1E-04	1.1E-01	0.0E+00
Photochemi cal oxidation	kg C2H4 eq	3.4E-04	8.1E-06	3.0E-05	6.7E-05	-5.6E-04	0.0E+00
Acidification	kg SO2 eq	5.2E-03	2.0E-04	7.5E-04	1.9E-03	-1.8E-02	0.0E+00
Eutrophicati on	kg PO4--- eq	8.1E-04	5.9E-05	1.9E-04	2.9E-04	5.2E-04	0.0E+00

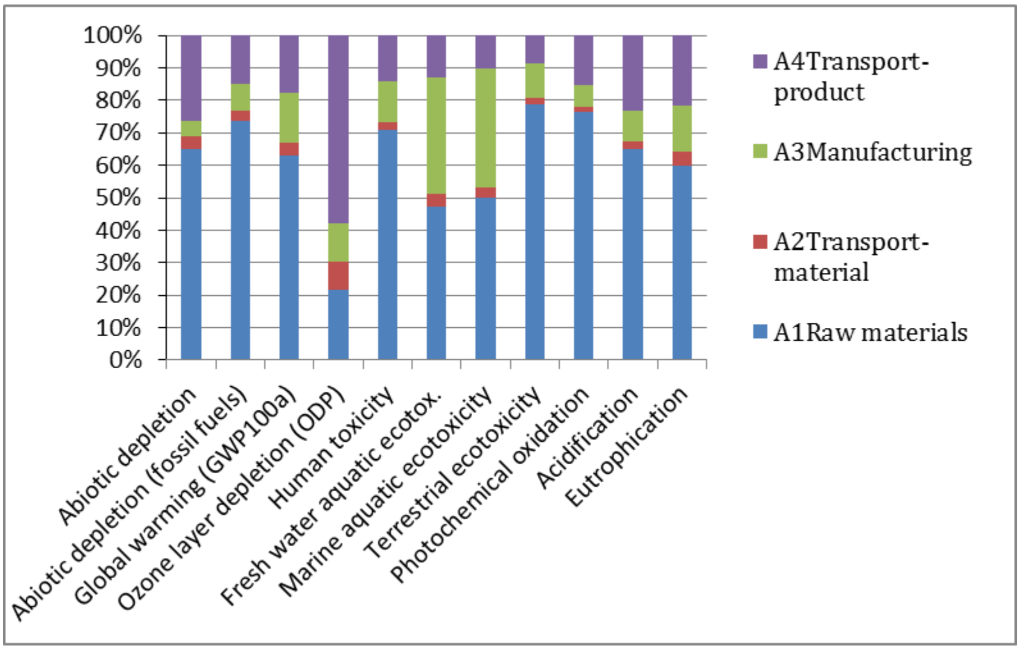


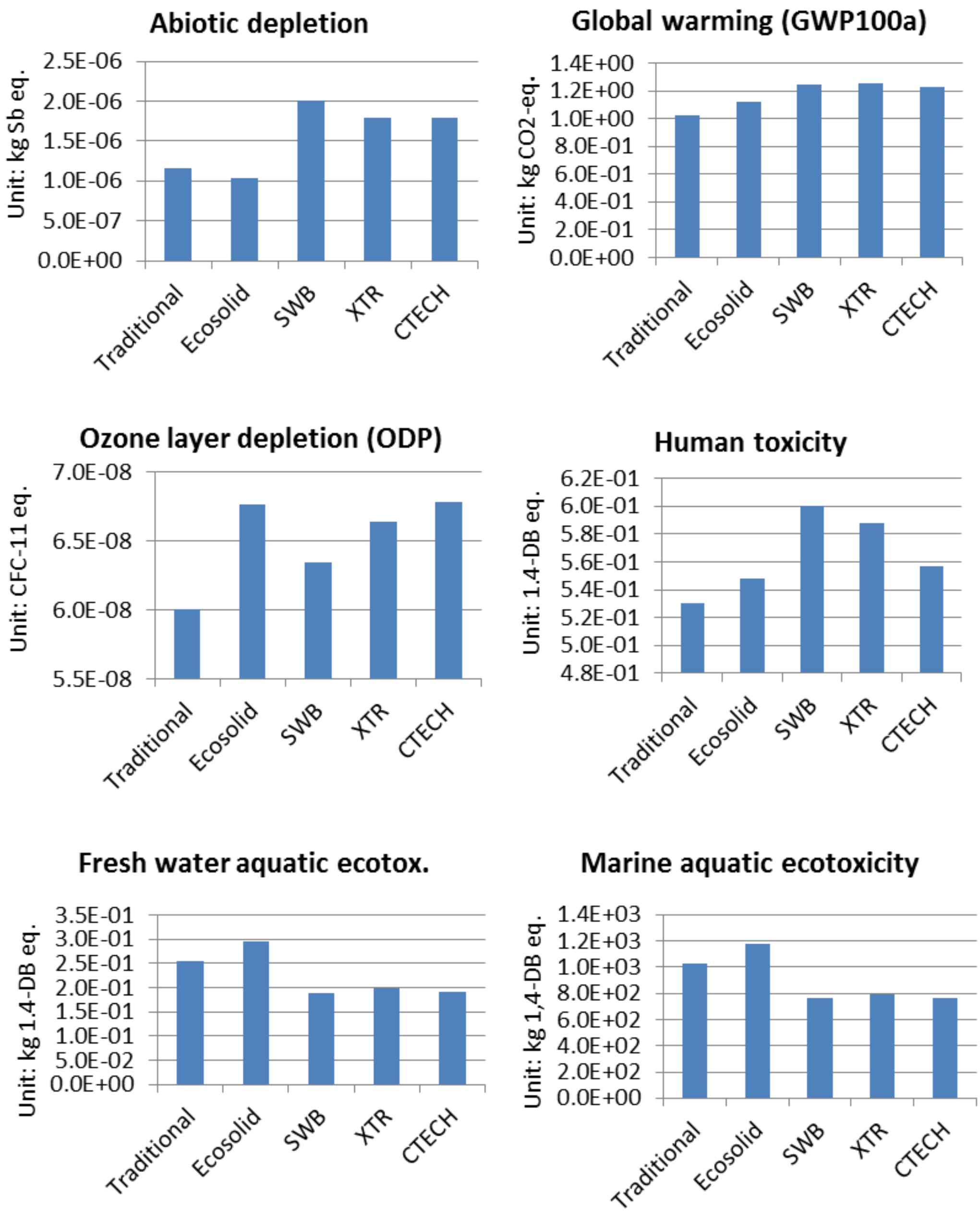
Figure 13 Life cycle contributions of dassoCTECH production

6.4 Comparison analysis of bamboo products

6.4.1 Comparison of environmental impact (A1-A4)

The environment impacts of five kinds of product are shown in figure. For environment impacts of Ozone layer depletion (ODP), Fresh water aquatic ecotoxicity, Acidification, Eutrophication, Marine aquatic ecotoxicity, the dasso Ecosolid bamboo product is the biggest one. For Photochemical oxidation, Terrestrial ecotoxicity, dasoXTR is the biggest one. For environment impacts of Abiotic depletion, Abiotic depletion(fossil fuels), Global warming (GWP100), Human toxicity, dasso strand woven bamboo is the biggest one.

In conclusion, the dasso Ecosolid bamboo has the heaviest environment burden, followed by dasso strand woven bamboo. The main reason is the A3 manufacturing stage. The manufacturing stage of dasso Ecosolid has more than 20 processes, which is the most among the five kinds of products. Processes such as removing outer joint, removing inner joint, width fixed, modeling etc. are the specific processes of dasso Ecosolid, which are electricity intensive.



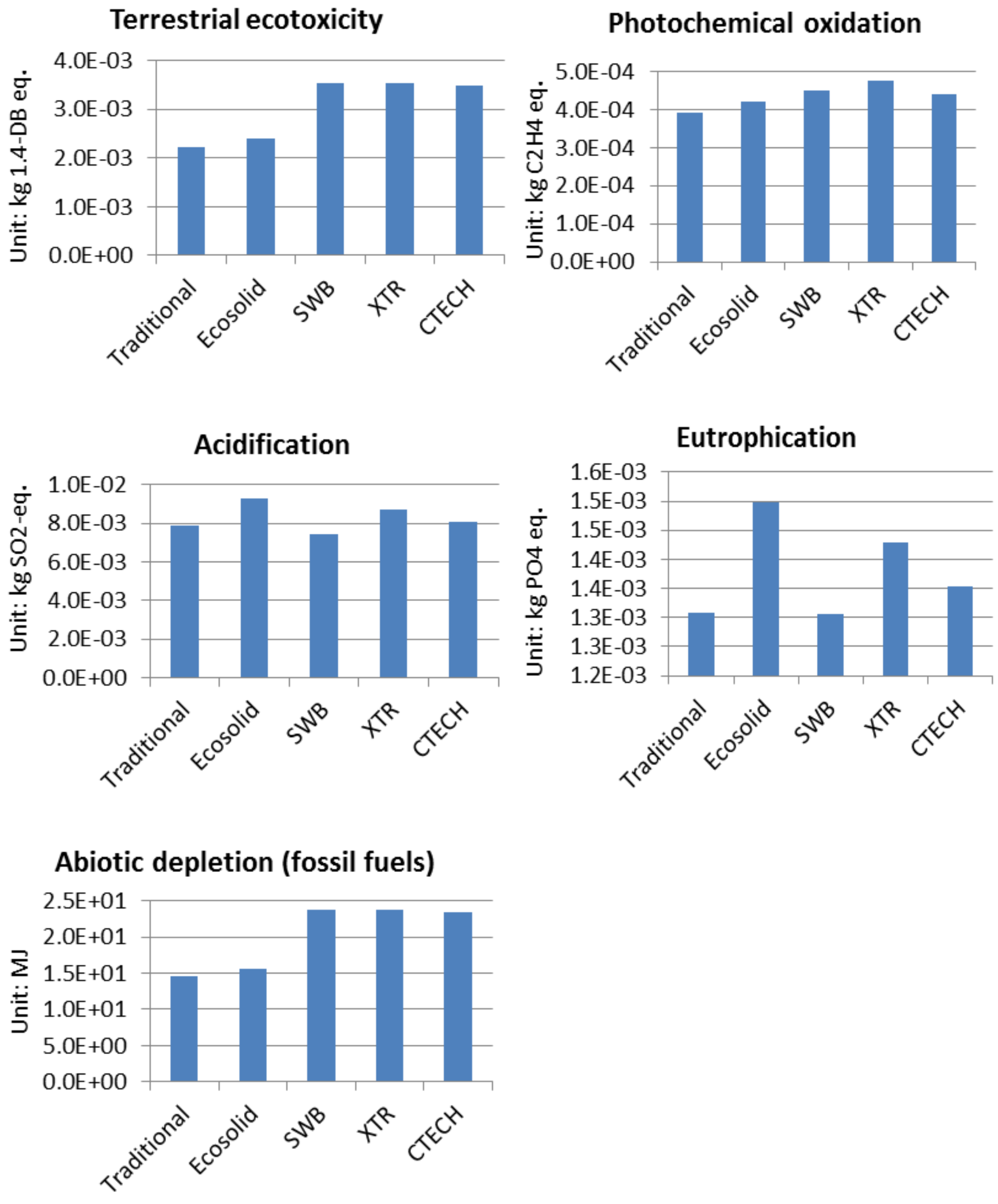


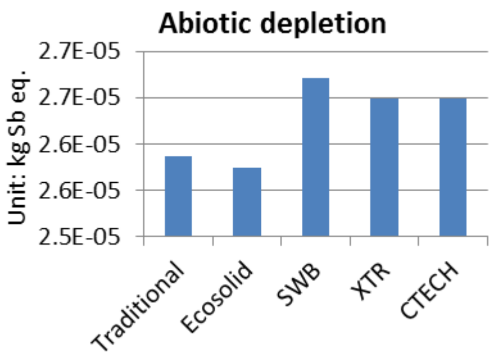
Figure 14 Life cycle environment impacts of A1-A4

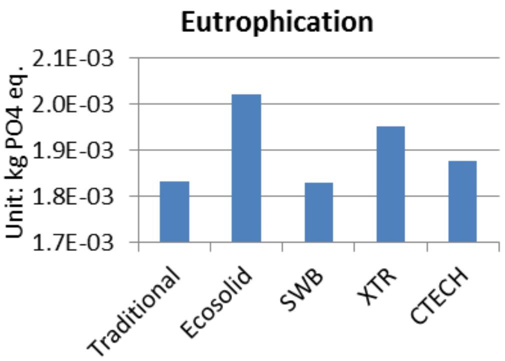
6.4.2 Comparison of environmental impact (A1-A4, C,D)

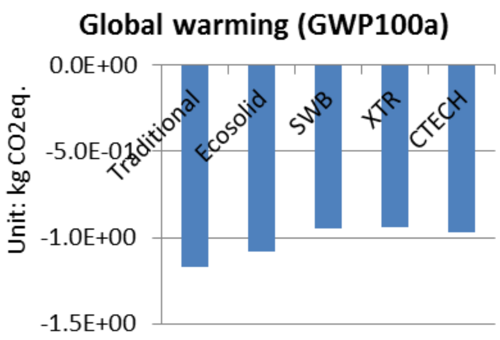
When stage of C-CN end of life was considered, the environment impacts of A1 to A4 changed a lot. Global warming potential, photochemical oxidation, acidification, and marine aquatic ecotoxicity becomes negative, however the other seven kinds of environment impacts is positive.

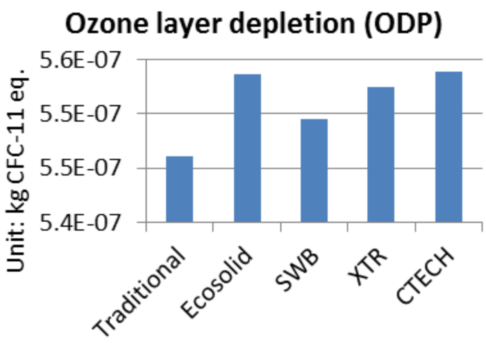
Regarding marine aquatic ecotoxicity, dassoCTECH has the most environment benefit. For acidification, dasso strand woven bamboo has the most environment benefit. For global warming potential, and photochemical oxidation, dasso traditional bamboo has the most environment benefit.

For environment impacts of Abiotic depletion, Abiotic depletion(fossil fuel), Human toxicity, dasso strand woven bamboo flooring is the biggest one, followed by dassoXTR. For Ozone layer depletion (ODP), Fresh water aquatic ecotoxicity, Eutrophication, dasso Ecosolid bamboo is the highest one. For Terrestrial ecotoxicity, dassoXTR is the highest one, followed by dasso strand woven bamboo.









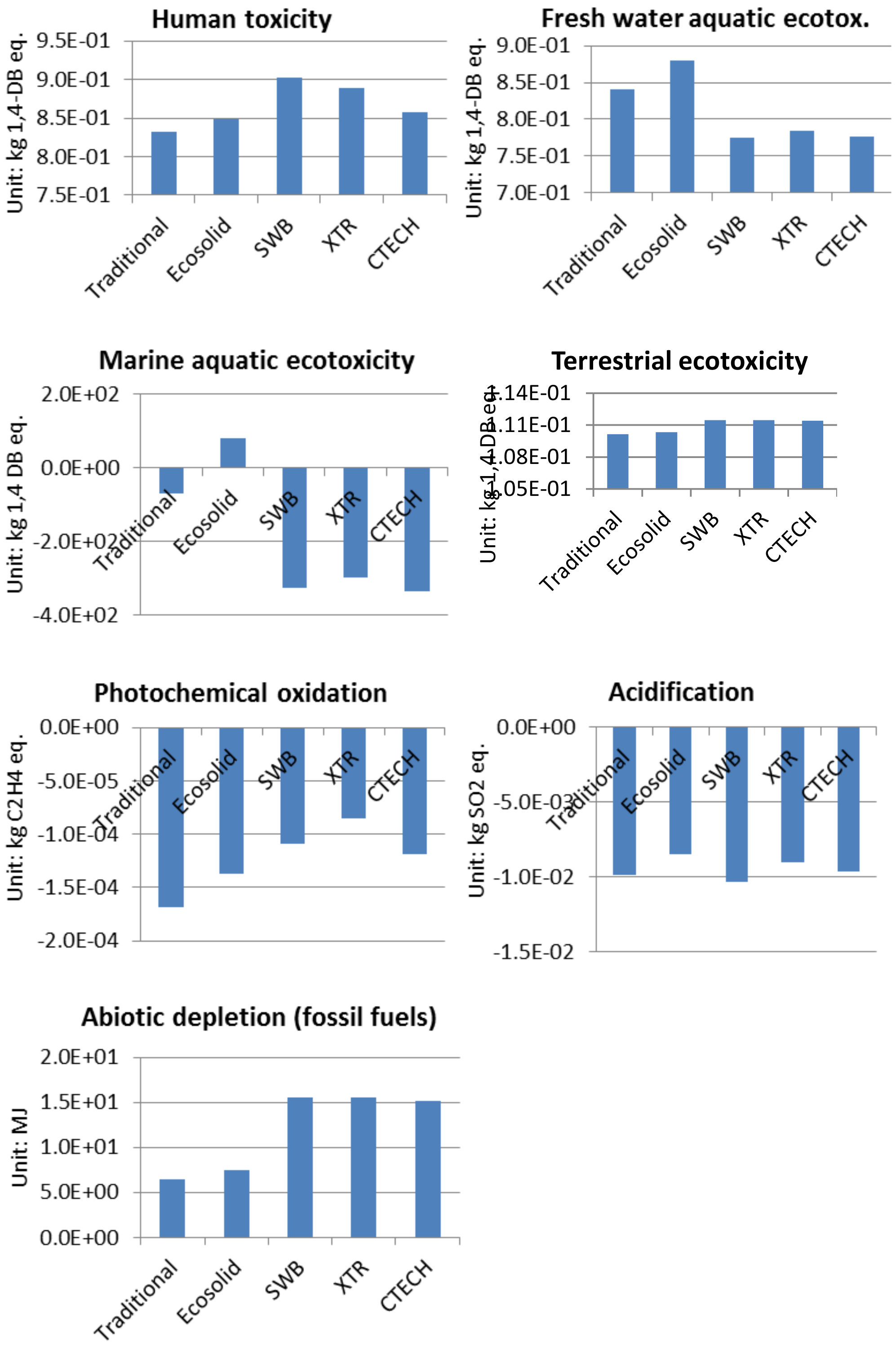


Figure 15 Life cycle environment impacts of A1-A4, C-CN and D

6.5 Discussion of benefit from end of life

When calculating benefit from end of life, China power generation scenario was adopted, however it might lead to overestimation of the benefit because the thermal power is dominant in China. Therefore, another scenario to replace the avoided product, i.e. electricity from China power generation based to EU average energy supply was simulated in this section.

6.5.1 Comparison of two scenarios at end of life

In the stage of end of life, for the product sold in China and oversea, the impact of global warming potential becomes positive due to the benefit of burning used bamboo product for energy i.e. electricity generation, hence avoiding potential CO2 emission, however since electricity generation is powered from various sources in China and oversea, in China most electricity was generated from coal and other non-renewable materials, meanwhile in Europe and many other developed countries, electricity is generated from largely non-coal based sources such as nuclear and water (hydropower), which means the level of reduction of CO2 emission and impact is different in China and oversea. Burning bamboo for electricity brings more environmental credit in China than burning in other developed countries, same results apply to impact category of Marine aquatic ecotoxicity, the impact becomes positive in both China and oversea market. But the patten does not apply to the rest 9 environment impacts categories, some impact categories become positive but others remains negative or even become worse off, due to the fact of pollutant emission during waste incineration process.

Comparing to scenario CN, the environment impacts of Eutrophication of end of life-EU has more credit. Two environment impacts including abiotic depletion and Terrestrial ecotoxicity are same in both scenario EU than CN. In the rest impact categories, EU scenario ends up with higher environmental impact or lower environmental credit than the CN scenario. The reason behind the difference is descripted in the paragraph above.

Table 23 Environment impact of end of life

Impact category	Unit	End of life-CN	End of life-EU
Abiotic depletion	kg Sb eq	2.5E-05	2.4E-05
Abiotic depletion (fossil fuels)	MJ	-8.2E+00	7.9E-01
Global warming (GWP100a)	kg CO2 eq	-2.2E+00	-7.2E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	4.9E-07	3.9E-07
Human toxicity	kg 1,4-DB eq	3.0E-01	2.8E-01
Fresh water aquatic ecotox.	kg 1,4-DB eq	5.8E-01	1.7E-01
Marine aquatic ecotoxicity	kg 1,4-DB eq	-1.1E+03	-4.3E+02
Terrestrial ecotoxicity	kg 1,4-DB eq	1.1E-01	1.1E-01
Photochemical oxidation	kg C2H4 eq	-5.6E-04	1.5E-04
Acidification	kg SO2 eq	-1.8E-02	9.9E-04
Eutrophication	kg PO4--- eq	5.2E-04	-8.6E-04

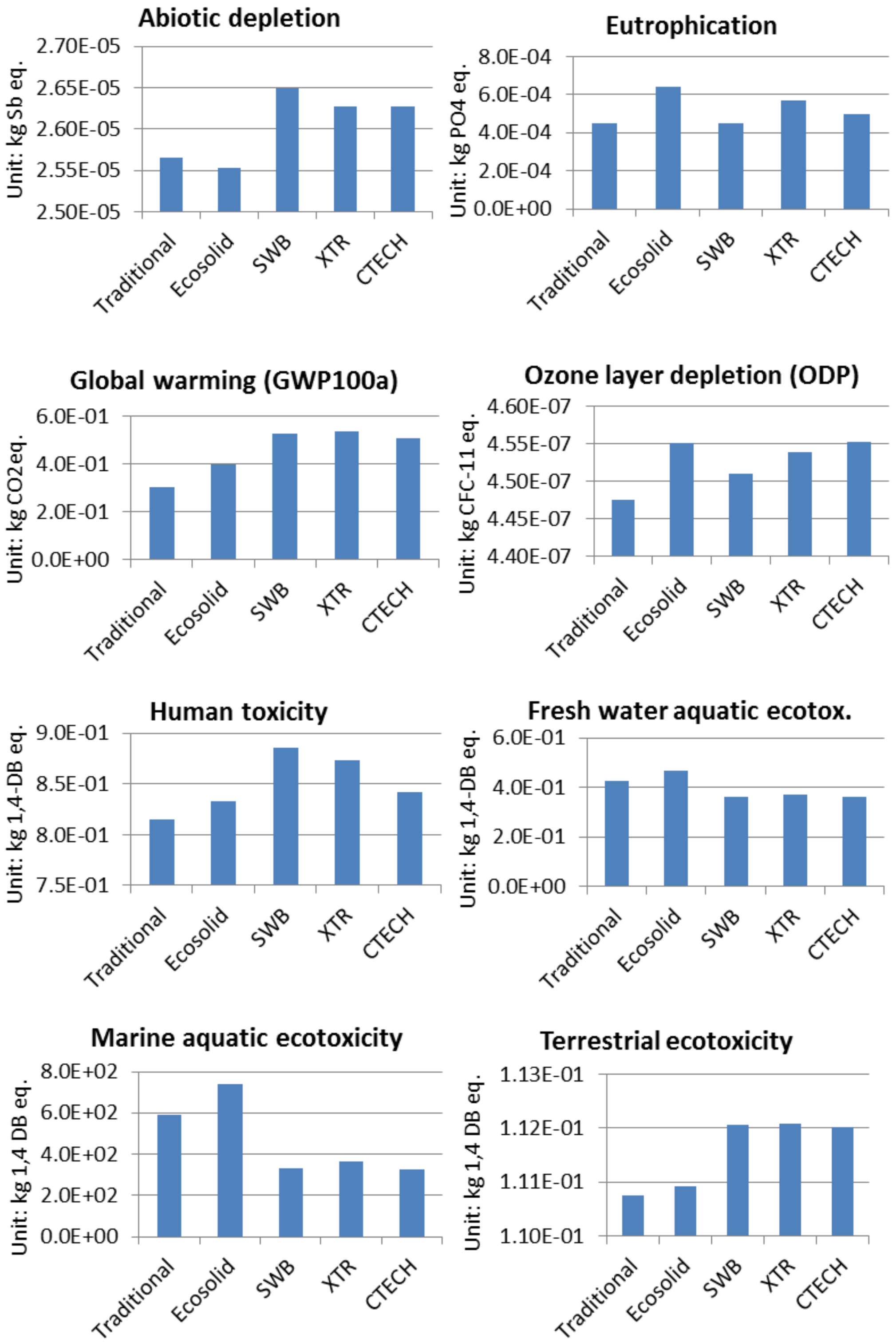
6.5.2 Environment impacts based on EU scenario

When consider the end of life using EU average electricity as avoided products, the environment impacts are shown in table. The results showed that there is no benefit under this scenario, although some kinds of environment impacts are negative.

Based on environment impact of A1-A4, considering scenario of end of life-EU, environment impacts of Abiotic depletion, Abiotic depletion (fossil fuels), Ozone layer depletion (ODP), Human toxicity, Fresh water aquatic ecotox., Terrestrial ecotoxicity, Photochemical oxidation, Acidification become worse. The environment impacts of Global warming (GWP100a), Marine aquatic ecotoxicity, and Eutrophication become smaller, but still positive although these environment impacts during end of life-EU are negative.

Table 24 life cycle environment impacts of product (A1-A4, C-EU,D)

Impact category	**Unit**	**Traditional**	**Ecosolid**	**SWB**	**XTR**	**CTECH**
Abiotic depletion	kg Sb eq	2.56E-05	2.55E-05	2.65E-05	2.63E-05	2.63E-05
Abiotic depletion (fossil fuels)	MJ	1.54E+01	1.64E+01	2.45E+01	2.45E+01	2.41E+01
Global warming (GWP100a)	kg CO2 eq	3.05E-01	4.00E-01	5.28E-01	5.36E-01	5.09E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	4.48E-07	4.55E-07	4.51E-07	4.54E-07	4.55E-07
Human toxicity	kg 1,4-DB eq	8.15E-01	8.33E-01	8.85E-01	8.73E-01	8.42E-01
Fresh water aquatic ecotox.	kg 1,4-DB eq	4.27E-01	4.67E-01	3.62E-01	3.72E-01	3.63E-01
Marine aquatic ecotoxicity	kg 1,4-DB eq	5.90E+02	7.41E+02	3.34E+02	3.62E+02	3.25E+02
Terrestrial ecotoxicity	kg 1,4-DB eq	1.11E-01	1.11E-01	1.12E-01	1.12E-01	1.12E-01
Photochemical oxidation	kg C2H4 eq	5.43E-04	5.74E-04	6.02E-04	6.26E-04	5.93E-04
Acidification	kg SO2 eq	8.86E-03	1.03E-02	8.41E-03	9.70E-03	9.06E-03
Eutrophication	kg PO4--- eq	4.52E-04	6.42E-04	4.49E-04	5.71E-04	4.96E-04


Abiotic depletion
Unit: kg Sb eq.
2.70E-05
2.65E-05
2.60E-05
2.55E-05
2.50E-05
Eutrophication
Unit: kg PO4 eq.
8.0E-04
6.0E-04
4.0E-04
2.0E-04
0.0E+00
Global warming (GWP100a)
Unit: kg CO2eq.
6.0E-01
4.0E-01
2.0E-01
0.0E+00
Ozone layer depletion (ODP)
Unit: kg CFC-11 eq.
4.60E-07
4.55E-07
4.50E-07
4.45E-07
4.40E-07
Human toxicity
Unit: kg 1,4-DB eq.
9.0E-01
8.5E-01
8.0E-01
7.5E-01
Fresh water aquatic ecotox.
Unit: kg 1,4-DB eq.
6.0E-01
4.0E-01
2.0E-01
0.0E+00
Marine aquatic ecotoxicity
Unit: kg 1,4 DB eq.
8.0E+02
6.0E+02
4.0E+02
2.0E+02
0.0E+00
Terrestrial ecotoxicity
Unit: kg 1,4 DB eq.
1.13E-01
1.12E-01
1.11E-01
1.10E-01
Traditional
Ecosolid
SWB
XTR
CTECH

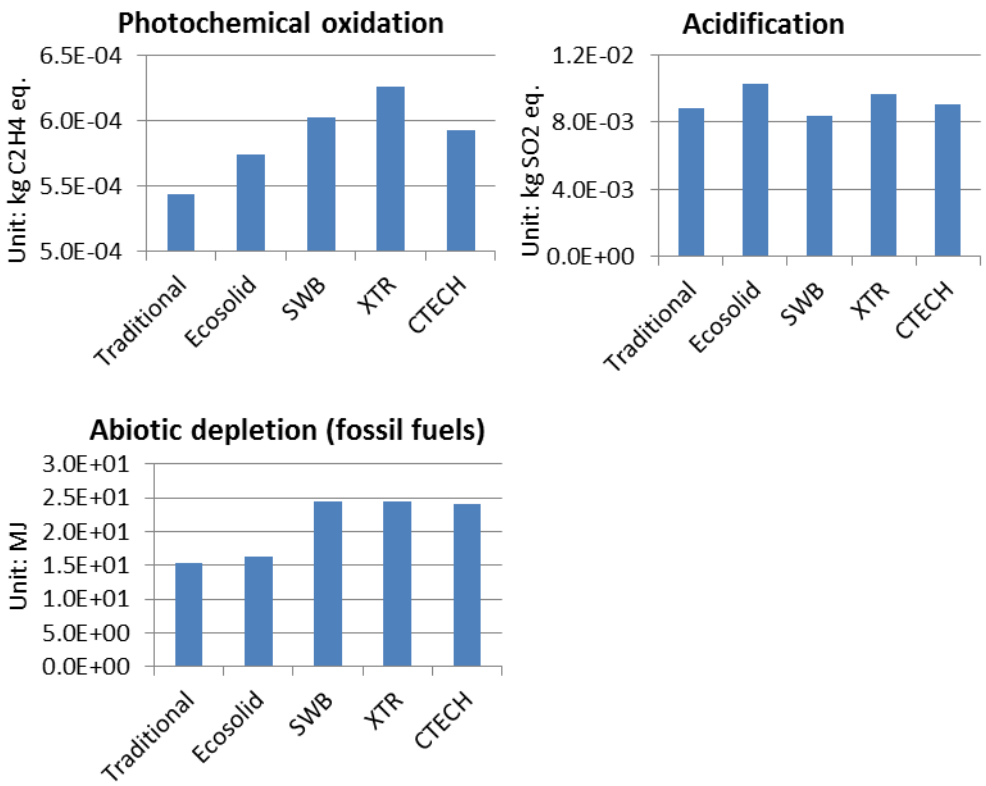


Figure 16 Life cycle environment impacts of A1-A4, C-EU and D

6.6 Discussion of biogenic carbon storage

According to PAS 2050 specification, when a product contains biomass carbon that is stored in product for more than one year, this biomass carbon can be accounted in the assessment of GHG emission of the product. The weighted average of this carbon is treated as negative GHG emission.

Due to the relatively long service life of the bamboo flooring, the effect of carbon stock was considered in the carbon footprint assessment of bamboo flooring. The biomass carbon stock was determined by multiplying the dry weight of the bamboo product by the carbon content of bamboo. The effect of carbon stock for bamboo scrimber flooring was calculated with formula:

$$C=M*0.76*T/100$$

Where,

C is the effect of carbon stock for bamboo scrimber flooring (kg CO_2 eq),

M is carbon stock in 1 m3 of bamboo flooring (kg CO_2 eq) which derived from the amount of dry weight of bamboo flooring, carbon density and transfer ratio of carbon to CO_2 (44/12),

T is the theoretical service lifetime for a specific bamboo flooring, (0.76* T)/100 is a weighted factor for carbon stock and only applicable for products with service life of 2–25 years.

The weight of $1m^3$ bamboo flooring is 680-1250kg, the carbon ration is considered 50%. The lifespan of bamboo flooring is assumed to be 20 years.

The carbon storage of five kinds of bamboo flooring are shown in table.

Table 25 Carbon storage of products

Name	Density: kg/m3	Carbon ratio	Carbon storage: kg
dasso traditional bamboo	680	0.5	189.49
dasso Ecosolid bamboo	750	0.5	209.00
dasso strand woven bamboo	1050	0.5	292.60
dassoXTR	1150	0.5	320.47
dassoCTECH	1250	0.5	348.33

7. Environmental parameters

The following environmental parameters data are applied on the LCI. They describe the use of renewable and non-renewable material resources, renewable and non-renewable primary energy and water. The description of parameters will be shown in appendix.

Table 26 Resource use categories based on scenario CN

Impact category	Unit	Traditional	Ecosolid	SWB	XTR	CTECH
PENRT	MJ	-3.0E-02	-1.5E-02	-6.1E-02	-6.0E-02	-6.4E-02
PENRM	MJ	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PENRE	MJ	-3.0E-02	-1.5E-02	-6.1E-02	-6.0E-02	-6.4E-02
PERT	MJ	4.7E+00	5.0E+00	4.1E+00	4.2E+00	4.2E+00
PERM	MJ	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PERE	MJ	4.7E+00	5.0E+00	4.1E+00	4.2E+00	4.2E+00
SM	MJ	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
RSF	MJ	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NRSF	MJ	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
FW	m3	0.0E+00	0.0E+00	1.7E-04	1.7E-04	1.5E-04
HWD	kg	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NHWD	kg	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
RWD	kg	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Non renewable, fossil	MJ	-2.6E-01	-2.4E-01	-2.8E-01	-2.8E-01	-2.9E-01
Non-renewable, biomass	MJ	2.3E-01	2.3E-01	2.2E-01	2.2E-01	2.2E-01
Non-renewable, nuclear	MJ	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Renewable, biomass	MJ	4.5E+00	4.6E+00	4.2E+00	4.3E+00	4.3E+00
Renewable, water	MJ	-4.9E-01	-4.5E-01	-5.9E-01	-5.8E-01	-5.9E-01
Renewable, wind, solar, geothe	MJ	7.6E-01	8.6E-01	5.1E-01	5.4E-01	5.4E-01
Fresh water resources	UBP	0.0E+00	0.0E+00	8.2E-02	8.2E-02	7.1E-02

Table 27 Resource use categories based on scenario EU

Impact category	Unit	Traditional	Ecosolid	SWB	XTR	CTECH
PENRT	MJ	2.9E-01	3.1E-01	2.6E-01	2.7E-01	2.6E-01
PENRM	MJ	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PENRE	MJ	2.9E-01	3.1E-01	2.6E-01	2.7E-01	2.6E-01
PERT	MJ	2.8E+00	3.0E+00	2.2E+00	2.3E+00	2.3E+00
PERM	MJ	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PERE	MJ	2.8E+00	3.0E+00	2.2E+00	2.3E+00	2.3E+00
SM	MJ	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
RSF	MJ	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

NRSF	MJ	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
FW	m3	0.0E+00	0.0E+00	1.7E-04	1.7E-04	1.5E-04
HWD	kg	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NHWD	kg	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
RWD	kg	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Non renewable, fossil	MJ	7.1E-02	8.6E-02	4.2E-02	4.2E-02	3.8E-02
Non-renewable, biomass	MJ	2.2E-01	2.2E-01	2.2E-01	2.2E-01	2.2E-01
Non-renewable, nuclear	MJ	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Renewable, biomass	MJ	3.7E+00	3.8E+00	3.4E+00	3.5E+00	3.5E+00
Renewable, water	MJ	-9.5E-01	-9.0E-01	-1.0E+00	-1.0E+00	-1.0E+00
Renewable, wind, solar, geothe	MJ	4.6E-02	1.4E-01	-2.0E-01	-1.7E-01	-1.8E-01
Fresh water resources	UBP	0.0E+00	0.0E+00	8.2E-02	8.2E-02	7.1E-02

8. Conclusions

The LCA results show that the stage of A1, A3, and A4 contribute the main environment burden. They contribute different share for different environment impacts. For product traditional and Ecosolid, the A3 manufacturing stage accounts for the largest share of impact. For product dasso strand woven bamboo, dassoXTR, and dassoCTECH, the A1 raw materials stage accounts for the largest.

When the stage of end of life was included, impacts such as acidification, global warming potential, and photochemical oxidation becomes negative. Other kinds of environment impacts become higher comparing to the results when end of life stage was not included.

It is advised to pay more attention to four points:

(1) In the manufacturing stage A3, some processes are energy intensive, such as heat treatment, profiling, drying, sanding etc. Measures should be taken to lower the level of energy consumption.

(2) In the raw material stage A1, packaging materials account for a large share of the environment impacts. It is advised to take some measures toward green package.

(3) In addition, transport has a significant environmental impact, how to reduce the environment burden through optimization of transportation is a key issue for bamboo products.

(4) Attention should be paid to waste bamboo flooring products, proper disposal management can bring a certain environmental benefits.

9. Appendix

9.1 Life cycle impact description based on CML

The following environment impacts were included in the study:

Depletion of abiotic resources

Two impact categories: Abiotic depletion (elements, ultimate reserves) and abiotic depletion (fossil fuels)

Abiotic depletion (elements, ultimate reserves) is related to extraction of minerals due to inputs in the system. The Abiotic Depletion Factor (ADF) is determined for each extraction of minerals (kg antimony equivalents/kg extraction) based on concentration reserves and rate of deaccumulation. Abiotic depletion of fossil fuels is related to the Lower Heating Value (LHV) expressed in MJ per kg of m3 fossil fuel. The reason for taking the LHV is that fossil fuels are considered to be fully substitutable.

Global warming

The characterisation model as developed by the Intergovernmental Panel on Climate Change (IPCC) is selected for development of characterisation factors. Factors are expressed as Global Warming Potential for time horizon 100 years (GWP100), in kg carbon dioxide equivalent/kg emission.

Ozone layer depletion (steady state)

The characterisation model is developed by the World Meteorological Organisation (WMO) and defines ozone depletion potential of different gases (kg CFC-11 equivalent/ kg emission).

Human toxicity (HTP inf), Freshwater aquatic ecotoxicity (FAETP inf), Marine aquatic ecotoxicology (MAETP inf) and Terrestrial ecotoxicity (TETP inf)

Characterisation factors, expressed as Human Toxicity Potentials (HTP), are calculated with USES-LCA, describing fate, exposure and effects of toxic substances for an infinite time horizon. For each toxic substance HTP's are expressed as 1,4-dichlorobenzene equivalents/ kg emission.

Photochemical oxidation (high NOx)

The model is developed by Jenkin & Hayman and Derwent and defines photochemical oxidation expressed in kg ethylene equivalents per kg emission.

Acidification (incl. fate, average Europe total, A&B)

Acifidication potential expressed in kg SO2 equivalents per kg emission. Model is developed by Huijbregts.

Eutrophication (fate not included)

Eutrophication potential developed by Heijungs et al and expressed in kg PO4 equivalents per kg emission.

9.2 Environmental parameters

PENRT = Total use of non-renewable primary energy resources;

PENRM = Use of non-renewable primary energy resources used as raw materials;

PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials;

PERT = Total use of renewable primary energy resources;

PERM = Use of renewable primary energy resources used as raw materials;

PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials;

SM =Use of secondary material;

RSF = Use of renewable secondary fuels;

NRSF = Use of non-renewable secondary fuels;

FW = Use of net fresh water

HWD = Hazardous waste disposed;

NHWD = Non-hazardous waste disposed;

RWD = Radioactive waste disposed;

CRU =Components for re-use;

MFR = Materials for recycling;

MER = Materials for energy recovery;

EEE = Exported electrical energy;

EET =Exported thermal energy