

Life Cycle Assessment on Green Loop Plastic Products by AB Mälarplast

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Mälarplast

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Miljögiraff

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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

CO₂ 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 58 plastic products produced by AB Mälärplast. The assessment is carried out according to a life cycle perspective using the ISO 14040 standard.

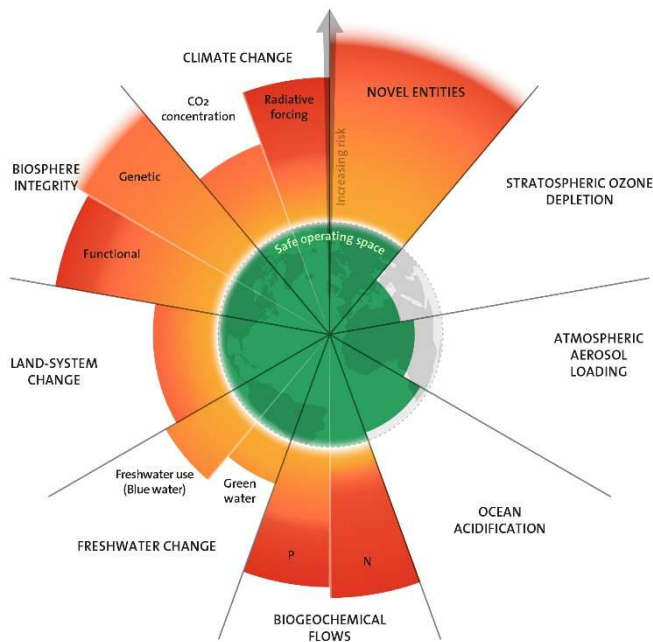
1.1 Reading Guide

The purpose of the report is to provide valuable insight to decision making and detailed information about how the study was made and the results. Readers can select sections of the report depending on their role and usage of it.

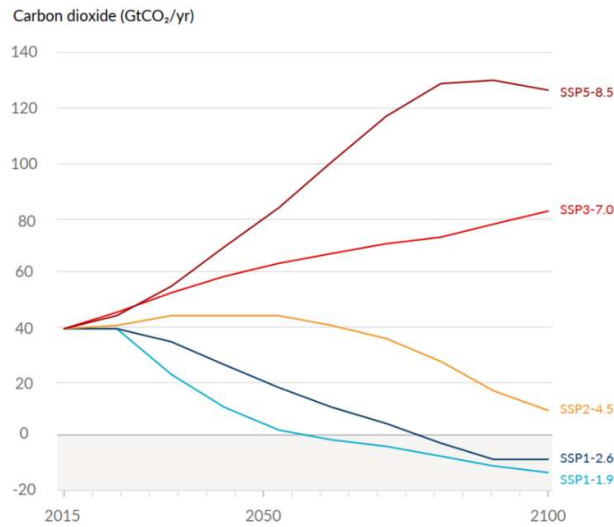
- 5 minutes - strategic planning
 - Section 7 explain in short, the purpose and the conclusions.
- 20 minutes - product development
 - Section 7 and section 6 give the reader some more nuance and depth as it includes interpretation and sensitivity analysis that underpins the conclusions.
- >20 minutes - Understanding
 - Section 7, section 6 and section 5 present detailed results through diagrams and tables for the different impact categories that support the conclusion.
- >60 minutes - Review and reproducibility
 - 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")

1.2 The Sustainability Challenge

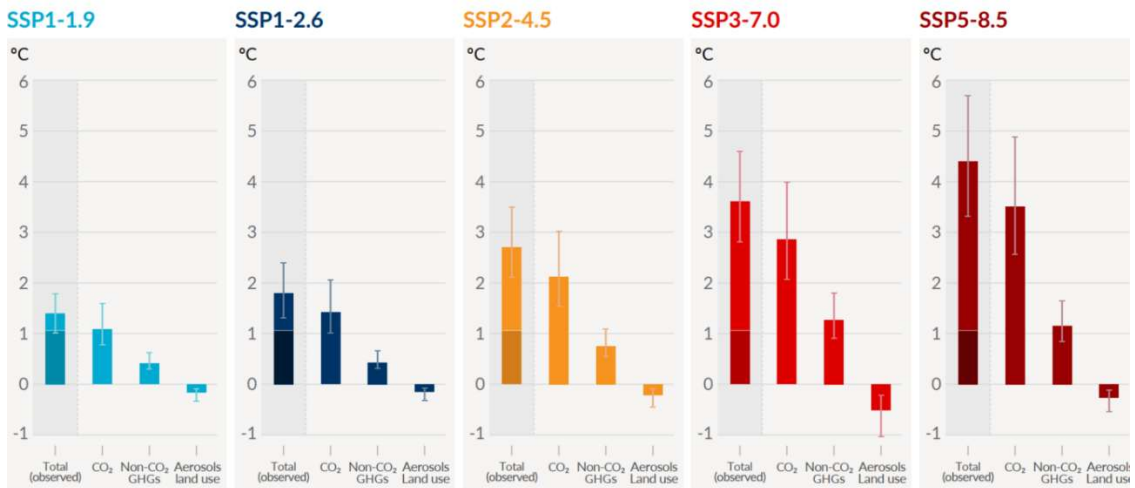
Sustainability comprises meeting our own needs without compromising the ability of future generations to meet their own needs. Industrial and natural systems depend on a stable Earth system to function. A quantitative planetary boundary within which humanity can continue to develop and thrive for generations to come has been proposed (Richardson et al., 2023). These researchers describe nine processes that determine the resilience and stability of the Earth system, such as climate change, water use, and land use. Crossing these boundaries increases the risk of abrupt and irreversible environmental change, while staying within the boundaries represents a safe operating space for a sustainable society, see Figure below.



One critical environmental problem we face today is climate change. The report from the Intergovernmental Panel on Climate Change (IPCC), shows that only the most ambitious of five scenarios for greenhouse gas emissions would result in a temperature increase within 2°C (IPCC, 2021a), see Figure 1. Considering that limiting temperature rise below 1.5°C is the ambition of the Paris Agreement 2016, it is evident that the available space for mitigating radical climate change is ever-shrinking, necessitating decisive action in all parts of society. This is also evident in the latest report from IPCC (IPCC, 2022).



Change in global surface temperature in 2081-2100 relative to 1850-1900 (°C)



Total warming (observed warming to date in darker shade), warming from CO₂, warming from non-CO₂ GHGs and cooling from changes in aerosols and land use

Figure 1: Future annual emissions of CO₂ (top) and contribution to global surface temperature increase from different emissions, with a dominant role of CO₂ emissions (bottom) across five illustrative scenarios. Image from IPCC (2021b).

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).

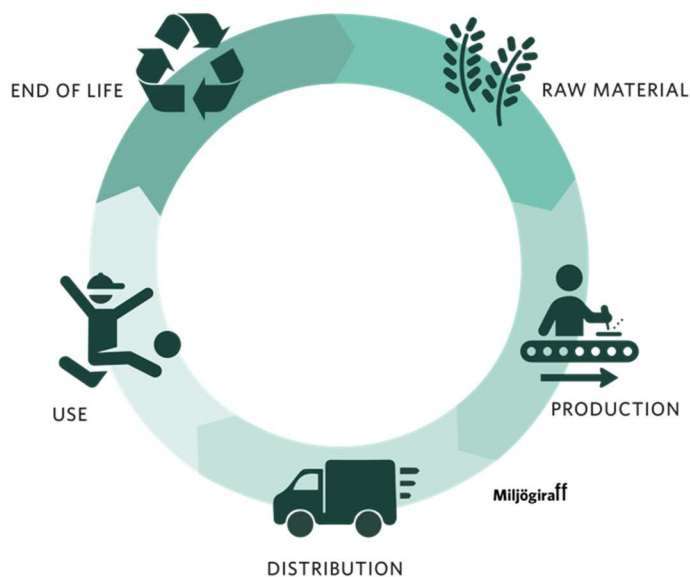


Figure 2: The Life Cycle concept, starting from raw material extraction, production, and distribution, followed by use and end-of-life.

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 3.)



Figure 3: 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 developing along with progressions within the field of LCA (Rebitzer et al., 2004). The guidelines for LCA are 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 method used in the study is Life Cycle Assessment (LCA) as described in:

- ISO 14040: 2006 - Principles and framework (ISO, 2006b)
- ISO 14044: 2006 - Requirements and guidelines (ISO, 2006c)

2.2 Standards and Frameworks

The ISO 14040 and 14044 standards (ISO, 2006b, 2006c) guide this LCA. This study follows an attributional LCA approach (accounting) defined in the ISO 14040 standard.

The standards and frameworks guiding this LCA are in Table 1.

Table 1: Standards and framework conformance.

Standards conformance

ISO 14040 and 14044 (ISO, 2006b, 2006c)

ISO 14025 (ISO, 2006a)

2.3 LCA Software

The life cycle impact assessment (LCIA) was calculated using the LCA software SimaPro 10.0.1 (PRé Sustainability, 2024) which includes regularly updated databases with libraries of LCI data (e.g. ecoinvent) and all relevant LCIA methods.

3 Goal and Scope

3.1 The goal of the Study

The reasons for carrying out the study is to calculate the climate impact of multiple products that are produced by Mälarpplast. The products are categorised based on different plastic materials and the assessment will be done through a life cycle perspective going from cradle-to-grave. In total there are 58 products analysed in this study, and three different materials being assessed. The different plastic materials are, one Polypropylene, henceforth referred to as PP, one PET materials that consist of the modified PCT-G, named Tritan, and one wood composite from Woodcomposite Sweden AB named Wood Compound Pure L40.

The goal of the LCA is:

- External communication: to produce an LCA report that fulfils the requirements for a third-party report (ISO 14044) intended to be used in external communication.
- Reduce environmental impact by pinpointing the stages or materials with the environmental impact and enable more informed decisions in product development, procurement, or process optimization.

3.1.1 Product description and Functional unit

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.

The functional unit is one plastic product with 8 use-phases, which is achieved with Mälarpplast internal recycling process. In this study there is a total of 58 plastic products which is assessed when they are made out of four different core materials. These three materials are as following

- Polypropylene, henceforth references as PP, with a material density of $0,95 \text{ g/cm}^3$, will be represented with generic data that been regionalized to represent location of supplier and their production site,
- Polycyclohexylene dimethylene terephthalate (PCT-G) which is a modified version of Polyethylene terephthalate (PET), material is called Tritan with a material density of $1,2 \text{ g/cm}^3$ and with specific supplier Eastman. Tritan will be represented with LCA calculation supplied by Eastman,
- Wood composite material, supplier is Woodcomposite Sweden AB, material is named Wood Compound Pure L40 with a material density of $1,0 \text{ cm}^3$, which is made of recycled wood and virgin-polypropylene, will be represented with specific information supplied from Woodcomposite Sweden AB.

In this LCA report the product of *Green Loop Tallrik Ø24cm* has been used as a representative product when presenting the results.

3.2 Scope of the Study

This section specifies the scope of an LCA, including a description of the system's functions (performance characteristics).

3.2.1 System Boundary

The system boundary for the study is defined as cradle-to-grave, going from Upstream processes to Core and Downstream processes. 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.

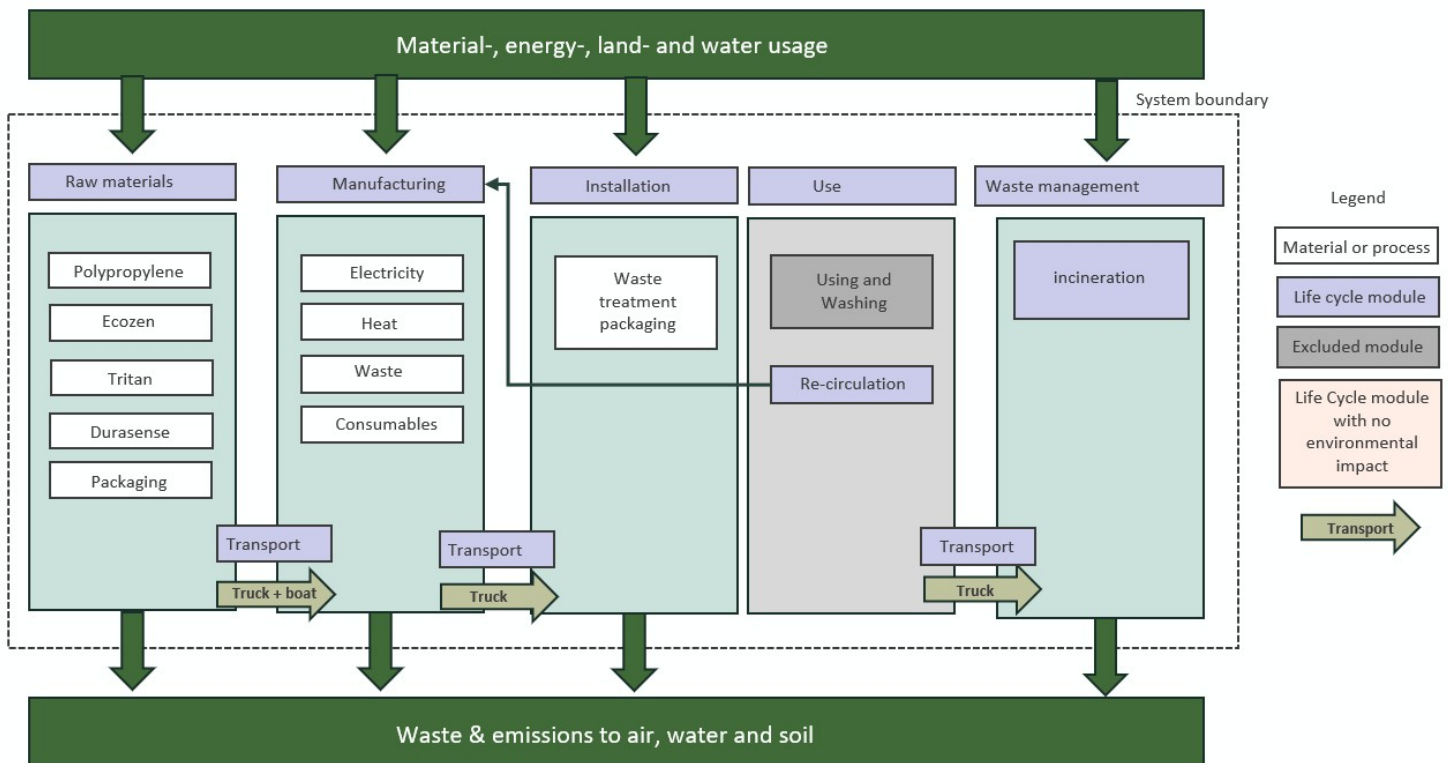


Figure 4: System boundaries for the model of the product system.

The method chosen for separating consecutive life cycles is the cut-off method. This allocation of 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 not considered in the main scenario, following 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.

3.2.2 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 simplified model, as it is too time-consuming to obtain data and model every flow in practice. Specific cut-off criteria facilitate the comparison of LCA for different products. To ensure that all relevant environmental impacts were represented in the study, the following cut-off criteria were used, following the PCR 2022:01:

Mass relevance

Mass relevance should be applied if the mass flow of a unit process is less than 1% of the cumulative mass of all the inputs and outputs of the LCI model.

Energy relevance

Energy relevance should be applied if the energy flow of a unit process is less than 1% of the cumulative energy of all the inputs and outputs of the LCI model.

Environmental relevance

Environmental relevance should be applied if the flow of a unit process meets the above exclusion criteria but has 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.

3.2.3 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.

3.2.4 Method of Life Cycle Impact Assessment (LCIA)

The methods used to calculate the relevant environmental effect categories in this study are summarised in Table 2 and Table 3. For further details on the LCIA method, see Appendix 2.

Table 2: Impact categories, indicators and methods used in the study.

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
Climate Change-fossil	GWP fossil	kg CO ₂ equivalents	The baseline model of 100 years of the IPCC based on IPCC 2021
Climate Change-biogenic	GWP biogenic	kg CO ₂ equivalents	The baseline model of 100 years of the IPCC based on IPCC 2021
Climate Change-land use and land use change	GWP luluc	kg CO ₂ equivalents	The baseline model of 100 years of the IPCC based on IPCC 2021
Indicator for climate impact GWP-GHG	GWP-GHG	kg CO ₂ equivalents	GWP total, excluding biogenic carbon dioxide emissions and uptakes, and biogenic carbon stored in the product
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, mineral and metals,	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 Deprivation Potential	WDP	m3 world eq. deprived	Available WAtER REmaining (AWARE) Boulay et al., 2018

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).

Table 3: Additional environmental impact indicators and methods used in the study.

Impact category	Indicator	Unit	Method
Climate change - total	GWP-GHG	kg CO ₂ -eq.	Baseline model of 100 years of the IPCC based on IPCC 2021
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)

Unit conversion for LCIA results.

Some methods report the LCIA results in different units than EF 3.1. Below some common unit conversions can be seen:

Acidification: 1.31 to report kg SO₂,eq as mol H⁺,eq

Eutrophication: 0.33 to report kg PO₄⁻³,eq. Kg P, eq

Photochemical Ozone Creation Potential: 1.69 to report kg C₂H₄, eq as kg NMVOC, eq

3.2.5 Data quality requirements (DQR)

Data were collected by Mälarplast by updating existing data on their own production which was used in an earlier LCA study performed by Mälarplast. Data was also collected in communication with suppliers, on e.g. material content and available EPDs.

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: Data of core processes: The collected data is representative for the technology used. Data of upstream and downstream processes: Data is representative for the technology used (for example at suppliers) if possible. Otherwise average technology in the relevant region.
- Time-related coverage: Data of core processes: The collected data is ideally representative for the last 12 months but not older than 5 years. Data of upstream and downstream processes: The collected data is as recent as possible but not older than 10 years.
- Multiple output allocation: **Physical property,**
- Substitution allocation: Not applicable
- Waste treatment allocation: Not applicable
- Cut-off rules: **Less than 1% environmental relevance**
- System boundary: **Second order (material/energy flows including operations)**
- The boundary with nature: **Agricultural production is part of the production system**

The assessment period is one-year averages for energy use in manufacturing production volumes etc, based on the year 2022 combined with additional data on production year 2024.

The data quality and representativeness will be assessed in part 0 based on the guidelines established in the EN 15804:A2 standard (CEN, 2019).

3.2.6 Type of critical review, if any

A critical review means that the study is reviewed by a third party. According to the standard, this is necessary if the result is to be communicated externally or if the result is to be compared with results from other studies.

A critical review will be carried out according to the International Standards ISO 14040 and 14044 (ISO 2006 b,c), as well as the applied PCR. The LCA will be reviewed according to the following five aspects outlined in ISO 14040. It is assessed whether:

- the methods used to carry out the LCA are consistent with this International Standard and in line with the applied PCR.
- the methods used to carry out the LCA are scientifically and technically valid
- the data used are appropriate and reasonable in relation to the goal of the study
- the interpretations reflect the limitations identified and the goal of the study, and
- the study report is transparent and consistent.

This LCA report was internally reviewed by Pär Lindman, who was also involved in the data inventory.

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 3.10 is used. Ecoinvent is a database 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 a comprehensive international LCI database. Ecoinvent's 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: (e.g., regional averages from Ecoinvent) or according to specific conditions calculated according to the Network for Transport and the Environment (NTM).
- 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 processes that contain market funds such as "Diesel burned in building machine {GLO} | market for | Cut-off, U" includes generic shipments from producer to end customer. 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

Data contact information	
Company	Mälarplast (Mälarplast AB)
Name	Peter Wall
e-mail	peter@malarplast.se
Phone number	+46 (0)16 51 72 41
Position in company	CEO
Name	Håkan Fridh
e-mail	hakan@malarplast.se
Phone number	+46 (0)76 807 46 46
Position in company	Vice CEO
Company	IMCD / Eastman
Name	Tim Toth

e-mail	Tim.toth@imcd.se
Phone number	+46 703 16 75 67
Position in company	Sales manager IMCD
Company	Nordic Polymers
Name	Ulrika Hultin
e-mail	uh@nordicpolymers.com
Phone number	+46 (0) 76 100 5541
Position in company	KAM
Company	SK Chemicals
Name	Bert Beuchel
e-mail	Beuchel@sk.com
Phone number	0049 170 7769 785
Position in company	Sales Europe
Company	Woodcomposite Sweden
Name	Renato Cosic
e-mail	renato.cosic@woodcomposite.se
Phone number	+46(0)702247809
Position in company	CEO

4.3 Product summary

This section gives an overview of all the different products being produced by Mälärplast in Eskilstuna. In Table 5 the products assessed in the study have been listed with the plastic material they consist of together with the volume of the products which can be used together with the density of calculate the final weight of each product.

Table 5: Products assessed in the study [Source of data: AB Mälärplast].

Article number - MP	Product Description	Material	Volume per product (cm ³)	Cardboard weight (kg)	Carboard weight per product (kg)
RECIRK082451	Green Loop Tallrik Ø24cm	PCT-G	117,54	0,22	0,0088
RECIRK083551	Green Loop Tallrik Ø23,5 cm	PCT-G	120,05	0,22	0,0088
RECIRK081651	Green Loop Tallrik Ø18 cm	PCT-G	63,08	0,10	0,0040
RECIRK081951	Green Loop Djup tallrik Ø24cm	PCT-G	102,31	0,22	0,0088
RECIRK081551	Green Loop Djup tallrik Ø23,5cm	PCT-G	135,26	0,22	0,0088
RECIRK081251	Green Loop Djup tallrik Ø18cm	PCT-G	69,23	0,10	0,0040
RECIRK083651	Green Loop Mugg med handtag	PCT-G	69,23	0,22	0,0088
RECIRK083661	Green Loop Mugg med två handtag	PCT-G	73,08	0,22	0,0088
RECIRK084207	Green Loop Kantin GN 1/9x100 mm	PP	85,89	0,15	0,038
RECIRK086307	Green Loop Kantin GN 1/6x65	PP	97,71	0,17	0,041
RECIRK084407	Green Loop Kantin GN 1/6x150	PP	177,16	0,25	0,063
RECIRK086007	Green Loop Kantin GN 1/4x65 mm	PP	146,02	0,18	0,045
RECIRK086107	Green Loop Kantin GN 1/4x100 mm	PP	210,44	0,25	0,063
RECIRK084607	Green Loop Kantin GN 1/4x150 mm	PP	241,58	0,25	0,063
RECIRK086907	Green Loop Kantin GN 1/3x65 mm	PP	227,62	0,22	0,055
RECIRK086807	Green Loop Kantin GN 1/3x100 mm	PP	265,20	0,25	0,063

RECIRK082307	Green Loop Kantin GN 1/3x150 mm	PP	327,47	0,25	0,063
RECIRK085007	Green Loop Kantin GN 1/2x65 mm	PP	354,32	0,22	0,055
RECIRK084907	Green Loop Kantin GN 1/2x100 mm	PP	391,89	0,25	0,063
RECIRK088907	Green Loop Kantin GN 1/1x150 mm	PP	982,42	0,30	0,150
RECIRK088000	Green Loop Skärbräda Vit 1/1	PP	2474,84	0,24	0,024
RECIRK088002	Green Loop Skärbräda brun 1/1	PP	2474,84	0,24	0,024
RECIRK088003	Green Loop Skärbräda röd 1/1	PP	2474,84	0,24	0,024
RECIRK088004	Green Loop Skärbräda grön 1/1	PP	2474,84	0,24	0,024
RECIRK088005	Green Loop Skärbräda blå 1/1	PP	2474,84	0,24	0,024
RECIRK088006	Green Loop Skärbräda gul 1/1	PP	2474,84	0,24	0,024
RECIRK088007	Green Loop Skärbräda svart 1/1	PP	2474,84	0,24	0,024
RECIRK088127	Green Loop serveringstång plast 18 cm	PCT-G	22,50	0,10	0,020
RECIRK081117	Green Loop serveringstång plast 24 cm	PCT-G	27,50	0,15	0,030
RECIRK083807	Green Loop stektång plast 28 cm	PCT-G	75,00	0,15	0,030
RECIRK080301	Green Loop Bricka 34,5x26,5cm Granit	PP	284,53	0,24	0,024
RECIRK080307	Green Loop Bricka 34,5x26,5cm Svart	PP	284,53	0,24	0,024
RECIRK080201	Green Loop Bricka granit 28x36 cm	PP	283,16	0,24	0,024
RECIRK080207	Green Loop Bricka svart 28x36 cm	PP	283,16	0,24	0,024
RECIRK080101	Green Loop Bricka granit 33x43cm	PP	493,89	0,30	0,030

RECIRK080107	Green Loop Bricka svart 33x43cm	PP	493,89	0,30	0,030
RECIRK088117	Green Loop serveringstång plast 27 cm	PCT-G	27,50	0,15	0,030
RECIRK084807	Green Loop Kantin GN 1/2x150 mm	PP	461,68	0,18	0,045
RECIRK087550	Green Loop Glas 24cl	PCT-G	29,23	0,18	0,0072
RECIRK084150	Green Loop Glas 28 cl	PCT-G	43,85	0,10	0,0040
RECIRK082650	Green Loop Glas Staplbart 28cl	PCT-G	45,38	0,10	0,0042
RECIRK080650	Green Loop Tillbringare med lock Ø110mm	PCT-G	211,54	0,35	0,019
RECIRK083250	Green Loop Lock Tillbringare Ø115mm	PCT-G	36,15	0,24	0,0027
RECIRK085850	Green Loop Skål 10cl	PCT-G	13,08	0,24	0,024
RECIRK083350	Green Loop Skål 30cl	PCT-G	34,62	0,24	0,024
RECIRK082150	Green Loop Skål 80cl	PCT-G	58,46	0,24	0,024
RECIRK082250	Green Loop Skål 1,5L	PCT-G	90,00	0,24	0,024
RECIRK080450	Green Loop Skål 3L	PCT-G	184,62	0,24	0,024
RECIRK088300	Green Loop Soppskål med Två Handtag ø13cm	PCT-G	75,04	0,10	0,10
TBD	Coffee-2-go 30 cl	PCT-G	42,50	0,24	0,0048
TBD	Coffee-2-go 40 cl	PCT-G	52,50	0,24	0,0048
TBD	Coffee-2-go 50 cl	PCT-G	56,67	0,24	0,0048
TBD	Lock till coffee- 2-go	PP	26,32	0,24	0,0048
TBD	Matlåda-2-go 500 ml	PCT-G	58,33	0,30	0,0060
TBD	Lock till matlåda- 2-go 500 ml	PP	15,79	0,30	0,0060
TBD	Matlåda-2-go 750 ml	PCT-G	69,17	0,35	0,0070
TBD	Matlåda-2-go 1200 ml	PCT-G	91,67	0,35	0,0070
TBD	Lock till matlåda- 2-go 1200 ml	PP	42,11	0,35	0,0070

4.4 Raw material

This section describes all the different raw materials needed for the manufacturing of plastic products by Mälärplast.

4.4.1 Polypropylene

The PP used as raw material in multiple of the products are produced by supplier Nordic Polymers. Information of specific production methods by supplier have not been gathered, as such generic data have been used to represent an average PP production. However, the upstream production of the supplier is known to be Geleen, Netherlands. As such the generic PP production have been regionalised to represent PP production in Netherlands, and transport of raw materials from Nordic Polymers in Geleen to Mälärplast in Eskilstuna.

Virgin PP is represented with ecoinvent 3.10 process: *Polypropylene, granulate {RER} | polypropylene production, granulate | Cut-off, U*, that's been modified to represent production in Netherland by changing the electricity dataset from a European one (RER), to the Dutch residual market mix. The dataset used to represent production in Netherlands is the Ecoinvent 3.10 process: *Electricity, medium voltage {NL} | electricity, medium voltage, residual mix | Cut-off, U*. The transportation of PP can be split into two steps. One from Geleen in Netherlands to storage facility in Tååstrup Denmark, and one from the storage facility to Mälärplast facility in Eskilstuna, Sweden. The respective distance is 794 km and 621 km. Both transportation steps were represented with the ecoinvent 3.10 process: *Transport, freight, lorry 16-32 metric ton, EURO5 {RER} | market for transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U*.

4.4.2 Tritan

Tritan is also a Polycyclohexylene dimethylene terephthalate (PCT-G) which is a modified version of Polyethylene terephthalate (PET) material but is instead supplied by the supplier Eastman. Eastman has shared LCA calculations on their Tritan materials that have been verified and used to represent the production of Tritan at supplier. A verification statement concerning the LC calculation done by Eastman and used in this study can be seen in Appendix 7. The material mainly used in the Mälärplasts' products are the TX2001-material, but the TX2001 Renew 50 will also be assessed in a scenario analysis to determine potential benefits of switching this other material in the future.

The manufacturing facility of the Tritan is Kingsport in USA. Total transportation to Mälärplast facility in Eskilstuna, Sweden is 1094 km by truck (717 km between Kingsport, USA – Norfolk, USA and 377 km between Gothenburg, Sweden – Eskilstuna, Sweden) and 6912 by freight ship (Norfolk, USA – Gothenburg, Sweden). The truck transportation is represented with the ecoinvent 3.10 process *Transport, freight, lorry 16-32 metric ton, EURO5 {RoW} | transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U* and *Transport, freight, lorry 16-32 metric ton, EURO6 {RER} | market for transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U* respectively, while the ship transport is represented with the ecoinvent 3.10 process *Transport, freight, sea, container ship {GLO} | transport, freight, sea, container ship | Cut-off, U*.

4.4.3 Wood Compound Pure L40 from Woodcomposite Sweden AB

Down below the composition of the Wood Compound Pure L40 wood composite from Woodcomposite Sweden is shown. Continuing this material will simply be referred to as WC Pure L40. It was here modelled per kg of WC Pure L40 to make it easy to translate into the amount needed as input to in producing the multiple products assessed in the study.

Table 6: Raw materials and transport to the production site per 1 kg of WC Pure L40.

Material	Weight (kg)	LCI database representation	Origin	Transport type	Transport distance (km)
Wood Chips	0,40	See section 4.4.3.1	Sweden	Truck, diesel	200
Polypropylene	0,60	See section 4.4.3.2	Europe	Truck, diesel	2000

4.4.3.1 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 200 km from Hyltebruk, Sweden. This transportation was represented with theecoinvent 3.10 process: *Transport, freight, lorry 16-32 metric ton, EURO6 {RER} | market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, U*. The wood chips are transported by diesel truck on a pallet which was modelled according to Table 7. To transport the wood chips a total of 0,016kg pallet was allocated per 1kg of wood chips.

Table 7: Details for modelling of EUR-pallet, weighting 25 kg.

Material	Amount	LCI data representation	Database	Comment
Particle board	0,0117 m ³	Particleboard, uncoated {RER} market for particleboard, uncoated Cut-off, U	Ecoinvent 3.10	
Sawnwood board - source 1	0,000133 m ³	Sawnwood, board, softwood, raw, dried (u=20%) {CH} market for sawnwood, board, softwood, raw, dried (u=20%) Cut-off, U	Ecoinvent 3.10	
Sawnwood board - source 2	0,0334 m ³	Sawnwood, board, softwood, raw, dried (u=20%) {Europe without Switzerland} market for sawnwood, board, softwood, raw, dried (u=20%) Cut-off, U	Ecoinvent 3.10	
Steel	0,195 kg	Steel, low-alloyed, hot rolled {GLO} market for steel, low-alloyed, hot rolled Cut-off, U	Ecoinvent 3.10	

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 55% main product and 45% of saw dust and saw chips, see Figure 5.



Figure 5, show the average yield of products from sawmills. 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).

Equation (1): Show how the economic allocation factor has been calculated.

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

This equals an allocation factor for the saw chips and saw dust by product to 0,0928. This is used when allocating the environmental burden of the multi output product process of sawing timber. The LCI representation is the ecoinvent 3.10 process: *Sawnwood, board, softwood, raw, dried (u=20%) {Europe without Switzerland}| market for sawnwood, board, softwood, raw, dried (u=20%) | Cut-off*. The process reflects 1 m³ dried sawnwood which corresponds to the dry mass density of 404,8 kg, which was changed into to represent the material flow in kg instead of m³.

The source of raw materials reflected the ecoinvent process *Sawnwood, softwood, raw {Europe without Switzerland}| sawing, softwood | Cut-off, U*, which was regionalised to Sweden by changing to Swedish electricity and the source of wood to Sweden. The processes used as raw material sources was thus changed into *Sawlog and veneer log, softwood, measured as solid wood under bark {SE}| softwood forestry, pine, sustainable forest management | Cut-off, U*, and *Sawlog and veneer log, softwood, measured as solid wood under bark {SE}| softwood forestry, spruce, sustainable forest management | Cut-off, U*. By using the values defined in the first raw material process, wood from pine forestry was put 45% and 55% for spruce in the Swedish market.

4.4.3.2 Virgin Polypropylene

Virgin Polypropylene (PP) was represented with the Ecoinvent 3.10 process: *Polypropylene, granulate {RER}| polypropylene production, granulate | Cut-off, U*.

The virgin PP is transported in average 2000 km to Hyltebruk by diesel truck. The PP granulates is packed in a plastic bag and 0,004 kg PE plastic bag is allocated per 1kg of PP raw material. The transportation was represented with the ecoinvent 3.10 process: *Transport, freight, lorry 16-32 metric ton, EURO6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, U*

4.4.3.3 Processing the raw material Woodcomposite Sweden

The raw material is processed by Woodcomposite Sweden in Hyltebruk, Sweden. A picture of the finished bio composite 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 0,24 kWh 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 0,44 kWh per kg material processed. The electricity used at Hyltebruk has guaranteed origin by the energy producer Vattenfall as nuclear power. The electricity was modelled with the Ecoinvent 3.10 dataset *Electricity, high voltage {SE}| electricity production, nuclear, boiling water reactor | Cut-off*, which was used based on data in the Ecoinvent dataset for the Swedish high voltage country mix, which showed that boiling water reactors are the most used type of available nuclear power technologies in Sweden.

The production waste in the process is 1,2% for PP and 0,8% of wood chips. All waste is transported 50 km by diesel truck to Halmstad for incineration. This transportation was modelled with the process *Municipal waste collection service by 21 metric ton lorry {CH}| municipal waste collection service by 21 metric ton lorry | Cut-off, U*.

The final product of the wood composite is then loaded on a diesel truck and is transported 386 km to Mälarplast located in Eskilstuna, Sweden. The weight of the modelled transport equals the weight of the raw material needed as input to Mälarplast. The transportation was represented with the ecoinvent 3.10 process: *Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U*.

4.5 Manufacturing

In this chapter, the activities carried out by Mälarplast are presented. All activities are presented per kg of manufactured product.

In this process, plastic granules are fed into a heated barrel where they are melted. The molten plastic is then pushed through a shaped die using a rotating screw, forming a continuous profile in the desired shape. As the plastic exits the die, it is cooled so it solidifies and retains its shape.

4.5.1 Energy

In this section the details are shown for how the electricity have been modelled that is used to process the plastic materials into the correct shape. Electricity demands for the respective product can be viewed in Appendix 4. The ecoinvent 3.10 dataset of *Electricity, high voltage {SE}| market for electricity, high voltage | Cut-off, U* have been modified according to only include the electricity sources listed in the table below but included all other material flows and infrastructures needed to capture the impact from these aspects. The total electricity use in the dataset reflects 1,03 kWh and this value was used to capture electricity losses in transmission and conversion from high-voltage to medium-voltage.

Table 8: Details on electricity composition used in production at Mälarplast facility in Eskilstuna [Source of data: Mälarplast].

Category	Energy source	Shares	LCI data representation	Certificate?
Electricity	Wind	56,8%	Electricity, high voltage {SE} electricity production, wind, 1-3MW turbine, onshore Cut-off, U	Yes, See Appendix 7
	Hydro	36,2%	Electricity, high voltage {SE} electricity production, hydro, run-of-river Cut-off, U	
	Bio	5,4%	Electricity, high voltage {SE} heat and power co-generation, biogas, gas engine Cut-off, U	
	Solar	1,6%	Electricity, low voltage {SE} electricity production, photovoltaic, 570kWp open ground installation, multi-Si Cut-off, U	

The products Coffee-2-go and Matlåda-2-go is currently being produced at a Belgian supplier and the electricity use in manufacturing of these product groups have therefore been represented with the ecoinvent 3.10 process *Electricity, medium voltage {BE}| market for electricity, medium voltage | Cut-off, U*, which corresponds to the Belgian electricity mix.

4.5.2 Consumables

Consumables is material used in the manufacturing of the product but is not part of the final product. The amount per functional unit is mass allocated based on the total usage of consumables divided by total production in kg. Consumables have very low environmental relevance and only the biggest consumables have been added and the rest fallen under the cut-off of environmental relevance. Transportation of consumables to the facility was represented with the ecoinvent 3.10 process *Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U*.

Table 9: Consumables used in production

Type of consumable	Material	Amount per FU in kg	LCI data representation in ecoinvent	Transport type	Transport distance (km)
Adhesive	Plastic based adhesive	6.99e-5	Polyurethane adhesive {GLO} polyurethane adhesive production Cut-off, U	Truck	374
Lubrication	Oil based lubricatns	3.94e-5	Lubricating oil {RER} lubricating oil production Cut-off, U	Truck	409
Solvent	Aceton	6.94e-5	Acetone, liquid {RER} market for acetone, liquid Cut-off, U	Truck	7,5

4.5.3 Packaging

All final products are packed in a cardboard box delivered from A-Pak. The exact weight used per product can be seen in Table 5. Production of the cardboard box takes place in A-Pak’s facility in Mölndal, and the transportation is represented with the process *Transport, freight, lorry 16-32 metric ton, EURO6 {RER}| transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, U*.

Down below details are shown on changes that been made to dataset “Corrugated board box {RER}| corrugated board box production | Cut-off, U” that was used to represent cardboard packaging. All other processes and materials flows have been left with original values except the electricity dataset and containerboard, fluting medium and linerboard, which was adjusted according to the cardboard compositions as exact content was controlled with fluting medium and linerboard medium processes listen in the table below. The electricity dataset was adjusted to the Swedish market mix of “Electricity, medium voltage {SE}| market for electricity, medium voltage | Cut-off, U” to better reflect the electricity use at A-Pak. The packaging used in the main results in this assessment reflects RELOOPEMB006 with dimensions 245x245x255 and contains 0% recycled material, which is the packaging used for *Green Loop Tallrik Ø24cm*. See Appendix 5 for the different cardboard packaging used and share of recycled material they contain.

Table 10: Details on modelling changes of cardboard dataset “Corrugated board box {RER}| corrugated board box production | Cut-off, U”.

Cardboard material	Composition (%)	LCI data representation	Comment
Fluting medium	47,2	Containerboard, fluting medium {RER} market for containerboard, fluting medium Cut-off, U	Share reflects the input of fluting medium container board. Added amount capture possible waste materials generated in process.

			Dataset has been adjusted to contain specific share of semi-chemical (virgin) and recycled material content according to the amount of recycled material in used cardboard products. See Appendix 9 for data on cardboard boxes.
Linerboard	64,7	Containerboard, linerboard {RER} market for containerboard, linerboard Cut-off, U	Share reflects the input of linerboard container board. Added amount capture possible waste materials generated in process. Dataset has been adjusted to contain specific share of kraftliner (virgin) and testliner (recycled) material according to the amount of recycled material content in used cardboard products. See Appendix 9 for data on cardboard boxes.

Table 11: Packaging used for product

Type of Packaging	Material	Amount (kg)	LCI data representation in ecoinvent	Transport type	Transport distance (km)
Cardboard box	Cardboard	See table 13	Corrugated board box {RER} corrugated board box production Cut-off, U	Truck	382

4.5.4 Production waste

The production waste is estimated to be 10,38% based on calculations that compare yearly production volume and purchased raw material at facility. All other waste is mass allocated from the total of the whole production facility divided with the production volume in kg. Transportation to waste treatment facility as represented with the econinvent 3.10 process *Municipal waste collection service by 21 metric ton lorry {CH}| municipal waste collection service by 21 metric ton lorry | Cut-off, U.*

Table 12: Production waste types and treatment

Type	Quantity per FU in kg	Treatment	LCI data representation in ecoinvent	Transport	Distance (km)	Comment
Production waste in the form of plastic	0,104	Incineration of PP	Waste polypropylene {CH} treatment of waste polypropylene, municipal incineration FAE Cut-off, U	Truck	1	
	0,104	Incineration of Tritan	Waste polyethylene terephthalate {CH} treatment of waste polyethylene terephthalate, municipal	Truck	1	

			incineration FAE Cut-off, U			
	0,104	Incineration of Wood compound Pure L40	60% Waste polypropylene {CH} treatment of waste polypropylene, municipal incineration FAE Cut-off, U & 40% Waste wood, untreated {CH} treatment of waste wood, untreated, municipal incineration FAE Cut-off, U	Truck	1	
Combustible waste	0,052	Incineration	Municipal solid waste {SE} treatment of municipal solid waste, municipal incineration Cut- off, U	Truck	4	
Hazardous waste	7.24e-4	Incineration	Hazardous waste, for incineration {Europe without Switzerland} treatment of hazardous waste, hazardous waste incineration Cut- off, U	Truck	103	
Wood waste	0,009	Incineration	Waste wood, untreated {CH} treatment of waste wood, untreated, municipal incineration FAE Cut-off, U	Truck	1	
Metal waste	5.27e-4	Material recycling	Steel and iron (waste treatment) {GLO} recycling of steel and iron Cut-off, U	Truck	1	Represents recycling of metal waste, added 0,42361 kWh to capture electricity demand in recycling process as a conservative approach. Value taken from process "Cast iron {RER} cast iron production Cut-off, U". Electricity was represented with the Swedish market mix dataset "Electricity, medium voltage {SE} market for electricity, medium voltage Cut- off, U"

Cardboard waste	5.24e-4	Material recycling	Core board (waste treatment) {GLO} recycling of core board Cut-off, U	Truck	1	Represents recycling of cardboard waste, added 0,578 kWh to capture electricity demand in recycling process as a conservative approach. Value taken from process "Core board {RER} core board production Cut-off, U". Electricity was represented with the Swedish market mix dataset "Electricity, medium voltage {SE} market for electricity, medium voltage Cut-off, U"
Plastic waste	0,004	Material recycling	Mixed plastics (waste treatment) {GLO} recycling of mixed plastics Cut-off, U	Truck	1	Represents recycling of plastic waste, added 0,6 kWh to capture electricity demand in recycling process as a conservative approach. Value taken from process used process. Electricity was represented with the Swedish market mix dataset "Electricity, medium voltage {SE} market for electricity, medium voltage Cut-off, U"

4.5.5 Transport of finished goods

The finished products are loaded on a truck and is on average transported 200 km to customers and was represented with the ecoinvent 3.10 process of *Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U*. The total weight will be product plus packaging.

4.6 Usage

All products within the Green-loop concept are reusable and designed to withstand washing. Every product has an expected amount of uses in its life cycle that ranges from 200-1,000 use cycles before the material deteriorates to a point where it is no longer functionally viable. Once the products reach end-of-life, they are returned to Mälarpplast for material recirculation.

The worn-out items are collected and transported by truck, with an average transport distance of approximately 200 km to Mälarpplast’s recycling facility in Eskilstuna, Sweden. At the facility, the recovered material is processed through mechanical grinding into granulate form. The grinding time is approximately 5 seconds for smaller items, such as cups and plates, and 25 seconds for larger items, such as cutting boards. There exist two grinders, one for smaller items and one for larger ones. These two grinders operate at an electrical power of 5 kW and 10 kW for small and larger products respectively, resulting in an energy consumption of approximately 0.0069 kWh for smaller products and 0.069 kWh for larger ones. The energy mix used corresponds to that described in section 4.6.1.

The grinded granulates is then added as input to the same manufacturing process described under 4.5.

The material can be recycled 7 times, meaning that 8 use phases for the materials are achieved, before the quality of the material is too low and is instead sent to energy recycling.

4.6.1 Disposal of packaging

In the table below, the disposal of the packaging that is delivered with the product is presented. It is assumed to be transported 100 km as a conservative representation and is uses the ecoinvent 3.10 process of *Municipal waste collection service by 21 metric ton lorry {CH}* | *municipal waste collection service by 21 metric ton lorry* | *Cut-off, U* to represent the transportation.

Table 13: Disposal of packaging delivered with the product

Type of Packaging	Material	Amount (kg)	Disposal method	LCI data representation in ecoinvent	Comment
Cardboard	Cardboard	See Table 5	97% Material recycling 3% Incineration	97% Core board (waste treatment) {GLO} recycling of core board Cut-off, U & 3% Waste paperboard {CH} treatment of waste paperboard, municipal incineration FAE Cut-off, U	

4.7 End-of-Life

When the material deteriorates to a point where it is no longer functionally viable it is sent to energy recovery. As Mälarpplast have control of the waste stream of its products it is assumed to go to 100% energy recovery with an average transport distance of 100km. Transportation was represented with the econinvent 3.10 dataset of *Municipal waste collection service by 21 metric ton lorry {CH}* | *municipal waste collection service by 21 metric ton lorry* | *Cut-off, U*.

Table 14: Transport to waste management site

Material	Amount in kg	Waste treatment	LCI Data representation	Road transport type	Road transport distance (km)	Comment
Polypropylene	1	Incineration	Waste polypropylene {CH} treatment of waste polypropylene, municipal incineration FAE Cut-off, U	Truck	100	
Tritan	1	Incineration	Waste polyethylene terephthalate {CH} treatment of waste polyethylene terephthalate, municipal incineration FAE Cut-off, U	Truck	100	

<p>Wood compound Pure L40</p>	<p>1</p>	<p>Incineration</p>	<p>60% Waste polypropylene {CH} treatment of waste polypropylene, municipal incineration FAE Cut-off, U & 40% Waste wood, untreated {CH} treatment of waste wood, untreated, municipal incineration FAE Cut-off, U</p>	<p>Truck</p>	<p>100</p>	
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5 Result of Life cycle impact assessment (LCIA)

In this section, the results from the different environmental impact assessment methods will be presented. The LCIA method follows the standard for Construction Products EN 15804:2012+A2:2019/AC:2021 (CEN, 2021). EN 15804:2012+A2:2019/AC:2021 uses the impact categories and characterization factors of the LCIA methods used in Environmental Footprint 3.1 (EF 3.1), with the only difference that biogenic carbon dioxide uptake is calculated as -1 and biogenic carbon dioxide emissions as +1, where EF 3.1 calculates this as 0 and 0, respectively.

In addition to the climate impact indicator required in EN 15804:2012+A2:2019/AC:2021, the PCR for Construction Products requires reporting of climate impact with the GWP-GHG indicator, where the characterization factor for biogenic carbon dioxide is set to zero. This is calculated with the IPCC 2021 GWP 100 method.

The results are presented in the following order

1. Environmental footprint midpoint using the EF 3.1 method, adapted to EN 15804:2012+A2:2019/AC:2021
2. Climate impact using the GWP-GHG indicator

For the product *Green Loop Tallrik Ø24cm with 8 use-phases and made from the following materials,*

- Polypropylene,
- PCT-G Tritan,
- Wood composite Pure L40,

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. For further details on the LCIA method and impact categories, see Appendix 1 - Appendix 4.

Disclaimer 1: The results of the environmental impact indicators Abiotic depletion for fossil and non-fossil resources, Water depletion potential, Ecotoxicity-freshwater, Human toxicity-cancer, Human toxicity-non-cancer and Land use shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.

Disclaimer 2: The indicator GWP-GHG includes all greenhouse gases included in GWP-total but excludes biogenic carbon dioxide uptake and emissions and biogenic carbon stored in the product. This indicator is thus equal to the GWP indicator originally defined in EN 15804:2012+A1:2013.

Disclaimer 3: The use of the results of modules A1-A3 without considering the results of module C is discouraged.

Disclaimer 4: The indicator Ionising radiation deals mainly with the eventual impact of low dose ionizing 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 ionizing radiation from the soil, from radon and from some construction materials is also not measured by this indicator.

Disclaimer 5: The results of the impact categories abiotic depletion of minerals and metals, land use, human toxicity (cancer), human toxicity, noncancer and ecotoxicity (freshwater) may be highly uncertain in LCAs that include capital goods/infrastructure in generic datasets, in case infrastructure/capital goods contribute greatly to the total results. This is because the LCI data of infrastructure/capital goods used to quantify these indicators in currently available generic datasets sometimes lack temporal, technological and geographical representativeness. Caution should be exercised when using the results of these indicators for decision-making purposes.

5.1 Results Green Loop Tallrik Ø24cm made with Polypropylene

5.1.1 Environmental Footprint Midpoint

Table 15 shows the result per *Green Loop Tallrik Ø24cm made from polypropylene and with 8 use-phases* according to the LCIA method Environmental footprint 3.1 midpoint level.

Table 15: Environmental footprint midpoint results per Green Loop Tallrik Ø24cm with 8 use-phases made from polypropylene.

Impact category	Unit	Total	Raw Materials	Transport of Raw Materials	Manufacturing	Transport to Customers	Waste Treatment of Packaging	End-of-Life
GWP Fossil	kg CO ₂ eq	1,29E+00	4,93E-01	8,61E-02	3,53E-01	3,66E-02	1,12E-02	3,08E-01
GWP Biogenic	kg CO ₂ eq	6,89E-02	2,49E-04	5,92E-05	-4,76E-02	2,54E-05	1,16E-01	2,98E-06
GWP LULUC	kg CO ₂ eq	9,52E-04	1,83E-04	2,83E-05	5,86E-04	1,22E-05	1,42E-04	1,73E-06
GWP Total	kg CO ₂ eq	1,36E+00	4,93E-01	8,61E-02	3,06E-01	3,67E-02	1,28E-01	3,08E-01
ODP	kg CFC11 eq	2,79E-08	2,28E-08	1,71E-09	2,01E-09	7,28E-10	2,30E-10	3,59E-10
AP	mol H ⁺ eq	2,35E-03	1,40E-03	2,38E-04	4,57E-04	7,63E-05	5,65E-05	1,15E-04
EP - Freshwater	kg P eq	1,51E-05	8,28E-06	6,65E-07	5,72E-06	2,86E-07	5,94E-08	5,87E-08
EP - Marine	kg N eq	6,08E-04	2,75E-04	7,32E-05	1,65E-04	1,79E-05	2,40E-05	5,29E-05
EP - Terrestrial	mol N eq	6,37E-03	3,01E-03	8,07E-04	1,51E-03	1,98E-04	2,65E-04	5,80E-04
POCP	kg NMVOC eq	3,91E-03	2,63E-03	3,79E-04	4,55E-04	1,27E-04	1,09E-04	2,11E-04
ADPE	kg Sb eq	5,32E-06	4,35E-06	2,77E-07	5,28E-07	1,19E-07	2,95E-08	1,47E-08
ADPF	MJ	1,89E+01	1,55E+01	1,21E+00	1,23E+00	5,15E-01	2,93E-01	2,23E-01
WDP	m ³ depriv.	2,73E-01	2,25E-01	4,98E-03	3,71E-02	2,14E-03	2,42E-03	7,51E-04

PM	disease inc.	2,94E-08	1,14E-08	6,59E-09	5,24E-09	2,68E-09	1,32E-09	2,16E-09
IR	kBq U-235 eq	1,86E-02	7,79E-03	6,06E-04	4,02E-03	2,38E-04	5,90E-03	5,06E-05
ETP - FW	CTUe	3,23E+00	1,69E+00	3,26E-01	9,74E-01	1,40E-01	2,61E-02	7,76E-02
HTP - C	CTUh	3,53E-09	1,87E-09	6,05E-10	7,08E-10	2,60E-10	2,88E-11	5,56E-11
HTP - NC	CTUh	7,30E-09	3,99E-09	7,56E-10	1,87E-09	3,23E-10	5,32E-11	3,05E-10
Land use, SQP	Pt	8,57E+00	1,47E+00	7,23E-01	5,99E+00	3,11E-01	4,95E-02	2,77E-02
GWP-GHG	kg CO2 eq	1,29E+00	4,93E-01	8,61E-02	3,56E-01	3,66E-02	1,14E-02	3,08E-01
Acronyms	GWP: Global Warming Potential, LULUC: Land Use and Land Use Change, ODP: Ozone Depletion Potential, AP: Acidification Potential. EP: Eutrophication Potential, POCP: Photochemical Ozone Creation Potential, ADPE: Abiotic Depletion Potential – Elements, ADPF: Abiotic Depletion Potential – Fossil Fuels, WDP: Water Scarcity Footprint, PM: Particulate Matter, IRP: Ionizing Radiation - Human Health, ETP-FW: Ecotoxicity Potential – Freshwater, HTP-C: Human Toxicity Potential – Cancer, HTP-NC: Human Toxicity Potential – Non-Cancer, SQP: Soil Quality Potential Index, GWP-GHG: Global Warming Potential, Greenhouse Gases							

5.1.2 Climate Impact (GWP-GHG)

Here the total climate impact over the life cycle is presented for the *Green Loop Tallrik Ø24cm made from polypropylene and with 8 use-phases*. Most of these emissions come from the raw material production (38%), as can be seen in Figure 7. Following the raw material production, the second and third largest contributing sources to the climate impact is the Manufacturing (28%) as well as the impact from End-of-Life of the products (26%). In Figure 8, a more in-depth illustration can be seen for the products life cycle. What can be seen here is that most of impact found for Manufacturing, can be connected to the waste treatment of the polypropylene created during production.

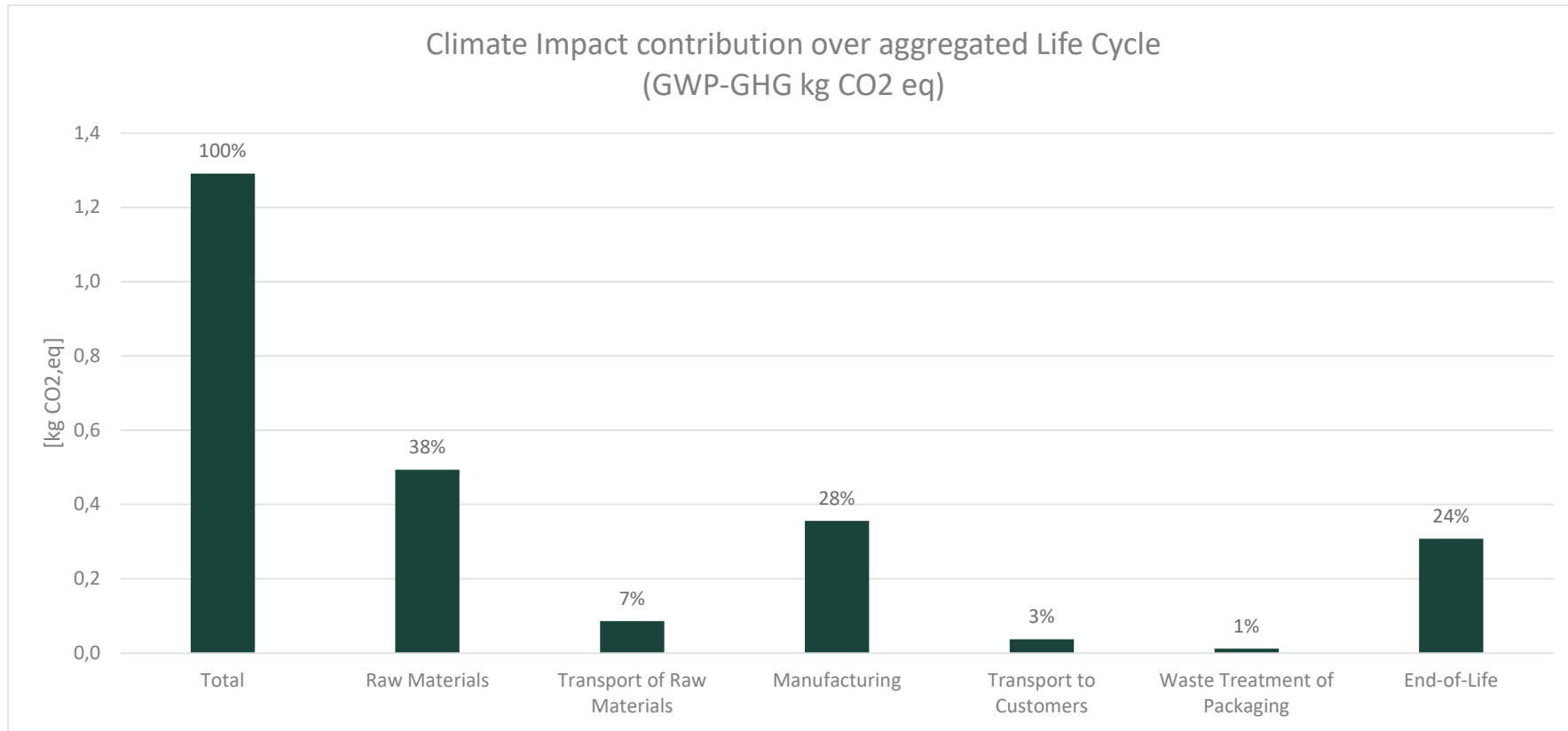


Figure 7: Climate impact per module according to the GWP-GHG method for the aggregated life cycle per Green Loop Tallrik Ø24cm with 8 use-phases made from Polypropylene.

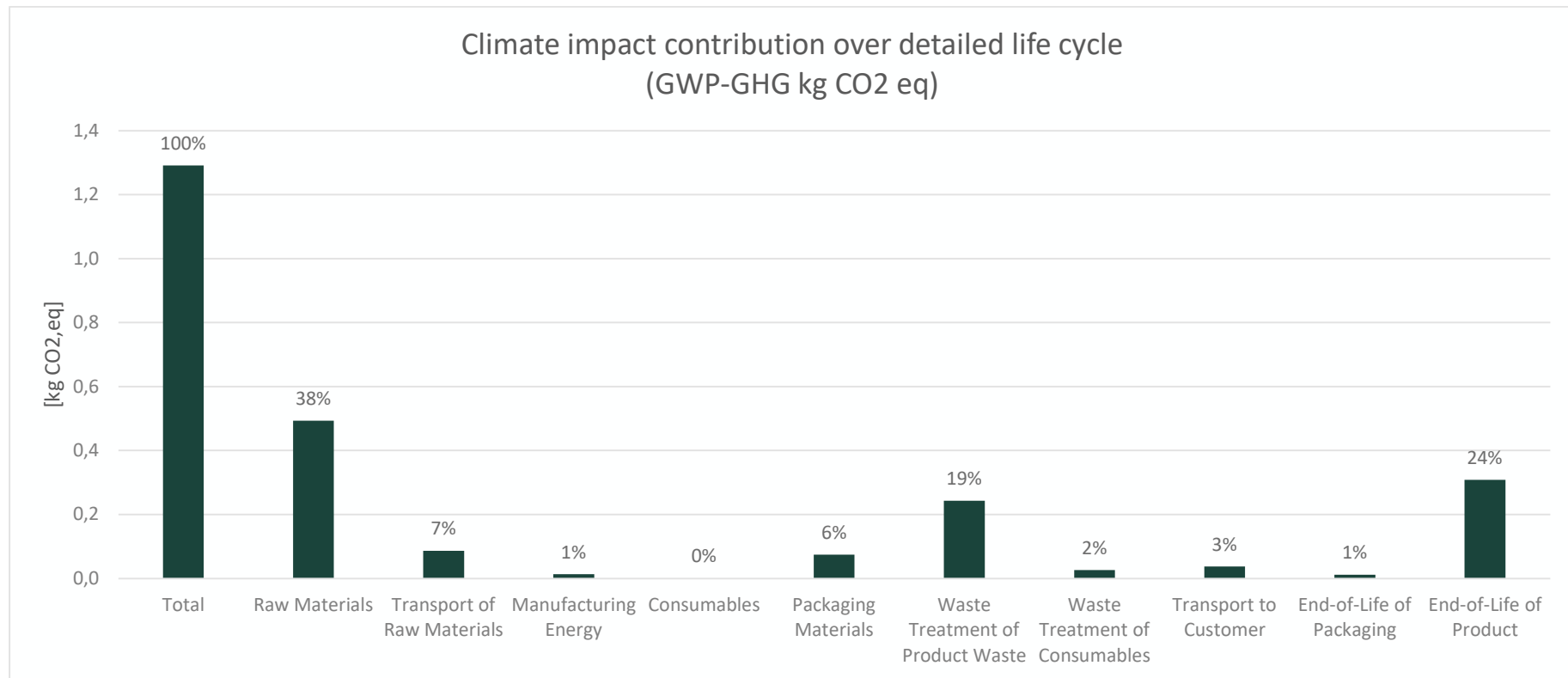


Figure 8: Climate impact per module according to the GWP-GHG method for the detailed life cycle per Green Loop Tallrik Ø24cm with 8 use-phases made from Polypropylene.

5.2 Results Green Loop Tallrik Ø24cm made with TX2001

5.2.1 Environmental Footprint Midpoint

Table 15 shows the result per *Green Loop Tallrik Ø24cm made from TX2001 and with 8 use-phases* according to the LCIA method Environmental footprint 3.1 midpoint level.

Table 16: Environmental footprint midpoint results per Green Loop Tallrik Ø24cm with 8 use-phases made from TX2001.

Impact category	Unit	Total	Raw Materials	Transport of Raw Materials	Manufacturing	Transport to Customers	Waste Treatment of Packaging	End-of-Life
GWP Fossil	kg CO ₂ eq	2,16E+00	1,33E+00	1,11E-01	3,59E-01	4,55E-02	1,12E-02	3,11E-01
GWP Biogenic	kg CO ₂ eq	8,11E-02	4,42E-04	3,40E-05	-3,56E-02	3,16E-05	1,16E-01	3,36E-06
GWP LULUC	kg CO ₂ eq	8,42E-04	5,20E-05	4,28E-05	5,88E-04	1,51E-05	1,42E-04	2,15E-06
GWP Total	kg CO ₂ eq	2,24E+00	1,33E+00	1,11E-01	3,24E-01	4,56E-02	1,28E-01	3,11E-01
ODP	kg CFC11 eq	4,94E-06	4,94E-06	1,90E-09	2,04E-09	9,06E-10	2,30E-10	4,60E-10
AP	mol H ⁺ eq	7,30E-03	5,72E-03	8,00E-04	4,78E-04	9,49E-05	5,65E-05	1,55E-04
EP - Freshwater	kg P eq	7,59E-06	5,20E-07	8,45E-07	5,74E-06	3,56E-07	5,94E-08	7,18E-08
EP - Marine	kg N eq	1,37E-03	8,58E-04	2,11E-04	1,77E-04	2,22E-05	2,40E-05	7,43E-05
EP - Terrestrial	mol N eq	1,59E-02	1,07E-02	2,34E-03	1,62E-03	2,46E-04	2,65E-04	7,88E-04
POCP	kg NMVOC eq	4,95E-03	3,12E-03	7,97E-04	4,83E-04	1,58E-04	1,09E-04	2,80E-04
ADPE	kg Sb eq	1,19E-06	1,51E-07	3,17E-07	5,30E-07	1,48E-07	2,95E-08	1,82E-08
ADPF	MJ	3,52E+01	3,12E+01	1,53E+00	1,25E+00	6,41E-01	2,93E-01	2,85E-01
WDP	m ³ depriv.	3,88E-01	3,38E-01	6,11E-03	3,80E-02	2,66E-03	2,42E-03	9,49E-04

PM	disease inc.	7,25E-08	5,20E-08	7,65E-09	5,41E-09	3,34E-09	1,32E-09	2,81E-09
IR	kBq U-235 eq	1,31E-02	2,16E-03	5,81E-04	4,13E-03	2,96E-04	5,90E-03	6,13E-05
ETP - FW	CTUe	2,05E+01	1,87E+01	3,90E-01	1,06E+00	1,74E-01	2,61E-02	1,45E-01
HTP - C	CTUh	2,10E-09	2,86E-10	6,65E-10	7,22E-10	3,23E-10	2,88E-11	7,01E-11
HTP - NC	CTUh	1,13E-07	1,09E-07	8,70E-10	2,16E-09	4,02E-10	5,32E-11	5,66E-10
Land use, SQP	Pt	7,32E+00	5,98E-02	8,00E-01	5,99E+00	3,87E-01	4,95E-02	3,42E-02
GWP-GHG	kg CO2 eq	2,17E+00	1,33E+00	1,11E-01	3,62E-01	4,56E-02	1,14E-02	3,11E-01
Acronyms	GWP: Global Warming Potential, LULUC: Land Use and Land Use Change, ODP: Ozone Depletion Potential, AP: Acidification Potential, EP: Eutrophication Potential, POCP: Photochemical Ozone Creation Potential, ADPE: Abiotic Depletion Potential – Elements, ADPF: Abiotic Depletion Potential – Fossil Fuels, WDP: Water Scarcity Footprint, PM: Particulate Matter, IRP: Ionizing Radiation - Human Health, ETP-FW: Ecotoxicity Potential – Freshwater, HTP-C: Human Toxicity Potential – Cancer, HTP-NC: Human Toxicity Potential – Non-Cancer, SQP: Soil Quality Potential Index, GWP-GHG: Global Warming Potential, Greenhouse Gases							

5.2.2 Climate Impact (GWP-GHG)

Here the total climate impact over the life cycle is presented for the *Green Loop Tallrik Ø24cm made from TX2001 and with 8 use-phases*. Most of these emissions come from the raw material production (61%), as can be seen in Figure 9. Following the raw material production, the second and third largest contributing sources to the climate impact is the Manufacturing of the products (17%), as well as End-of-Life of the products (14%). In Figure 10, a more in-depth illustration can be seen for the products life cycle. What can be seen here is that most of impact found for Manufacturing, can be connected to the waste treatment of the polypropylene created during production.

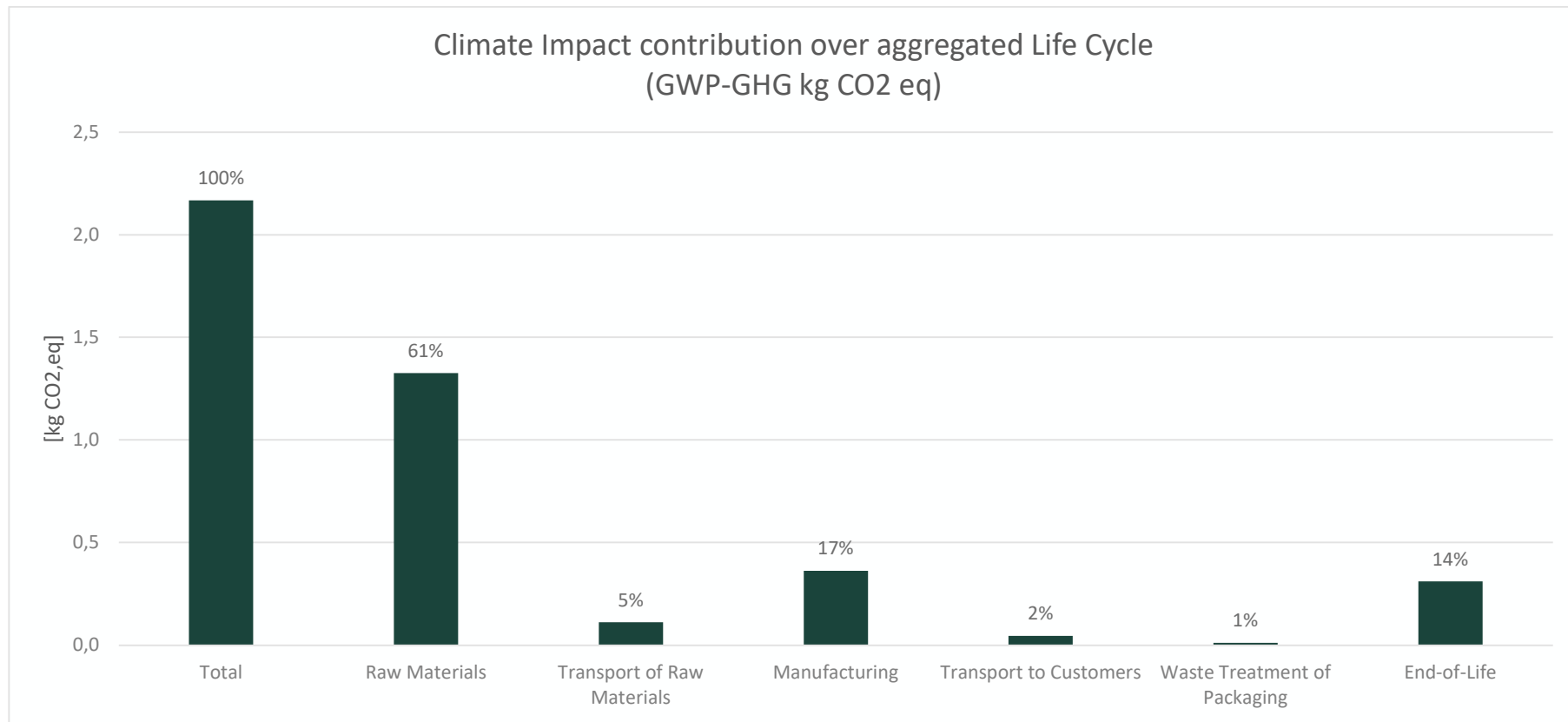


Figure 9: Climate impact per module according to the GWP-GHG method for the aggregated life cycle for Green Loop Tallrik Ø24cm with 8 use phases made from TX2001.

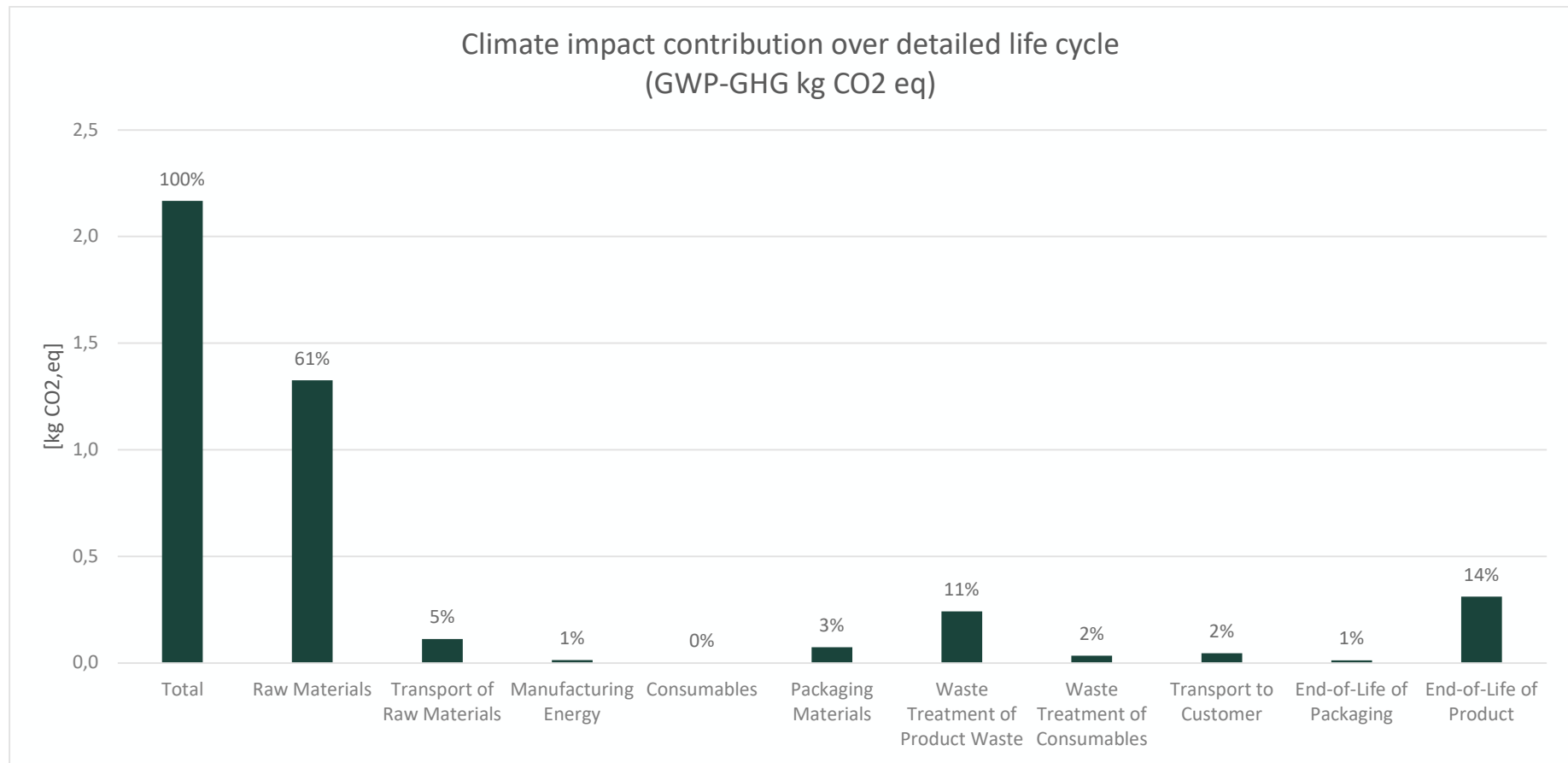


Figure 10. Climate impact per module according to the GWP-GHG method for the detailed life cycle for Green Loop Tallrik Ø24cm with 8 use phases made from TX2001.

5.3 Results Green Loop Tallrik Ø24cm made with Wood Compound Pure L40

5.3.1 Environmental Footprint Midpoint

Table 15 shows the result per *Green Loop Tallrik Ø24cm made from Wood Compound Pure L40 and with 8 use-phases* according to the LCIA method Environmental footprint 3.1 midpoint level.

Table 17: Environmental footprint midpoint results per Green Loop Tallrik Ø24cm with 8 use-phases made from Wood Compound Pure L40.

Impact category	Unit	Total	Raw Materials	Transport of Raw Materials	Manufacturing	Transport to Customers	Waste Treatment of Packaging	End-of-Life
GWP Fossil	kg CO ₂ eq	9,48E-01	3,82E-01	4,74E-02	2,33E-01	3,84E-02	1,12E-02	2,36E-01
GWP Biogenic	kg CO ₂ eq	7,03E-02	-1,40E-01	3,27E-05	1,78E-02	2,66E-05	1,16E-01	7,59E-02
GWP LULUC	kg CO ₂ eq	9,58E-04	2,00E-04	1,57E-05	5,86E-04	1,27E-05	1,42E-04	1,78E-06
GWP Total	kg CO ₂ eq	1,02E+00	2,43E-01	4,75E-02	2,51E-01	3,84E-02	1,28E-01	3,12E-01
ODP	kg CFC11 eq	1,99E-08	1,56E-08	9,44E-10	2,01E-09	7,64E-10	2,30E-10	3,73E-10
AP	mol H+ eq	1,93E-03	1,11E-03	1,16E-04	4,57E-04	8,00E-05	5,65E-05	1,18E-04
EP - Freshwater	kg P eq	1,38E-05	7,27E-06	3,68E-07	5,72E-06	3,00E-07	5,94E-08	6,22E-08
EP - Marine	kg N eq	5,12E-04	2,17E-04	3,21E-05	1,66E-04	1,87E-05	2,40E-05	5,40E-05
EP - Terrestrial	mol N eq	5,29E-03	2,36E-03	3,54E-04	1,52E-03	2,07E-04	2,65E-04	5,90E-04
POCP	kg NMVOC eq	3,05E-03	1,94E-03	1,88E-04	4,56E-04	1,33E-04	1,09E-04	2,17E-04
ADPE	kg Sb eq	3,89E-06	3,04E-06	1,53E-07	5,27E-07	1,25E-07	2,95E-08	1,49E-08
ADPF	MJ	1,53E+01	1,23E+01	6,67E-01	1,23E+00	5,40E-01	2,93E-01	2,33E-01
WDP	m3 depriv.	2,15E-01	1,70E-01	2,76E-03	3,72E-02	2,24E-03	2,42E-03	7,31E-04

PM	disease inc.	2,71E-08	1,18E-08	3,56E-09	5,30E-09	2,81E-09	1,32E-09	2,28E-09
IR	kBq U-235 eq	7,96E-02	6,90E-02	3,19E-04	4,04E-03	2,49E-04	5,90E-03	5,13E-05
ETP - FW	CTUe	2,80E+00	1,39E+00	1,81E-01	9,87E-01	1,47E-01	2,61E-02	6,98E-02
HTP - C	CTUh	3,03E-09	1,63E-09	3,35E-10	7,09E-10	2,73E-10	2,88E-11	5,76E-11
HTP - NC	CTUh	6,25E-09	3,19E-09	4,18E-10	1,94E-09	3,39E-10	5,32E-11	3,13E-10
Land use, SQP	Pt	1,22E+01	5,42E+00	4,01E-01	5,99E+00	3,26E-01	4,95E-02	2,86E-02
GWP-GHG	kg CO2 eq	9,52E-01	3,83E-01	4,75E-02	2,36E-01	3,84E-02	1,14E-02	2,36E-01
Acronyms	GWP: Global Warming Potential, LULUC: Land Use and Land Use Change, ODP: Ozone Depletion Potential, AP: Acidification Potential, EP: Eutrophication Potential, POCP: Photochemical Ozone Creation Potential, ADPE: Abiotic Depletion Potential – Elements, ADPF: Abiotic Depletion Potential – Fossil Fuels, WDP: Water Scarcity Footprint, PM: Particulate Matter, IRP: Ionizing Radiation - Human Health, ETP-FW: Ecotoxicity Potential – Freshwater, HTP-C: Human Toxicity Potential – Cancer, HTP-NC: Human Toxicity Potential – Non-Cancer, SQP: Soil Quality Potential Index, GWP-GHG: Global Warming Potential, Greenhouse Gases							

5.3.2 Climate Impact (GWP-GHG)

Here the total climate impact over the life cycle is presented for the *Green Loop Tallrik Ø24cm made from Wood Compound Pure L40 and with 8 use-phases*. Most of these emissions come from the raw material production (40%), as can be seen in Figure 11. Following the raw material production, the second and third largest contributing sources to the climate impact is the End-of-Life of the products and the impacts from the Manufacturing of the products, both at a contribution of 25% of the total impact. In Figure 12, a more in-depth illustration can be seen for the products life cycle. What can be seen here is that most of impact found for Manufacturing, can be connected to the waste treatment of the polypropylene created during production.

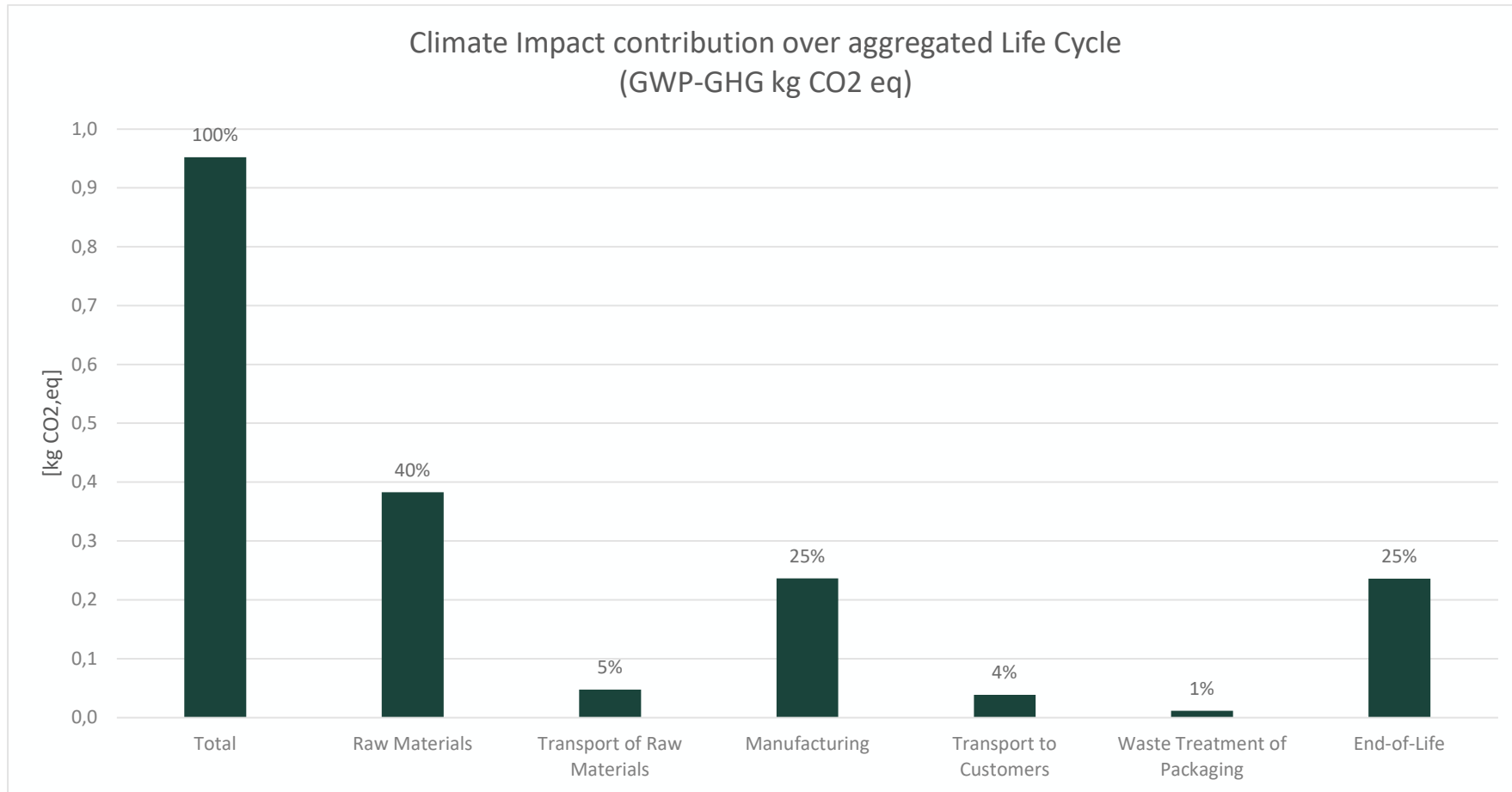


Figure 11: Climate impact per module according to the GWP-GHG method for the aggregated life cycle for Green Loop Tallrik Ø24cm with 8 use phases made from Wood Compound Pure L40.

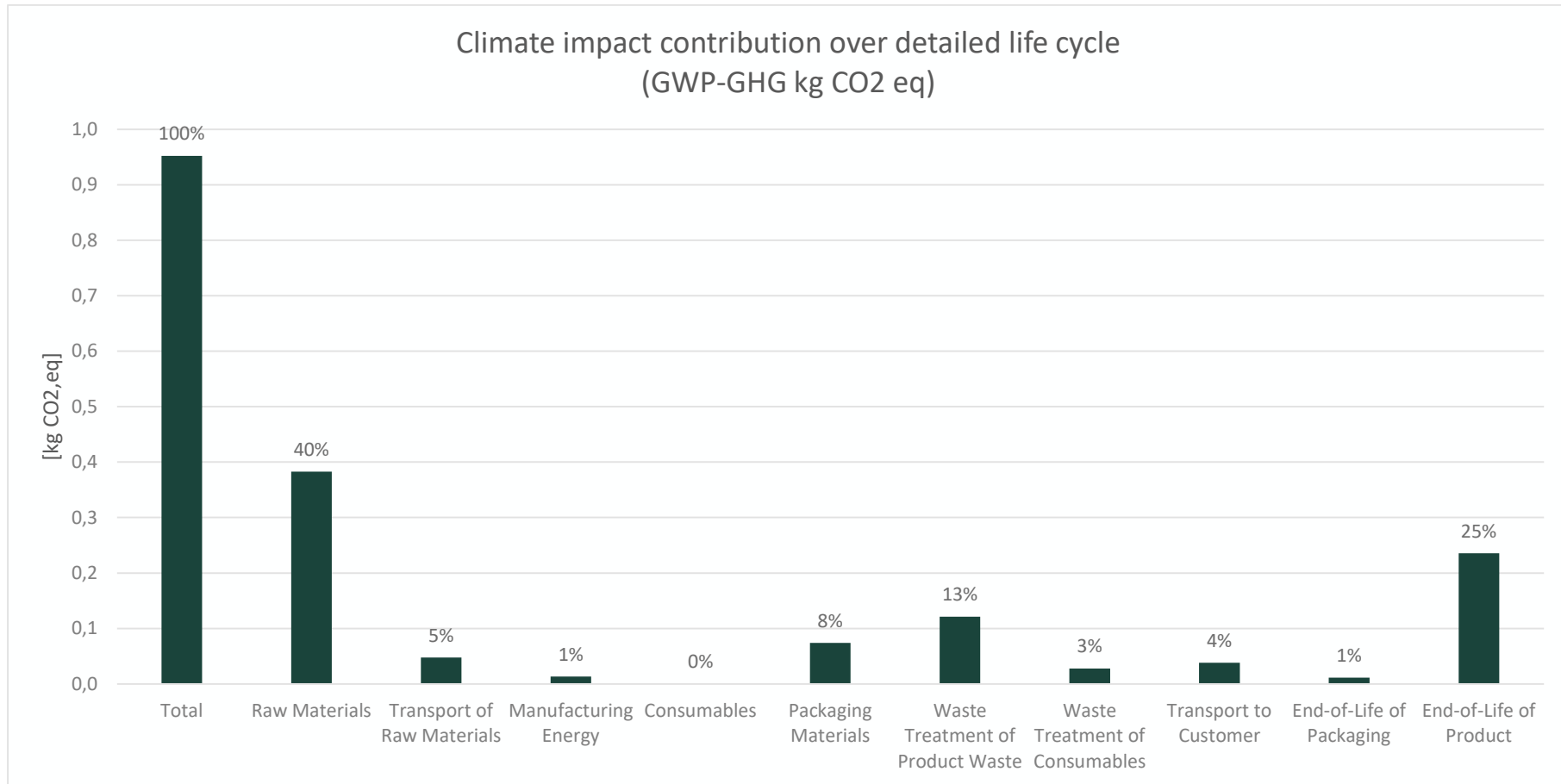


Figure 12. Climate impact per module according to the GWP-GHG method for the detailed life cycle for Green Loop Tallrik Ø24cm with 8 use phases made from Wood Compound Pure L40.

5.4 Biogenic carbon content

Equation 1 Biogenic carbon content according to EN 16449.

$$\text{Biogenic carbon content} = \text{Biogenic carbon fraction} \cdot \frac{\text{Wet density of the biomass} \cdot \text{Wet volume of the biomass}}{1 + \frac{\text{Moisture percentage}}{100}}$$

Standard Values:

Moisture: 12% for wood standard

Biogenic Carbon fraction: 0,5 for wood (0,45 softwood and 0,55 hardwood).

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 Key aspects of results

This life cycle assessment evaluates the environmental performance of 58 products produced by Mälarplast from a cradle-to-grave perspective. In this assessment the product of Green Loop Tallrik Ø24cm was chosen as a representative product to evaluate the impact of using the three raw materials of: Polypropylene, Tritan (TX2001), and Wood Compound Pure L40.

The results indicate that Tritan (TX2001) have the highest total climate impact at 2.17 kg CO₂-eq per product, primarily driven by emissions associated with raw material production, which accounts for 61% of its total impact. In contrast, Polypropylene and Wood Compound Pure L40 demonstrate a lower climate impact, at 1.29 kg CO₂ eq, and 0,952 kg CO₂ eq respectively, representing a reduction of approximately 40-55% in total climate impact compared to Tritan.

Across all materials, the three most impactful life cycle stages are:

- Raw material production,
- Manufacturing, particularly the waste treatment of raw material waste, and
- End-of-life treatment.

For Polypropylene and Wood Compound Pure L40, the raw material phase contributes 38% and 40% of total emissions respectively, while for Tritan it dominates at 61%. Manufacturing is a major contributor, responsible for a large part of the total climate impact, largely due to waste handling during processing. End-of-life treatment ranges from 14-28% of total climate impact contribution across all materials, underlining the importance of downstream waste strategies.

In conclusion, the selection of Wood Compound Pure L40 offers the most climate-efficient alternatives for the Green Loop Tallrik Ø24cm when measured by GWP-GHG. Additionally, the results emphasize opportunities to further reduce emissions through improved waste management during manufacturing and enhanced end-of-life processing, regardless of material choice.

6.2 Scenario analysis

In this scenario analysis, the three main materials of Polypropylene, Tritan TX2001 and Wood Compound Pure L40 will be compared to five other materials that can be used in similar products as those produced by Mälarpplast for the representative product Green Loop Tallrik Ø24cm. These additional materials have exclusively been modelled with generic data and details on how these materials have been modelled can be found in Table 18 below. Additionally, another version of Tritan (TX2001 Renew 50) will also be added to this comparison, which uses new input data for the raw material that is based on LCA data shared by supplier. The rest of the life cycle of the Tritan TX2001 Renew 50 have been modelled the same way as the Tritan TX2001.

Table 18. Modelling details for materials, paper, melamine, glass and ceramic products based on generic data.

Product material	Process	LCI database representation Ecoinvent 3.10	Amount	Comment
Paper (single-use)	Raw material	Paper, woodfree, coated {RER} paper production, woodfree, coated, at non-integrated mill Cut-off, U	1 kg	Represents raw material
	Transport to customers,	Transport, freight, lorry 16-32 metric ton, EURO5 {RER} transport, freight, lorry 16-32 metric ton, EURO5 Cut-off, U	200 kgkm	Represents transportation of finished products to customers,
	Transport at end-of-life	Municipal waste collection service by 21 metric ton lorry {CH} municipal waste collection service by 21 metric ton lorry Cut-off, U	100 kgkm	Represents transportation of production waste and products at end-of-life to waste treatment facility
	Waste treatment at end-of-life	Waste graphical paper {CH} treatment of waste graphical paper, municipal incineration FAE Cut-off, U	1 kg	Represents waste treatment of product at end-of-life
Melamine	Raw material	Melamine formaldehyde resin {RER} market for melamine formaldehyde resin Cut-off, U	1,01 kg	Represents raw material. Additional value represents losses occurring in processing.
	Processing	Injection moulding {GLO} market for injection moulding Cut-off, U	1,01 kg	Represents processing of raw material. Additional value represents losses occurring in processing.

	Transport to customers,	Transport, freight, lorry 16-32 metric ton, EURO5 {RER} transport, freight, lorry 16-32 metric ton, EURO5 Cut-off, U	200 kgkm	Represents transportation of finished products to customers,
	Transport at end-of-life f	Municipal waste collection service by 21 metric ton lorry {CH} municipal waste collection service by 21 metric ton lorry Cut-off, U	101 kgkm	Represents transportation of production waste and products at end-of-life to waste treatment facility
	Waste treatment at end-of-life	Municipal solid waste {SE} treatment of municipal solid waste, municipal incineration Cut-off, U	1,01 kg	Represents waste treatment of product at end-of-life
Glass	Raw material	Packaging glass, white {GLO} market for packaging glass, white Cut-off, U	1 kg	Represents raw material
	Transport to customers,	Transport, freight, lorry 16-32 metric ton, EURO5 {RER} transport, freight, lorry 16-32 metric ton, EURO5 Cut-off, U	200 kg	Represents transportation of finished products to customers,
	Transport at end-of-life	Municipal waste collection service by 21 metric ton lorry {CH} municipal waste collection service by 21 metric ton lorry Cut-off, U	100 kg	Represents transportation of production waste and products at end-of-life to waste treatment facility
	Waste treatment at end-of-life	Waste glass {SE} market for waste glass Cut-off, U	1 kg	Represents waste treatment of product at end-of-life
Ceramic	Raw material	Sanitary ceramics {GLO} market for sanitary ceramics Cut-off, U	1 kg	Represents raw material
	Transport to customers,	Transport, freight, lorry 16-32 metric ton, EURO5 {RER} transport, freight, lorry 16-32 metric ton, EURO5 Cut-off, U	200 kg	Represents transportation of finished products to customers,
	Transport at end-of-life	Municipal waste collection service by 21 metric ton lorry {CH} municipal waste collection service by 21 metric ton lorry Cut-off, U	100 kg	Represents transportation of production waste and products at end-of-life to waste treatment facility
	Waste treatment at end-of-life	Inert waste, for final disposal {CH} treatment of inert waste, inert material landfill Cut-off, U	1 kg	Represents waste treatment of product at end-of-life

Down below a comparison has been made that illustrates the total life cycle impact (linear life cycle) per kg material.

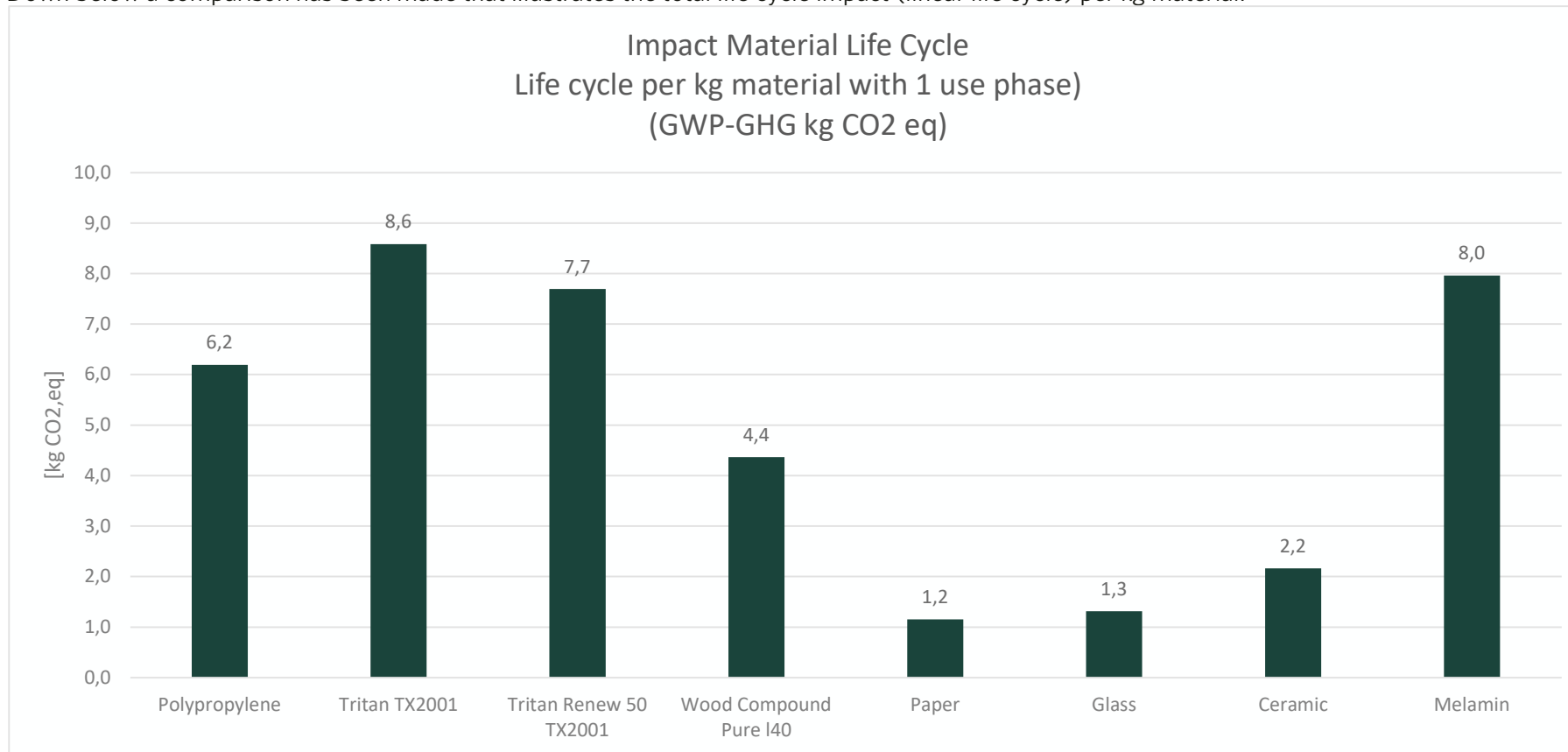


Figure 13. Scenario analysis that compares the climate impact (GWP-GHG / kg material) for the main materials and 5 additional materials over a linear life cycle.

However, one of the most important qualities of Mälarplast's products is that they can collect used products after each life cycle and through their internal recycling process make new products of now collected material again. Through this method they can extend the complete life cycle to a total of 8 use phases per material, while the other materials have been used up and thus needs to be exchanged with a new product. In the figure below the results are illustrated for the materials used by Mälarplast when they have 8 use phases and the materials been rotated and put onto the market again, while the other materials, paper, melamine, glass and ceramic have 7 additional products that are needed to fulfil as many use-phases.

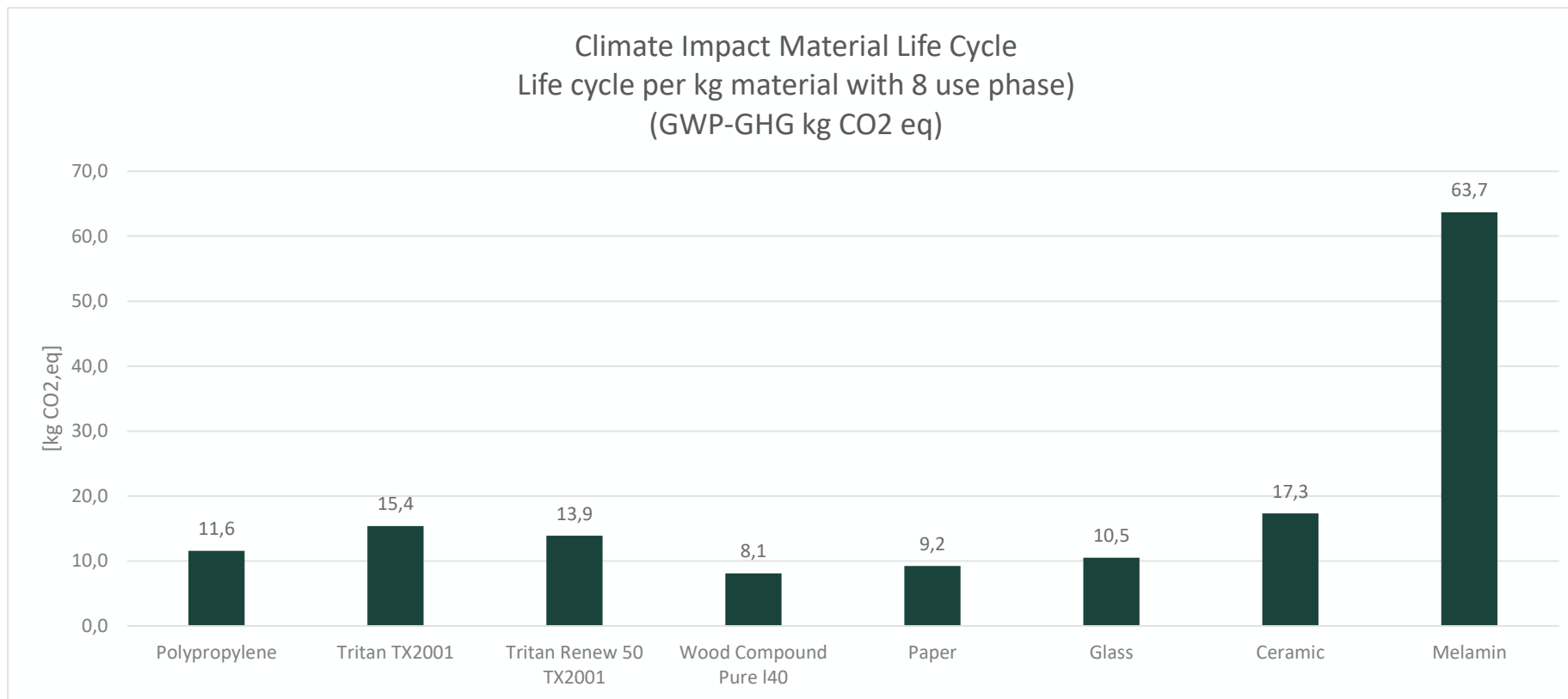


Figure 14. Scenario analysis that compares the climate impact (GWP-GHG / kg material) for the main materials and 5 additional materials over 8 use-phases (a full life cycle for Mälarpplast's products).

From these two comparisons, it can be seen that while other materials can have a lower impact per kg produced materials for a single (linear) life cycle and virgin materials, e.g. paper or glass, the possibility of extending the materials life cycle of Mälarpplast's products gives another result. In this second comparison the Wood Compound Pure L40 has the lowest impact overall.

However, one should also consider the function of the materials, which in this case is the use of one product, e.g. one Green Loop Tallrik Ø24cm to be used as a plate. Characteristics that are needed to translate the earlier results into one per function are, density of material which defines the amount of materials that are needed to produce a product, the estimated years of possible use before breakage, which gives a total number of rotations (uses) per use-phase of each material. In this comparison the dimensions of the products have been assumed to be the same for all materials, which reflects a volume of 117,5 cm³.

The use of Mälarpplasts products is mainly aimed at school cafeterias to be used for daily lunches. In such an environment an estimated number of uses is 200 per year in total. Down below in Table 19 estimated values are listed for the compared materials. These values are assumptions which been made with estimated judgments together with Mälarpplast with the aim that they should reflect realistic capabilities of similar products made from these materials. As Mälarpplast's material can be recycled 7 times, the use-phases can be extended an additional 7 times, which increases the maximum number of possible rotations per complete life cycle of the material.

Table 19: Details on characteristics of the main materials and additional materials used in the comparison.

Product material	Density [g/cm ³]	Weight of product [g]	Estimated use phase	Estimated number of rotations (uses)	Maximum number of rotations over life cycle
Polypropylene	0,950	112	2 years	400	3200
TX2001	1,20	141	5 years	1000	8000
Wood Compound Pure L40	1,00	118	2 years	400	3200
TX2001 Renew 50	1,20	141	5 years	1000	8000
Paper ¹ (single-use)	0,350	41,1	Single-use	1	1
Melamine ²	1,50	176	2 years	400	400
Glass ³	2,40	282	2 years	400	400
Ceramic ⁴	2,40	282	2 years	400	400

¹ Source used when estimating material density (Semple et al., 2022)

² Source used when estimating material density (Jin Jiang Chemical Industry, n.d.)

³ Source used when estimating material density (Specialty Glass Products, n.d.)

⁴ Source used when estimating material density (Holst Porzellan, n.d.)

The maximum number of rotations (uses) per complete life cycle is 8000, which was reached for the products created with the two TX2001 materials as can be seen in the table above. This number of rotations have been used as a reference point in the comparison to illustrate the maximum function of one Green Loop Tallrik Ø24cm to be used the 8000 times for each material. This means that the materials that do not fulfil this function in one complete life cycle, needs additional life cycles that are added to fulfil the same number of uses. E.g. for the Polypropylene Green Loop Tallrik Ø24cm, a total of 3 products is needed to support 8000 uses, while a ceramic or glass product needs a total of 20 products to fulfil the same amount of uses. For the single-use paper product this means that a total of 8000 products needs to be produced to fulfil the same criteria as the defined function above. However, the calculated weight of the additional products considers a product of similar volume, which in the specific example of the single-use paper product can be considered unrealistic as the thickness of such products can be much thinner than for example a glass or plastic product, thus should have a much lower final weight. In this comparison additional results are presented when the estimated weight of the paper product is 50% lower compared to the value presented in the table above.

To translate between the impact per use and total climate impact per 8000 uses below, one first takes the *Impact per use* in Table 20, multiplied with *Maximum number of rotations per life cycle* correlating to the specific material from Table 19, and then multiply this value with the *Number of use-phases needed to reach maximum rotations (uses)*. If one takes the Polypropylene material as an example one here multiply 0,000403 kg CO₂eq per use x 3200 uses x 3 life cycles = impact per 8000 uses. Figures and tables for the comparison can be viewed directly below that illustrates the impact per 8000 uses. In Appendix 8 additional figures can be found that illustrate results per use instead.

Table 20: Results from the comparisons assessing the impact of using the different materials per product.

Product material	Impact per use [kg CO ₂ eq / product]	Number of extra use-phases to reach maximum rotations (uses)	Climate impact per fulfil s 8000 uses [kg CO ₂ eq / product]	Comment
Polypropylene	0,000403	3	3,23	
TX2001	0,000271	-	2,17	
Wood Compound Pure L40	0,000298	3	2,38	
TX2001 Renew 50	0,000245	-	1,96	
Paper (single-use)	0,0475	8000	379,6	The impact when paper product consists of 50% less material results are instead a total impact of 184,6 kg CO ₂ eq and an impact per use of 0,0238 kg CO ₂ eq
Melamine	0,00351	20	28,1	

Glass	0,000926	20	7,41	
Ceramic	0,00153	20	12,2	

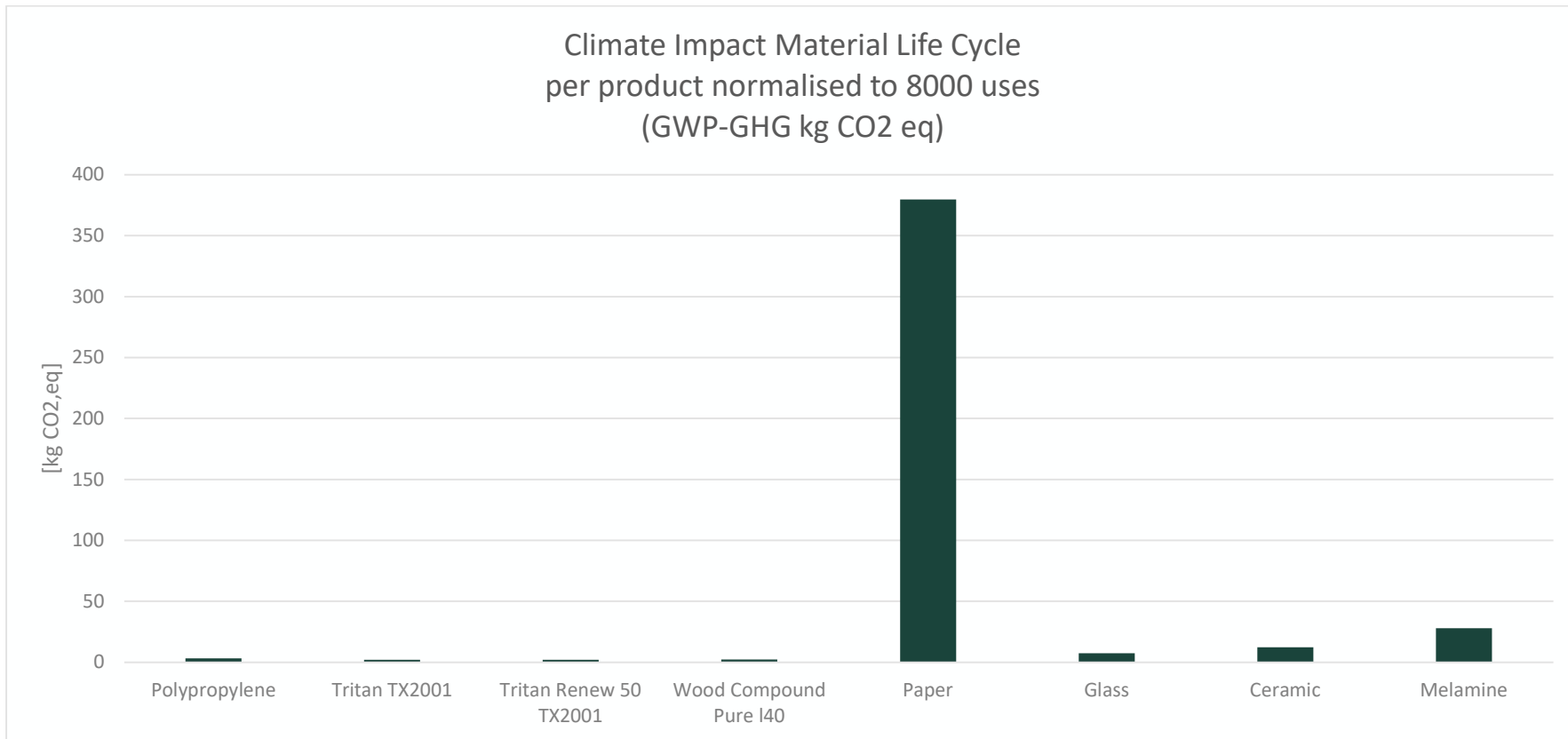


Figure 15: Results illustrating the climate impact between the materials used in a Green Loop Tallrik Ø24cm for 8000 rotations.

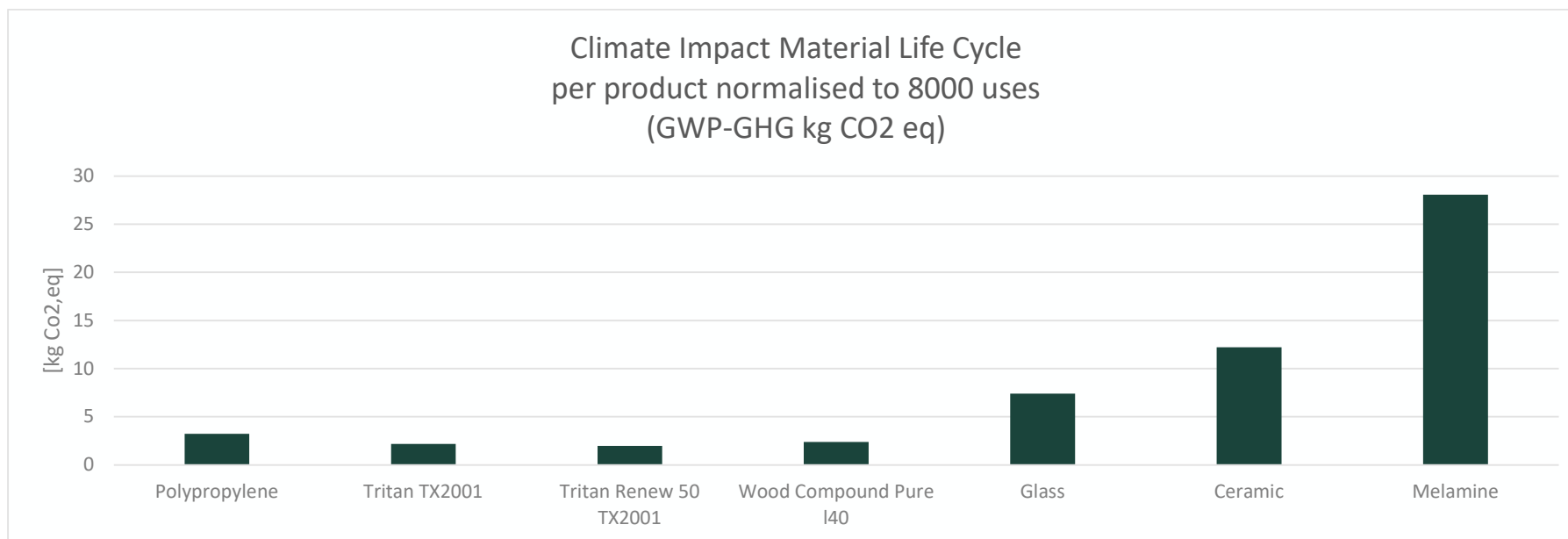


Figure 16: Results illustrating the climate impact between the materials used in a Green Loop Tallrik Ø24cm for 8000 rotations, (excluding the paper material).

From this evaluation it can be seen that the materials used in the product that have the lowest impact per use, and that fulfills 8000 rotations (uses) are, TX2001 Renew 50, TX2001. Compared to the earlier comparison in Figure 14, which assessed the use per kg material over 8 use phases, it can be noticed that now the two TX2001 material has a lower impact compared to the Wood Compound Pure L40 and Polypropylene. The reason behind this change is that these materials are more durable and thus can be used for more rotations, 8000, compared to 3200. Same is true when comparing the main materials with the additional products which are assumed to only be able to withstand 400 rotations before they are exchanged with new products. The number of rotations is therefore a critical parameter for this comparison, and in the case of TX2001, TX2001 Renew 50, if the 8000 rotations do not take place in full, the results will be different. A final evaluation is here performed on the main materials, assessing the situation when the products can only be used for 2 years of the life cycle, e.g. either through breakage of a product earlier than expected, or that a product is not collected after its use-phase by Mälarpplast's due to products either being lost or limited resources at customers.

Table 21: Comparison of main materials when not full life cycle can be achieved.

Product material	Achieved use-phase	New number of rotations (uses)	Maximum number of rotations over life cycle	Impact per use [kg CO ₂ eq / product]	Number of extra use-phases to reach maximum rotations (uses)	Climate impact per fulfilled 8000 uses [kg CO ₂ eq / product]
Polypropylene	2 years	400	3200	0,000403	3	3,23
TX2001	2 years	400	3200	0,000542	3	6,50
Wood Compound Pure L40	2 years	400	3200	0,000298	3	2,38
TX2001 Renew 50	2 years	400	3200	0,000490	3	5,88

As can be seen from this assessment, the importance of achieving a complete life cycle, and the maximum use-phases that are possible for a material is the single most important aspect when assessing the climate performance of these products. Recommendations from this assessment are therefore to focus on communication on the importance of collecting the products after each use-phase with relevant actors and customers. To ensure that products are recollected, so that the material can be reused in new products and thus extending the life cycle. By maximising the number of uses, the impact per use will decrease as the number of uses increase, while the opposite is also true, if a product is not collected and the material cannot be reused in a new product, the full potential of these products cannot be achieved.

6.3 Data quality assessment

The data is valid for production in Eskilstuna. 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 3.2.5. The data quality assessment is based on the requirements in the ISO 14044 standard. A DQA of individual datasets covering at least 80% of impacts are presented in Appendix 6.

Table 22: Data quality assessment for the study.

Aspect	Notes
Data quality assessment scheme	The data quality level and criteria from the product category rules have been applied in this study
Geographical coverage	Upstream data: Very good/Good depending on raw material (Specific EPDs or regionalised data based on location of suppliers) Core module (A3): Very good (site-specific) Downstream: Good, (Representative region)
Technological representativeness	Upstream data: Very good/Good depending on raw material (Specific EPDs or regionalised data based on location of suppliers) Core module (A3): Very good (site-specific)
Time-related coverage	Upstream data: Very good, less than 3 years, Core module (A3): Very good (2022 and 2024 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 (production of plastic materials) have been checked for plausibility, using as reference EPDs or generic data for similar products.
Precision	Material and energy flow quantified based on generic data from the ecoinvent database.
Completeness	Data accounts for all known sub-processes. All upstream processes were modelled using generic data from the ecoinvent database, using country-specific datasets whenever available, otherwise using European datasets.
Consistency, allocation method, etc.	Allocation follows a physical causality in line with EN 15804.
Completeness and treatment of missing data	No data is found missing.
Final result of data quality assessment	Data quality as required in EN15804 is met.

6.3.1 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 6.2.

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. A histogram showing the probability of the results of the GWP-GHG impact using the EF3.1 method, performed with 1000 iterations and presented for the main materials Polypropylene, and Wood Compound Pure L40, in Figure 17, and Figure 18, and details in Table 23, and Table 24 respectively.

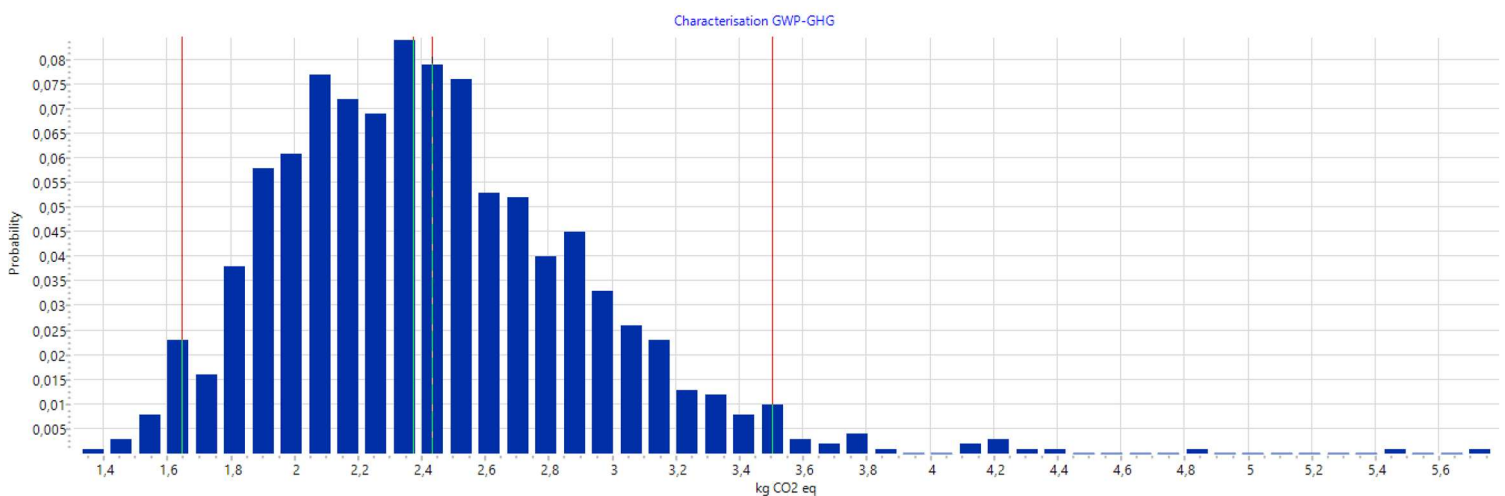


Figure 17: Show the distribution of results from the Monte Carlo analysis for the raw material phase on the Polypropylene material.

Table 23: Details concerning the Monte Carlo analysis for the Polypropylene material

Mean	Median	Standard deviation	Coefficient of variation %	Low 2.5%	High 97.5%	Standard error of mean
2,43	2,37	0,497	20,4%	1,64	3,5	0,0157

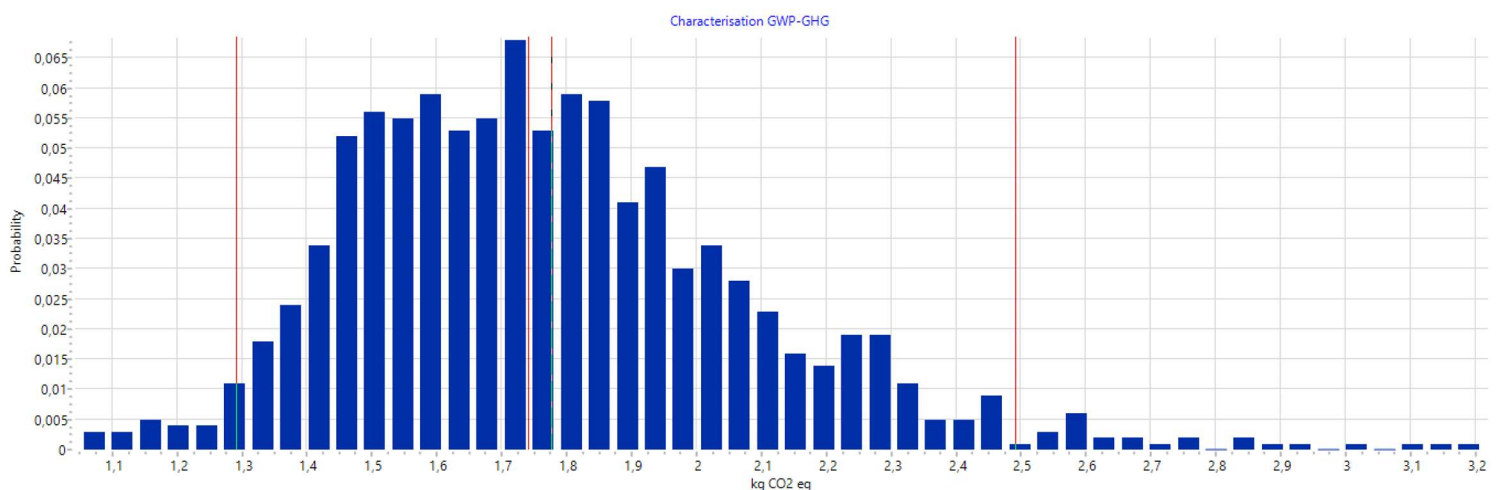


Figure 18: Show the distribution of results from the Monte Carlo analysis for the raw material phase on the Wood Compound Pure L40 material.

Table 24: Details concerning the Monte Carlo analysis for the Polypropylene material

Mean	Median	Standard deviation	Coefficient of variation %	Low 2.5%	High 97.5%	Standard error of mean
1,78	1,74	0,311	17,5%	1,29	2,49	0,00985

The uncertainty is considered acceptable for a complex LCA study.

6.4 Limitations

While this life cycle assessment provides valuable comparative insights into the climate impact of different material choices for the Mälarpplast’s plastic products, several limitations inherent to LCA methodology—particularly in the context of plastic products—should be acknowledged.

A key limitation in this study stems from differences in the availability and quality of life cycle inventory (LCI) data for the three assessed materials: Polypropylene, Tritan (TX2001), and Wood Compound Pure L40. Some materials have Environmental Product Declarations (EPDs) or manufacturer-specific primary data, while others rely on generic data. This discrepancy introduces uncertainties in the results, for example for the upstream impacts such as raw material extraction, energy sources, and production efficiencies, which can vary between datasets.

The parameters used in the comparison are based on judgment and assumptions with the help of Mälarpplast. These parameters are important to the comparison, and if the values vary, e.g. possible years of use of a product before breakage is longer than assumed in this assessment, the results can have a completely different outcome. It is therefore recommended that more studies are performed with collaboration with experts on these different materials to give further insights into the characteristics of listed materials to decrease the uncertainty

End-of-life treatment of plastic products is highly dependent on local infrastructure, recycling technologies, and consumer behaviour, all of which vary widely by geography. In this study, a generalised European end-of-life scenario has been applied, which may not reflect the actual fate of the product in specific markets. Materials with biogenic content or designed for recyclability may appear less favourable if the modelled system does not capture those end-of-life benefits.

Assessing plastic products with multiple use-phases introduces complexity, particularly when it comes to modelling durability, cleaning impacts (if applicable), and the functional equivalence of different materials. While this study assumes a fixed number of uses per product across all materials, in practice, material-specific wear, damage rates, or consumer habits could affect the results.

7 Conclusions

This life cycle assessment has evaluated the environmental performance of 58 products manufactured by Mälarplast, using a cradle-to-grave approach. The product Green Loop Tallrik Ø24cm was selected as a representative case to assess the climate impacts of three raw materials: Polypropylene, Tritan (TX2001), and Wood Compound Pure L40. These materials were evaluated based on their total environmental impact and across all life cycle stages, including an extended life cycle with seven use phases thanks to Mälarplast's internal recycling process.

The results show that Tritan (TX2001) carries the highest climate impact, with 2.17 kg CO₂ eq per product—largely driven by emissions from raw material production (61% of total impact). In contrast, Polypropylene and Wood Compound Pure L40 demonstrate a lower climate impact, at 1.29, and 0.952 kg CO₂ eq respectively representing a reduction of approximately 40-55% compared to Tritan.

Across all materials, the most impactful life cycle stages are:

- Raw material production,
- Manufacturing, particularly related to waste treatment of material spillage, and
- End-of-life treatment.

A scenario analysis was also performed to comparing the above four main materials to five additional materials, that are commonly used in similar products: coated paper, melamine resin, glass, ceramic. These additional materials were modelled using generic life cycle inventory data and serve as reference points for understanding the relative climate performance of Mälarplast's material choices.

When comparing the climate impact per kg of material, several of these alternative materials appear favourable in a linear life cycle scenario. However, Mälarplast's products are designed to enable material reuse with their internal recycling process, allowing the material to have up to seven life cycles with the same base material. When this extended function of Mälarplast's products are taken into account, the total impact is drastically reduced. In this circular-use scenario, a win-win situation is created for Mälarplast's products, especially one consisting of Wood Compound Pure L40, which sees a reduction in climate impact but also total resource use.

A further perspective is gained when considering impact per rotation in the use phase. Studies such as De Jong et al. (2021) suggest plastic-based products may achieve up to 1000 rotations per cycle, highlighting the significant environmental advantage of durable, reusable designs. In contrast, materials such as paper may only support single or limited number of uses, potentially requiring thousands of replacement units to match the functional lifespan of Mälarplast material. The comparison performed in this study gives validation to these arguments, and stresses the importance of using materials that have the possibility of reusing materials to extend the materials life cycle to minimise the impact with the function of a product.

In conclusion, material selection combined with circular design and high product durability are important factors for minimising products climate impact as well as resource use. Mälarplast's approach of using recyclable materials in closed-loop systems, particularly when using materials the TX2001 materials which has high expected number of uses, and Wood Compound Pure L40 which has a low impact per material use. Use of these materials represents a robust and climate-conscious product strategy, especially when viewed over extended use cycles. Future assessments should continue to integrate durability, number of rotations, and actual user behaviour to more fully capture product performance and environmental value.

7.1 How to communicate the results

The study and report were carried out following the standards provided in ISO 14044. The report's aim is to create a better understanding of the different options and in which material, being Polypropylene, TX2001 and Wood Compound Pure L40, are preferred from an environmental point of view through its life cycle in different scenarios. These four main materials evaluated in this study have also been compared to other common materials that can be used in products that Mälarplast produce. Results on these other materials are entirely based on generic data which should be taken into account when comparing the main results with the scenario results. This LCA report can be used as a third-party report or as a basis for the development of such a report.

For enhanced robustness and transparency, it is advisable to conduct a critical review and obtain a verification statement. A critical review may assist in discovering errors or more reasonable assumptions, as well as generally ensuring the integrity of a study, in addition to preventing abuse and unsubstantiated claims, hence increases the LCA's robustness and the confidence in its findings and recommendations (Rosenbaum & Olsen, 2018). Overall, a critical review gives credibility to the study results.

According to ISO, LCA studies for external communication need to be summarised in a third party report (ISO, 14040):

"When results of the LCA are to be communicated to any third party (i.e. interested party other than the commissioner or the practitioner of the study), regardless of the form of communication, a third-party report shall be prepared. The third-party report can be based on study documentation that contains confidential information that may not be included in the third-party report. The third-party report constitutes a reference document, and shall be made available to any third party to whom the communication is made."

7.2 How to reduce uncertainties

The product systems were modelled to the best knowledge regarding the materials provided. However, some of the materials were modelled in a simplified way. This may lead to results not being specifically representative. To reduce this uncertainty, Mälarplast must collaborate even closer with the supply chain upstream. While certificates and labels can be an indication of a better environmentally performing product, no material is environmentally burden free. Also such certificates often fail to provide the required inputs to quantitative assessments such as LCA. To reduce uncertainties and generate results which can be confidently relied upon, it is important that Mälarplast take a step further and gain further awareness in terms of the contents of the raw materials, their production process, including which are the sources of the raw materials further up the supply chain.

The scenario of the use phase has several limitations, such as not assessing the use of washing machines and consumables needed to wash the products during the use phase. In this assessment it was assumed that all products would need as much water and detergents. In future assessments it would be advisable to also include and evaluate these aspects to further improve the results and give a complete picture of all impacts that surrounds the products life cycle.

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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 19. In sections Appendix 1A - Appendix 1D further details on each life cycle phase are presented.

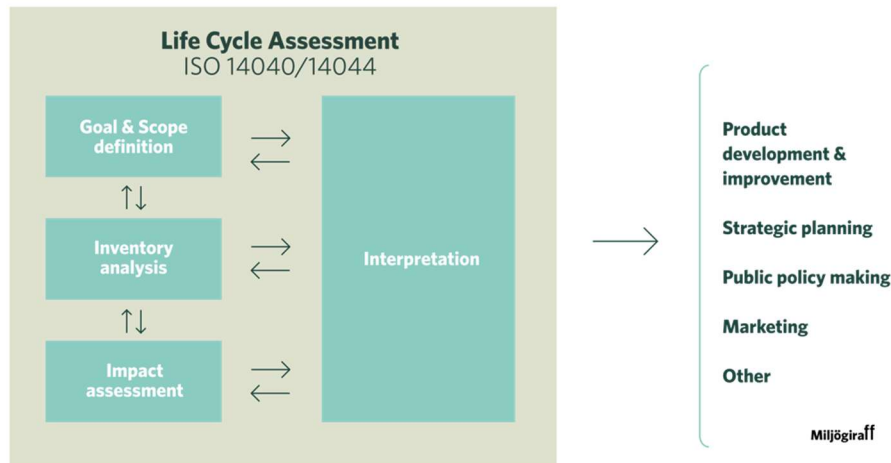


Figure 19. The four phases of the Life Cycle Assessment

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.

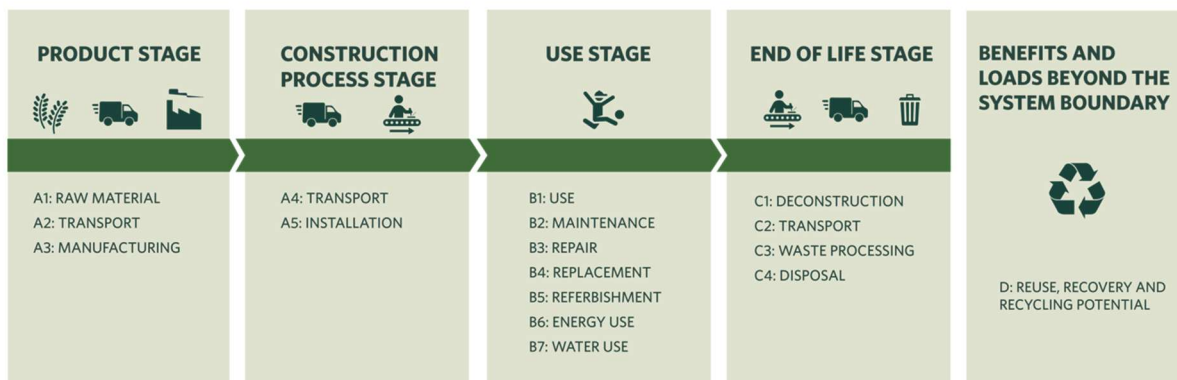


Figure 20: General summary of the modules included in an LCA, based on EN 15804.

In this LCA, boundaries with other systems, and the allocation of environmental burdens between them, are based on the recommendations of the international EPD system⁵, 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 21). 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.

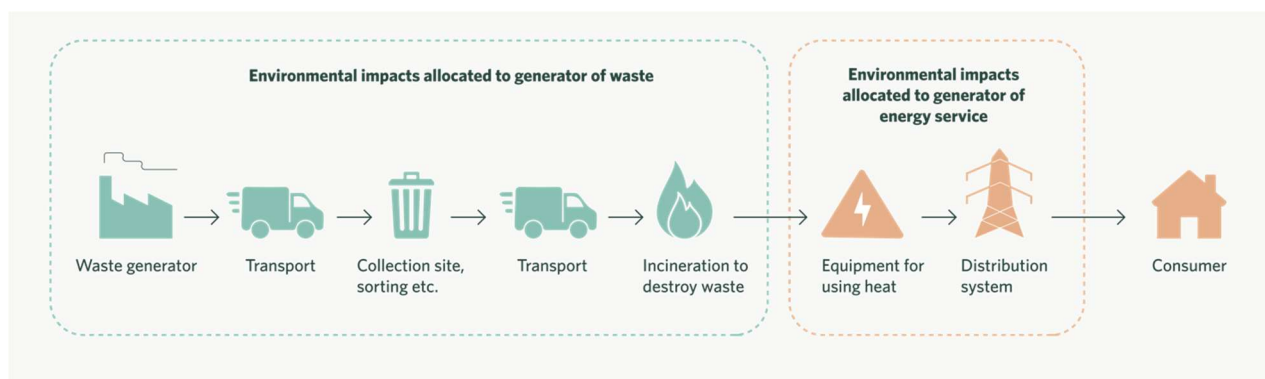


Figure 21: Allocation of environmental impacts between two life cycles according to the PP allocation method. Here in regard to the incineration of waste and resulting energy products.

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

⁵ EPD (Environmental Product Declarations) by EPD International®

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 LCI data from ecoinvent or other databases.

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 - Appendix 3.

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 22 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.

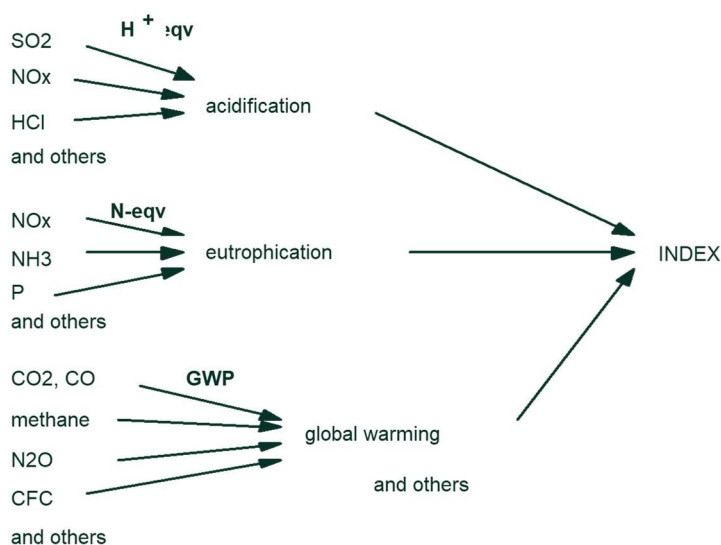


Figure 22: An illustration of the Impact Assessment of an LCA.

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 EF3.1 will now be summarised:

Acidification - EF impact category that addresses impacts due to acidifying substances in the environment. Emissions of NO_x, NH₃ and SO_x 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 (NO_x), 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 (NO_x) 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 global 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 25 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 25: Planetary boundaries and mid-point environmental impact indicators in LCA recommended by EF3.0. Adapted from (Tillman et al., 2020).

Planetary boundaries	Mid-point indicators in LCA as per EF3.1	Level of correspondence between impact categories
Climate change	Climate change	High level of correspondence
Stratospheric ozone depletion	Ozone layer depletion	
Biogeochemical flows (nitrogen and phosphorus cycles)	Freshwater, marine and terrestrial eutrophication	
Novel entities (chemical pollution)	Freshwater ecotoxicity Human toxicity (cancer and noncancer)	
Atmospheric aerosol loading	Photochemical ozone creation Respiratory effects, inorganic	Some correspondence

Ocean acidification	Freshwater acidification	No correspondence
Biospheric integrity (biodiversity loss)	Resources land use	
Land system change	Resources land use	
Freshwater Use	Resources dissipated water	
-	Resources minerals and metals	
-	Resources fossils	
-	Ionising radiation	

Appendix 3 IPCC 2021

Direct solar radiation heats the Earth. The heated crust emits heat radiation, is partially trapped by gases, in the Earth's atmosphere. These gases are known as greenhouse gases. Some of this heat radiation radiates back to Earth and heats it. This natural greenhouse effect is essential for life on Earth. However, because of human activity, the concentration of greenhouse gases in the atmosphere, such as carbon dioxide, methane, and nitrous oxide, has increased. This affects the natural radiation balance, which leads to global warming and climate change.

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.

Appendix 4 Data input on Mälarplast products

Sys - Art nr	MP - Art nr	Utökad benämning	Maskin	KWh / Tim	Skotttid i sekunder	Energi per st	Råmaterial	Vikt i Kg	Rotationer	Förpackning	Kartong	Antal i detaljist förp	Vikt i gram	Volym produkt (cm3)
901343	RECIRK082451	Green Loop Tallrik Ø24cm	160T	7,0	29,0	0,0564	PCT-G	0,153	1000	Kartong	245x245x255	25	220	117,54
901344	RECIRK083551	Green Loop Tallrik Ø23,5 cm	160T	7,0	37,0	0,0719	PCT-G	0,156	1000	Kartong	245x245x255	25	220	120,05
901345	RECIRK081651	Green Loop Tallrik Ø18 cm	80T	5,0	32,0	0,0444	PCT-G	0,0820	1000	Kartong	185x185x180	25	100	63,08
901346	RECIRK081951	Green Loop Djup tallrik Ø24cm	160T	7,0	38,0	0,0739	PCT-G	0,133	1000	Kartong	245x245x255	25	220	102,31
901347	RECIRK081551	Green Loop Djup tallrik Ø23,5cm	160T	7,0	26,1	0,0508	PCT-G	0,176	1000	Kartong	245x245x255	25	220	135,26
901348	RECIRK081251	Green Loop Djup tallrik Ø18cm	80T	5,0	35,0	0,0486	PCT-G	0,0900	1000	Kartong	185x185x180	25	100	69,23
901349	RECIRK083651	Green Loop Mugg med handtag	80T	5,0	31,5	0,0438	PCT-G	0,090	1000	Kartong	245x245x385	25	220	69,23
901350	RECIRK083661	Green Loop Mugg med två handtag	120T	6,0	32,0	0,0533	PCT-G	0,095	1000	Kartong	245x245x385	25	220	73,08
901351	RECIRK084207	Green Loop Kantin GN 1/9x100 mm	160T	7,0	34,0	0,0661	PP	0,0816	1000	Kartong	200x110x220	4	150	85,89
901352	RECIRK086307	Green Loop Kantin GN 1/6x65	160T	7,0	27,2	0,0529	PP	0,0928	1000	Kartong	200x200x230	4	165	97,71
901353	RECIRK084407	Green Loop Kantin GN 1/6x150	160T	7,0	37,0	0,0719	PP	0,168	1000	Kartong	350x220x280	4	250	177,16
901354	RECIRK086007	Green Loop Kantin GN 1/4x65 mm	160T	7,0	39,0	0,0758	PP	0,139	1000	Kartong	280x170x270	4	180	146,02
901355	RECIRK086107	Green Loop Kantin GN 1/4x100 mm	150T	7,0	51,0	0,0992	PP	0,200	1000	Kartong	350x220x280	4	250	210,44
901356	RECIRK084607	Green Loop Kantin GN 1/4x150 mm	350T	20,0	48,0	0,2667	PP	0,230	1000	Kartong	350x220x280	4	250	241,58
901357	RECIRK086907	Green Loop Kantin GN 1/3x65 mm	500T	35,0	48,0	0,4667	PP	0,216	1000	Kartong	335x185x275	4	220	227,62

901358	RECIRK086807	Green Loop Kantin GN 1/3x100 mm	350T	20,0	48,0	0,2667	PP	0,252	1000	Kartong	350x220x280	4	250	265,20
901359	RECIRK082307	Green Loop Kantin GN 1/3x150 mm	350T	20,0	40,0	0,2222	PP	0,311	1000	Kartong	350x220x280	4	250	327,47
901360	RECIRK085007	Green Loop Kantin GN 1/2x65 mm	350T	20,0	45,0	0,2500	PP	0,337	1000	Kartong	335x185x275	4	220	354,32
901361	RECIRK084907	Green Loop Kantin GN 1/2x100 mm	350T	20,0	46,0	0,2556	PP	0,372	1000	Kartong	350x220x280	4	250	391,89
901362	RECIRK088907	Green Loop Kantin GN 1/1x150 mm	775T	40,0	55,8	0,6200	PP	0,933	1000	Kartong	540x350x220	2	300	982,42
901363	RECIRK088000	Green Loop Skärbräda Vit 1/1	775T	40,0	225,0	2,5000	PP	2,35	1000	Kartong	540x340x190	10	240	2474,8 4
901364	RECIRK088002	Green Loop Skärbräda brun 1/1	775T	40,0	225,0	2,5000	PP	2,35	1000	Kartong	540x340x190	10	240	2474,8 4
901365	RECIRK088003	Green Loop Skärbräda röd 1/1	775T	40,0	225,0	2,5000	PP	2,35	1000	Kartong	540x340x190	10	240	2474,8 4
901366	RECIRK088004	Green Loop Skärbräda grön 1/1	775T	40,0	225,0	2,5000	PP	2,35	1000	Kartong	540x340x190	10	240	2474,8 4
901367	RECIRK088005	Green Loop Skärbräda blå 1/1	775T	40,0	225,0	2,5000	PP	2,35	1000	Kartong	540x340x190	10	240	2474,8 4
901368	RECIRK088006	Green Loop Skärbräda gul 1/1	775T	40,0	225,0	2,5000	PP	2,35	1000	Kartong	540x340x190	10	240	2474,8 4
901369	RECIRK088007	Green Loop Skärbräda svart 1/1	775T	40,0	225,0	2,5000	PP	2,35	1000	Kartong	540x340x190	10	240	2474,8 4
901370	RECIRK088127	Green Loop serveringstång plast 18 cm	85T	6,0	40,0	0,0667	PCT-G	0,0270	1000	Kartong	185x185x180	5	100	22,50
901371	RECIRK081117	Green Loop serveringstång plast 24 cm	85T	6,0	45,0	0,0750	PCT-G	0,0330	1000	Kartong	200x110x220	5	150	27,50
901372	RECIRK083807	Green Loop stektång plast 28 cm	80T	5,0	25,0	0,0347	PCT-G	0,0900	1000	Kartong	Menigo valt att avvakta	5	150	75,00
901373	RECIRK080301	Green Loop Bricka 34,5x26,5cm Granit	350T	20,0	40,0	0,2222	PP	0,270	1000	Kartong	Menigo valt att avvakta	10	240	284,53

901374	RECIRK080307	Green Loop Bricka 34,5x26,5cm Svart	350T	20,0	35,0	0,1944	PP	0,270	1000	Kartong	Menigo valt att avvakta	10	240	284,53
901375	RECIRK080201	Green Loop Bricka granit 28x36 cm	350T	20,0	38,0	0,2111	PP	0,269	1000	Kartong	540x340x190	10	240	283,16
901376	RECIRK080207	Green Loop Bricka svart 28x36 cm	350T	20,0	38,0	0,2111	PP	0,269	1000	Kartong	540x340x190	10	240	283,16
901377	RECIRK080101	Green Loop Bricka granit 33x43cm	350T	20,0	57,0	0,3167	PP	0,469	1000	Kartong	540x350x220	10	300	493,89
901378	RECIRK080107	Green Loop Bricka svart 33x43cm	350T	20,0	57,0	0,3167	PP	0,469	1000	Kartong	540x350x220	10	300	493,89
901379	RECIRK088117	Green Loop serveringstång plast 27 cm	85T	6,0	45,0	0,0750	PCT-G	0,0330	1000	Kartong	200x110x220	5	150	27,50
901380	RECIRK084807	Green Loop Kantin GN 1/2x150 mm	350T	20,0	42,0	0,2333	PP	0,439	1000	Kartong	280x280x330	4	180	461,68
901381	RECIRK087550	Green Loop Glas 24cl	85T	6,0	31,0	0,0517	PCT-G	0,0380	1000	Kartong	280x170x270	25	180	29,23
901382	RECIRK084150	Green Loop Glas 28 cl	80T	5,0	30,0	0,0417	PCT-G	0,0570	1000	Kartong	Menigo valt att avvakta	25	100	43,85
901383	RECIRK082650	Green Loop Glas Staplbart 28cl	120T	6,0	44,0	0,0733	PCT-G	0,0590	1000	Kartong	185x185x180	24	100	45,38
901384	RECIRK080650	Green Loop Tillbringare med lock Ø110mm	400T	20,0	84,0	0,4667	PCT-G	0,275	1000	Kartong	570x380x340	18	350	211,54
901385	RECIRK083250	Green Loop Lock Tillbringare Ø115mm	85T	6,0	32,0	0,0533	PCT-G	0,0470	1000	Kartong	Säljs ej löst	90	240	36,15
901386	RECIRK085850	Green Loop Skål 10cl	50T	4,0	14,0	0,0156	PCT-G	0,0170	1000	Kartong	Menigo valt att avvakta	10	240	13,08
901387	RECIRK083350	Green Loop Skål 30cl	45T	4,0	17,0	0,0189	PCT-G	0,0450	1000	Kartong	Menigo valt att avvakta	10	240	34,62
901388	RECIRK082150	Green Loop Skål 80cl	160T	7,0	31,0	0,0603	PCT-G	0,0760	1000	Kartong	Menigo valt att avvakta	10	240	58,46
901389	RECIRK082250	Green Loop Skål 1,5L	160T	7,0	47,0	0,0914	PCT-G	0,117	1000	Kartong	Menigo valt att avvakta	10	240	90,00
901390	RECIRK080450	Green Loop Skål 3L	350T	20,0	41,0	0,2278	PCT-G	0,240	1000	Kartong	Menigo valt att avvakta	10	240	184,62

901391	RECIRKO88300	Green Loop Soppskål med Två Handtag ø13cm	160T	7,0	35,3	0,0686	PCT-G	0,0976	1000	Kartong	Menigo valt att avvakta	1	100	75,04
TBD	TBD	Coffee-2-go 30 cl	80T	5,0	30,0	0,0417	PCT-G	0,0510	200	Kartong	Menigo valt att avvakta	50	240	42,50
TBD	TBD	Coffee-2-go 40 cl	160T	7,0	30,0	0,0583	PCT-G	0,0630	200	Kartong	Menigo valt att avvakta	50	240	52,50
TBD	TBD	Coffee-2-go 50 cl	160T	7,0	30,0	0,0583	PCT-G	0,0680	200	Kartong	Menigo valt att avvakta	50	240	56,67
TBD	TBD	Lock till coffee-2-go	80T	5,0	20,0	0,0278	PP	0,0250	200	Kartong	Menigo valt att avvakta	50	240	26,32
TBD	TBD	Matlåda-2-go 500 ml	80T	5,0	35,0	0,0486	PCT-G	0,0700	200	Kartong	Menigo valt att avvakta	50	300	58,33
TBD	TBD	Lock till matlåda-2-go 500 ml	80T	5,0	25,0	0,0347	PP	0,0150	200	Kartong	Menigo valt att avvakta	50	300	15,79
TBD	TBD	Matlåda-2-go 750 ml	160T	7,0	35,0	0,0681	PCT-G	0,0830	200	Kartong	Menigo valt att avvakta	50	350	69,17
TBD	TBD	Matlåda-2-go 1200 ml	160T	7,0	35,0	0,0681	PCT-G	0,110	200	Kartong	Menigo valt att avvakta	50	350	91,67
TBD	TBD	Lock till matlåda-2-go 1200 ml	160T	7,0	25,0	0,0486	PP	0,0400	200	Kartong	Menigo valt att avvakta	50	350	42,11

Appendix 5 Data input of Cardboard packaging from A-Pak

		APAK PN		Andel återvunnet	Vikt g	vikt kg
RELOOPEMB001	EMBALLAGE	209-947	SYSCO BOX 570x380x340	0	240	0,24
RELOOPEMB002	EMBALLAGE	209-948	SYSCO BOX 540x340x190	0	550	0,55
RELOOPEMB003	EMBALLAGE	207-237	SYSCO BOX 335x185x275	90	220	0,22
RELOOPEMB004	EMBALLAGE	209-951	SYSCO BOX 280x170x270	0	180	0,18
RELOOPEMB005	EMBALLAGE	207-182	SYSCO BOX 245x245x385	90	220	0,22
RELOOPEMB006	EMBALLAGE	209-949	SYSCO BOX 245x245x255/185	0	220	0,22
RELOOPEMB007	EMBALLAGE	209-950	SYSCO BOX 185x185x180	40	100	0,1
RELOOPEMB008	EMBALLAGE	207-181	SYSCO BOX 200x200x230	90	150	0,15

Appendix 6 DQA of individual datasets

Data quality assessment of individual datasets covering more than 80% of impact across all impact categories, according to Annex E, table E.1 in EN 15804.

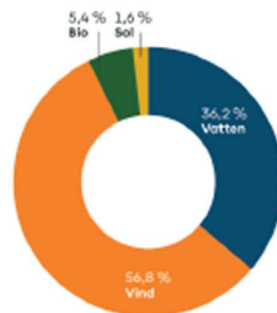
Database process	Comment	Representativeness		
		Geogra- phical	Techni- cal	Time
Polypropylene - Polypropylene, granulate {NL} polypropylene production, granulate Cut-off, U	Regionalised generic data	Good	Good, current	Very good
Tritan	Verified LCA results shared from supplier	Very good	Very good	Very good
Wood Compound Pure L40	Use generic datasets that was modified according to specific information from supplier to give specific representation	Very good	Very good	Very good
Waste treatment of production waste & end-of-life	Used generic data on waste treatment of core materials, processes are representative for the European and Swedish region	Very good	Good	Very Good

Appendix 7 Guarantees of Origin and other certificates



Mälarplast AB

köper 100 % förnybar el.
Tillsammans skapar vi en hållbar framtid.




Linköping 2024

Klas Liljegren
Klas Liljegren, VD Bixia



CERTIFICATE

Certificate-ID:	C01-2025-01-21265255
Certificate for:	Life Cycle Assessment (LCA) Methodology
Certified:	Eastman Chemical Company 301 South Wilcox Dr Kingsport, TN 37660 USA
	
Accounting Scope:	Cradle to Gate (incl. raw materials, production and logistics): evaluation of 1 kg unpacked Eastman product
Applied Standard:	ISO 14040:2006 + A1:2020 /ISO 14044:2006 + A1:2018 + A2:2020, ISO 14067:2018 and Tfs PCF-Guideline:2024
Review Report:	CF-2025-01-21265255
Valid until:	January 31 st 2026

In accordance with the standards ISO 14040:2006 + A1:2020 /ISO 14044:2006 + A1:2018 + A2:2020, ISO 14067:2018 and Tfs PCF-Guideline 2024, the reviewers conclude that the LCA/PCF methodology developed by Eastman Chemical Company is scientifically based and reflects the state of the art. The approach and principles behind the methodology are generally appropriate for the assessment of potential environmental impacts of chemical products. Furthermore, the data used are appropriate for the goal and scope of the method. Necessary recommendations for the documentation and the methodology were discussed during the online meeting as well as through email exchanges and were implemented by Eastman Chemical Company. For the future, TÜV Rheinland recommends to continually enhance the methodology in line with the developments in science and technology and to adapt the methodology accordingly. Specifications and assessment limits can be found in the review report. The validity can be authenticated using the QR code, or the test mark ID: 87919 at www.certipedia.com.

Cologne, January 14th, 2025



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Appendix 8 Additional figure on impact per use

