# Life Cycle Assessment of WoodSafe by FrostPharma

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Miljögiraff

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#### ISSUED BY: MILJÖGIRAFF AB

Miljögiraff is an environmental consultant specialising in product Life Cycle Assessment and Life Cycle Design. We believe that combining analysis and creativity is necessary to meet today's challenges. Therefore, we provide Life Cycle Assessment to evaluate environmental aspects and design methods to develop sustainable solutions.

We create measurability in environmental work based on a life cycle perspective on ecological aspects. The LCA methodology establishes the basis for modelling complex systems of aspects with a credible assessment of potential environmental effects.

Miljögiraff is part of a global network of experts in sustainability metrics piloted by PRé Sustainability.

## Abbreviations and expressions

Clarification of expressions and abbreviations used in the report

$CO_2$ eq – Carbon dioxide equivalents
EPD – Environmental Product Declaration
GWP – Global Warming Potential
ISO – International Organization for Standardisation
IPCC – Intergovernmental Panel on Climate Change
LCA – Life Cycle Assessment
LCI – Life Cycle Inventory Analysis
LCIA – Life Cycle Impact Assessment
PCR - Product Category Rules
RER – The European region
RoW – Rest of the world
GLO – Global
APOS – Allocation at the point of substitution (system model in ecoinvent)
Cut-off in ecoinvent – Allocation cut off by classification (system model in ecoinvent)
Cut-off in general – Environmental impact that contributes insignificantly to the overall results.

Environmental aspect - An activity that might contribute to an environmental effect, for example, “electricity usage”.

Environmental effect - An outcome that might influence the environment negatively (Environmental impact), for example, “Acidification”, “Eutrophication”, or “Climate change”.

Environmental impact - The damage to a safeguarding object (i.e., human health, ecosystems, health, and natural resources).

Life Cycle Inventory (LCI) data – Inventory of input and output flows for a product system

# 1 Introduction

Life cycle assessment (LCA) is a standardised method to quantify the potential environmental impact of a product or service from a holistic perspective. With its holistic perspective, LCA avoids the so-called burden-shifting from one part of the lifecycle to another or across impact categories. LCA results provide an understanding of a product's life cycle burdens and hotspots and allow for identifying opportunities to mitigate adverse effects.

This report presents the results for the environmental impacts calculated for WoodSafe hazardous waste container system produced by Frost Pharma. The assessment is carried out according to a life cycle perspective using the ISO 14040 standard.

## 1.1 Reading guide

Readers can select sections of the report depending on their time availability:

- 5 minutes
  - Section 6.6 gives the briefest summary of the most relevant conclusions and recommendations.
- 10 minutes
  - Section 6.6 and section 6 give the reader some more nuance and depth as it includes interpretation and sensitivity analysis that underpins the conclusions.
- 20 minutes
  - Section 6.6, section 6 and section 5 present detailed results through flowcharts or diagrams for the different impact categories that support the conclusion and recommendations.
- >30 minutes
  - For in-depth detail and transparent documentation on the modelling of each part of the life cycle, see section 4 ("Life Cycle Inventory")
  - For information about methodology, scope and functional unit, see sections 2 ("Life Cycle Assessment") and section 3 ("Goal and Scope")

# 2 Life Cycle Assessment (LCA)

## 2.1 LCA Methodology background

Understanding the potential environmental impact in connection with the manufacture and use of products is increasingly important. LCA is an accepted standardised method that is applied to create this understanding. Being a quantitative tool, LCA can contribute to more sustainable development by identification of hotspots and by guiding actionable measures to reduce environmental impacts. A business can use the results of an LCA to develop strategy, management and communication of environmental issues related to products. By including environmentally relevant input and output flows through a product's entire supply chain, from raw material extraction to final disposal, LCA provides a comprehensive basis for the environmental impact of a product's supply chain (see Figure 3).

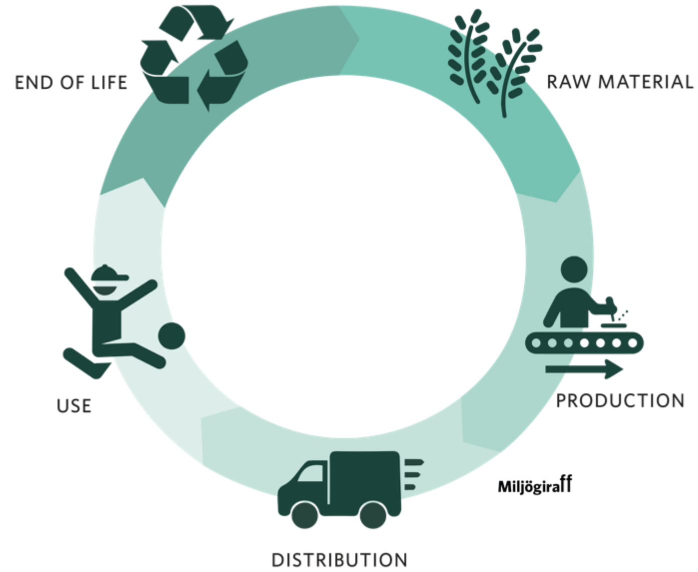


Figure 1: The Life Cycle concept, starting from raw material extraction, production, and distribution, followed by use and end-of-life.

Products' supply chains are complex and involve numerous connections. Therefore, in order to analyse a product's entire life cycle, LCA practitioners must simplify it into a model which involves limitations, as those as summarised by Guinée et al. (2002):

- Localised aspects are typically not addressed, and LCA is not a local risk assessment tool
- LCA is typically a steady-state approach rather than a dynamic approach
- LCA does not include market mechanisms or secondary effects on technological development
- Processes are considered linear, both in the economy and the environment, meaning that impact increases linearly with increased production.
- LCA involves several technical assumptions and value choices that are not purely science-based
- LCA focuses on environmental aspects and excludes social, economic, and other characteristics

The study presented in this report is a result of Miljögiraff's work which combines the confidence and objectiveness of the strong and accepted ISO standard with the scientific and reliable LCI data from ecoinvent and with the world-leading LCA software SimaPro for calculation and modelling (see Figure 2.)


Figure 2: ISO standard combined with reliable data from ecoinvent and the LCA software SimaPro.

Already in 1997, the European Committee for Standardisation published their first set of international guidelines for the performance of LCA. This ISO 14040 standard series has become widely accepted amongst the practitioners of LCA and is continuously being developed along with progressions within the field of LCA (Rebitzer et al., 2004). The guidelines for LCA are described in two documents; ISO 14040, which contains the main principles and structure for performing an LCA, and ISO 14044, which includes detailed requirements and recommendations. Furthermore, a document containing the format for data documentation (ISO/TS 14048) and technical reports with guidelines for the different stages of an LCA are available in ISO/TR 14047 and ISO/TR 14049 (ISO, 2012b, 2012a).

The environmental management method Life Cycle Assessment (LCA) is used in this study. The LCA has been performed according to the ISO 14040 series standards.
ISO 14040: 2006 – Principles and framework (ISO, 2006b)
ISO 14044: 2006 – Requirements and guidelines (ISO, 2006c)

# 3 Goal and Scope

## 3.1 The aim of the study

The goal is to calculate the metrics for the environmental impact of WoodSafe produced by Frost Pharma from a life cycle perspective. The results are calculated according to ISO 14020 and ISO 14044 standard and guidelines. The goal is to have a transparent and clear result that lay the basis for product development, to mitigate the environmental burden and for external communication about the environmental burden.

The result from the study is interpreted, followed by recommendations for mitigating the environmental impact.

## 3.2 Standards and frameworks

This is an attributional LCA approach (accounting) defined in the ISO 14040 standard.
The standards and frameworks guiding this LCA are presented in Table 1.

Table 1: Standards and framework conformance.

| Standards conformance |
|---|
| ISO 14020, 14040 and 14044 (ISO, 2006b, 2006c) |

## 3.3 Scope of the Study

In this section, the scope of an LCA is specified, including a description of the functions (performance characteristics) of the system being studied.

### 3.3.1 Name and Function of the Product

In this study, the system studied are a WoodSafe container system used for storing and transporting hazardous waste. See Figure 3

Figure 3, show a picture of different sizes of Woodsafe containers.

The container is made in two versions that have identical look and function; the only difference is the source of the plastic raw material. For more information about the differences see section 4.3.

The finished products are called:

- WoodSafe Bio80
- WoodSafe Bio100

### 3.3.2 The Functional Unit and reference flow

The functional unit is the basis that enables alternative goods, or services, to be compared and analysed. The primary purpose of a functional unit is to provide a reference to which the result and the input and output data are normalised and can therefore be compared.

For this study, the functional unit used was 1kg of WoodSafe container.

The containers are offered in several different sizes.

| Volume in litre (L) | Weight in kg | Quantity per FU |
|---|---|---|
| 0,5 | 0,08 | 12,5 |
| 2,3 | 0,215 | 4,65 |
| 3,3 | 0,265 | 3,77 |
| 6 | 0,460 | 2,17 |
| 12 | 0,625 | 1,60 |
| 25 | 0,945 | 1,06 |
| 50 | 1,600 | 0,63 |

### 3.3.3 System Boundary

The system boundary defines what parts of the life cycle that is included in the study. The aim of a LCA is always initially to include the whole life cycle to get a full understanding of the environmental burden of the studied system. However, parts might be excluded if they are considered not relevant to the studied system or for the goal and scope of the study. All omissions of life cycle stages must be justified and proven based on the reasons above. In this study all life cycle stages will be studied and included even if the usage stage has no effect to the overall result.

The system boundary for the study is defined as cradle-to-grave. Meaning that all processes needed for raw material extraction, manufacturing, transport, usage, and end-of-life are included in the study. A simplified schematic representation of a cradle-to-grave system under study is presented in Figure 4.

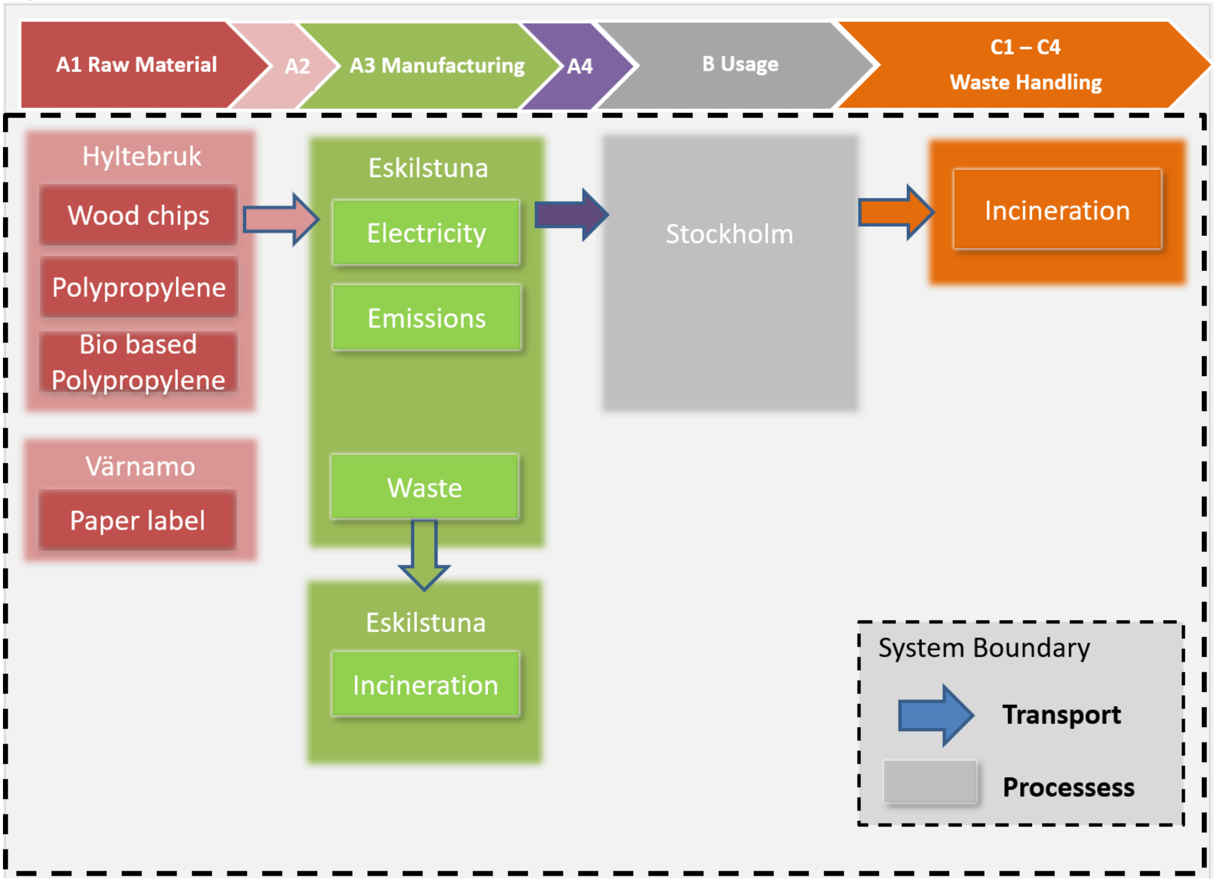


Figure 4: System boundaries for the model of the product system

### 3.3.4 Cut-off criteria

Life cycle assessment aims to include all relevant environmental flows related to a product's entire supply chain. Quantifying these impacts is done through a model, and simplification must be introduced, as it is impossible to obtain data and model every flow in practice. To maintain the comparability between products, a set of rules is applied. This study applies the following cut-off criteria:

– **Mass relevance**

Applied if the mass flow was less than 1% of the cumulative mass of all the inputs and outputs of the LCI model.

- **Energy relevance**
  Applied if the energy flow was less than 1% of the cumulative energy of all the inputs and outputs of the LCI model.

- **Environmental relevance**
  If the flow met the above criteria for exclusion yet was thought to have a potentially significant environmental impact. The environmental relevance was evaluated with experience and relevant external research on similar products. If an excluded material significantly contributed to the overall LCIA, more information was collected and assessed in the system.

In addition to the cut-off of material- and energy flows, also life cycle stages can be excluded if they are deemed to be of low relevance or do not cause any adverse environmental effects.

An overview of processes that are excluded in this study is presented in Table 2.

Table 2: Overview of aspects that are excluded.

| Excluded processes | Reason |
|---|---|
| Consumables manufacturing Mälarplast AB | Low environmental relevance. |
| | |

### 3.3.5 Allocation procedure

When dealing with a multi-output process, in other words, if a process creates several products or one product along with by-products, this is referred to in LCA as an allocation problem. This is the case for materials like wool, for which production processes produce both meat and wool.

Allocation is described in ISO 14044 section 4.3.4.2 (ISO, 2006c). ISO 14044 recommends avoiding allocation whenever possible by division into subprocesses or expanding the product system. Where allocation cannot be avoided, it is recommended to base the allocation on the physical relationship between products. This can be physical characteristics that are representative of the quality of the function provided. Where the physical relationship between products is not suitable as the basis for allocation, other relationships between them can be used. Commonly the economic value is such a relationship that can be used for allocating inputs and outputs of a process to its products.

Allocation of waste is described in ISO 14044 section 4.3.4.3.3 (ISO, 2006c) and uses the method of Allocation cut-off by classification per EPD guidelines (EPD International, 2021b). Avoided materials due to recycling are typically not considered in the main scenario, per the International EPD system's recommendation of the Polluter Pays Principle. In other words, only if the generating life cycle uses recycled material as input material will it account for the benefits of recycling.

In this report, allocation in specific data was done for the co-product of saw dust from the saw plant owned by Stora Enso, see section 4.3.3 for more information.

### 3.3.6 Method of Life Cycle Impact Assessment (LCIA)

The methods used is Environmental Footprint 3.0. The included environmental effect categories in this method are summarised in Table 3. For further details on the LCIA method, see Appendix 2-**Fel! Hittar inte referenskälla.**.

Table 3: Impact categories, indicators and methods used in the study. The chosen indicators follow the standard for EN 15804:2012+A2:2019 (CEN, 2019).

| Impact category | Abbreviation | Category indicator | Method |
|---|---|---|---|
| Climate Change-total | GWP total | kg $CO_2$ equivalents | The baseline model of 100 years of the IPCC based on IPCC 2021 |
| Ozone-depleting gases | ODP20 | CFC 11-equivalents | Steady-state ODPs, WMO 2014 |
| Acidification potential (fate not included)’) | AP | mol H+ eq | Accumulated Exceedance, Seppälä et al. 2006, Posch et al., 2008 |
| Eutrophication aquatic freshwater | EP-freshwater | kg P equivalents | EUTREND model, Struijs et al., 2009b, as implemented in ReCiPe |
| Eutrophication aquatic marine | EP-marine | kg N equivalents | EUTREND model, Struijs et al., 2009b, as implemented in ReCiPe |
| Eutrophication aquatic terrestrial | EP-terrestrial | mol N equivalents | Accumulated Exceedance, Seppälä et al. 2006, Posch et al. |
| Photochemical ozone creation potential | POCP | kg NMVOC eq. | LOTOS-EUROS, Van Zelm et al., 2008, as applied in ReCiPe |
| Abiotic resource depletion, elements | ADPe | kg Sb eq | CML 2002, Guinée et al., 2002, and van Oers et al. 2002. |
| Abiotic resource depletion, fossil fuels | ADPf | MJ | CML 2002, Guinée et al., 2002, and van Oers et al. 2002. |
| Water Depletion | WD | m3 world eq. deprived | Available WAter REmaining (AWARE) Boulay et al., 2018 |
| Particulate Matter emissions | Potential incidence of disease due to PM emissions (PM) | Disease incidence | SETAC-UNEP, Fantke et al. 2016 |

| | | | |
|---|---|---|---|
| Ionising radiation, human health | Potential Human exposure efficiency relative to U235 (IRP) | kBq U235 eq. | Human health effect model as developed by Dreicer et al. 1995 and updated by Frischknecht et al., 2000 |
| Eco-toxicity (freshwater) | Potential Comparative Toxic Unit for ecosystems (ETP-fw) | CTUe | USEtox 2.1. model (Rosenbaum et al, 2008) |
| Human toxicity, cancer effects | Potential Comparative Toxic Unit for humans (HTP-c) | CTUh | USEtox 2.1. model (Rosenbaum et al, 2008) |
| Human toxicity, noncancer effects | Potential Comparative Toxic Unit for humans (HTP-nc) | CTUh | USEtox 2.1. model (Rosenbaum et al, 2008) |
| Land-use-related impacts/Soil quality | Potential soil quality index (SQP) | dimensionless | Soil quality index based on LANCA (Beck et al. 2010 and Bos et al. 2016) |

Note that for Climate Change Biogenic, removals of biogenic CO2 into biomass (with the exclusion of biomass of native forests) and transfers from previous product systems shall be characterised in the LCIA as –1 kg CO2 eq./kg CO2 when entering the product system. Emissions of biogenic CO2 from biomass and transfers of biomass into subsequent product systems (with the exclusion of biomass of native forests) shall be characterised as +1 kg CO2 eq./kg CO2 of biogenic carbon, see EN ISO 14067:2018, 6.5.2 (CEN, 2020).

### 3.3.7 Data requirements (DQR)

The following requirements are used for all the central LCI data. The more peripheral aspects may deviate from the DQI based on the rule for "cut off".

- Geographical coverage: **The processes included in the data set are well representative of the geography stated in the "location" indicated in the metadata**
- Technology representativeness: **Average technology or BAT**[1]
- Time-related coverage: **2019 and after**
- Multiple output allocation: **Physical causality**
- Substitution allocation: Not applicable
- Waste treatment allocation: Not applicable

[1] BAT (Best Available Technology or Best Available Techniques) signifies the latest stage in development of activities, processes and their method of operation which indicate the practical suitability of particular techniques as the basis of emission limit values, linked to environmental regulations, such as the European Industrial Emissions Directive (IED, 2010/75/EU). In determining whether operational methods are BAT, consideration is given to economic feasibility and the availability of techniques to carry out the required function. The BAT concept is closely related to BEP (Best Environmental Practice), which is the best environment-friendly company practice.

- Cut-off rules: **See section 3.3.4**
- System boundary: **Second order (material/energy flows including operations)**
- The boundary with nature: **Agricultural production is part of the production system**

The data quality and representativeness will be assessed in part 6.5 based on the guidelines established in the EN 15804:A2 standard (CEN, 2019).

## 3.4 LCA Software

The life cycle impact assessment (LCIA) was calculated using the LCA software SimaPro 9.5 (PRé Sustainability, 2022) developed by PRé Consultants. SimaPro is a powerful tool for calculations of complex product systems and in-depth comparisons of life cycles with documentation that conforms to the ISO 14000 standard. This software allows access to databases with LCI data (e.g. ecoinvent) and several readymade LCIA methods.

# 4 Life Cycle Inventory (LCI)

In the life cycle inventory, the product system is defined and described. Firstly, the material flows and relevant processes required for the product system are identified. Secondly, relevant data (i.e., resource inputs, emissions and product outputs) for the system components are collected, and their amounts are related to the defined functional unit.

For data referring to processes beyond the control of the core production, the ecoinvent database is used. Ecoinvent is one of the world's leading databases with consistent, open, and updated Life Cycle Inventory Data (LCI). With several thousand LCI datasets in the fields of agriculture, energy supply, transport, biofuels and biomaterials, bulk and special chemicals, construction and packaging materials, basic and precious metals, IT and electronics and waste management, ecoinvent offers the most comprehensive international LCI database. ecoinvent's high-quality LCI datasets are based on industrial data and have been compiled by internationally recognized research institutes and LCA consultants.

## 4.1 Assumptions

Assumptions that are general to the entire LCA are:

- choice of energy model: (e.g. regional averages obtained from the Ecoinvent LCI database or according to specific conditions);
- Choice of transport model: Fi not otherwise stated all truck transport is represented with the LCI data Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off
- Transport distances have been based on Google Maps for road transportation and a port routing tool (e.g. Sea Distances or Port World) for sea transport. Possible deviating routes have not been included in the calculations.
- Ecoinvent market processes includes generic shipments from supplier to producer. Therefore, these data sets have no further transport.

## 4.2 Input data references

Table 4 shows the supplier contacts that have supplied the sources for data input.

Table 4 Input data references

| **Supplier** | |
|---|---|
| **Name** | Maria Stockenberg |
| **e-mail** | maria@malarplast.se |
| **Phone number** | +46(0)73-510 94 39 |
| **Position in company** | CEO-Assistant |
| **Supplier** | Mälarplast |
| | |
| **Name** | Matthew Ekholm |
| **e-mail** | matthew.smyth@storaenso.com |
| **Phone number** | +46 76 148 5224 |
| **Position in company** | Director of Circular Services |
| **Supplier** | Stora Enso |

| | |
|---|---|
| **Name** | Henrik Alfredsson |
| **e-mail** | henrik.alfredsson@frostpharma.com |
| **Phone number** | +46 733 370 200 |
| **Position in company** | CEO |
| **Supplier** | Frost Pharma |

## 4.3 Raw material (A1 + A2)

This section describes the different raw materials needed for the manufacturing of the two versions of WoodSafe. The Woodsafe containers is made of bio-composite, meaning a mixture of wood and plastic.

### 4.3.1 Raw material for Woodsafe Bio80

Table 5: Raw materials and transport to the production site

| Material | Weight (kg) | LCI database representation | LCI Library | Origin | Transport type | Transport distance (km) | Comment |
|---|---|---|---|---|---|---|---|
| Wood Chips | 0,408 | See section 4.3.3 | | Sweden | Truck, diesel | 200 | The raw material comes from several sources |
| Polypropylene | 0,204 | Polypropylene, granulate {RER}\| polypropylene production, granulate \| Cut-off, | ecoinvent 3.9 | Europe | Truck, diesel | 2000 | Average of several European suppliers. Technique covers 76% of production capacity in Europe. |
| Biobased Polypropylene | 0,408 | See section 4.3.5 | | Europe | Truck, diesel | 793 | |
| Paper | 0,001 | See section 4.4.3 | | Sweden | Truck, diesel | 341 | |

### 4.3.2 Raw material for Woodsafe Bio100

Table 6: Raw materials and transport to the production site

| Material | Weight (kg) | LCI database representation | Database | Origin | Transport type | Transport distance (km) | Comment |
|---|---|---|---|---|---|---|---|
| Wood chips | 0,408 | See section 4.3.3 | | Sweden | Truck, diesel | 200 | The raw material comes from several sources |
| Biobased Polypropylene | 0,612 | See section 4.3.5 | | Europe | Truck, diesel | 793 | |
| Paper | 0,001 | See section 4.4.3 | | Sweden | Truck, diesel | 341 | |
| | | | | | | | |
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| | | | | | | | |

### 4.3.3 Wood chips

The saw chips used is a by-product from sawmills that normally is incinerated for energy recovery. The source is from Swedish sawmills in average 200km from Hyltebruk, Sweden. The wood chips are transported by diesel truck on a pallet which 0,016kg wood pallet is allocated per 1kg of wood chips.

To allocate the environmental burden of the saw chips an economic allocation has been done. The product yield ratio between the primary product timber and the by-products of saw chips and saw dust in Sweden is roughly 50% main product and 45% of saw dust and saw chips, see Figure 5.

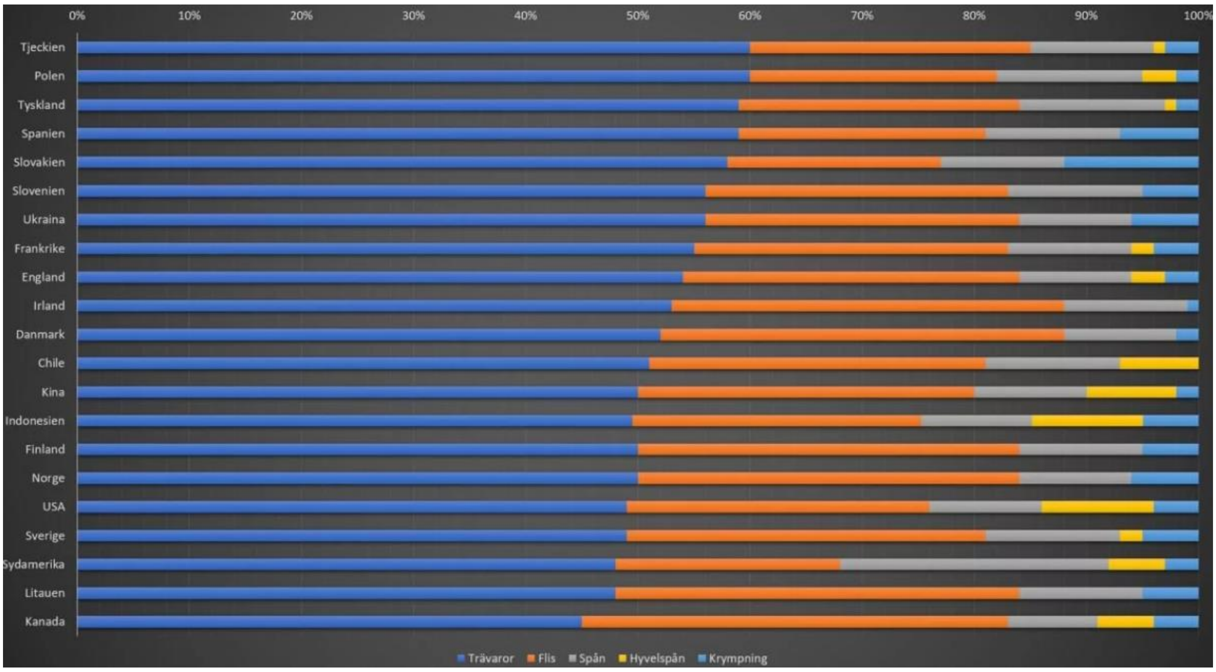



Figure 5, show the average yield of products from saw mills. Source: FAO, ITTO and United Nations. 2020. Forest product conversion factors. Rome.

The difference in price between sawn timber and saw chips is around 1/8. (Ekholm, 2023) To calculate the economic allocation factor the following equation described in Equation 1.

$$Allocation\ factor = \frac{Mass\ produced\ by-products * Price\ by-products}{Mass\ produced\ primary\ product * Price\ primary\ products}$$

Equation 1, show how the economic allocation factor have been calculated.

This equals an allocation factor for the saw chips and saw dust by product to 0,1125. This is used when allocating the environmental burden of the multi output product process of sawing timber.

The LCI representation will be the ecoinvent 3.9 process: *Sawnwood, board, softwood, raw, dried (u=20%) {Europe without Switzerland}| market for sawnwood, board, softwood, raw, dried (u=20%) | Cut-off*
The process has been regionalized to Sweden by changing to Swedish electricity and heat and source of wood.

### 4.3.4 Virgin polypropylene

To make the biocomposite granulates Woodsafe Bio80 uses 20% virgin Polypropylene (PP). The source of the PP are several different suppliers in southern Europe, mainly Italy and Spain.

The LCI representation will be the ecoinvent 3.9 process: Polypropylene, granulate {RER}| polypropylene production, granulate | Cut-off

The virgin polypropylene is transported in average 2000km to Hyltebruk by diesel truck. The polypropylene granulates is packed in a plastic bag and 0,004kg PE plastic bag is allocated per 1kg of polypropylene raw material.

### 4.3.5 Bio based Polypropylene

The biobased PP comes from the company Braskem and is based on tall oil. Tall oil is a byproduct of the pulp and paper industry that is composed of a mixture of fatty acids, rosin acids, and other components. To model the bio-based PP based on tall oil a modification of the ecoinvent 3.9 LCI process for fossil PP production have been done:

The monomer that is polymerised when producing PP is mainly propylene. The polymerisation process is the same no matter if the monomer comes from propylene or tall oil. Propylene is usually a fossil-based product. To use tall oil as a substitute for propylene in polypropylene production, it would first need to be chemically modified to produce a suitable monomer that can be polymerized to form polypropylene. This involve converting the fatty acids and other components in tall oil into a monomer that is structurally like propylene, such as a fatty acid derivative or an unsaturated hydrocarbon. This is done in two steps:

1. Fractionation: Tall oil is fractionated to separate the different components, such as fatty acids, rosin acids, and unsaponifiable.
2. Esterification or transesterification: The fatty acids in tall oil is converted into esters or other derivatives through a chemical reaction with an alcohol This can be done using either an acid-catalyzed esterification process.

To represent this in the LCA model first the process called *Fatty acid {GLO}| tall oil refinery operation | Cut-off* was added. This is a process that represents the fractionation of the tall oil. Then a generic tall oil LCI data called *Tall oil, crude {GLO}| market for tall oil, crude | Cut-off, U* was added in a generic data set for esterification of rape oil in ecoinvent 3.9 called: *Fatty acid methyl ester {Europe without Switzerland}| esterification of rape oil | Cut-off.* The dataset for tall oil was modified to only contain European sources of tall oil but in the same ratio as the market process defines.

Then Propylene and ethylene was changed to the same amount of the processed tall oil in the ecoinvent dataset representing generic PP production called: *Polypropylene, granulate {RER}| polypropylene production, granulate | Cut-off.*

The biobased polypropylene is transported in 793km from Schkopau, Germany to Hyltebruk by diesel truck. The polypropylene granulates is packed in a plastic bag and 0,004kg PE plastic bag is allocated per 1kg of polypropylene raw material.

### 4.3.6 Processing the raw material

The raw material is processed by Stora Enso in Hylte Bruk, Sweden. A picture of the finished bio compiste material can be seen in Figure 6.

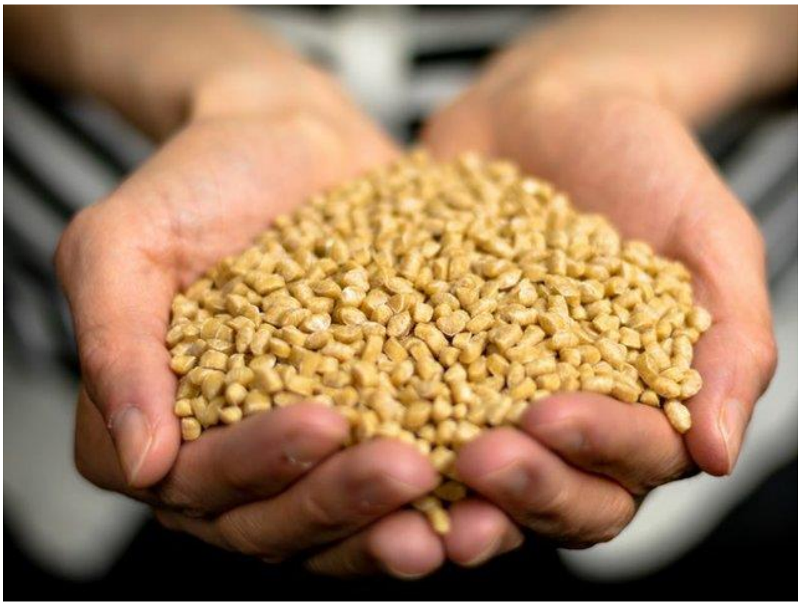


Figure 6, show a picture of finished bio composite granulates.

The first step of processing the saw chips is a mechanical size reduction of the chips with controlled size distribution. This process uses 0,24kWh per kg material processed. When the saw chips are of homogenous size it is mixed with PP to produce a bio composite called S-fibre. The process of blending is made by a twin-screw compounding where polymer and fibres are mixed together in a heated chamber and blended together with rotating screws. The blend is then cut into pellets, dried, and packed. This process uses 0,20kWh per kg material processed.

In total the whole process uses 0,44kWh per kg material processed. The electricity used at Hylte Bruk has guaranteed origin by the energy producer Vattenfall as nuclear power. A guarantee of Origin certificate can be seen in Appendix 6.

The production waste in the process is 1,2% of PP and 0,8% of wood chips. All waste is transported 50km by diesel truck to Halmstad for incineration.

The final product of the bio composite is packaged in a plastic bag made of 90% PP and 10% PE and loaded on a diesel truck. The finished and packed product is transported 390km to the company Mälarplast, located in Eskilstuna, Sweden.

## 4.4 Manufacturing (A3)

In this chapter, the activities carried out by Mälarplast AB are presented. All activities are presented per 1kg of finished product. The raw material from Stora Enso is treated the same way regardless of the product is Bio100 or Bio80.

At Mälarplast the biocompisite material from Stora Enso is dried, then injection moulded, cooled, label is applied and then is the finished product packed for delivery.

### 4.4.1 Energy

The total energy consumption is 0,3178kWh divided on injection moulding including drying 0,3kWh and cooling 0,0178kWh. 90% of the electricity comes from the Swedish energy mix without certified origin. 10% comes from electricity produced by Mälarplast owned photovoltaic system with a total yield of 121,52MWh 2022.

Table 7: Energy use in production

| Energy type | Energy source | LCI data representation in ecoinvent 3.9 | Amount kWh | Certificate? |
|---|---|---|---|---|
| Electricity | Swedish Residual mix | Electricity, high voltage {SE}\| electricity, high voltage, residual mix \| Cut-off | 0,286 | |
| Electricity | Photovoltaic system | Electricity, low voltage {SE}\| electricity production, photovoltaic, 570kWp open ground installation, multi-Si \| Cut-off | 0,03178 | See appendix 7 |

### 4.4.2 Direct emissions

Some leakage of refrigerant occurs from the cooling system. In total 4kg of the refrigerant R-410A leaked 2022. This amount will be divided on the total volume produced 2022. R-410a has a GWP of 2088kg CO2 eqv per kg.

Table 8: Direct emissions

| Emission | Amount per FU (kg) | Compartment (Air, water, ground) |
|---|---|---|
| R-410a | 1,16e-5 | Air |

### 4.4.3 Consumables and extra materials

No consumables are added since very small amount with no environmental relevance.

A label is put on the finished container. The label comes from Värnamo Print AB in Värnamo Sweden and is made of FSC certified paper. The label weighs 1g and come with glue on and part of the label that protect the glue before applying to the container is thrown as waste.

The label is white, one side machine coated, woodfree printing paper with semi-gloss appearance. The paper is made from FSC® certified paper (FSC Mix Credit, chain-of-custody number: CU-COC-807907, Licence Code: FSC-C004451)

The glue is called: Adhesive S2045N and is a rubber-based adhesive.
The adhesive S2045N is suitable for contact with dry and moist, non-fatty foodstuffs. Adhesive S2045N has attained the two-star certification for biobased content according to EN 16640, meaning that S2045N contains certified Biobased Carbon Content of at least 40%. (TÜV AUSTRIA licensee number: S0259)

| Type of material | Material | Amount (kg) | LCI data representation in ecoinvent 3.9 | Transport type | Transport distance (km) |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Label | Paper | 0,0009 | Paper, woodfree, coated {RER}\| paper production, woodfree, coated, at integrated mill \| Cut-off | Diesel, truck | 341 |
| Glue | Rubber | 0,0001 | Polyurethane adhesive {GLO}\| polyurethane adhesive production \| Cut-off, U | Diesel, truck | 341 |

### 4.4.4 Production waste

0,5% of the input material ends up as waste. This is mainly due to starting of the injection moulding machines. Most of the waste from quality issues can be re-processed since the hazardous waste containers have high tolerance on esthetical issues. The waste is transported by truck 1km for incineration.

Table 9: Production waste types and treatment

| Waste type | Waste transport type | Waste transport distance (km) | Waste quantity (kg) | Waste treatment |
|---|---|---|---|---|
| Bio-composite | Truck, diesel | 1 | 0,005 | Incineration |
| Paper-label | Truck, diesel | 1 | 0,0003 | Incineration |

### 4.4.5 Packaging

The finished product is packed in a cardboard box that is wrapped in LDPE film and put on a wooden pallet. The cardboard box and LDPE film comes from Packoplock AB in Norrköping Sweden. The cardboard box is made of 100% recycled material. The wooden pallet is assumed to be re-used.

Table 10: Packaging used for product.

| Type of Packaging | Material | Amount (kg) | LCI data representation in ecoinvent 3.9 | Transport type | Transport distance (km) | Comment |
|---|---|---|---|---|---|---|
| Plastic film | LDPE | 0,01 | Packaging film, low density polyethylene {GLO}\| market for packaging film, low density polyethylene \| Cut-off, U | Truck, diesel | 112 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Cardboard box | Cardboard | 0,065 | Folding boxboard carton {RER}\| folding boxboard carton production \| Cut-off, U | Truck, diesel | 112 | Raw material input changed to 100% recycled |

## 4.5 Transport of finished goods (A4)

The finished products from Mälarplast AB are loaded on a truck owned by the transport company Pihl AB. The first transport is to a warehouse 8km from Mälarplast. They are then distributed from the warehouse to places around Europe. Most common is transport to Stockholm and that will be the main scenario.
How much transports to Amsterdam, Netherlands and London, UK would affect the results are studied in a scenario analysis, see section 6.4.

Table 11: Distribution of products

| Product | Road transport type | Road transport distance (km) | Sea transport type | Sea transport distance (km) | Comment |
|---|---|---|---|---|---|
| Woodsafe | Truck, diesel | 120 | | | |

### 4.5.1 Disposal of packaging

In the table below, the disposal of the packaging that is delivered with the product is presented.

Table 12: Disposal of packaging delivered with the product.

| Type of Packaging | Material | Amount (kg) | Disposal method | LCI data representation in ecoinvent 3.9 | Comment |
|---|---|---|---|---|---|
| Cardboard box | Cardboard | 0,065 | Recycling | Waste polyethylene {CH}\| treatment of waste polyethylene, municipal incineration with fly ash extraction \| Cut-off | |
| Plastic film | LDPE | 0,01 | Incineration | Waste polyethylene {CH}\| treatment of waste polyethylene, municipal incineration with fly ash extraction \| Cut-off | |

Assumed transportation by truck 10 km to a nearby incineration plant.

## 4.6 Usage

No environmental aspects occur during the usage phase of the containers.

## 4.7 End-of-Life (C1-C4)

The end-of-life phase handles the product and the material it consists of after its use. Because the containers are used for hazardous waste it is legal requirements that the containers are incinerated after usage. Meaning that the End-of-Life scenario is 100% incinerations.

Incineration of the virgin PP part will be represented with the ecoinvent 3.9 LCI data called: *Waste polypropylene {CH}| treatment of waste polypropylene, municipal incineration with fly ash extraction | Cut-off.*

The wood chip part will be represented with the ecoinvent 3.9 LCI data called: *Waste wood, untreated {CH}| treatment of waste wood, untreated, municipal incineration with fly ash extraction | Cut-off, U*

Incineration of the bio-PP part will be represented with the same ecoinvent 3.9 LCI data as for virgin PP with the modification that the fossil emissions of CO2 is changed to have biogenic source instead. This way no other emission from the incineration of the PP is missed.

The transport distance from user to waste treatment plant is assumed to be 25km and done by diesel truck.

# 5 Result of Life cycle impact assessment (LCIA)

In this section, the result from the different environmental impact assessment methods will be presented. First, the results for WoodSafe Bio80 calculated with the method Environmental Footprint 3.1 (EF) Midpoint and Endpoint are presented, second WoodSafe Bio100.
For further details on the LCIA method and impact categories, see Appendix 2 - Appendix 3.

Sankey diagrams are used to display the results as flow diagrams where the thickness of the arrows reflects the relative amount of that flow. All the nodes cannot be displayed simultaneously due to the vast amounts of background data. Therefore, only processes that contribute to a minimum of 5% of total impacts are shown in the diagram.

**Disclaimers and conversion factors**
For the impact category Eutrophication, freshwater, the result per unit kg P is used as a basis for calculating the result per unit kg $PO_4^{-3}$ eq, using the factor 3,07.

The results of the environmental impact indicators for ADPE, ADPF, WSF, ETP-FW, HTP-C, and HTP-NC shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.

The impact category for IR deals mainly with the eventual impact of low-dose ionising radiation on human health of the nuclear fuel cycle. It does not consider effects due to possible nuclear accidents, occupational exposure nor due to radioactive waste disposal in underground facilities. Potential ionising radiation from the soil, from radon and from some construction materials is also not measured by this indicator.

Note that the LCIA results are relative expressions, which means that they do not predict impacts on category endpoints or the exceeding of thresholds, safety margins or risk.

## 5.1 Result LCIA WoodSafe Bio80

### 5.1.1 Environmental Footprint 3.1 Midpoint WoodSafe Bio80

Table 13 shows the result per FU according to the LCIA method Environmental footprint 3.1 midpoint level.

Table 13: Environmental footprint midpoint results per functional unit

| Impact category | Unit | Total Cradle-to-Grave | Raw Material | Transport raw material | Manufacturing | Transport finished product | Usage (Disposal of packaging) | End-Of-Life |
|---|---|---|---|---|---|---|---|---|
| Acidification | kg $CO_2$ eq | 0.0066 | 0.0055 | 0.0002 | 0.0006 | 0.0001 | 0.0000 | 0.0003 |
| Climate change | kg CFC11 eq | 1.9369 | 1.1276 | 0.0739 | 0.1546 | 0.0226 | 0.0302 | 0.5281 |
| Ecotoxicity, freshwater | mol H+ eq | 7.0190 | 5.4036 | 0.5162 | 0.5624 | 0.1580 | 0.0058 | 0.3729 |
| Particulate matter | kg $PO_4^{-3}$ eq | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Eutrophication, marine | kg P eq | 0.0021 | 0.0017 | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0001 |
| Eutrophication, freshwater | kg N eq | 0.0005 | 0.0005 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Eutrophication, terrestrial | mol N eq | 0.0180 | 0.0141 | 0.0009 | 0.0013 | 0.0003 | 0.0000 | 0.0014 |
| Human toxicity, cancer | kg NMVOC eq | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Human toxicity, non-cancer | kg Sb eq | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Ionising radiation | MJ | 0.7589 | 0.4503 | 0.0014 | 0.3063 | 0.0004 | 0.0000 | 0.0004 |
| Land use | m3 depriv. | 150.6501 | 148.1028 | 0.6228 | 1.6509 | 0.1907 | 0.0006 | 0.0823 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Ozone depletion | disease inc. | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Photochemical ozone formation | kBq U-235 eq | 0.0066 | 0.0053 | 0.0004 | 0.0005 | 0.0001 | 0.0000 | 0.0004 |
| Resource use, fossils | CTUe | 39.0643 | 31.5821 | 1.0463 | 5.8921 | 0.3203 | 0.0022 | 0.2214 |
| Resource use, minerals and metals | CTUh | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Water use | CTUh | 0.9818 | 0.8851 | 0.0043 | 0.0873 | 0.0013 | 0.0001 | 0.0039 |

### 5.1.2 Environmental Footprint Endpoint WoodSafe Bio80

The environmental footprint endpoint shows the contribution of each environmental impact category to the total environmental impact.

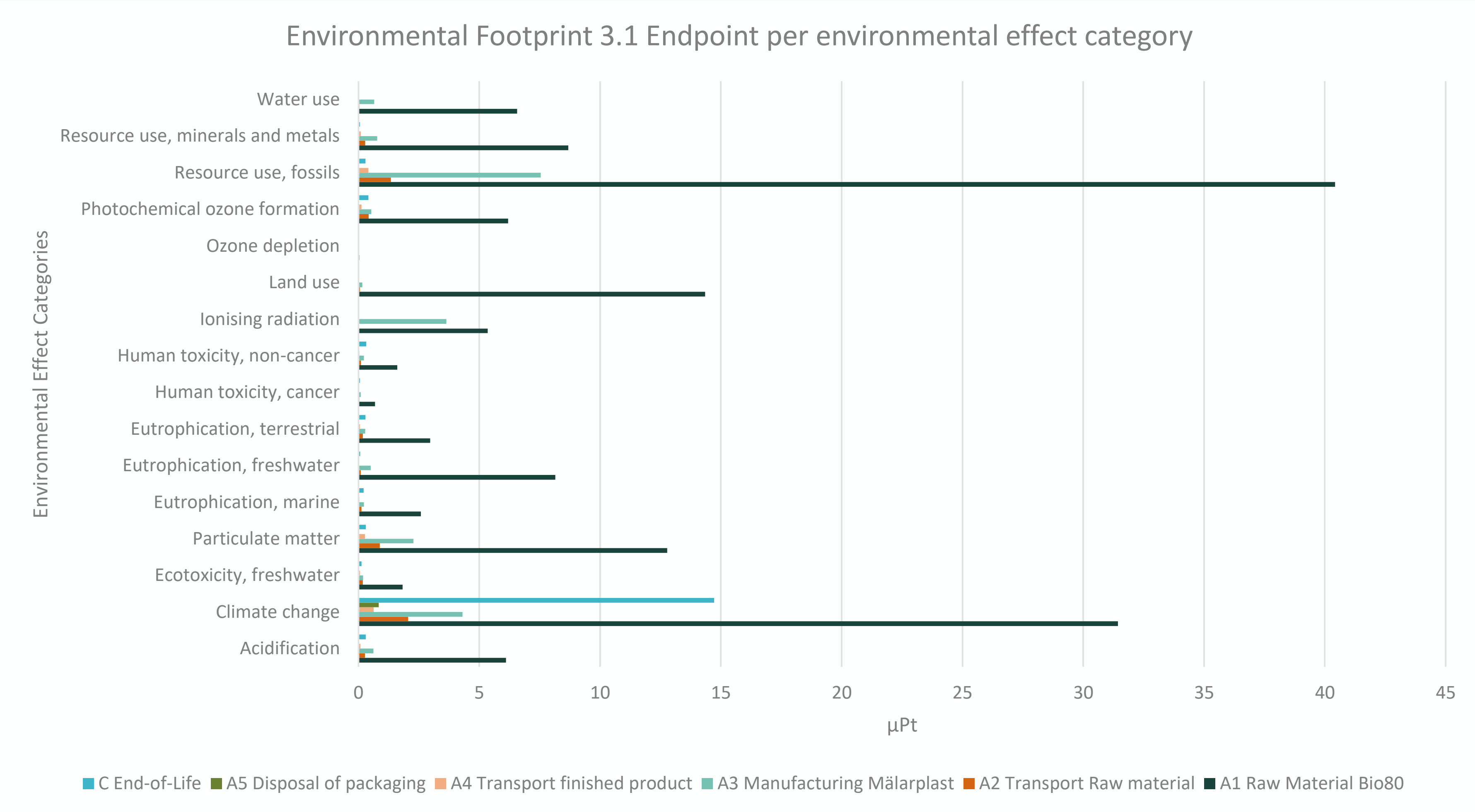



Figure 7: Share of environmental impact per impact category

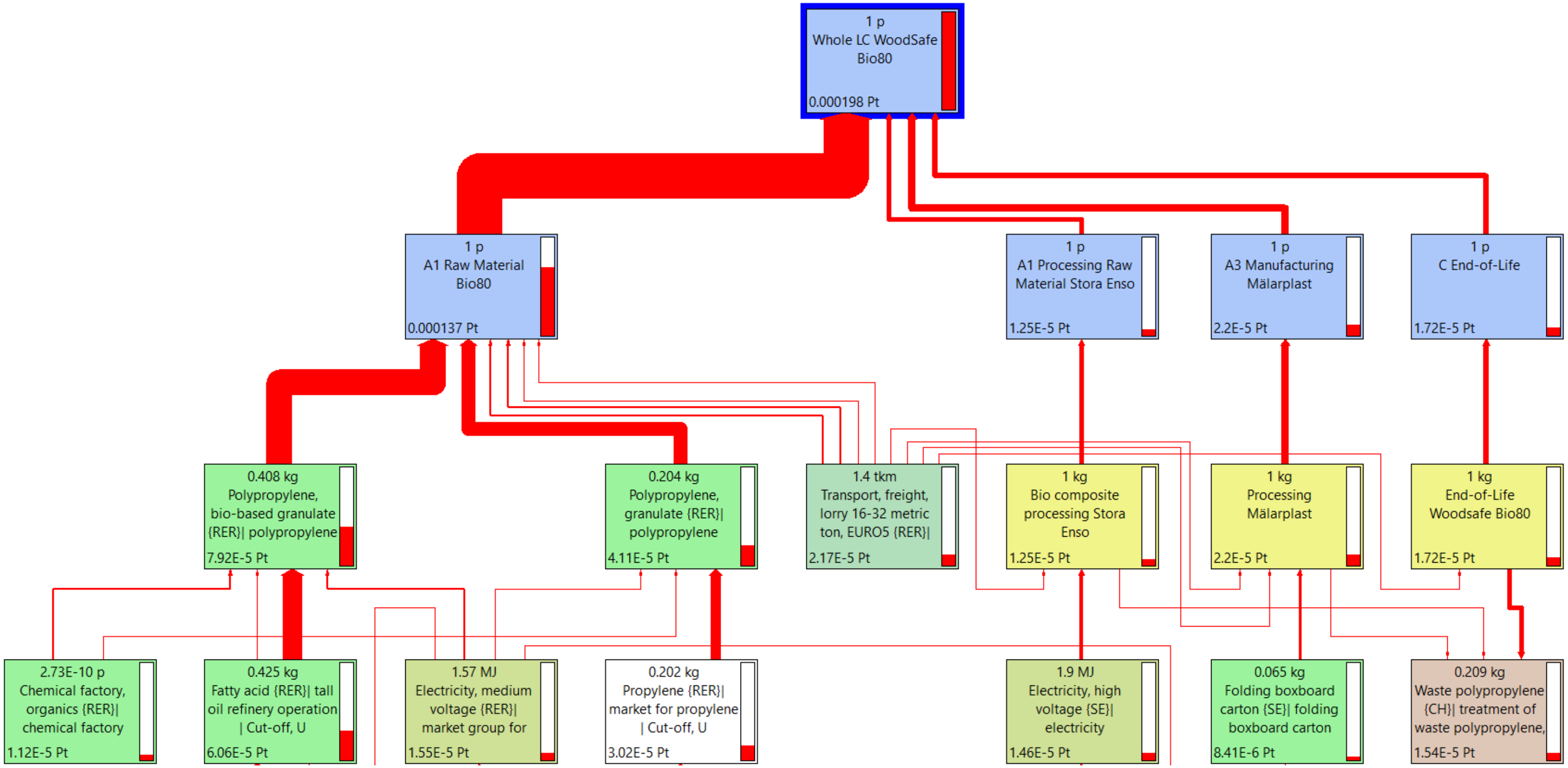


Figure 8: Sankey diagram over share of environmental impact contributions per module and per functional unit. Show 18 of 14711 contributing processes.

### 5.1.3 Climate impact (GWP) WoodSafe Bio100 - IPCC GWP 2021 100

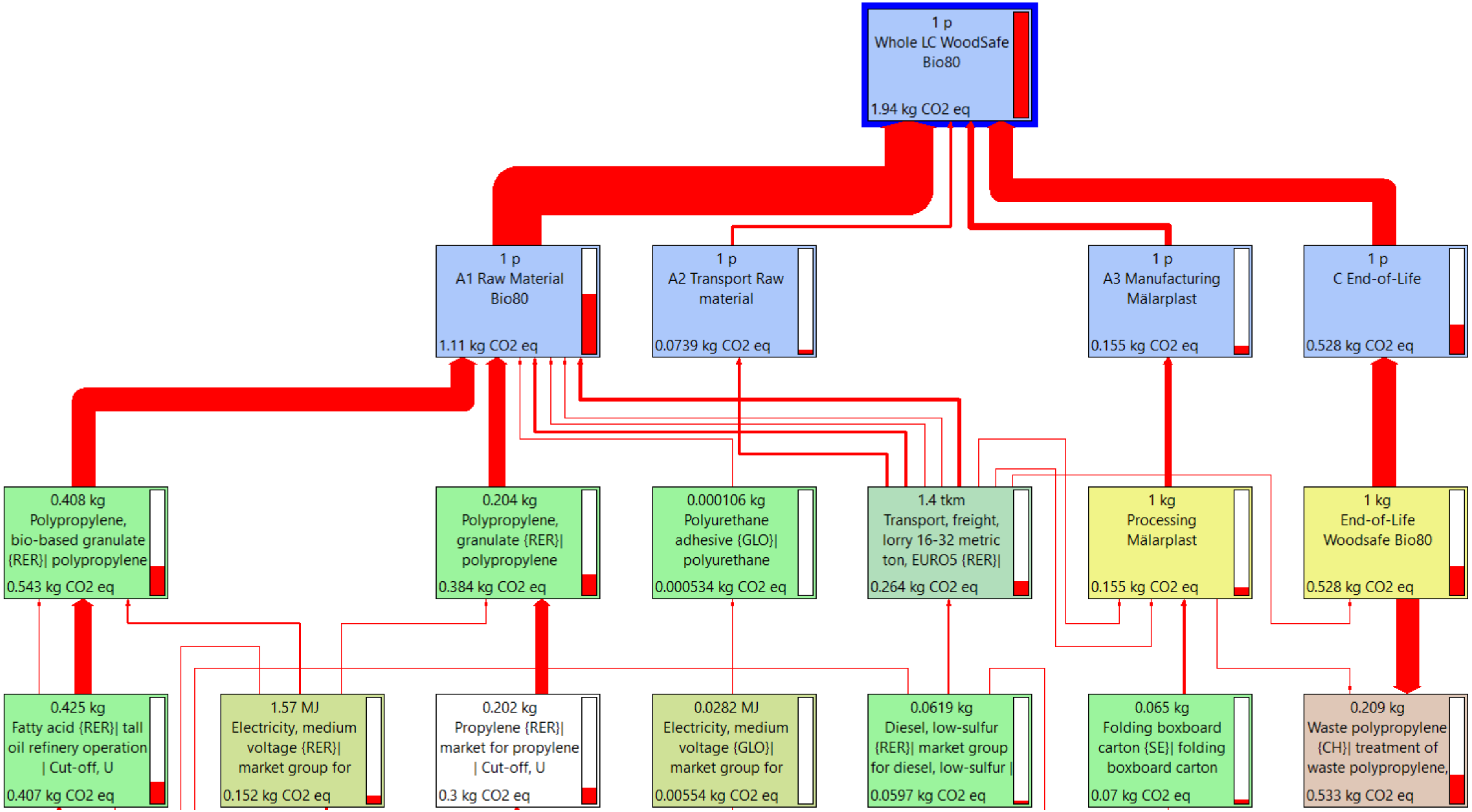


Figure 9, show a Sankey diagram of the climate change potential according to IPCC 2021 GWP 100. 17 of 14711 contributing processes are visible.

## 5.2 Result LCIA WoodSafe Bio100

### 5.2.1 Environmental Footprint 3.1 Midpoint WoodSafe Bio100

Table 13 shows the result per FU according to the LCIA method Environmental footprint 3.1 midpoint level.

Table 14: Environmental footprint midpoint results per functional unit

| Impact category | Unit | Total Cradle-to-Grave | Raw Material | Transport raw material | Manufacturing | Transport finished product | Usage (Disposal of packaging) | End-Of-Life |
|---|---|---|---|---|---|---|---|---|
| Acidification | kg $CO_2$ eq | 0.0068 | 0.0057 | 0.0002 | 0.0006 | 0.0001 | 0.0000 | 0.0003 |
| Climate change | kg CFC11 eq | 1.2688 | 0.9655 | 0.0739 | 0.1546 | 0.0226 | 0.0302 | 0.0221 |
| Ecotoxicity, freshwater | mol H+ eq | 8.1462 | 6.5308 | 0.5162 | 0.5624 | 0.1580 | 0.0058 | 0.3729 |
| Particulate matter | kg $PO_4^{-3}$ eq | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Eutrophication, marine | kg P eq | 0.0024 | 0.0020 | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0001 |
| Eutrophication, freshwater | kg N eq | 0.0007 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Eutrophication, terrestrial | mol N eq | 0.0195 | 0.0157 | 0.0009 | 0.0013 | 0.0003 | 0.0000 | 0.0014 |
| Human toxicity, cancer | kg NMVOC eq | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Human toxicity, non-cancer | kg Sb eq | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Ionising radiation | MJ | 0.7908 | 0.4822 | 0.0014 | 0.3063 | 0.0004 | 0.0000 | 0.0004 |
| Land use | m3 depriv. | 217.7429 | 215.1956 | 0.6228 | 1.6509 | 0.1907 | 0.0006 | 0.0823 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Ozone depletion | disease inc. | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Photochemical ozone formation | kBq U-235 eq | 0.0066 | 0.0054 | 0.0004 | 0.0005 | 0.0001 | 0.0000 | 0.0004 |
| Resource use, fossils | CTUe | 27.8141 | 20.3319 | 1.0463 | 5.8921 | 0.3203 | 0.0022 | 0.2214 |
| Resource use, minerals and metals | CTUh | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Water use | CTUh | 0.9589 | 0.8621 | 0.0043 | 0.0873 | 0.0013 | 0.0001 | 0.0039 |

### 5.2.2 Environmental Footprint Endpoint WoodSafe Bio100

The environmental footprint endpoint shows the contribution of each environmental impact category to the total environmental impact.

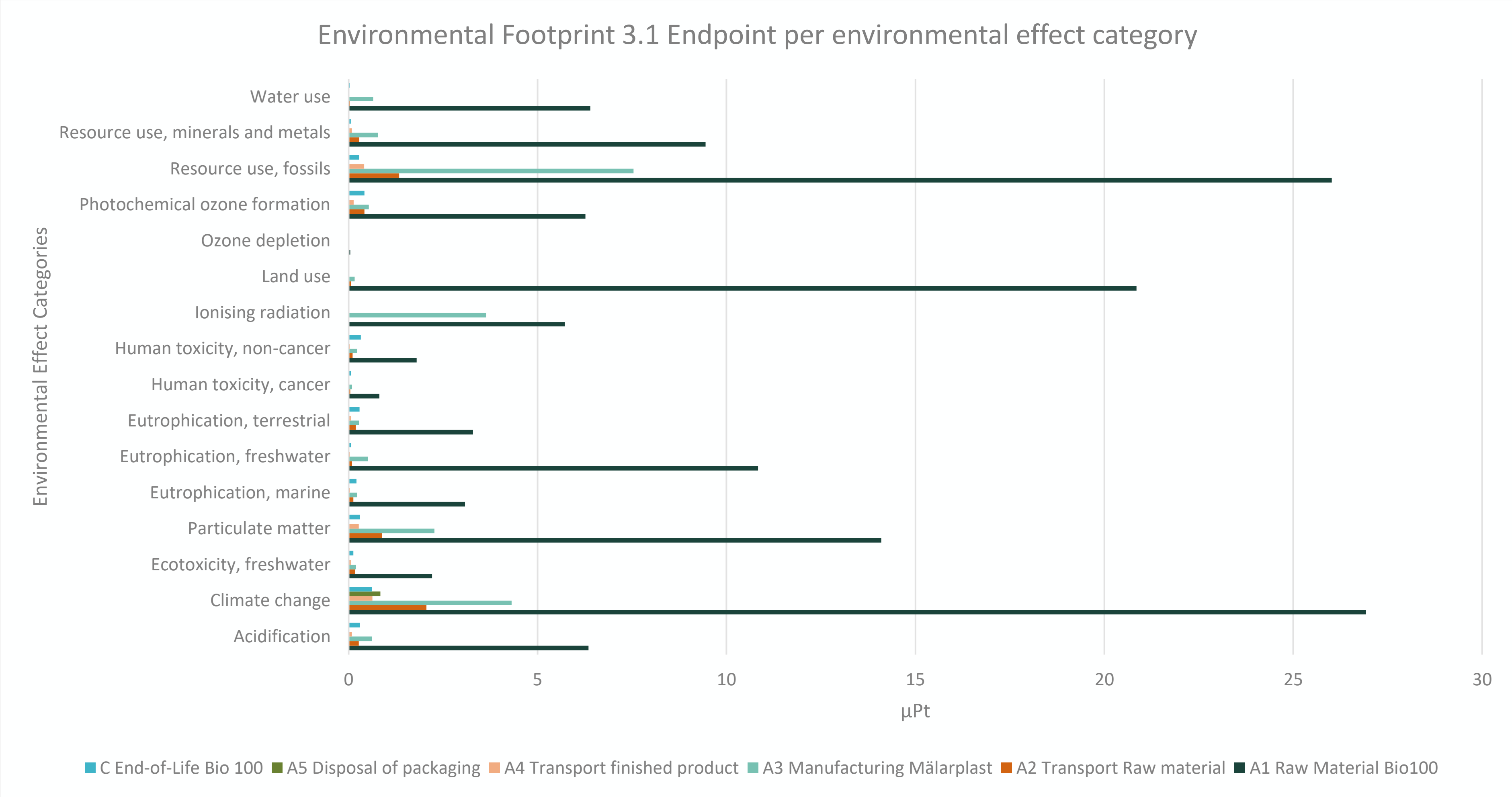



Figure 10: Share of environmental impact per impact category

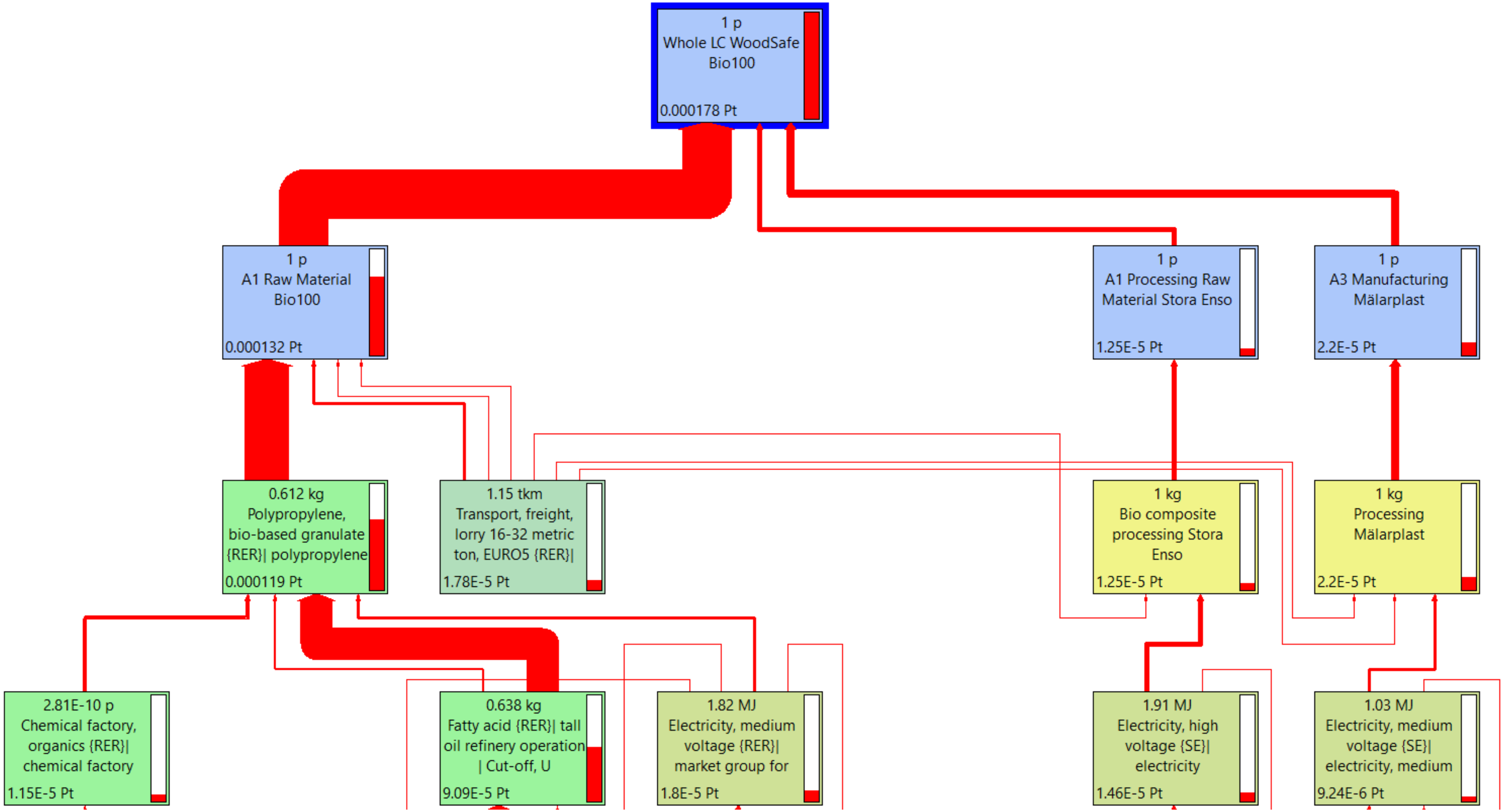



Figure 11: Sankey diagram over share of environmental impact contributions per module and per functional unit. Show 18 of 14711 contributing processes.

### 5.2.3 Climate impact (GWP) WoodSafe Bio100- IPCC GWP 2021 100

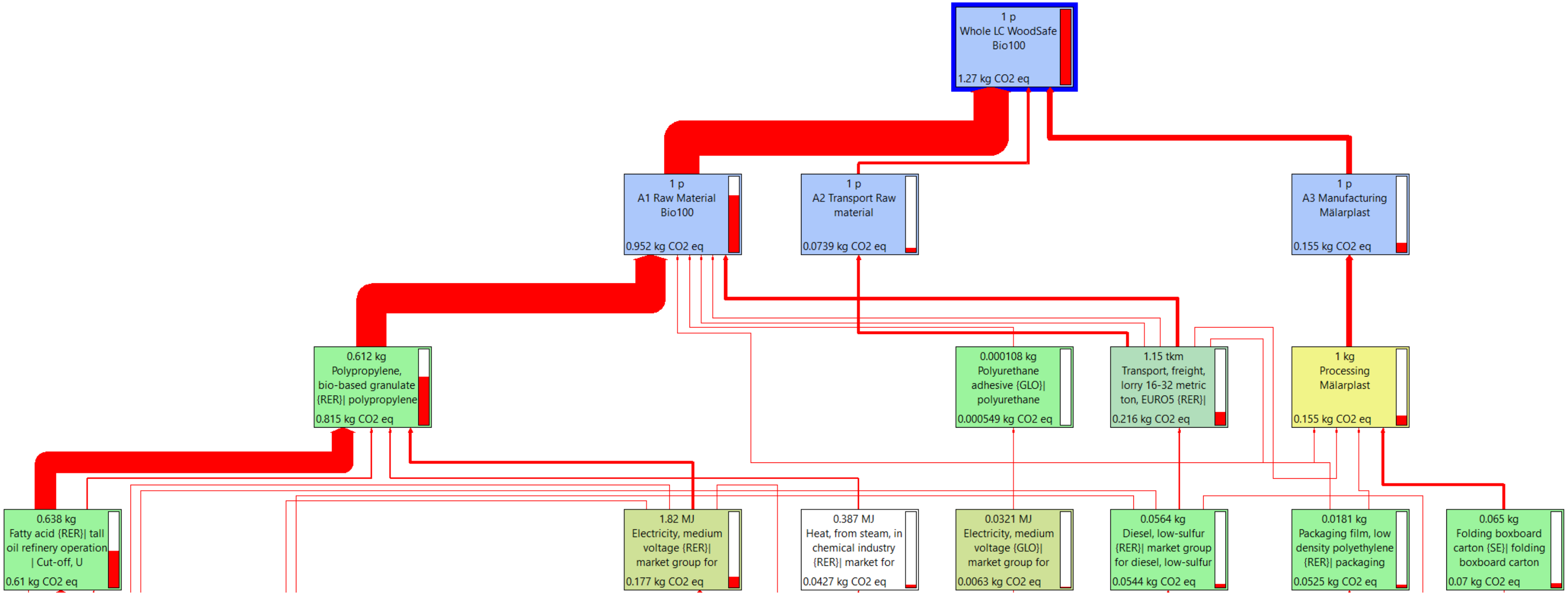
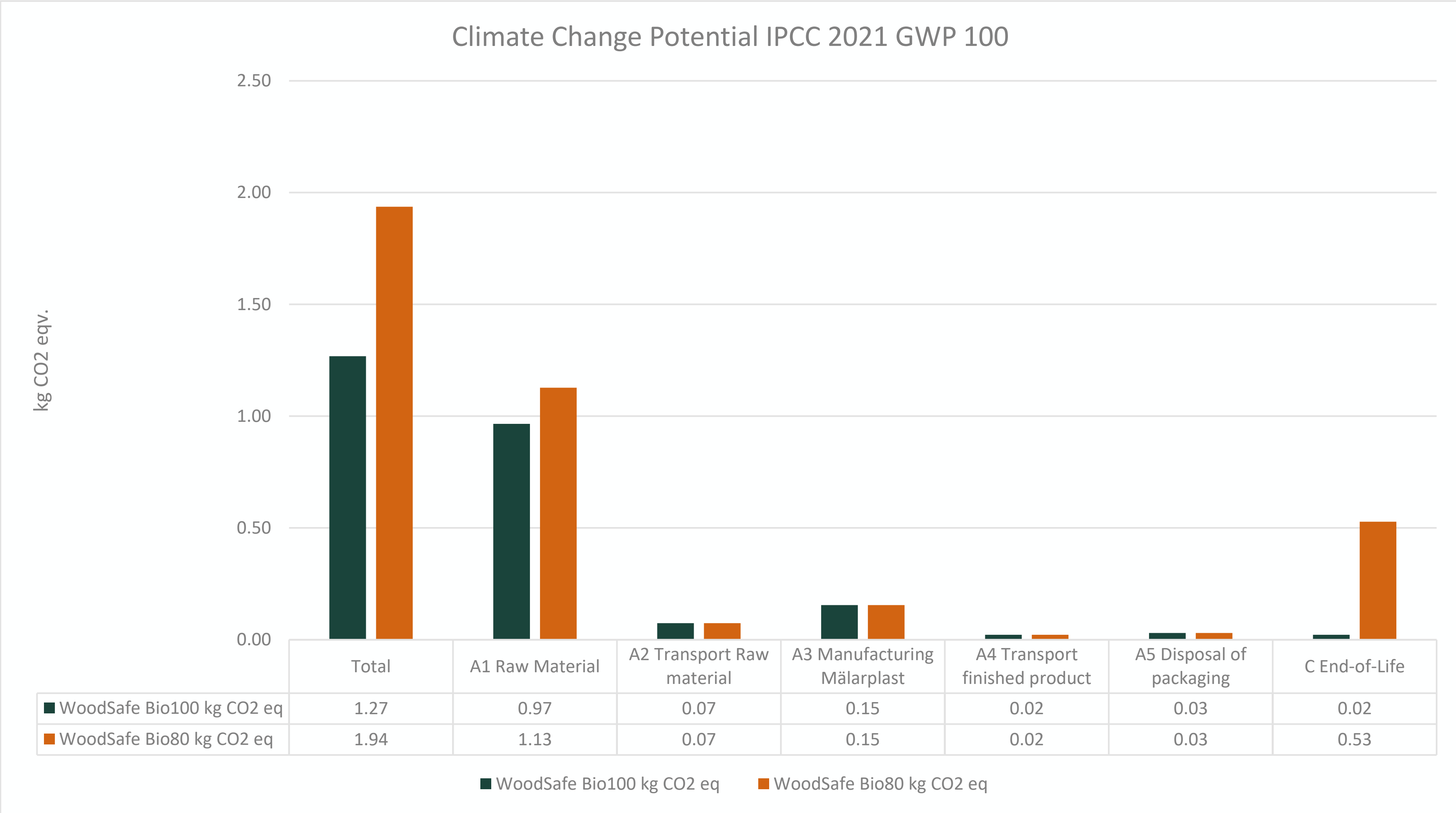


Figure 12, show a Sankey diagram of the climate change potential according to IPCC 2021 GWP 100. 17 of 14711 contributing processes are visible.

## 5.3 Comparison Climate Change Potential WoodSafe Bio80 and WoodSafe Bio100

Figure 13 show a comparison of Climate change potential of WoodSafe Bio80 and WoodSafe Bio100 according to IPCC 2021 GWP 100.




| | Total | A1 Raw Material | A2 Transport Raw material | A3 Manufacturing Mälarplast | A4 Transport finished product | A5 Disposal of packaging | C End-of-Life |
|---|---|---|---|---|---|---|---|
| WoodSafe Bio100 kg CO2 eq | 1.27 | 0.97 | 0.07 | 0.15 | 0.02 | 0.03 | 0.02 |
| WoodSafe Bio80 kg CO2 eq | 1.94 | 1.13 | 0.07 | 0.15 | 0.02 | 0.03 | 0.53 |

Figure 13, show a comparison of Climate change potential of WoodSafe Bio80 and WoodSafe Bio100 according to IPCC 2021 GWP 100.

# 6 Interpretation

This section covers the key aspects of the results, sensitivity analyses, scenario analyses and an evaluation of the model and underlying data.

The quantitative impact assessment results are interpreted to understand the possibilities of reducing environmental impact most efficiently.

## 6.1 Overall comparison WoodSafe Bio80 and WoodSafe bio100

When comparing the result from Figure 13 WoodSafe Bio80 show 53% higher climate change potential than WoodSafe Bio100. This is mainly because of lower emissions of fossil CO2eqv in the End-of-Life stage and secondly because of lower climate change potential in the raw material stage. This shows that the usage of more renewable material has many advantages from a climate change perspective.

If the end point results are compared the change is not as big, WoodSafe Bio80 show 11% higher total environmental burden compared to WoodSafe Bio100. This show that the benefit of lower climate change potential of plant based raw material comes with the cost of higher environmental burden in other environmental effect categories. When comparing Figure 7 and Figure 10 it is clear that WoodSafe Bio100 have higher results in the categories Land Use and Eutrophication.

The endpoint results also show that resource use fossil and Climate change is the most relevant effect categories, and therefore will the interpretation be around these issues primarily.

### 6.1.1 Raw material

For both materials the Raw Material phase is the one with the highest climate change potential. 58% for WoodSafe Bio80 and 76% for WoodSafe Bio100.

For WoodSafe Bio100 64% of the climate change potential of the raw material phase comes from the production of tall oil. This is almost half (48%) of the total climate change potential of WoodSafe Bio100. How the result would change with other renewable sources for doing bio-based PP can be seen in 6.3.

For WoodSafe Bio80 48% of the climate change potential comes from tall oil and 35% from the virgin PP. Virgin PP is now represented with generic dataset since several suppliers are used. How the production of PP is done do not differ much depending on the region, what can affect the climate change potential is the source of electricity and heat. Since all suppliers are from southern Europe and European market data is used with similar GWP per kWh electricity it should give a good representation.

### 6.1.2 Manufacturing

Manufacturing is done at Mälarplast AB. This stage stands for 8% of the total climate change potential for WoodSafe Bio80 and 12% for WoodSafe Bio100.

Mälarplast have modern machines for injection molding with high efficiency. (Wall, 2023) The bio-composite material does not need to be heated as much as normal PP since lower melting temperature. (Wall, 2023) This also give an energy efficient process. Mälarplast also have some of their electricity produced on site using solar cells, this also lowers the GWP.

Figure 14 show how the climate change potential is distributed on the manufacturing process.

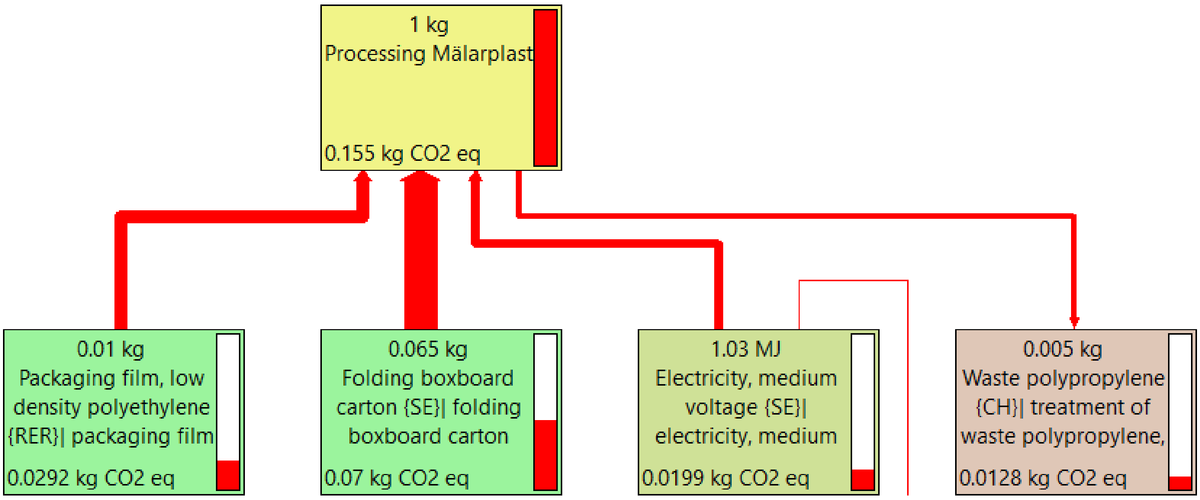


Figure 14, show how the climate change potential is distributed on the manufacturing process.

The packaging in the form of cardboard box and packaging film stands for a big part (64%) of the total climate change potential for manufacturing. The cardboard box is now represented with a regionalized generic LCI data set and specific data could change the results.

### 6.1.3 Transport

In total WoodSafe Bio80 cause 1,4tkm of truck transport from its life cycle. This adds 0,264kg $CO_2$ eqv to the total climate change potential or 14%.

In total WoodSafe Bio100 cause 1,15tkm of truck transport from its life cycle. This adds 0,216kg $CO_2$ eqv to the total climate change potential or 17%.

In theory if all the transport was instead done with electrical train that can lower the climate change potential from transport with one fifth. Changing the total to 0,052kg CO2 eqv for Woodsafe Bio80 and 0,043kg CO2 eqv for WoodSafe Bio100.

### 6.1.4 Usage

Even thou usage have no environmental aspects the way the HWC is utilized at the healthcare facilities decides the amount of HWC that needs to be produced and eventually its environmental burden. The amount of HWC needed can be minimized by smart management. The size of the HWC containers should not be unnecessary big and not discarded unnecessary frequent. If for instance a 2,3L HWC is used when only a 0,5L is needed the environmental burden will be almost tripled, which makes that choice equally important as the material of the HWC. The degree of filling of the HWC container should be as high as possible. This can be achieved by not routinely discard the HWC but instead wait until it is full.

### 6.1.5 End-of-Life

The biggest difference between the two products is in the End-of-life stage. 27% of the total climate change potential originates from this stage for WoodSafe Bio80, compared to only 2% for WoodSafe Bio100. The difference is explained by the 100% biogenic raw material used when producing

WoodSafe Bio100 and which therefore do no emit any fossil emissions of $CO_2$ when incinerated. The 20% fossil part of WoodSafe Bio80 cause 0,53kg of $CO_2$ eqv. This shows the benefit of using renewable material for products that get incinerated as end-of-life. Recycled fossil material emits the same amount of fossil $CO_2$ emissions when incinerated as virgin fossil material. Incineration and energy recovery should be the last option when handling waste after re-use and recycling of material. If incineration cannot be avoided, it should have as small percentage of fossil material as possible to minimize the amount of added CO2 to the atmosphere. The importance of this gets highlighted when the result is compared to other common materials under 6.2.

## 6.2 Comparison with common material on market today

To understand the result further the climate change potential can be set in context of similar products. As part of the interpretation the results from climate change potential will be compared to the most common materials for HWC today.

The most common material for HWC is PP. For PP the most common is that is made of virgin PP but there are also variants with different percentages of recycled PP.

A big majority of PP for HWC comes from southern Europe, most common is Italy and Spain. (Mårdberg, 2023) Therefore, a generic market process for Europe was chosen to represent the virgin PP and the transport distance was set to an average from southern Europe.
The recycled PP will follow the Polluter Pays Principle (PPP) and only the refinement of the post-consumer PP waste will be allocated to the subsequent life of the PP waste. That means sorting, washing, and granulating of the post-consumer PP waste. No specific LCI data for PP post-consumer waste is available in ecoinvent 3.9 and therefore a LCI data for PET plastic is used instead, but the process and environmental burden is considered very similar. The recycled PP granulates is also assumed to come from southern Europe. The end-of-Life scenario will be identical with the scenario for Woodsafe described in 4.7.

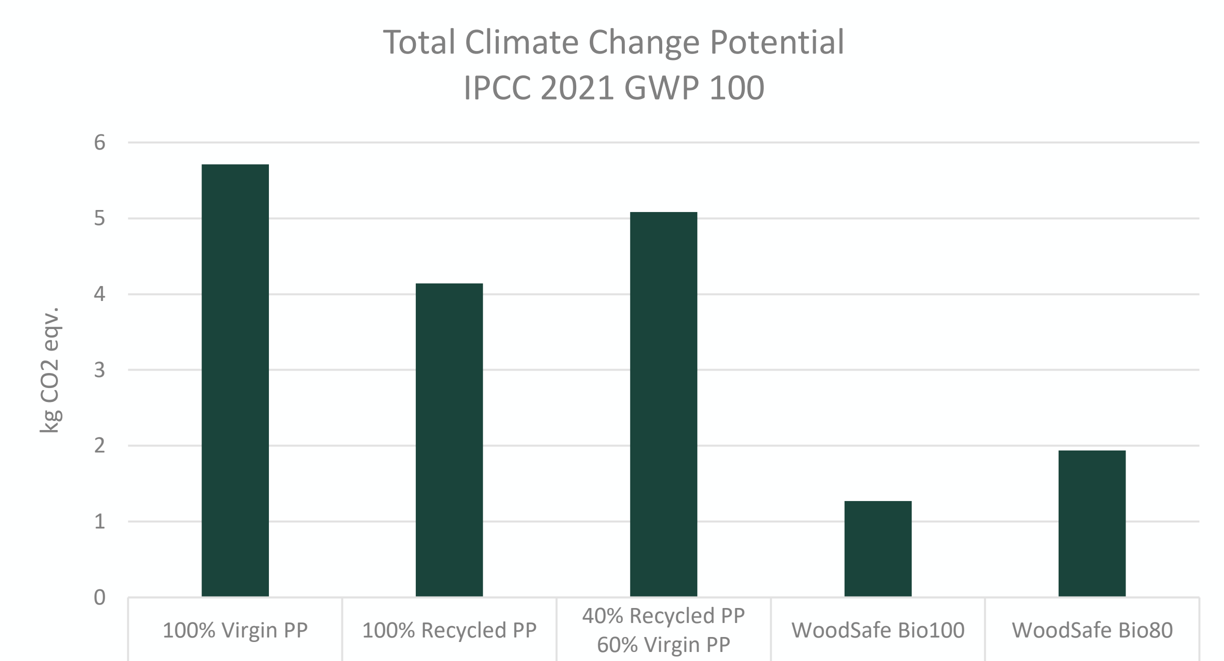
**Virgin PP ecoinvent 3.9 LCI data:**

- Granulates: 1kg, Polypropylene, granulate {RER}| polypropylene production, granulate | Cut-off
- Injection molding processing: 1kg, Injection moulding {RER}| injection moulding | Cut-off
- Transport: 2000kgkm. Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off

**Recycled PP ecoinvent 3.9 LCI data:**

- For granulates: Waste polyethylene terephthalate, for recycling, sorted {Europe without Switzerland}| treatment of waste polyethylene terephthalate, for recycling, unsorted, sorting | Cut-off
- Injection molding processing: 1kg, Injection moulding {RER}| injection moulding | Cut-off
- Transport: 2000kgkm. Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off

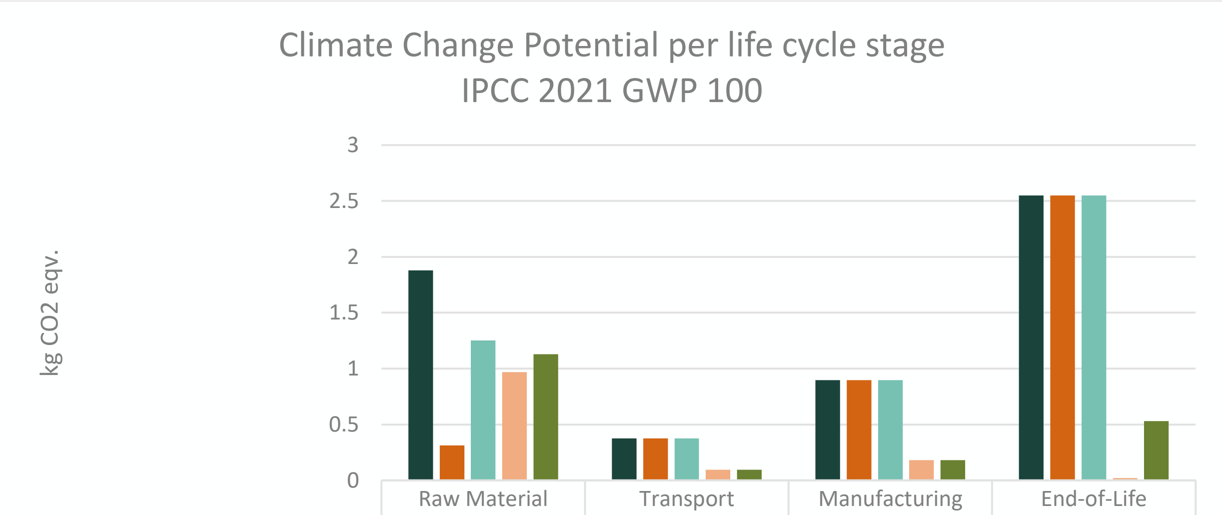
A comparison of the two Woodsafe products with 100% virgin PP and different ratios of recycled vs. virgin PP can be seen in Figure 15.




| | 100% Virgin PP | 100% Recycled PP | 40% Recycled PP 60% Virgin PP | WoodSafe Bio100 | WoodSafe Bio80 |
|---|---|---|---|---|---|
| Total | 5.71 | 4.14 | 5.08 | 1.27 | 1.94 |

Figure 15, show a comparison of total climate change potential for common HWC materials on the market today and WoodSafe.

To understand further why WoodSafe show lower climate change potential a comparison also with the different life cycle stages can be seen in Figure 16.




| | Raw Material | Transport | Manufacturing | End-of-Life |
|---|---|---|---|---|
| 100% Virgin PP | 1.88 | 0.377 | 0.898 | 2.55 |
| 100% Recycled PP | 0.313 | 0.377 | 0.898 | 2.55 |
| 40% Recycled PP 60% Virgin PP | 1.25 | 0.38 | 0.90 | 2.55 |
| WoodSafe Bio100 | 0.97 | 0.10 | 0.18 | 0.02 |
| WoodSafe Bio80 | 1.13 | 0.10 | 0.18 | 0.53 |



Figure 16, show the climate change potential per life cycle stage for WoodSafe and other common HWC materials on the market.

The 100% recycled PP is not a material available for this product today, but it is still interesting to add to the comparison to show the pros and cons of the different materials more clearly. 100% recycled PP show the lowest climate change potential in the raw material stage and 100% virgin the highest. Transportation phase is higher for the 100% PP alternatives since they are assumed to be produced in southern Europe and the usage location is Stockholm, Sweden. This parameter can however change and if usage location will be London instead this stage will be similar. Manufacturing stage is higher for the 100% PP alternatives due mainly to the higher GWP of electricity in Europe compared to Sweden where the WoodSafe products are produced. Also, this is a parameter that might change if specific data is used for the 100% PP alternatives instead of the generic approach now used. The biggest difference is however in the End-of-Life stage where the 100% PP alternatives show much higher climate change potential. This is a parameter that will not change no matter the usage location or if specific data is used since the End-of-Life scenario for HWC is 100% incineration and the climate change potential for this is almost identical no matter where the product is incinerated.

This once again underlines the importance of using renewable raw materials for products that is incinerated as end-of-life, as the downside of this exceeds the benefit of lower climate impact in raw material acquisition. Recycled material, especially made on non-renewable raw material should be kept in the loop for as long as possible for maximizing its benefits.

As shown in part 6.1 the biggest benefit for WoodSafe Bio100 is in climate change potential, therefore the results should also be compared when weighting in a total environmental impact perspective such as the endpoint does, this can be seen in Figure 17.

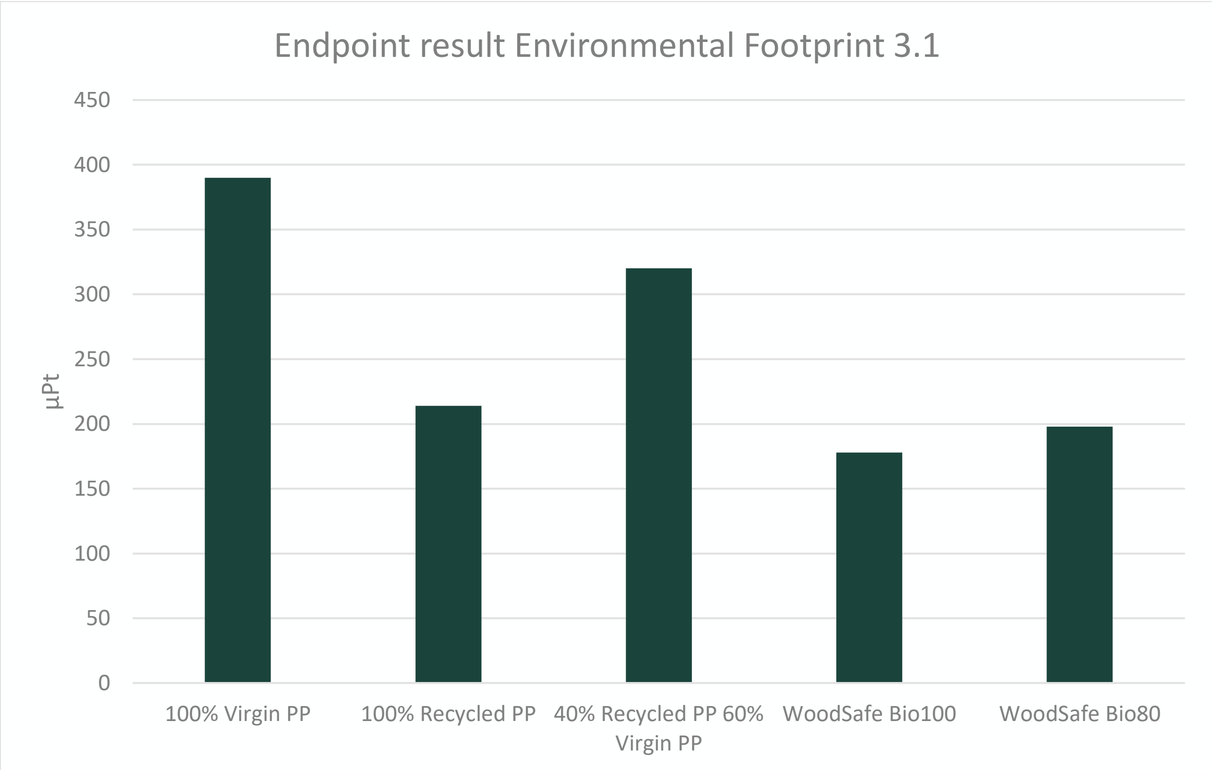



Figure 17, show a comparison of endpoint result according to Environmental Footprint 3.1.

The result in Figure 17 shows that using plant based raw material, that have big benefit from a climate change perspective, comes with a significant impact on other environmental impact categories. It is still apparent that the result concerning both climate change potential and the overall environmental impact still recommend WoodSafe alternatives, especially considering that the 100% recycled alternative is not available on the market today.

The result does however emphasize the necessity to broaden the discussion when trying to assess the best alternative for the environment. As shown in this result it can be a big discrepancy between the result concerning climate change and the result of the overall environmental impact. Meaning, what is best when looking at climate change potential do not necessarily mean the best alternative for the planet, and the best alternative when looking at the overall environmental impact should be the main guiding result.

## 6.3 Sensitivity analysis

LCA provides a holistic perspective on an entire system. To succeed in this ambitious goal, certain simplifications and value-based choices to cover the entire system are required. By changing these choices, one can, based on the result, assess its relevance and whether there is a reason to revise the assumptions or choices that have been made.

### 6.3.1 Different source of renewable raw material for biobased PP

The source of the bio-based PP affects its environmental impact. In this study tall oil was used since that was established by the supplier. However, there might in the future be different sources of renewable raw material used and to assess whether this changes the conclusions from the study or not. Four other potential sources of renewable raw material for the biobased PP are analyzed, palm oil, soybean oil, vegetable oil and coconut oil.

All other options show higher GWP than tall oil, so this is the preferred choice. Tall oil has a climate change potential advantage compared to the other alternatives analyzed here because it is wood-based which is a more land effective way of producing the oil raw material and also is still not the primary driver of the market, instead it is a by-product of wood building material. The worst option is soybean oil. If the renewable part of the bio-based oil is changed to this the total climate change potential for Woodsafe Bio 80 is increased from 1,94kg $CO_2$ eqv. to 4,67kg $CO_2$ eqv. a significant increase. This shows that the type of renewable raw material used can have big effects on the overall results. This also shows that the results cannot be generalized to say that renewable raw material always is a preferred option. An answer needs to be a little more nuanced and investigated since the widespread climate change potential of renewable raw material from especially agriculture and is dependent on several local circumstances.

## 6.4 Scenario analysis

### 6.4.1 Different usage locations

The Woodsafe container can be sold all over Europe. To see how much different usage location affect the overall result two different scenarios will be analysed. The first is with usage in London, England and the other is usage in Amsterdam, Netherlands. The End-of-Life scenario is the same no matter where the products are sold.

The transport from Eskilstuna, Sweden to Stockholm, Sweden that was used in the main scenario is then replaced with the distance to London (1840km) and the distance to Amsterdam (1383km). All transportation is assumed to be done with truck. How this affects the overall results can be seen in Figure 18.

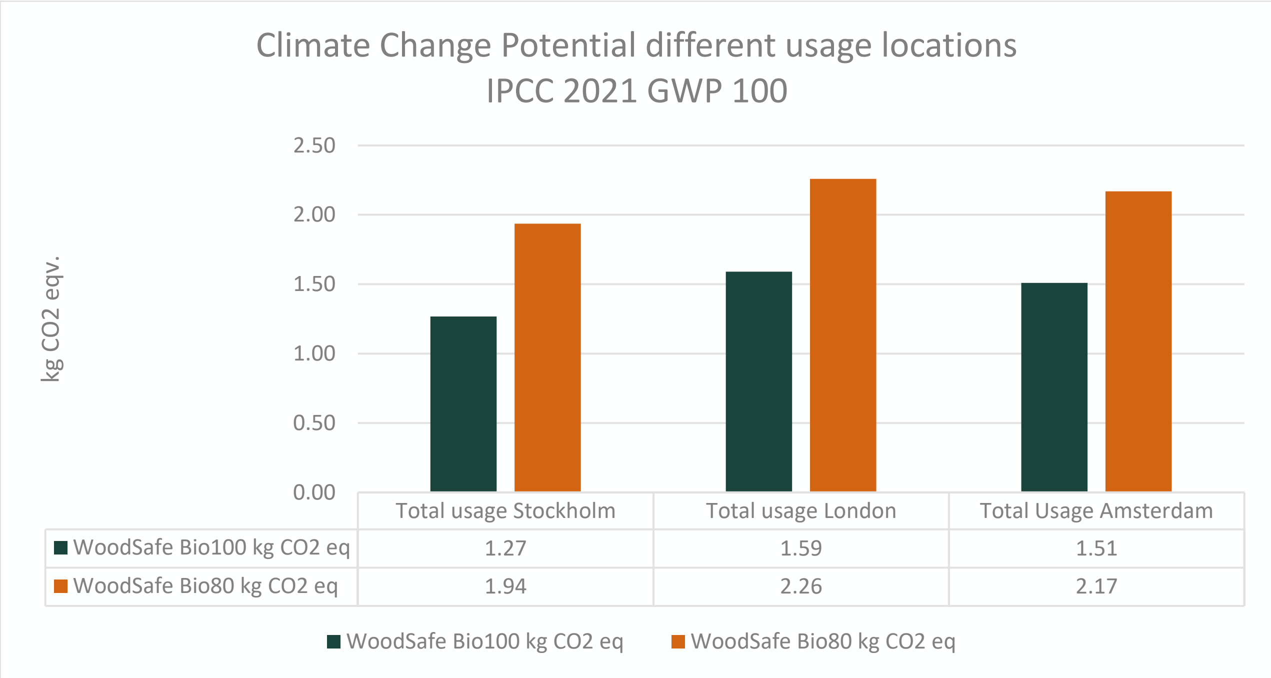



Figure 18, show the climate change potential with different usage locations.

For WoodSafe Bio80 the longer transport of the finished product adds 16% for usage in London and 12% for usage in Amsterdam. For WoodSafe Bio100 the longer transport of the finished product adds 25% for usage in London and 19% for usage in Amsterdam. A significant increase in climate change potential and transportation with lower GWP than truck is relevant to calculate. If instead train was used for the transportation the total GWP would only increase 4% WoodSafe Bio100 and 2% for WoodSafe Bio 80. The climate change potential is still low in comparison to other common materials but how the transport is done is a factor that is recommended to investigate for longer travels.

## 6.5 Data quality assessment

An evaluation of the model and underlying data is made by a data quality assessment which includes a completeness check, assessing the validity of data and a consistency check.

The data are assessed according to the DQR defined in part 3.3.7. The data quality assessment is based on the requirements in the ISO 14044 standard.

Table 15: Data quality assessment for the study.

| Aspect | Notes |
|---|---|
| Geographical coverage | Upstream data: Good (Country specific)<br>Core module (A3): Very good (site-specific) |
| Technological representativeness | Upstream data: Good (Generic data based on plant averages)<br>Core module (A3): Very good (site-specific) |
| Time-related coverage | Upstream data: Good<br>Core module (A3): Very good (2022 data) |
| Validity | The technological and geographical coverage of the data chosen reflects the physical reality of the product system modelled. |
| Plausibility | The data used for the core process and some upstream processes have been checked for plausibility, using EPDs and generic LCI data from ecoinvent for similar material. |

| | |
|---|---|
| Precision | Material and energy flow quantified based on generic data from the ecoinvent 3.9 database. |
| Completeness | Data accounts for all known sub-processes. All upstream processes were modelled using generic data from the ecoinvent 3.9 database, using country-specific datasets whenever available, otherwise using European datasets. |
| Consistency, allocation method, etc. | Allocation follows a physical causality. |
| Completeness and treatment of missing data | No data is found missing. |
| Final result of data quality assessment | Data quality as defined in DQR section 3.3.7 is met. |

### 6.5.1 Uncertainty analysis

Uncertainty analysis is performed in two ways. Monte Carlo analysis will be performed to take into account the uncertainty in the inventory data obtained from the ecoinvent database. Uncertainty concerning specific data and assumptions are analysed in a sensitivity analysis described under 6.3.

Monte Carlo simulation was performed using the SimaPro software. For each inventory input or output that contains a distribution and standard deviation, a random value that falls in the distribution range is selected in numerous iterations. The LCA results are recalculated for each iteration. 70% of input data have an uncertainty distribution. A histogram showing the probability of the results of the climate change impact using the EF3.1 method, performed with 1000 iterations and presented in Figure 19 and details in Table 16.

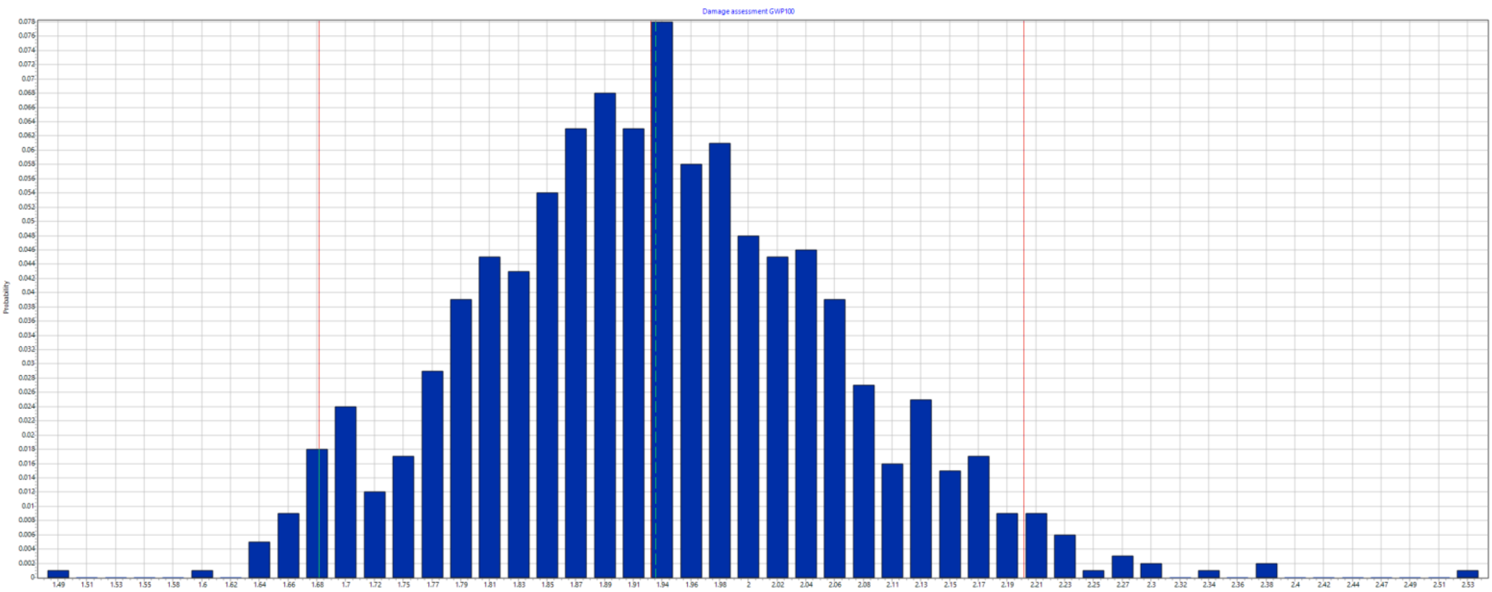



Figure 19: Show the distribution of results from the Monte Carlo analysis.

Table 16: Details concerning the Monte Carlo analysis

| Mean | Median | Standard deviation | Coefficent of variation % | Low 2.5% | High 97.5% | Standard error of mean |
|---|---|---|---|---|---|---|
| **1,93** | 1,93 | 0,132 | 6,86 | 1,68 | 2,20 | 0,00419 |

The uncertainty is considered acceptable for a complex LCA study.

## 6.6 Conclusions and recommendations

This section will summaries the conclusions from the study in terms of highlighting the most important aspects of the results and the interpretation.

- A higher proportion of renewable raw material have environmental advantages. The renewable source of tall oil is a good choice for minimizing the environmental burden. In the context of healthcare where the HWC get incinerated it is even more important than in other applications to avoid fossil based raw material. WoodSafe Bio100 with no fossil raw material is the preferred choice for minimizing environmental burden.
- It is of high importance concerning the environmental burden that healthcare institutions optimize the size and frequency of discarding. HWC should be discarded when full not routinely.
- For applications outside Sweden possibility to use train transportation should be investigated.

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# Appendix 1 Basics of Life Cycle Assessment

There are four phases in an LCA study; the goal and scope definition phase, the inventory analysis phase, the impact assessment phase and the interpretation phase. Below is a conceptual picture of this in Figure 20. In sections Appendix 1A - Appendix 1D further details on each life cycle phase are presented.

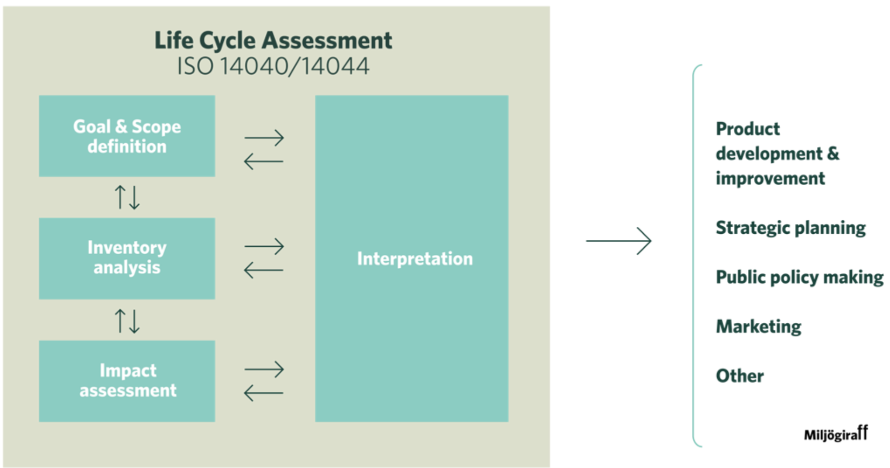



Figure 20. The four phases of the Life Cycle Assessment

## A. Goal and scope definition

The first phase is the definition of goal and scope. The goal and scope, including system boundary and level of detail, of an LCA depend on the subject and the intended use of the study. The depth and breadth of LCA can differ considerably depending on the goal of a particular LCA. The goal also affects the choice of system boundaries and data requirements. See further details below.

### i. System boundary

The system boundary determines which modules and activities are included within the LCA. The selection of the system boundary shall be consistent with the goal of the study. A system boundary chosen to include all contributing processes for the system while facilitating the modelling and analysis of the system. Therefore, there may be reasons to exclude activities that contribute insignificantly to the environmental effects (so-called “cut-off”). However, the omission of life cycle stages, processes, inputs, or outputs is permitted only if it does not significantly change the study’s overall conclusions. It should be clearly stated if life cycle stages, processes, inputs, or outputs are not included; and the reasons and implications for their exclusion must be explained.

When the life cycle is defined by the system boundary, the environmental aspects included, and the data used to represent the different aspects is in detail described under the LCI part.

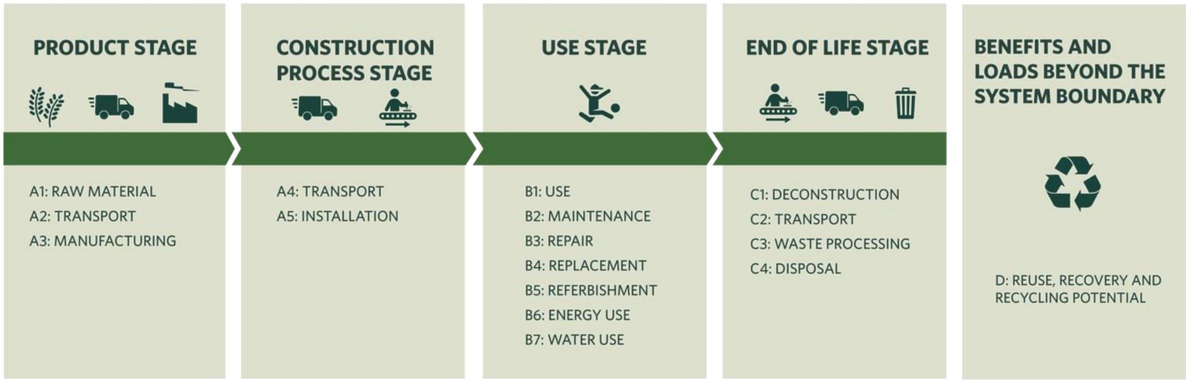



Figure 21: General summary of the modules included in an LCA, based on EN 15804.

In this LCA, boundaries with other systems, and the allocation of environmental burdens between them, are based on the recommendations of the international EPD system[2], which are also in line with the requirements and guidelines of the ISO14040/14044 standards. Following these recommendations, the Polluter Pays (PP) allocation method is applied (see Figure 22). For the allocation of environmental burdens when incinerating waste, all processes in the waste treatment phase, including emissions from the incineration, are allocated to the life cycle in which the waste is generated. Subsequent procedures for refining energy or materials to be used as input in a following/receiving process are allocated to the next life cycle.

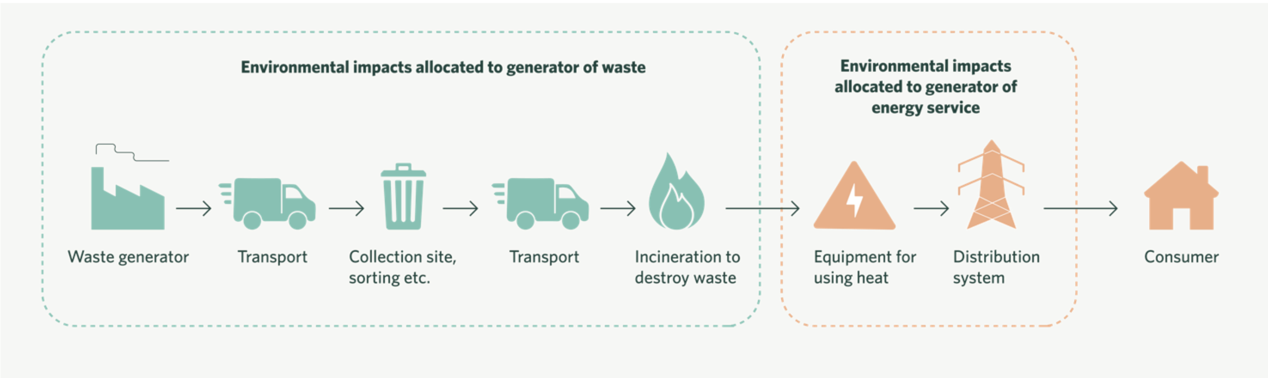



Figure 22: Allocation of environmental impacts between two life cycles according to the PP allocation method. Here in regard to the incineration of waste and resulting energy products.

In the case of recycling, environmental burdens are accounted for outside of the generating life cycle. They have thus been allocated to the subsequent life cycle, which uses the recycled materials as input.

Avoided materials due to recycling are typically not considered in the main scenario, per the International EPD system's recommendation of the Polluter Pays Principle. In other words, only if the

[2] EPD (Environmental Product Declarations) by EPD International®

generating life cycle uses recycled material as input material will it account for the benefits of recycling.

### ii. Cut-off

It is common to scan for the most important factors (a "cut off" of 95% is a minimum) to avoid putting time and effort into irrelevant parts of the life cycle. In general, LCA focuses on the essential material and energy flows, while the flows that can be considered negligible are excluded. By setting cut-off criteria, a lower limit is defined for the flows to be included. Flows below the limit can be assumed to have a negligible impact and are thus excluded from the study. For example, cut-off criteria can be determined for inflows concerning mass, energy, or outflows, e.g., waste.

### iii. Allocation

The study shall identify the processes shared with other product systems as co-products, and deal with them according to the stepwise procedure presented below:

- **Step 1**: Wherever possible, the allocation should be avoided by dividing the unit process into two or more sub-processes and collecting the input and output data related to these sub-processes or expanding the product system to include the additional functions related to the co-products.
- **Step 2**: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them; i.e., they should reflect how the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system.
- **Step 3**: Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products.

When other allocation methods are used, it should be documented and assessed whether it may be significant to the results.

### iv. Data requirements (DQR)

General LCI databases contain a large amount of third-party reviewed LCI data compiled according to the ISO 14048 standard. Certified LCI data forms a basis for a robust and transparent study. However, it is crucial to understand that specific producers may differ considerably from general practice and average data.

The LCI data can be either specific or general. Specific data means that all data concerning material, energy and waste are specifically modelled for the conditions at the manufacturing facility and the technology used. Generic data means that material or energy are represented using average LCI data from ecoinvent 3.8.

Specific data
1. Environmental Product Declarations (type III)
2. Collected data (web format, site visits and interviews).
3. Reported data (EMS, Internal data systems or spreadsheets)

Selected generic data
1. Close proxy with data on a similar product
2. Statistics

3. Public documents

Generic data

1. Public and verified libraries with LCI data
2. Trade organisations' libraries with LCI data

Sector-based IO data, national

## B. Inventory analysis (LCI)

The life cycle inventory analysis phase (LCI phase) is the second phase of LCA. It is an inventory of input/output data with regard to the system being studied. It involves the collection of the data necessary to meet the goals of the defined study.

## C. Impact assessment (LCIA)

The life cycle impact assessment phase (LCIA) is the third phase of the LCA. The purpose of LCIA is to provide additional information to help assess a product system's LCI results so as to better understand their environmental significance. Mandatory steps in the lifecycle impact assessment are classification and characterisation. An optional step is weighting.

Readymade methods for classification, characterisation and weighting have been used to evaluate environmental effects (either from a broad perspective or for a single issue) and find the categories or parts of a system with the most potential impact. Some of the most common LCIA methods are presented in Appendix 2 - **Fel! Hittar inte referenskälla.**.

Classification, characterisation and weighting will here be briefly explained.

### i. Classification and characterisation

The process of determining what effects an environmental aspect can contribute to is called classification, e.g. that the use of water contributes to the environmental effect of water depletion, see Figure 23 for an illustration. The characterisation, in turn, means defining how much an environmental aspect contributes to the environmental impact category to which it is classified, e.g. the use of 1 tonne of river water contributes a factor of 0.5 to water depletion. Evaluating how critical it is in a specific area depends on the current environmental impact, the pressure from resource consumption and the ecosystem's carrying capacity. This is done through normalisation.

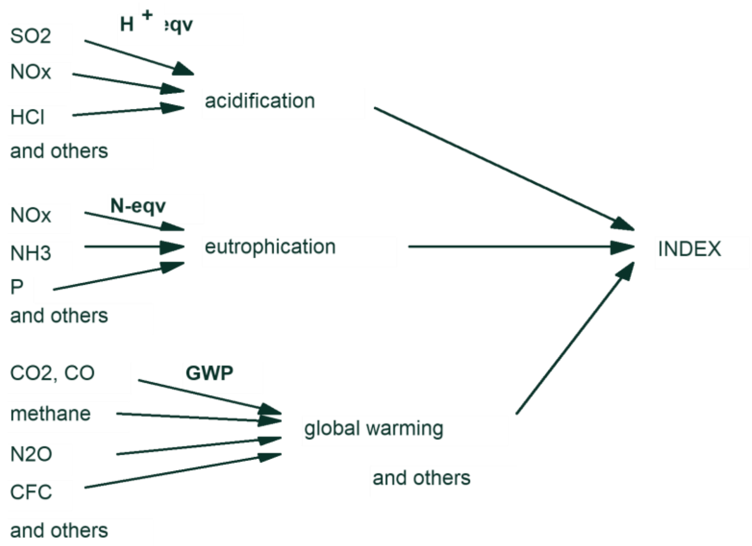


Figure 23: An illustration of the Impact Assessment of an LCA.

### ii. Weighting

To compare different environmental effects and to identify "hot spots", so-called *weighting* is applied. The calculated environmental effects are weighted together to form an index called a "*single score*" which describes the total environmental impact.

Because weighting involves subjective weighting (e.g. by an expert panel), it is recommended for internal communication only. Otherwise, there is a risk of mistrust if the choice of weighting method used leads to results that emphasise the "upsides" and hide the "downsides" of the analysed product. For external communication, only *Single issues* should be communicated.

## D. Interpretation

The life cycle interpretation phase of an LCA or an LCI study comprises several elements:

- identification of the significant issues based on the results of the LCI and LCIA phases of LCA
- an evaluation that considers completeness, sensitivity and consistency checks
- conclusions, limitations, and recommendations.

The interpretation of the results in this study is carried out by first identifying the aspects that contribute the most to each individual environmental effect category. After that, the sensitivity of these aspects is evaluated, and the completeness and consistency of the study are assessed. Conclusions and recommendations are then based on the results and a clear understanding of how the LCA was conducted with any subsequent limitations.

### i. Evaluation of the results

The objectives of the evaluation element are to establish and enhance confidence and the reliability of the results of the LCA or the LCI study, including the significant issues identified in the first element of the interpretation. The evaluation should use the following three techniques:

- Completeness check
  The objective of the completeness check is to ensure that all relevant information and data needed for the interpretation are available and complete. If any relevant information is

missing or incomplete, the necessity of such information for satisfying the goal and scope of the LCA shall be considered. This finding and its justification shall be recorded.

- Sensitivity check
  The objective of the sensitivity check is to assess the reliability of the final results and conclusions by determining how they are affected by uncertainties in the data, allocation methods or calculation of category indicator results, etc.
- Consistency check
  The objective of the consistency check is to determine whether the assumptions, methods and data are consistent with the goal and scope.
- Uncertainty check
  Is a systematic procedure to quantify the uncertainty introduced in the results of a life cycle inventory analysis due to the cumulative effects of model imprecision, input uncertainty and data variability

# Appendix 2 Environmental footprint 3.1

One of the most commonly used LCIA methods is the Environmental footprint 3.1 (EF3.1) method (European Commission, 2012). It includes classification, characterisation and optional normalisation and weighting as well as the possibility to calculate a single score including all weighted impacts.

To give a brief description of each type of environmental impact, the impact categories from EF3.0 will now be summarised:

**Acidification** – EF impact category that addresses impacts due to acidifying substances in the environment. Emissions of NOx, NH3 and SOx lead to releases of hydrogen ions (H+) when the gases are mineralised. The protons contribute to the acidification of soils and water when they are released in areas where the buffering capacity is low, resulting in forest decline and lake acidification.

**Climate change** - Climate change is defined as the warming of the climate system due to human activities. Human activities emitting greenhouse gases (GHG) are the leading cause of global warming. GHG emissions have the property of absorbing radiation, resulting in a net warming effect called the greenhouse effect. These will then perturb the Earth's natural balance, increasing temperature and affecting the climate with disturbances in rainfall, extreme climate events and rising sea levels. Climate change is an impact affecting the environment on a global scale.
GHG sources can be classified of three main types: fossil sources, biogenic sources, and land use change. Fossil sources are formed from the decomposition of buried carbon-based organisms that died millions of years ago. Burning fossil sources leads to an increase in GHG in the atmosphere. Biogenic sources are often considered natural and refer to carbon taken up during the cultivation of a crop, considering that there is no net increase of carbon dioxide in the atmosphere. Another source of carbon dioxide emissions is the effect of land use on plant and soil carbon. For example, carbon is stored naturally in nature, and by changing the characteristics of a land area, this carbon is then released. Land use change hence measures the GHGs emissions that occur when changing the vegetation or other characteristics of the land used for a product's lifecycle.

**Ecotoxicity, freshwater** – Environmental footprint impact category that addresses the toxic impacts on an ecosystem, which damage individual species and change the structure and function of the ecosystem. Ecotoxicity is a result of a variety of different toxicological mechanisms caused by the release of substances with a direct effect on the health of the ecosystem.

**Eutrophication** – Nutrients (mainly nitrogen and phosphorus) from sewage outfalls and fertilised farmland and this affects the nutrient cycling in the aquatic and terrestrial ecosystems. Three EF impact categories are used to assess the impacts due to eutrophication: Eutrophication, terrestrial; Eutrophication, freshwater; Eutrophication, marine. In aquatic bodies, this accelerates the growth of algae and other vegetation in the water. The degradation of organic material consumes oxygen resulting in oxygen deficiency and, in some cases, fish death. Terrestrial vegetation can be affected by excess nitrogen, which can lead to changed tolerance to disease or other stressors like drought and frost. The three impact categories hence communicate which environment compartment the eutrophication occurs. Regardless of where it occurs, it changes the structure and function of ecosystems which may result in overall biodiversity and productivity changes.

**Human toxicity, cancer –** Impact category that accounts for adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food and water ingestion, penetration through the skin insofar as they are related to cancer.

**Human toxicity, non-cancer–** Impact category that accounts for the adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food and water ingestion, penetration through the skin insofar as they are related to non-cancer effects that are not caused by particulate matter/respiratory inorganics or ionising radiation.

**Ionising radiation, human health** – EF impact category that accounts for the adverse health effects on human health caused by radioactive releases.

**Land use –** The land use impact category reflects the damage to ecosystems due to the effects of occupation and transformation of the land. Although there are many links between the way land is used and the loss of biodiversity, this category concentrates on the following mechanisms:

1. Occupation of a certain area of land during a certain time;
2. Transformation of a certain area of land.

Both mechanisms can be combined, often occupation follows a transformation, but often occupation occurs in an area that has already been converted (transformed). In such cases, the transformation impact is not allocated to the production system that occupies an area.

**Ozone depletion** – EF impact category that accounts for the degradation of stratospheric ozone due to emissions of ozone-depleting substances, for example, long-lived chlorine and bromine-containing gases (e.g. CFCs, HCFCs, Halons).

**Particulate matter formation** – Fine Particulate Matter with a diameter of smaller than 10 µm (PM10) represents a complex mixture of organic and inorganic substances. PM10 causes health problems as it reaches the upper part of the airways and lungs when inhaled. Secondary PM10 aerosols are formed in the air from emissions of sulphur dioxide (SO2), ammonia (NH3), and nitrogen oxides (NOx), among others (World Health Organisation, 2003). Inhalation of different particulate sizes can cause different health problems.

**Photochemical ozone formation** – EF impact category that accounts for the formation of ozone at the ground level of the troposphere caused by photochemical oxidation of volatile organic compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NOx) and sunlight. High concentrations of ground-level tropospheric ozone damage vegetation, human respiratory tracts and manmade materials through reaction with organic materials.
**Resource use, fossil**: Impact category that addresses the use of non-renewable fossil natural resources (e.g. natural gas, coal, oil).

**Resource use, minerals and metals**: Impact category that addresses the use of non-renewable abiotic natural resources (minerals and metals). When using these non-renewable resources, there is a decrease in the global stock. Depending on how large the global reserve is assessed to be and the extraction rate of the resource, this impact category regards how rare the mineral and metal are and how much is being used. Hence, this impact category measures the impacts on the gobal stocks of minerals and metals in the future.

**Resource use, fossil**: Impact category that addresses the use of non-renewable abiotic natural resources (fossil). Similar to resource use, minerals and metals, when using fossil fuels, there is a decrease in the global stock. Since the industrial revolution, we have created societies highly dependent on fossil resources. Fossil resources are today commonly used to power processes and transports throughout a product's lifecycle. This impact category aggregates this total use of fossil resources throughout the lifecycle. The use of fossil resources is strongly interlinked to many of the other impact categories like climate change, particulate matter formation, and acidification.

**Water use** – It represents the relative available water remaining per area in a watershed after the demand of humans and aquatic ecosystems has been met. It assesses the potential of water deprivation to either humans or ecosystems, building on the assumption that the less water remaining available per area, the more likely another user will be deprived (see also http://www.wulca-waterlca.org/aware.html).

### i. LCA impact categories vs planetary boundaries

Global environmental impacts are sometimes discussed in terms of planetary boundaries (Steffen et al., 2015). It can be relevant to note that the impact categories used in LCA do not have a one-to-one correlation with the planetary boundaries as described by Steffen et al.
Table 17 maps the planetary boundaries to mid-point indicators in LCA (when possible) and classifies whether there is a high or low level of correspondence between the indicators.

Climate change, ozone depletion, eutrophication and human- and ecotoxicity are included in similar ways in the two frameworks (Böckin et al., 2020). However, the impact categories of photochemical ozone creation potential and respiratory effects in EF3.0 are meant to represent direct human health impacts. The corresponding planetary boundary is atmospheric aerosol loading, but this is instead mainly meant to represent the effects of monsoon rains. Furthermore, acidification in EF3.0 represents impacts from, e.g., nitrogen and sulphur oxides on land and water ecosystems, while ocean acidification in the planetary boundaries instead represents the effects of carbon dioxide being dissolved in oceans, thus lowering pH levels and affecting marine life. Moreover, the impact categories in EF3.0 does not include an indicator that matches the planetary boundary of biospheric integrity, while the closest category can be said to be land use since it is a driver of biodiversity loss. Lastly, there are some differences between land system change and freshwater use in the planetary boundaries and land use and water use in EF3.0, while the planetary boundaries do not include a category for abiotic resource depletion.

Table 17: Planetary boundaries and mid-point environmental impact indicators in LCA recommended by EF3.0. Adapted from (Tillman et al., 2020).

<table>
<tr><th>Planetary boundaries</th><th>Mid-point indicators in LCA as per EF3.0</th><th>Level of correspondence between impact categories</th></tr>
<tr><td>Climate change</td><td>Climate change</td><td rowspan="5">High level of correspondence</td></tr>
<tr><td>Stratospheric ozone depletion</td><td>Ozone layer depletion</td></tr>
<tr><td>Biogeochemical flows (nitrogen and phosphorus cycles)</td><td>Freshwater, marine and terrestrial eutrophication</td></tr>
<tr><td rowspan="2">Novel entities (chemical pollution)</td><td>Freshwater ecotoxicity</td></tr>
<tr><td>Human toxicity (cancer and noncancer)</td></tr>
</table>

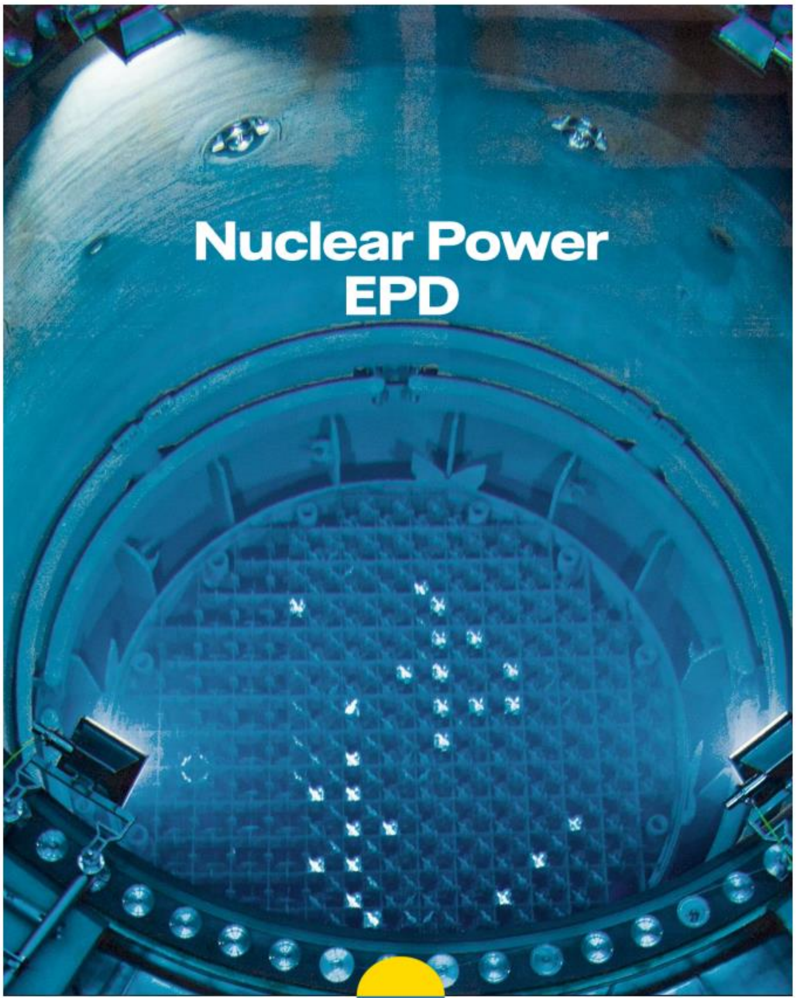
| | | |
|---|---|---|
| Atmospheric aerosol loading | Photochemical ozone creation | Some correspondence |
| | Respiratory effects, inorganic | |
| Ocean acidification | Freshwater acidification | |
| Biospheric integrity (biodiversity loss) | Resources land use | |
| Land system change | Resources land use | |
| Freshwater Use | Resources dissipated water | |
| - | Resources minerals and metals | No correspondence |
| - | Resources fossils | |
| - | Ionising radiation | |

# Appendix 3 IPCC 2021

The potential impact on the climate is calculated using the IPCC 2021 GWP 100 v.1.0 model for Global Warming Potential, GWP. The impact of climate gases is expressed as carbon dioxide equivalents, CO2 eq. It is the most established scientific method and has been implemented (with adaptations) in other methods, such as the GHG protocol and EF3.0. GWP-GHG is a mandatory indicator to include in EPDs of construction products. GWP-GHG accounts for all greenhouse gases except biogenic carbon dioxide uptake and emissions and biogenic carbon stored in the product.

As such, the indicator is identical to GWP-total except that the characterization factor for biogenic CO2 is set to zero.

# Appendix 4 Appendix 4, Guarantees of Origin electricity Stora Enso




VATTENFALL

| | |
|---|---|
| Customer: | **Stora Enso AB** |
| Contract period: | **2022-01-01 - 2022-12-31** |
| Delivery (MWh): | **1 942 598 MWh** |
| Salesperson: | **Jukka Virtala** |

# Appendix 5, Cerificate of solar production Mälarplast AB

2023-04-25 11:04 Annual Comparison - Mälarplast - Sunny Portal

SUNNY PORTAL US-English

SMA Online Store Peter Wall

PV System Selection

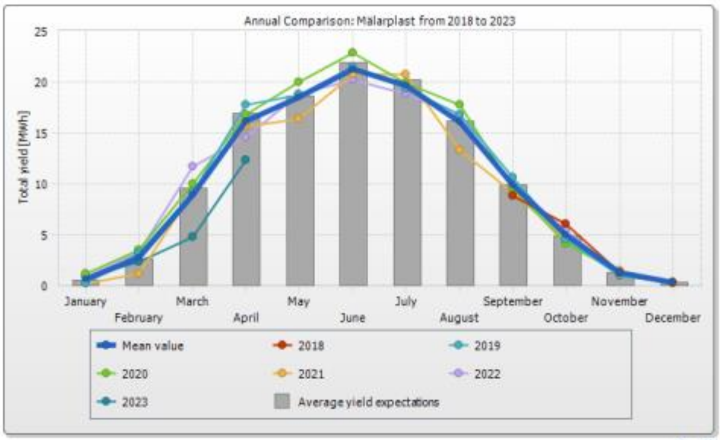
Mälarplast

- PV System Overview
- PV System Profile
- Energy and Power
- Annual Comparison
- PV System Monitoring
- PV System Logbook: 112
- Inverter

Configuration

## Annual Comparison | Mälarplast

**Total yield** Specific PV System Yield




**Total yield [MWh]**

| | January | February | March | April | May | June | July | August | September | October | November | December | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2018 | | | | | | | | | 8.83 | 6.12 | 1.32 | 0.34 | 16.60 |
| 2019 | 0.26 | 3.20 | 9.16 | 17.74 | 18.70 | 21.44 | 19.35 | 16.85 | 10.66 | 4.59 | 0.98 | 0.27 | 123.21 |
| 2020 | 1.12 | 3.47 | 9.96 | 16.80 | 19.97 | 22.91 | 19.94 | 17.75 | 9.62 | 4.19 | 1.31 | 0.32 | 127.37 |
| 2021 | 0.21 | 1.22 | 9.26 | 15.63 | 16.41 | 20.74 | 20.72 | 13.30 | 9.19 | 4.60 | 1.46 | 0.21 | 112.96 |
| 2022 | 0.80 | 3.35 | 11.67 | 14.60 | 18.81 | 20.17 | 18.87 | 16.55 | 9.94 | 5.42 | 1.11 | 0.24 | 121.52 |
| 2023 | 0.86 | 2.34 | 4.82 | 12.38 | | | | | | | | | 20.40 |
| | | | | | | | | | | | | | 522.06 |
| Mean value | 0.65 | 2.72 | 8.97 | 16.19 | 18.47 | 21.32 | 19.72 | 16.11 | 9.85 | 4.98 | 1.23 | 0.28 | 120.50 |
| Year portion | 0.54% | 2.25% | 7.45% | 13.44% | 15.33% | 17.69% | 16.37% | 13.37% | 8.18% | 4.14% | 1.02% | 0.23% | 100.00% |
| Yield expectations * | 0.54 | 2.66 | 9.57 | 16.92 | 18.58 | 21.95 | 20.24 | 16.15 | 9.94 | 4.93 | 1.28 | 0.27 | 123.02 |

**Commissioning:** 9/4/2018

* The expected average yield results from a manual specification. Depending on the orientation and the irradiation fluctuations between the individual years, there might be considerably larger deviations in contrast to the expected average yield.

Edit Prediction Values

Configuration - Annual Comparison



https://www.sunnyportal.com/FixedPages/YearComparison.aspx 1/1