Life Cycle Assessment

Of Coloreel

Title: Life Cycle Assessment of Coloreel
Date: 30/05/2022
Ordered by: Coloreel
Report number: 1032
Name of database: MiljogiraffEmber
Author: Marcus Bernhard, Miljögiraff

MILJÖGIRAFF

Table of Contents

Ordered by: Coloreel
Coloreel is a Swedish textile innovation brand with a groundbreaking technology for embroidery that enables high-quality coloring of textile thread on demand.

We use our technology to both preserve the craftsmanship of embroidery and take embroidery to the next level. The unique solution makes previously complicated designs accessible, including gradients, textures, and other stunning effects. Using only a single thread and needle means that it also significantly improves quality and efficiency, enabling immediate start up and faster delivery. In short, Coloreel empowers creativity and enhances quality and efficiency, making the ordinary extraordinary. In the future, the technology can also be used for sewing, knitting, weaving and more.

Coloreel is also part of the movement to reduce waste and move the textile industry towards more sustainable production. By coloring the thread directly, there is no wastewater, hence no water pollution. And using a single reel of thread and needle also means minimized thread waste and minimized microfiber pollution.

Issued by: Miljögiraff AB
Miljögiraff is an environmental consultant specializing in Life Cycle Assessment and Ecodesign. We believe that a combination of analysis and creativity is necessary to meet today's challenges. Therefore, we provide Life Cycle Assessment to evaluate environmental aspects and design methods to develop sustainable solutions.

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

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

Abbreviations and expressions

Clarification of expressions and abbreviations used in the report

CO_2 eq – Carbon dioxide equivalents
EPD – Environmental Product Declaration
GWP – Global Warming Potential
ISO – International Organization for Standardisation
IPCC – Intergovernmental Panel on Climate Change
LCA – Life Cycle Assessment
LCI – Life Cycle Inventory Analysis
LCIA – Life Cycle Impact Assessment
PCB – Printed circuit board
PCR - Product Category Rules
RER – The European region
RoW – Rest of the world
GLO – Global
Cut-off – Allocation cut off by classification (system model in ecoinvent)

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

Abstract

This goal of this LCA study is to find metrics for the cradle to grave environmental impact of the Coloreel Instant Thread Coloring Unit (ITC-U) from a life cycle perspective. The result will to be used for product development prioritization, and for the creation of an EPD for external communication and for future benchmarking with other types of thread coloring- and textile decoration procedures. The report describes the results in a transparent and reproducible way according to the ISO 14040/14044 standard. The results are interpreted, followed by recommendations for further reduction of the environmental impact. For the creation of the EPD according to the International EPD system, the product category rule (PCR) “Other special-purpose and general-purpose machinery and parts thereof” will be used. However, the final version of the PCR hasn’t been released yet.

The product is based on Coloreel’s patented technology for digital dyeing of textile thread. The technology enables digital dyeing of a textile thread simultaneously as it is used in production. In this way traditionally used color baths are not needed and obsolescence of thread in the wrong color is avoided. The thread is made of 100% post-consumer recycled polyester, and the ink is of sublimation type, delivered in reusable ink cartridges. The unit weights 66 kg and the lifetime is 10 000 hours. Results are presented for the full life cycle of one declared unit as well as with the functional unit of 1000 stiches. The LCA study covers only the impact from the Coloreel unit meaning that the embroidery machine which is sold separately is not included in the scope.

Given the almost water free process, the environmental impact of Coloreel in a cradle-to-grave perspective comes mainly from the use of **electricity in the use phase** followed by the production of **raw materials** and the **polyester thread,** highlighted by Figure 1. The high impact from electricity comes from the generally high use of fossil fuels for production of electricity in the markets where the Coloreel unit is used. Manufacturing, transportation, and packaging stands for a minor part of the overall impact.

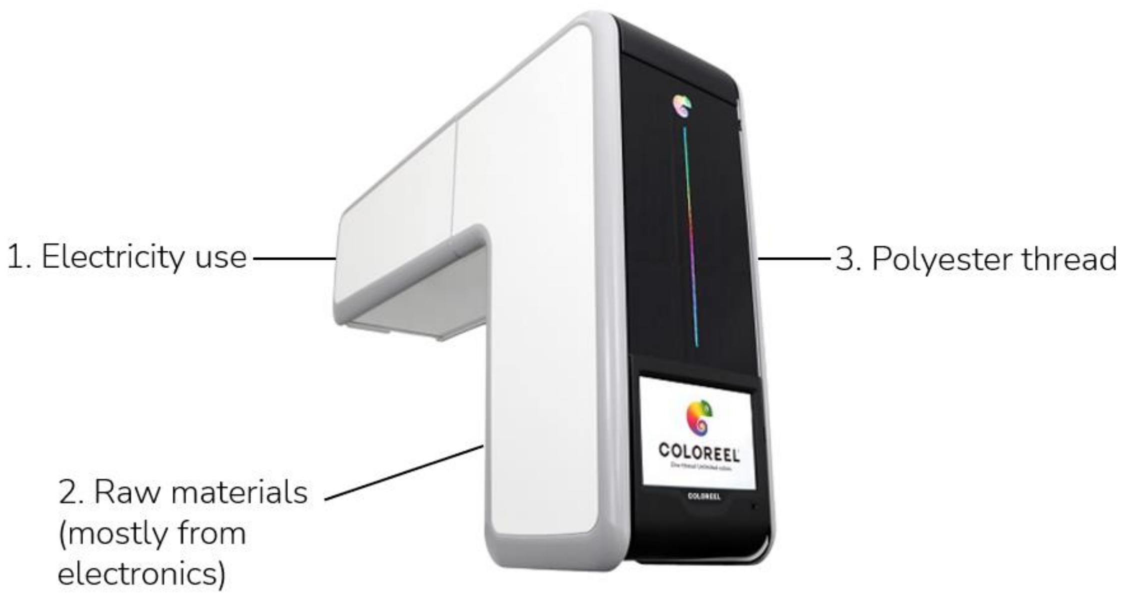

Figure 1: Part of the life cycle with highest environmental impact.

The environmental impact categories to which Coloreel contributes the most according to the method Environmental footprint 3.0 are “*Resource use, minerals and metals*”, “*Climate change”* and “*Resource use, fossils*”. It is the use of gold and silver in the integrated circuits on the printed circuit boards that is having the biggest impact in the category “*Resource use, minerals and metals*”. For “*Climate change*” and “*Resource use, fossils*”, it is the electricity consumption in the use phase that is having the biggest impact. The Water deprivation potential, which has a non-significant impact, mainly comes from the downstream electricity consumption during use and from the upstream production of raw materials. The on-site water consumption used by the Coloreel unit during thread coloring is small. It is only the washing fluid and the ink that is consuming water. For the full lifetime of the unit the total on-site water consumption is 36,2 liters (32,1 liters for the washing fluid and 4,1 liters for the ink).

The most critical components are electronics such as PCBs, power units and motors, followed by the steel in the chassis. The impact from the production of the recycled polyester thread do also have a clear impact.

Miljögiraff suggests that Coloreel can reduce the potential environmental impacts by reducing the energy consumption in the use phase. Another area of improvement is to prolong the lifetime of the Coloreel unit. This will lower the environmental impact per functional unit. Lastly, the impact from the recycled polyester thread is also relevant. Finding more site-specific data on the production of the thread would give more accurate results.

1. Introduction

This report presents the total environmental footprint for the Coloreel Instant Thread Coloring Unit from a life cycle perspective using the ISO 14040 standard approach. The LCA report will be used for the creation of an Environmental Product Declaration.

1.1 Reading guide to the report

Readers of this report can choose different parts to read, depending on their time availability:

- 5 minutes
  - Section 7 gives the briefest summary of the most relevant conclusions and recommendations.
- 10 minutes
  - Section 0 gives some more nuance/depth, including interpretation and sensitivity analysis that underpins the conclusions
- 20 minutes
  - Section 5 presents detailed results and flowcharts/diagrams for the different impact categories
- >30 minutes
  - For in-depth detail and transparent documentation on the modelling of each part of the life cycle, see section 4 (“Life Cycle Inventory”)
  - For information about methodology, scope and functional unit, see sections 2 (“Life Cycle Assessment”) and section 3 (“Goal and Scope”)

1.2 General description of the product and its context

Coloreel technology is an innovation that enables high-quality coloring of thread on demand. It provides a new thread coloring process by instantly coloring a white base thread in any desired color during the embroidery production, without the need to change the thread. The thread can be used for the same/whole embroidery regardless of required color changes in the motive. The Coloreel unit provides new design possibilities, allows freedom in the use of colors and it improves efficiency by minimizing re-threading time as well as significantly reducing the need for keeping stock of thread. By coloring the thread directly, there is no wastewater, hence no water pollution. And using a single reel of thread and needle also means minimized thread waste and minimized microfiber pollution. The Coloreel unit is coloring the thread while it is an embroidery machine that is performing the embroidery. The Coloreel unit is compatible with several embroidery machines brands. The embroidery machine is sold separately and is out of scope of the LCA.

A picture of the Coloreel unit attached to the embroidery machine can be seen in Figure 2.

Figure 2: Full setup of the Coloreel unit with embroidery machine. (1) Thread, (2) The Coloreel unit, (3,4,5) The embroidery machine not included in the LCA.

The Coloreel system contains of 15 key hardware and software components. All information concerning the Coloreel unit and processes comes from Coloreel.

HARDWARE

1. Power Supply Module, converting the standard 110-220V/50Hz input to internal voltage standards.
2. Bobbin Module, which holds our special raw thread.
3. Entry Thread Feeder Module, which mechanically insert the thread into the system and control its speed.
4. Print Engine: customized CMYK printer device co-developed with Ricoh. The proprietary Coloreel ink that match our unique thread provide a perfect concentration and tone of color into the thread.
5. Fixation Module, which fix the color to the thread and ensures that the best fastness and quality of the color is achieved.

6 & 9. Thread Buffer & Dispenser Module: these "buffer" mechanisms control and minimize the error of thread rate according to the embroidery work and stitches made. They also control the thread tension inside the unit and the output thread tension.

7. Thread Washing Module, where the minor residual dried color on the thread is precisely removed and collected.

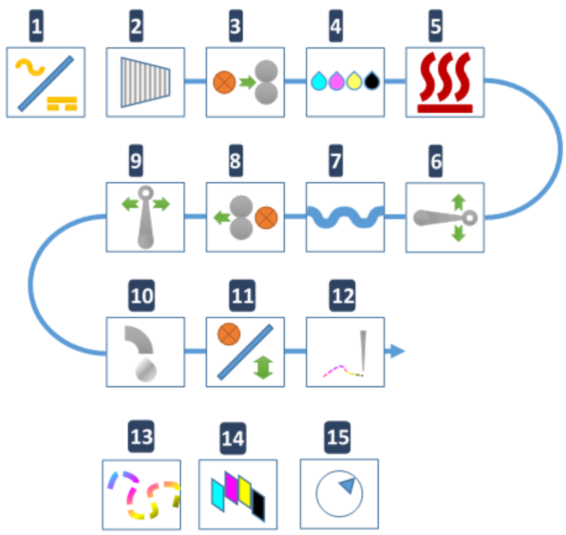

Figure 3 – Coloreel concept

8. Exit Thread Feeder Module, which mechanically control the thread exit speed at the end of the process.
10. Thread Lubrication Module: decrease the friction of the thread just before the embroidery work.
11. Sensor Devices, counting in real-time the stiches to monitor the synchronization of the Coloreel and embroidery machines.

SOFTWARE

13. Embroidery Coloring Software: in-house software to design the embroidery work and generate the files for both the Coloreel unit and embroidery machines.
14 & 15. Coloreel Machine Control & Color Manager Software: in-house software for the complete digitalization of the design and associated colors. It also monitors all the components and overall process throughout the system operations (e.g. maintenance, idle, operating).

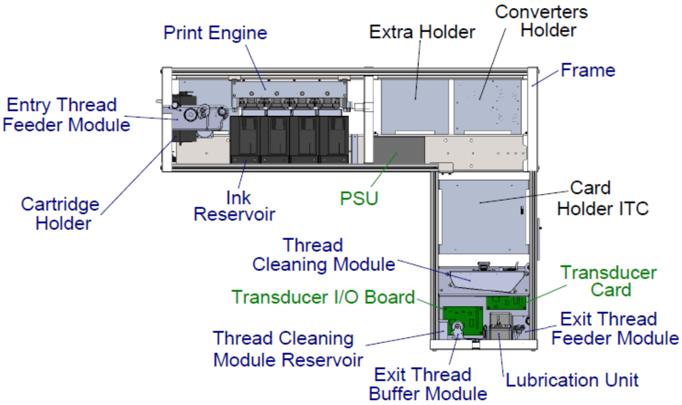

Figure 4, show side view drawings of the Coloreel unit.

The five most innovative parts are the thread, the feeder mechanisms (Entry/Exit feeders), the print engine and associated ink, the sensor devices and the software platform. They will be described more closely below.

1. COLOREEL THREAD: In close collaboration with industrial partner and expert in industrial thread Madeira, www.madeira.com engineers at Coloreel have developed and validated a unique thread which reaches the desired properties of color absorption, dispersion and fastness while maintaining the mechanical strength of normal embroidery threads.

2. THE ENTRY AND EXIT THREAD FEEDER MECHANISMS pull the thread – from a reel into the Coloreel system and from Coloreel system to the embroidery machine – and control mechanically the required tension throughout the process while reaching thread speed up to 200 mm/s, all in respect to the rate of the downstream embroidery machine. The feeder mechanisms have been designed to pull the thread constantly with minimal resistance, to maintain the precision required by the embroidery machine.

3. PRINT ENGINE – DYE MODULE, core of the Coloreel innovation, is composed by a customized CMYK printer device (engineered with multiple nozzles x 3 [CMY] + optional K (Black)), which produces and releases the quantity of dye concentrated in a single drop while the thread passes through the printing area, accurately distributing the color in less than 1mm hit and with negligible color waste, and no use of water in the coloring process. Specific ink formulations to be used on the white thread has been developed with a global leader in color manufacturing. The system has been designed to easily access the ink cartridges from the back and it includes intermediate ink reservoir to allow continuous use of the system while changing the color or during maintenance (no downtime due to ink cartridge changes).

4. OUTPUT SENSORS DEVICES: The Coloreel technology has been developed to be stand-alone and perform independently, allowing easy retrofit on existing embroidery machinery. To guarantee the quality of work and synchronization of both machines – Coloreel and embroidery –, engineers at Coloreel have developed an optical sensor device that can be retro-fitted to any embroidery machine. This allows counting in real time of the stitches and to know exactly the position of the needle in respect to the embroidery work in progress.

1 Dye module
2 Fixation module
3 Cleaning & lubrication module

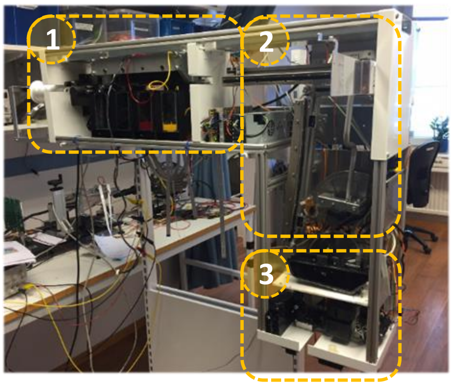

Figure 5, show parts of the Coloreel unit and the special Coloreel thread.

5. THE SOFTWARE PLATFORM includes 3 complementary in-house software:
The Coloreel unit controller software controls all the mechanical and electronics aspects of the Coloreel system and monitors them, along with all the functionalities of the system, throughout the process. Linked to this program is a 2nd software, the **Color manager software**, which converts the embroidery design file in thread length (stitches numbers are converted into mm) and the selected colors of the embroidery design are translated into C,M,Y,K-color parameters (quantity/mix) for the Coloreel print module. Both software's are integrated into the Coloreel system and grouped under the ICM (Coloreel & color manager) software.

The Coloreel studio software, which has been developed as a designer software to create the embroidery work and its associated color effects. This program allows design of new and redesign of existing embroidery files, is configured with streamline color (color variation, gradient, effects) and font functionalities. It will also automatically adjust the sewing/embroidery attributes for the embroidery based on the pre-selected fabric. The program is designed to suit all the embroidery common design file formats and, at launch, will support the main formats and can be transferred to the Coloreel and embroidery machine through cables or USB interfaces.

1.3 The sustainability challenges

The industrial and natural systems depend on a stable Earth system. Steffen et al. (Steffen, W., K. Richardson, J. Rockström, S.E. Cornell, 2015) 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 6.

In LCA, the effect of a product system on the environment and on human health is quantified. These quantifications are divided into different impact categories that represent different types of environmental impact. Note that the division into categories in LCA is done according to a somewhat different logic compared to the planetary boundaries, see 0.

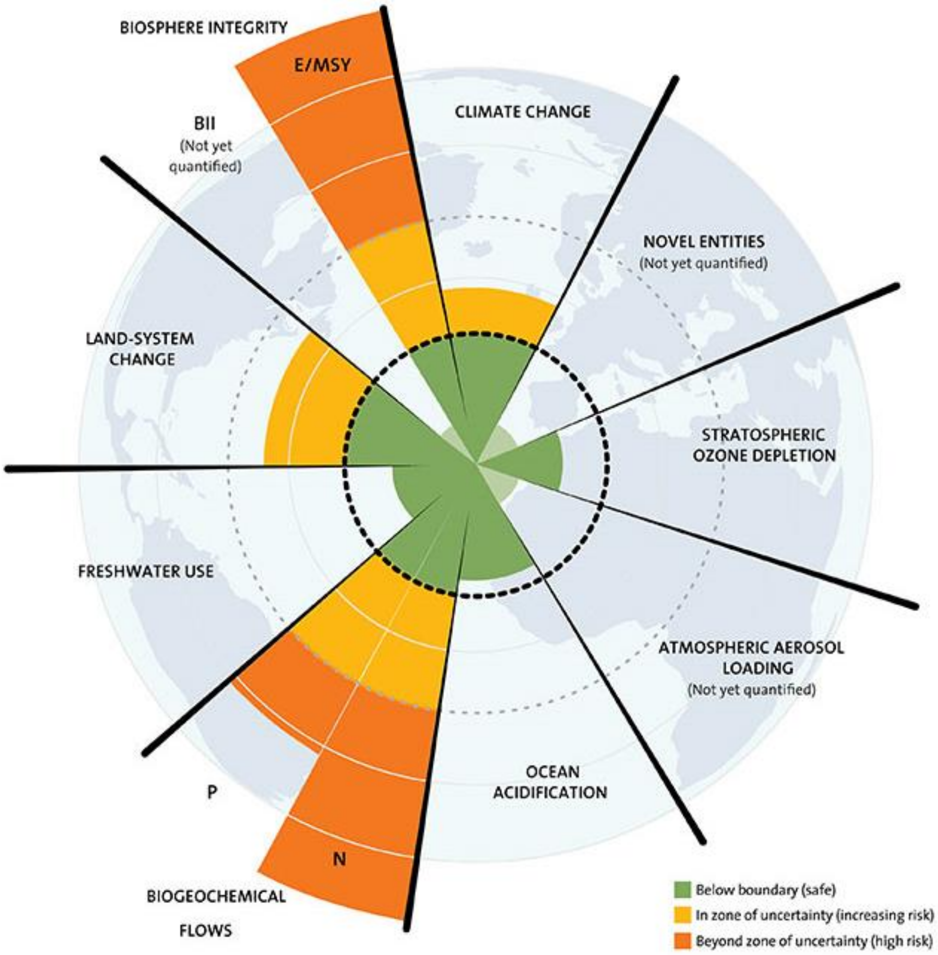

Figure 6: Show the state of the planetary boundaries, where the green area represents a safe operating space. From J. Lokrantz/Azote based on Steffen et al. 2015.

Looking at the textile industry, one of the most polluting steps is the dying of textiles (Chequer et al., 2013). Due to inefficient dyeing processes, large amount of dye is lost to the environment where it persists for a long time due to its high stability to light, temperature, and water. Some dyes are highly toxic and mutagenic limiting the downstream use of river water for recreation, drinking and irrigation

(Chequer et al., 2013). Considering the importance- and high use of colored products today, optimizing the coloring processes thus avoiding water pollution is of high importance.

2. Life Cycle Assessment (LCA)

Chapter 2 is a theoretical chapter which gives information about the LCA methodology.

2.1 LCA Methodology background

The importance of understanding the potential environmental impact in connection with the manufacture and use of products is constantly increasing. LCA is the accepted and scientific method that exists to create this understanding. LCA forms a basis for the development of strategy, management and communication of environmental issues related to products.

The purpose of LCA is to provide a basis that describes the environmental impact in such a way that it provides conditions for change and measures in the analyzed life cycle that can contribute to a more sustainable development. LCA provides a comprehensive basis for environmental impact as all incoming and outgoing flows of environmental significance during a product's life cycle are measured (see Figure 7).

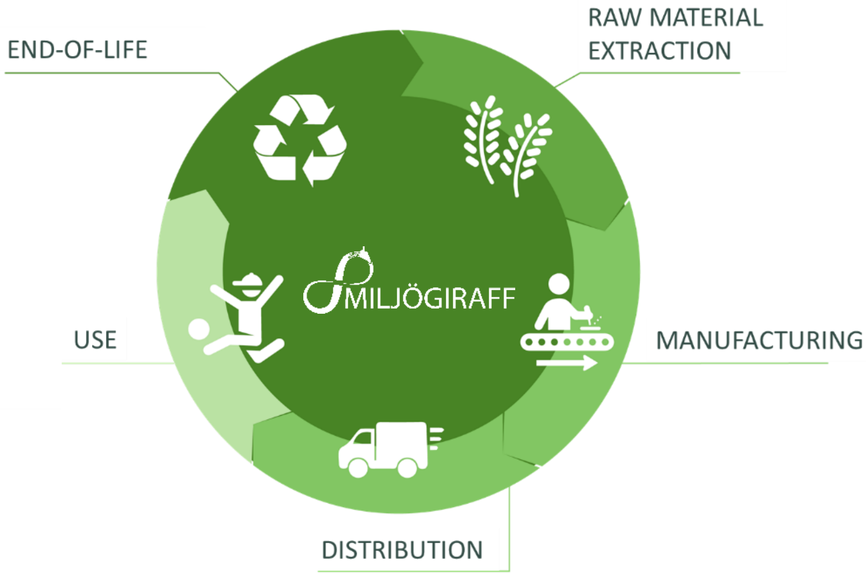

Figure 7: The Life Cycle concept, starting from raw material extraction, manufacturing, and distribution, followed by use and end-of-life.

Miljögiraff 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 8.).

Figure 8: ISO standard combined with reliable data from ecoinvent and the LCA software SimaPro.

2.1.1 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 characterization. An optional step is weighting. Classification, characterization, weighting and examples of common impact categories will now briefly be explained. The LCIA-method is explained in more details in 0.

2.1.1.1 *Classification and characterization*

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. Characterization 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 metric ton 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 normalization.

2.1.1.2 *Weighting*

To compare between 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 emphasize the "upsides" and hide the "downsides" of the analyzed product. For external communication, only *Single issues* should be communicated.

2.1.1.3 *Impact categories*

An impact category groups different emissions into one effect on the environment. The impact categories from the Environmental footprint 3.0 method will now be presented (European Commission, 2012).

Acidification – EF impact category that addresses impacts due to acidifying substances in the environment. Emissions of NOx, NH3 and SOx lead to releases of hydrogen ions (H+) when the gases are mineralized. 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 - All inputs or outputs that result in greenhouse gas emissions. The consequences include increased average global temperatures and sudden regional climatic changes. Climate change is an impact affecting the environment on a global scale.

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 fertilized farmland accelerate the growth of algae and other vegetation in water. The degradation of organic material consumes oxygen resulting in oxygen deficiency and, in some cases, fish death. Eutrophication translates the quantity of substances emitted into a common measure expressed as the oxygen required for the degradation of dead biomass. Three EF impact categories are used to assess the impacts due to eutrophication: Eutrophication, terrestrial; Eutrophication, freshwater; Eutrophication, marine.

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/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/water ingestion, penetration through the skin insofar as they are related to noncancer effects that are not caused by particulate matter/respiratory inorganics or ionizing radiation.

Ionizing 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 air from emissions of sulphur dioxide (SO2), ammonia (NH3), and nitrogen oxides (NOx) among others (World Health Organisation, 2003). Inhalation of different particulate sizes can cause different health problems.

Photochemical ozone formation – EF impact category that accounts for the formation of ozone at the ground level of the troposphere caused by photochemical oxidation of volatile organic compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NOx) and sunlight. High concentrations of ground-level tropospheric ozone damage vegetation, human respiratory tracts and manmade materials through reaction with organic materials.

Resource use, fossil: Impact category that addresses the use of non-renewable fossil natural resources (e.g. natural gas, coal, oil).

Resource use, minerals and metals: Impact category that addresses the use of non-renewable abiotic natural resources (minerals and metals).

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).

2.2 Environmental product declaration

An Environmental Product Declaration (EPD) is defined by ISO 14025 as a Type III declaration that "quantifies environmental information on the life cycle of a product to enable comparisons between products fulfilling the same function."

EPDs are primarily intended to facilitate business-to-business communication, although they may also be of benefit to consumers who are environmentally focused when choosing goods or services.

As shown in Figure 9 several standard documents are used when creating an EPD.

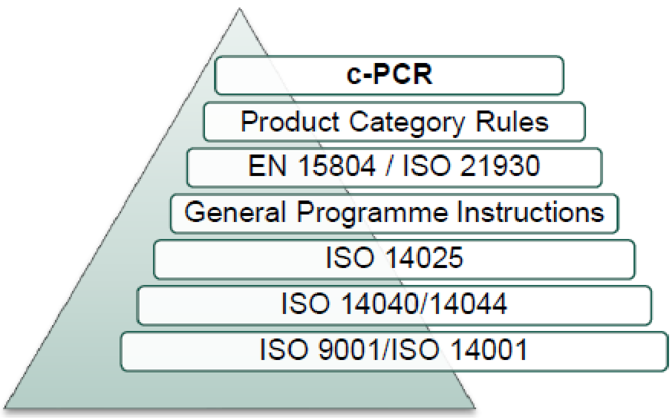

Figure 9, shows the hierarchy of standards used to create and EPD according to the International EPD system.

2.2.1 General Program Instructions (GPI)

General Program Instructions constitutes the General Programme Instructions (GPI) of the International EPD® System. It forms the basis of the overall administration and operation of a programme for Type III environmental declarations according to ISO 14025.

2.2.2 Product Category Rules (PCR)

Product Category Rules (PCRs) provide guidance that enables fair comparison among products of the same category. PCRs include the description of the product category, the goal of the LCA, functional units, system boundaries, cut-off criteria, allocation rules, impact categories, information on the use phase, units, calculation procedures, requirements for data quality, and other information. The goal of PCRs is to help develop EPDs for products that are comparable to others within a product category. ISO 14025 establishes the procedure for developing PCRs and the required content of a PCR, as well as requirements for comparability.

2.3 Limitations of LCA

Practitioners can only achieve the broad scope of analyzing the entire life cycle of a product using a holistic approach at the expense of simplifying some aspects. Thus, the following limitations must be taken into account as summarized by Guinée et al. (Guinée et al., 2002):

- Localized 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 focuses on environmental aspects and excludes social, economic, and other characteristics
- LCA involves several technical assumptions and value choices that are not purely science based.

3. Goal and Scope

3.1 The aim of the study

The study's goal was to find metrics for the environmental impact of the Coloreel unit from a life cycle perspective. The LCA report will serve as a basis for the creation of an EPD. The report describes the results in a transparent and reproducible way. The results are interpreted, followed by recommendations for mitigating the environmental impact.

The results are to be used for future product development and as for communication with customers. An EPD will be created based on the results of the LCA report and will be used in communication with customers.

The intended audience are thus both internal and external (mainly business-to-business). No comparative assertions with external products are made.

3.2 Standards and frameworks

The standards and frameworks that has been followed in this LCA are presented in Table 1.

Table 1: Guiding standards and frameworks.

Standards and frameworks
ISO 14040 and 14044 (ISO, 2006a)
General program instructions for the International EPD System, version 4 (EPD International, 2021)
PCR: Other special-purpose and general-purpose machinery and parts thereof. Version 4.0 (EPD International, 2022)

3.3 Scope of the Study

3.3.1 Name and Function of the Product/System

The system studied was the life cycle of the Coloreel Instant Thread Coloring Unit. Its function is to color thread on demand during an embroidery process. Notice that it is only the Coloreel unit that is included in the scope. The embroidery machine is not included. See section 1.2 for more information.

3.3.2 The Declared/functional Unit and reference flow

According to the PCR, the environmental impact shall be given per declared unit. The declared unit (DU) shall be one (1) product unit including the product use stage. The lifetime of the product is 10 000 hours and has been evaluated by wear testing of the components in the Coloreel unit, separate documents from the tests exists. All results in section 5.1 to 5.4 is presented per declared unit.

As a complement to the declared unit, a functional unit has been developed. The result of the functional unit will not be presented in the EPD but only in the LCA report. The functional unit is the coloring of thread used in 1000 stitches. In addition to operational impacts, impacts related to upstream processes, maintenance and decommissioning has been allocated into 1000 stitches of use according to the expected lifetime of 10 000 hours. 1 stitch is on average equal to 4,4 mm of thread. That means that 1000 stiches equal 4,4 meters of coloured thread. The uptime for when the unit is preforming coloring is set to 75%. With a shift time of 8 hours per day the Coloreel unit have an approximate lifetime of 7 years (1500 hours work per year). During the lifetime of the unit a few components are replaced. This is further explained in the LCI chapter, see section 4.7. Examples of embroidery motives and the corresponding number of stitches are presented in Table 2.

Table 2: Examples of embroidery motives and the corresponding number of stitches.

Type embroidery	Consumed thread length total [m]	Stitch count	Length/stitch [mm]
PBX2	26	4684	5,6
Audi11	39	7968	4,9
Flower D-house	70	22337	3,1
EQT	74	18301	4,0
Average	52,3	13322,5	4,4

During the full lifecycle of the Coloreel unit (10 000 hours) a total of 360 000 000 stitches are performed. To translate the result per declared unit to per 1000 stitches, the result is divided by 360 000.

3.3.3 System Boundary

This study goes from cradle to grave. That means that all processes needed for raw material extraction, manufacturing, transport, usage, and end-of-life is included in the study. The D-module (in the LCA-model) has not been included as little is known about the end-of-life of the product. For the purpose of different data quality rules and for the presentation of results, the life cycle of products is divided into three different life cycle stages:

- Upstream processes (from cradle-to-gate)
- Core processes (from gate-to-gate)
- Downstream processes (from gate-to-grave)

Upstream processes

The following attributional processes are part of the product system and classified as upstream processes:

- Extraction and production of raw materials for all main parts and components.
- Production of electricity and fuels used in the upstream module.
- Production of semi products used in the core process, if applicable.
- Manufacturing of primary and secondary packaging.
- Transport between raw material extraction and processing of materials.

Core processes

The following attributional processes are part of the product system and classified as core processes.

- External transportation to the core processes.
- Manufacturing process for main parts and components.
- Internal transports within the manufacturing plant.

- Assembly/preparation of the final product.
- Maintenance (e.g., of the manufacturing machines).
- Pollutant emissions (to air, soil and water) produced in the factory
- Waste treatment of waste generated during manufacturing, including waste transport to waste manager.
- Production of electricity and fuels used in the core module.

The following processes shall not be included:

- Manufacturing of production equipment, buildings and other capital goods.
- Building, maintenance, decommissioning and disposal of service facilities.
- Business travel of personnel.
- Travel to and from work by personnel.
- Research and development activities.

Downstream processes

The following attributional processes are part of the product system and classified as downstream processes:

- Energy used for product operation (shall be evaluated by physical measurements).
- Consumption of chemicals and consumables used during the normal use of the machine and for the cleaning and maintenance of the equipment, including the consumption of maintenance and spare parts.
- Consumption of chemicals and consumables specified by the manufacturer of the machinery shall be included. Other consumed chemicals and consumables not identified by the manufacturer and used during the use stage are not included within the limits of the system.
- Production of maintenance and spare parts.
- Production of chemicals and consumables.
- Waste generation from maintenance materials, consumables and spare parts.
- Waste generation from test runs and other unusable outputs.
- Transport of chemicals, consumables and waste. An average distance of 50km can be assumed.
- Disassembling of the product, including the impact of the disassembling process (if existent), transport to waste management and waste treatment.

Figure 10 shows all the life cycle stages included in an LCA, divided into upstream, core and downstream.

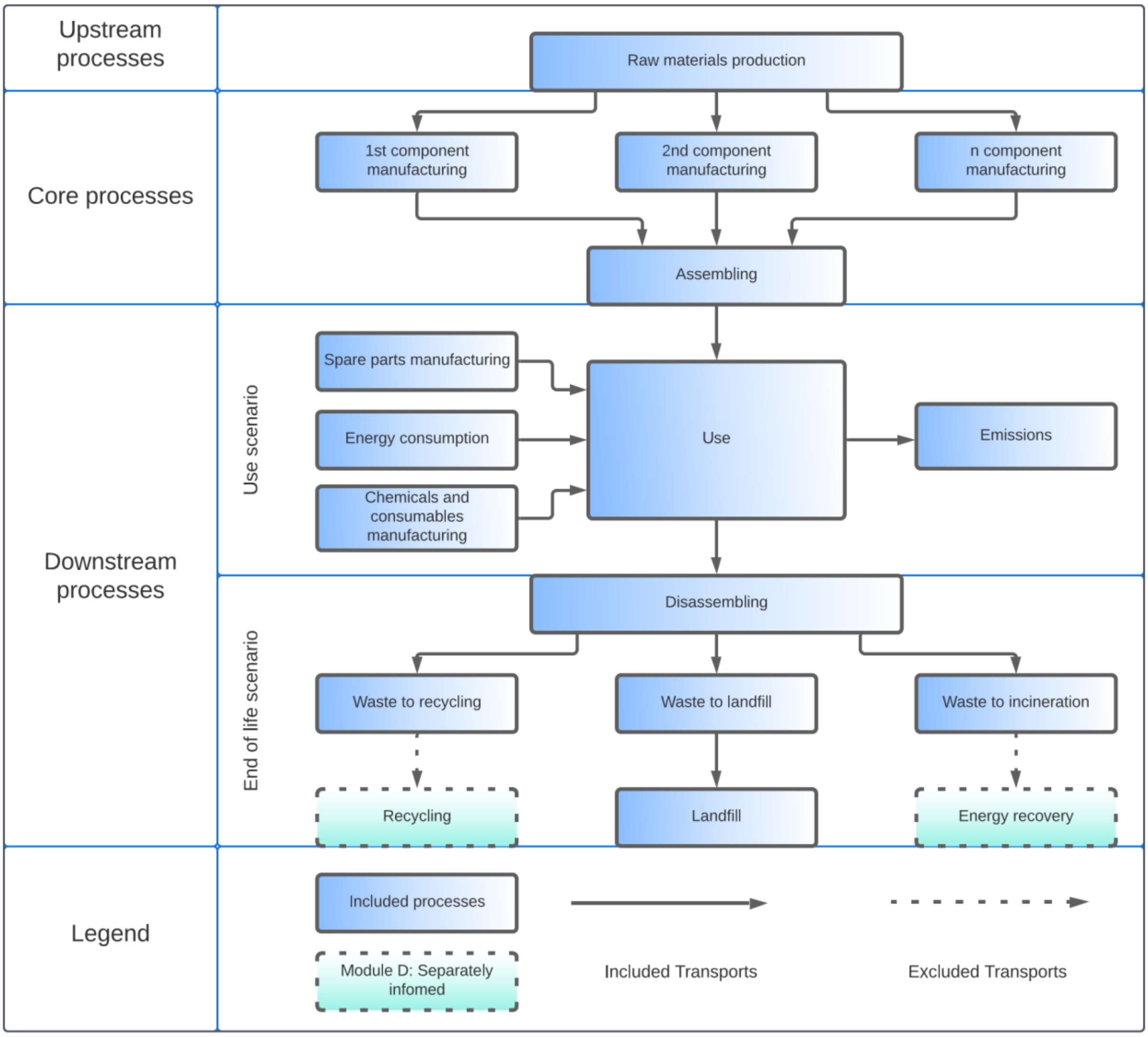

Figure 10: System diagram illustrating the processes that are included in the product system, divided into upstream, core and downstream processes., based on PCR Other special-purpose machinery.

Excluded parts are presented in Table 3.

Table 3: Overview of aspects that are excluded.

Excluded
Infrastructure in core processes (infrastructure included in ecoinvent background data)
Business travel of personnel
Travel to and from work by personnel
Research and development activities

The data used to represent the different parts of the life cycle is described in detail under the Life cycle inventory (LCI) chapter.

In this LCA, boundaries with other systems, and the allocation of environmental burdens between them, are based on the recommendations of the international EPD system[1], 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 11). For 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.

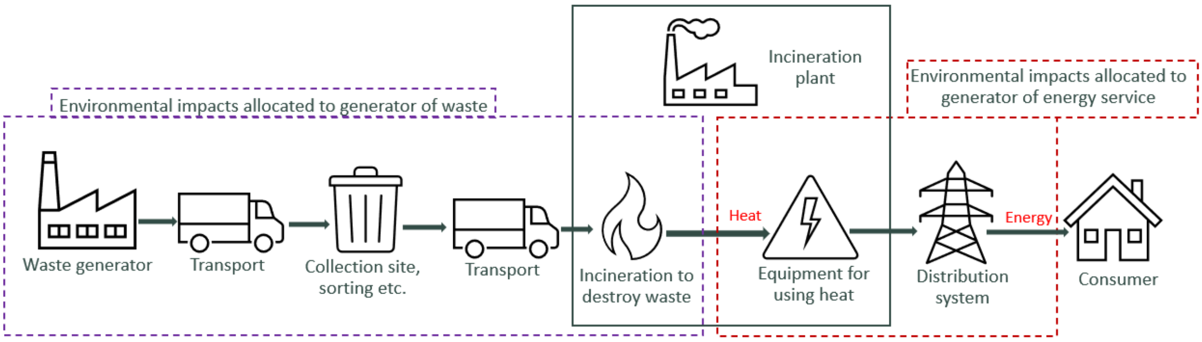

Figure 11: Allocation of environmental impacts between two life cycles according to the PP allocation method. Here in regard to incineration of waste and resulting energy products.

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.

3.3.4 Cut-off rules

The cut-off rules as defined by the PCR has been used. Data for elementary flows to and from the product system contributing to a minimum of 99% of the declared environmental impacts shall be included (not including processes that are explicitly outside the system boundary as described in Section 3.3.3).

The check for cut-off rules in a satisfactory way is through the combination of expert judgment based on experience of similar product systems and a sensitivity analysis in which it is possible to understand how the un-investigated input or output could affect the final results.

3.3.5 Allocation procedure

The following hierarchy of allocation methods shall be followed for co-product allocation:

1. Allocation shall be avoided, if possible, by dividing the unit process into two or more sub-processes and collecting the environmental data related to these sub-processes.
2. If allocation cannot be avoided, the inputs and outputs of the system shall be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them; i.e., they should reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system.

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

Allocation based on physical properties can be done when the difference of the economic value of the coproducts is low.

3. Where physical relationships alone cannot be established or used as the basis for allocation (or they are too time consuming), the inventory data should be allocated between the co-products in a way that reflects other relationships between them. For example, inventory data might be allocated between co-products in proportion to their economic values. If economic allocation is used, a sensitivity analysis exploring the influence of the choice of the economic value shall be included in the LCA report.

The only relevant allocation issue in this LCA is when the share of energy of an entire production plant should be allocated to one produced unit. This is evaluated in section 6.4.

3.3.6 Reuse, recycling, and recovery

In the framework of the International EPD® System, the methodological choices for allocation for reuse, recycling and recovery have been set according to the polluter pays principle (PPP). This means that the generator of the waste shall carry the full environmental impact until the point in the product's life cycle at which the waste is transported to a scrapyard or the gate of a waste processing plant (collection site). The subsequent user of the waste shall carry the environmental impact from the processing and refinement of the waste but not the environmental impact caused in the "earlier" life cycles. See General Program Instruction for further information and examples.

3.3.7 Method of Life Cycle Impact Assessment (LCIA)

The methods used to calculate the relevant environmental effect categories in this study are summarized in Table 4. The impact categories have been selected based on the mandatory and optional impact categories from the international EPD system, version 2.0[2]. The method Environmental Footprint 3.0 as implemented in SimaPro has been used for all impact categories. The LCIA-method is explained in more details in 0.

Table 4: Impact categories, indicators and methods used in the study. SimaPro calculation method Environmental Footprint 3.0 was used.

Impact category		Category indicator	Method
Global warming potential (GWP)	Fossil	kg CO2 eq.	GWP100, EN 15804. Version: August 2021. Original reference IPCC (2013)
	Biogenic	kg CO2 eq.	
	Land use and land transformation	kg CO2 eq.	
	TOTAL	kg CO2 eq.	
Depletion potential of the stratospheric ozone layer (ODP)		kg CFC 11 eq.	ODP, EN 15804. Version: August 2021. Original reference WMO 2014
Acidification potential (AP)		kg mol H+ eq.	AP, accumulated exceedance, EN 15804. Version: August 2021. Original references

[2] Indicators | EPD International (environdec.com)

			Seppälä et al. 2006, Posch et al. 2008
Eutrophication potential (EP)	Aquatic freshwater	kg P eq.	EP, aquatic freshwater, EUTREND model, EN 15804. Version: August 2021. Original reference Struijs et al. 2009 as implemented in ReCiPe
	Aquatic marine	kg N eq.	
	Aquatic terrestrial	mol N eq.	
Photochemical oxidant creation potential (POCP)		kg NMVOC eq.	POCP, LOTOS-EUROS as applied in ReCiPe, EN 15804. Version: August 2021. Original reference Van Zelm et al. 2008, ReCiPe 2008
Abiotic depletion potential (ADP)	Metals and minerals	kg Sb eq.	ADP minerals & metals, EN 15804. Version: August 2021. Original references Guinée et al. 2002, van Oers et al. 2002, CML 2001 baseline (Version: January 2016)
	Fossil resources	MJ, net calorific value	ADP fossil resources, EN 15804. Version: August 2021. Original references Guinée et al. 2002, van Oers et al. 2002, CML 2001 baseline (Version: January 2016)
Water deprivation potential (WDP)		m3 world eq.	Available water remaining (AWARE) method Original reference Boulay et al (2017)

Other values to be reported in the EPD is presented in Table 5 and Table 6.

Table 5: Resource use to be declared in the study.

Resource	Unit
Use of renewable primary energy excluding primary energy resources used as raw material (PERE)	MJ
Use of renewable primary energy resources used as raw material (PERM)	MJ
Total use of renewable primary energy (PERT)	MJ
Use of non-renewable primary energy excluding primary energy resources used as raw material (PENRE)	MJ

Use of non-renewable primary energy resources used as raw material (PENRM)	MJ
Total use of non-renewable primary energy (PENRT)	MJ
Use of recycled or recycled materials (secondary materials)	Kg
Use of renewable secondary fuels	MJ
Use of non-renewable secondary fuels	MJ
Net use of freshwater	m3

Table 6: Waste materials to be declared in the study.

Rest materials	Unit
Hazardous waste	Kg
Non-hazardous waste	Kg
Radioactive waste, disposed/stored	Kg
Outputs, secondary materials and exported energy	
Material for reuse	Kg
Recycling material	Kg
Material for energy recovery	Kg
Exported energy	MJ

3.3.8 Data quality requirements

The data quality requirements as defined in the PCR will now be presented.

Upstream processes

The following requirements apply to the upstream processes:

- Data referring to processes and activities upstream in a supply chain over which an organisation has direct management control shall be specific and collected on site.
- Data referring to contractors that supply main parts, packaging, or main auxiliaries should be requested from the contractor as specific data, as well as infrastructure, where relevant.
- The transport of main parts and components along the supply chain to a distribution point (e.g., a stockroom or warehouse) where the final delivery to the manufacturer can take place based on the actual transportation mode, distance from the supplier, and vehicle load.
- In case specific data is lacking, selected generic data may be used. If this is also lacking, proxy data may be used.
- For the electricity used in the upstream processes, electricity production impacts shall be accounted for in this priority when specific data are used in the upstream processes:
    1. Specific electricity mixes as generated, or purchased, from an electricity supplier, demonstrated by a Guarantee of Origin (or similar, where reliability, traceability, and the avoidance of double-counting are ensured) as provided by the electricity supplier. If no specific mix is purchased, the residual electricity mix from the electricity supplier shall be used[3].
    2. National residual electricity mix or residual electricity mix on the market
    3. National electricity production mix or electricity mix on the market.

  The mix of electricity used in upstream processes shall be documented in the EPD, where relevant.

[3] The residual electricity mix is the mix when all contract-specific electricity that has been sold to other customers has been subtracted from the total production mix of the electricity supplier.

- ❖ Packaging: specific data shall be used for the consumer packaging production if it is under the direct control of the organization or if the environmental impact related to the consumer packaging production is more than 10% of the total product environmental indicators. In other cases, generic data may be used. When consumer packaging shows the organization's logo, the LCA report should report the exerted/non exerted direct control on the production of consumer packaging by the organization.

Core processes

The following requirements apply to the core processes:

- ❖ Specific data shall be used for the assembly of the product and for the manufacture of main parts as well as for on-site generation of steam, heat, electricity, etc., where relevant.
- ❖ For the electricity used in the core processes, electricity production impacts shall be accounted for in this priority:
    1. Specific electricity mixes as generated, or purchased, from an electricity supplier, demonstrated by a Guarantee of Origin (or similar, where reliability, traceability, and the avoidance of double-counting are ensured) as provided by the electricity supplier. If no specific mix is purchased, the residual electricity mix from the electricity supplier shall be used.
    2. National residual electricity mix or residual electricity mix on the market
    3. National electricity production mix or electricity mix on the market.

The mix of electricity used in the core processes shall be documented in the EPD, where relevant.

- ❖ Transport from the final delivery point of raw materials, chemicals, main parts, and components (see above regarding upstream processes) to the manufacturing plant/place of service provision should be based on the actual transportation mode, distance from the supplier, and vehicle load, if available.
- ❖ Waste treatment processes of manufacturing waste should be based on specific data, if available.

Downstream processes

The following requirements apply to the downstream processes:

- Data for the use stage are usually based on scenarios, but specific data should be used when available and relevant.
- Data on the pollutant emissions from the use stage should be based on documented tests, verified studies in conjunction with average or typical product use, or recommendations concerning suitable product use. Whenever applicable, test methods shall be internationally recognised.
- The use of electricity in the region/country where the product is used (as specified in the geographical scope of the EPD) shall be accounted for in the following priority:
    1. National residual electricity mix or residual mix on the market
    2. National electricity production mix or electricity mix on the market

The mix of electricity used in the downstream processes shall be documented in the EPD, where relevant.

- ❖ The transport of the product to the customer shall be described in the reference PCR, which should reflect the actual situation to the best extent possible. The following priority should be used:
    1. Actual transportation distances and types.
    2. Calculated as the average distance of a product of that product type transported by different means of transport modes.

3. Calculated as a fixed long transport, such as 1 000 km transport by lorry or 10 000 km by airplane or boat, according to product type.

In the case that transportation distances (of raw materials to the factory and/or of the product to the customer) are unknown, the following default distances shall be assumed as necessary:

- Truck or train transportation: 1.000 km
- Ship or plane transportation: 10.000 km

Both or either one of the transportation distances specified above shall be assumed as the case may be.

If transportation distance of the product to the waste management in the end-of-life stage is unknown, 50 km truck transportation shall be assumed.

- Scenarios for the end-of-life stage shall be technically and economically practicable and compliant with current regulations in the relevant geographical region based on the geographical scope of the EPD. An end-of-life scenario shall be defined as example and declared into the EPD. The potential benefit of recycling and waste treatment of the products according to the specified scenarios shall be presented in the EPD as Module D.

The data quality and representativeness will be assessed in section 6.4 based on the requirements specified in this section.

3.3.9 Type of critical review

A critical review will be carried out according to the International Standards ISO 14040 and 14044 (ISO, 2006a, 2006b) 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.

The LCA- and EPD report will be reviewed by Niels Jungbluth at ESU-Services from Switzerland. He is a well-known LCA expert with long experience within the field of LCA.

3.4 LCA Software

The life cycle impact assessment (LCIA) was made with the LCA software SimaPro 9.3[4], developed by PRé Consultants. It is the world's leading LCA software chosen by industry, research institutes and consultants in more than 80 countries. SimaPro is a powerful tool for calculations of complex product systems and in-depth comparisons of life cycles with documentation that conform to the ISO 14000 standard. This software includes databases with generic LCI data (e.g. ecoinvent[5]) and several readymade LCIA-methods.

---

[4] SimaPro Version 9.3 described at support.simapro.com.

[5] Ecoinvent 3.8, ecoinvent

3.4.1 LCI data library

The ecoinvent 3.8, Cut-Off system model was used as background LCI data. Ecoinvent is one of the world's leading databases with consistent, open, and updated Life Cycle Inventory Data (LCI). With several thousand LCI datasets in the fields of agriculture, energy supply, transport, biofuels and biomaterials, bulk and specialty chemicals, construction and packaging materials, basic and precious metals, metals, IT and electronics and waste management, ecoinvent offers the most comprehensive international LCI database.

Ecoinvent's high-quality LCI datasets are based on industrial data and have been compiled by internationally recognized research institutes and LCA consultants.

4. 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 related to the defined functional unit.

4.1 Product content declaration

This part describes all the different components and packaging materials. Coloreel Group AB has declared that the Coloreel unit follows the *Restriction of Hazardous Substances (RoHS)* directive and the *Registration, Evaluation, Authorisation and restriction of Chemicals (REACH)* regulation (Coloreel Group AB, n.d.).

Table 7: Content declaration

Product components	Weight (kg)
Coloreel product	
Steel	47,6
Electronics	7,0
Plastic other	3,1
ABS	2,9
PC ABS	2,5
PMMA	0,8
Nylon	0,7
Aluminium	0,6
Rubber	0,5
Other	0,3
Total:	**66,0**
Packaging materials	
Cardboard	5,7
Paper	4,5
Plastic	2,6
Cables	1,4
Other	0,1
Total:	14,3

4.2 Assumptions

Assumptions that are general to the entire LCA are:

- Transports are assumed to be done with Euro5 classification.

4.3 Input data references

Table 8 shows the contact details for the suppliers who have provided data to the LCA.

Table 8: List of supplier contacts

Supplier	**Scanfil Åtvidaberg AB Sweden**

Comment	Supplier who is performing the final assembly of the Coloreel unit.
Name	Peter Bergenrot
e-mail	peter.bergenrot@scanfil.com
Phone number	Mobile +46 70 359 1525
Position in company	Program Manager
Supplier	**Ricoh UK Products Ltd**
Comment	The producer of the print engine
Name	Simon Frost
e-mail	Simon.Frost@ricoh-rpl.com
Position in company	Assistant Manager, Design Engineering
Supplier	**AQ Components Västerås AB**
Comment	The producer of the chassis
Name	Erik Dahlén
e-mail	erik.dahlen@aqg.se
Phone number	+46 70 745 14 54
Position in company	Sales

4.4 Raw material (upstream)

This part describes all the different raw materials needed for the manufacturing of Coloreel. The total weight of the Coloreel unit is 66 kg. Coloreel has provided a Bill of material containing 500 entries that has been used as a basis for the LCA. As the weights in the BOM (from the CAD-system) was inaccurate the total weight and all 500 parts have been weighted by the assembly company Scanfil Åtvidaberg AB Sweden. The weighting of the components was performed in February 2022. Specific data has been collected from the manufacturing of the main parts as presented in Table 9. Excluding the print engine and chassis parts, the weight of the next biggest component is around 1 kg. Due to the low weight of each remaining component, no more part is considered a main part.

Table 9: Main parts for which specific data has been collected.

Part	Weight (kg)	Supplier
Print engine	9,0	Ricoh UK Products Ltd
Chassis parts	34,0	AQ Components Västerås AB
Remaining parts	23,0	Generic data from ecoinvent.

4.4.1 Raw materials and components

The raw material used in the Coloreel unit is presented in Table 10. First the Coloreel unit without the print engine and chassis will be presented, then the chassis and lastly the print engine. The data for the Coloreel unit is based on the BOM list containing 500 entries received from Coloreel. To make it manageable, all entries have been classified into 40 material groups. These are now presented. No specific data on recycled material has been reported. However, the market processes in ecoinvent contain recycled material as input.

Table 10: Raw materials for one Coloreel unit, excluding print engine and chassis.

Material	Weight (kg)	LCI database representation	Comment
Cold Rolled Low Carbon Steel	3,2844	[1032] Cold rolled steel	Sheet rolling, steel {RER}| processing | Cut-off, U +

Material	Weight (kg)	LCI database representation	Comment
			Steel, unalloyed {RER}| steel production, converter, unalloyed | Cut-off, U
ABS	2,7739	Acrylonitrile-butadiene-styrene copolymer {RER}| production | Cut-off, U	
Plastic	2,2337	Polyethylene, low density, granulate {RER}| production | Cut-off, U	
Galvanised Steel	2,0339	[1032] Galvanized Steel	Per kg: 1 kg Steel, unalloyed {RER}| steel production, converter, unalloyed | Cut-off, U + 60/1000 m2 Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U. From dataset. 60 m2/ton.
PC ABS	1,7481	[1032] PC 83% ABS 17% - plastic	83% Polycarbonate {GLO}| market for | Cut-off, U + 17% Acrylonitrile-butadiene-styrene copolymer {GLO}| market for | Cut-off, U Share of PC vs ABS is an assumption based on the same data as received from the manufacturer Ricoh.
Power Supply Unit	1,3380	Power supply unit, for desktop computer {RoW}| production | Cut-off, U	Converted ecoinvent process from pieces to kg.
Stainless Steel	1,2692	Steel, chromium steel 18/8 {GLO}| market for | Cut-off, U	
75% Cold Rolled Low Carbon Steel 25% PTFE	1,1665	[1031] 75% Cold rolled steel 25% PTFE	[1032] Cold rolled steel, see first row. + Metal working, average for metal product manufacturing {RER}| processing | Cut-off, U + Tetrafluoroethylene {GLO}| market for | Cut-off, U +

Material	Weight (kg)	LCI database representation	Comment
			Injection moulding {RER}| processing | Cut-off, U
Stepmotor	0,8841	Electric motor, for electric scooter {GLO}| production | Cut-off, U	
PMMA	0,8128	Polymethyl methacrylate, beads {RER}| production | Cut-off, U	
Steel	0,6361	Steel, low-alloyed {GLO}| market for | Cut-off, U	
Cable	0,6122	Cable, printer cable, without plugs {GLO}| market for | Cut-off, U	Converted ecoinvent process from pieces to kg.
Nylon 6	0,5564	Nylon 6 {RER}| market for nylon 6 | Cut-off, U	
Aluminium	0,5215	Aluminium, primary, ingot {IAI Area, EU27 & EFTA}| market for | Cut-off, U	
Fan	0,5033	Fan, for power supply unit, desktop computer {GLO}| market for | Cut-off, U	
Rubber	0,4853	Synthetic rubber {GLO}| market for | Cut-off, U	
Pump	0,4675	Fan, for power supply unit, desktop computer {GLO}| market for | Cut-off, U	Rough estimation. The pump was estimated by Coloreel to contain 50% plastic and 50% steel. A computer fan is assumed as a proxy by Marcus Bernhard.
Mainboard PCB	0,3993	Printed wiring board, mounted mainboard, desktop computer, Pb free {GLO}| market for | Cut-off, U	
Steel Alloyed	0,2983	Steel, low-alloyed {GLO}| market for | Cut-off, U	
Printed circuit board assembly (PCBA)	0,2719	Printed wiring board, surface mounted, unspecified, Pb free {GLO}| market for | Cut-off, U	

Material	Weight (kg)	LCI database representation	Comment
Nylon	0,1307	Nylon 6 {RER}| market for nylon 6 | Cut-off, U	
Magnet Nd	0,1061	Permanent magnet, for electric motor {GLO}| market for permanent magnet, for electric motor | Cut-off, U	
Transducer Card	0,0866	Printed wiring board, surface mounted, unspecified, Pb free {GLO}| market for | Cut-off, U	
PC	0,0847	Polycarbonate {GLO}| market for | Cut-off, U	
Ferrite	0,0631	Ferrite {GLO}| market for | Cut-off, U	
LED	0,0596	Light emitting diode {GLO}| market for | Cut-off, U	
Ultrasonic Piezo Generator	0,0410	Electronics, for control units {GLO}| market for | Cut-off, U	
Display	0,0402	Liquid crystal display, unmounted {GLO}| market for | Cut-off, U	
Brass	0,0319	Brass {RoW}| market for brass | Cut-off, U	
POM	0,0316	Polyoxymethylene (POM)/EU-27	Industry data 2.0
Nylon 66	0,0247	Nylon 6-6 {RER}| market for nylon 6-6 | Cut-off, U	
Nylon 610	0,0110	Nylon 6-6 {RER}| market for nylon 6-6 | Cut-off, U	Nylon 6-10 not available in ecoinvent. Nylon 6-6 used as proxy.
EPDM Rubber	0,0071	Synthetic rubber {GLO}| market for | Cut-off, U	
Polyester	0,0053	Polyester resin, unsaturated {RER}| market for polyester resin, unsaturated | Cut-off, U	

Material	Weight (kg)	LCI database representation	Comment
China Encoder Pd3006E1024Bst5 Electronics	0,0052	Potentiometer, unspecified {GLO}| market for | Cut-off, U	
Color Sensor Board Long Electronics	0,0038	Printed wiring board, surface mounted, unspecified, Pb free {GLO}| market for | Cut-off, U	
Opto Sensor Slot Type 5 mm Panel Electronics	0,0037	Electronic component, active, unspecified {GLO}| market for | Cut-off, U	
Carbon Filter	0,0024	[Air filter, decentralized unit, 180-250 m3/h {RER}| production | Cut-off, U	Converted ecoinvent process from pieces to kg.
Indicator tilt watch Electronics	0,0014	Electronic component, active, unspecified {GLO}| market for | Cut-off, U	
Color Sensor Board Short Electronics	0,0004	Printed wiring board, surface mounted, unspecified, Pb free {GLO}| market for | Cut-off, U	

The chassis parts in manufactured by AQ Components in Västerås, Sweden. The total weight of the chassis is 34 kg. The chassis parts, their weight and LCI representation is presented in Table 11.

Table 11: Raw materials for the Coloreel chassis parts as manufactured by AQ Components Västerås AB. Chassis for one Coloreel unit.

Description	**Material**	**Weight (kg)**	LCI database representation	Comment
3924 CHASSI-Y	Cold rolled low-carbon steel	15,0	[1032] Cold rolled steel	Sheet rolling, steel {RER}| processing | Cut-off, U + Steel, unalloyed {RER}| steel production, converter, unalloyed | Cut-off, U
3746 DOOR INNER PLATE WITH FASTENERS	Cold rolled low-carbon steel	3,0	[1032] Cold rolled steel	-:-
5745 DOOR OUTER PLATE	Cold rolled low-carbon steel	2,8	[1032] Cold rolled steel	-:-

4708 DOOR INNER PLATE WITH FASTENERS	Cold rolled low-carbon steel	2,0	[1032] Cold rolled steel	-:-
3798 DOOR INNER PLATE WITH FASTENERS	Cold rolled low-carbon steel	1,7	[1032] Cold rolled steel	-:-
4041 UNDER COVER PLATE	Cold rolled low-carbon steel	1,6	[1032] Cold rolled steel	-:-
5662 FIXATION UNIT BASE PLATE	Cold rolled low-carbon steel	1,6	[1032] Cold rolled steel	-:-
4084 TOP COVER PLATE	Cold rolled low-carbon steel	1,3	[1032] Cold rolled steel	-:-
5741 DOOR OUTER PLATE	Cold rolled low-carbon steel	1,2	[1032] Cold rolled steel	-:-
4705 DOOR INNER PLATE WITH FASTENERS	Cold rolled low-carbon steel	1,1	[1032] Cold rolled steel	-:-
4077 BACK MODULE WELDMENT	Cold rolled low-carbon steel	1,1	[1032] Cold rolled steel	-:-
5744 DOOR OUTER PLATE	Cold rolled low-carbon steel	0,7	[1032] Cold rolled steel	-:-
5740 DOOR OUTER PLATE	Cold rolled low-carbon steel	0,7	[1032] Cold rolled steel	-:-

The print engine is manufactured by Ricoh UK Products Ltd. Ricoh has provided a BOM list from 2022 with over 200 entries listing all materials and components assembled in the print engine. All entries in the BOM list have been classified into 32 material groups and implemented in SimaPro according to Table 12. A part of the print engine that is replaced after 5000 hours of use is the print head. The materials in the print head have been extracted from the BOM-list into a separate table, see Table 13. The total weight of the print head is 55 grams.

Table 12: Raw materials for the print engine (excluding print head). One print engine is used in one Coloreel unit.

Material	Weight (kg)	LCI database representation	Comment
Steel	4,94	Steel, low-alloyed {GLO}| market for | Cut-off, U	
Stepmotor	1,22	Electric motor, for electric scooter {GLO}| market for | Cut-off, U	
PC ABS	0,76	[1032] PC 83% ABS 17% - plastic	83% Polycarbonate {GLO}| market for | Cut-off, U

Material	Weight (kg)	LCI database representation	Comment
			+ 17% Acrylonitrile-butadiene-styrene copolymer {GLO}| market for | Cut-off, U Share of PC vs ABS estimated by Ricoh.
Circuit board	0,36	Printed wiring board, surface mounted, unspecified, Pb free {GLO}| market for | Cut-off, U	
Cable	0,33	[1032] Cable, printer cable, without plugs {GLO}| market for | Cut-off, U, converted to kg	
PS	0,27	Polystyrene, general purpose {RER}| production | Cut-off, U	
POM PE	0,21	[1032] POM 91% PE 9% - plastic	91% Polyoxymethylene (POM)/EU-27 (Industry data 2.0) + 9 % Polyethylene, low density, granulate {GLO}| market for | Cut-off, U
Dc Solenoid	0,18	Electric motor, for electric scooter {GLO}| market for | Cut-off, U	
Dc Motor	0,13	Electric motor, for electric scooter {GLO}| market for | Cut-off, U	
POM	0,10	Polyoxymethylene (POM)/EU-27	Industry data 2.0
ABS	0,09	Acrylonitrile-butadiene-styrene copolymer {RER}| production | Cut-off, U	
Rubber	0,05	Synthetic rubber {RER}| production | Cut-off, U	
Aluminium	0,04	Aluminium, primary, ingot {IAI Area, EU27 & EFTA}| market for | Cut-off, U	
Copper	0,04	Copper, cathode {GLO}| market for | Cut-off, U	

Material	Weight (kg)	LCI database representation	Comment
Fan	0,03	Fan, for power supply unit, desktop computer {GLO}| market for | Cut-off, U	
PC	0,03	Polycarbonate {GLO}| market for | Cut-off, U	
Stainless steel	0,03	Steel, chromium steel 18/8 {GLO}| market for | Cut-off, U	
PP	0,03	Polypropylene, granulate {GLO}| market for | Cut-off, U	
FEP	0,03	Tetrafluoroethylene {GLO}| market for | Cut-off, U	
SASI ABS	0,02	Acrylonitrile-butadiene-styrene copolymer {RER}| production | Cut-off, U	SASI material unknown, only ABS used.
PE	0,02	Polyethylene, low density, granulate {GLO}| market for | Cut-off, U	
PBT ABS	0,01	[1032] PBT 50% ABS 50% - plastic	Share 50% vs 50% assumption by Marcus Bernhard.
Nylon	0,00836	Nylon 6 {RER}| market for nylon 6 | Cut-off, U	
EP Rubber	0,00482	Synthetic rubber {RER}| production | Cut-off, U	
PPE PP	0,00268	[1032] PPE 50% PP 50% - plastic	Share 50% vs 50% assumption by Marcus Bernhard.
CEM 3	0,00162	Glass fibre reinforced plastic, polyester resin, hand lay-up {GLO}| market for | Cut-off, U	
PET	0,00142	Polyethylene terephthalate, granulate, amorphous {Europe without Switzerland}| polyethylene terephthalate, granulate, amorphous, recycled to generic market for amorphous PET granulate | Cut-off, U	
PVC	0,00099	Polyvinylchloride, bulk polymerised {GLO}| market for | Cut-off, U	
PO PET	0,00066	Polyethylene terephthalate, granulate, amorphous {Europe without Switzerland}| polyethylene	PO not available, only PET used.

Material	Weight (kg)	LCI database representation	Comment
		terephthalate, granulate, amorphous, recycled to generic market for amorphous PET granulate | Cut-off, U	
Silicon rubber	0,00040	Silicone product {RER}| market for silicone product | Cut-off, U	
PVA	0,00040	Ethylene vinyl acetate copolymer {RER}| market for ethylene vinyl acetate copolymer | Cut-off, U	
Fluorine rubber	0,00002	Tetrafluoroethylene {GLO}| market for | Cut-off, U	Material approximation by Marcus Bernhard. Very low weight.

Table 13: Raw materials for the print head used in the print engine.

Material	Weight (kg)	LCI database representation	Comment
Stainless steel	0,0304	Steel, chromium steel 18/8 {GLO}| market for | Cut-off, U	
Epoxy	0,0220	Epoxy resin, liquid {RER}| market for epoxy resin, liquid | Cut-off, U	
Pet	0,0008	[1032] PC 83% ABS 17% - plastic	83% Polycarbonate {GLO}| market for | Cut-off, U + 17% Acrylonitrile-butadiene-styrene copolymer {GLO}| market for | Cut-off, U Share of PC vs ABS estimated by Ricoh.
Si	0,0008	Silicone product {RER}| market for silicone product | Cut-off, U	

Material	Weight (kg)	LCI database representation	Comment
Ni	0,0008	Nickel, class 1 {GLO}| market for nickel, class 1 | Cut-off, U	
Fluorine rubber	0,0002	Tetrafluoroethylene {GLO}| market for | Cut-off, U	Material approximation by Marcus Bernhard.

4.4.2 Upstream processing of raw materials and components

Specific data has been collected regarding the manufacturing of the chassis and print engine as well as for the final assembly of the Coloreel unit, see section 4.5. For all other parts, generic manufacturing processes from ecoinvent 3.8 has been used, see Table 14.

Table 14: Upstream material processing

Plastics	**Injection moulding {RER}| processing | Cut-off, U**
Stainless steel	Metal working, average for chromium steel product manufacturing {RER}| processing | Cut-off, U
Steel	Metal working, average for steel product manufacturing {RER}| processing | Cut-off, U
Aluminium	Impact extrusion of aluminium, 1 stroke {RER}| processing | Cut-off, U
Copper	Metal working, average for copper product manufacturing {RER}| processing | Cut-off, U
Brass	Casting, brass {RoW}| processing | Cut-off, U

4.4.3 Packaging

The Coloreel unit is packaged in cardboard boxes for distribution to the customer. Plastic foam is added to the boxes for protection. The unit is sent with a rather high amount of installation and operation manuals in a variety of languages. The unit is also sent with three cables, one for the EU market, one for the UK market and one for the US market. The packaging has been provided as a BOM list containing 31 entries. Each entry has been individually weighted by Scanfil. All entries have been classified into material groups. These are presented in Table 15. The use of an EUR pallet for the transportation has been added as separate information. Normally two units are loaded per pallet for transport to distributors and end customers.

Table 15: Packaging used for one Coloreel unit.

Material	Amount (kg)	LCI data representation in ecoinvent 3.8	Comment
Cardboard	5,74	Corrugated board box {RER}| production | Cut-off, U	Boxes and protection
Paper	4,50	Printed paper {GLO}| market for | Cut-off, U	Manuals
Plastic foam	2,32	Polyurethane, flexible foam {RER}| market for polyurethane, flexible foam | Cut-off, U	Protective plastic foam
Cable	1,36	[1032] Cable, connector for computer, without plugs {GLO}| market for | Cut-off, U, converted to kg + [1032] Plug, inlet and outlet, for computer cable {GLO}| production | Cut-off, U, converted to kg	3 cables are sent in the packaging, for EU, UK and US. 3 x 29 grams per plug is used for the plug data set (weight of plug from ecoinvent dataset). The remaining weight is for the cable.
Plastic	0,28	Polyethylene, low density, granulate {GLO}| market for | Cut-off, U + Extrusion, plastic film {RER}| extrusion, plastic film | Cut-off, S	Type of plastic unknown. PE assumed. For bags etc.
Steel	0,05	Steel, low-alloyed {GLO}| market for | Cut-off, U + Metal working, average for steel product manufacturing {RER}| processing | Cut-off, U	Screws etc.

Material	Amount (kg)	LCI data representation in ecoinvent 3.8	Comment
Si	0,03	Silicone product {RER}| market for silicone product | Cut-off, U	Absorbent
EUR pallet	(WeightEuPallet/ AmountEuPalletReuse) /2 = 0,5 kg	[1032] EUR-flat pallet {RER}| market for EUR-flat pallet | Cut-off, U, converted to kg	WeightEuPallet = 25 kg[6] AmountEuPalletReuse = 25 times[7] 2 Coloreel units per pallet.

4.5 Manufacturing (core)

In this chapter, the manufacturing activities for the main parts and the final assembly is presented. All activities are presented per Coloreel unit.

4.5.1 Energy

The energy used in the production of the print engine has been estimated by the producer Ricoh. Based on their factory in China, they have estimated the energy used for the print engine as follows "Total energy consumption of factory/Total floor area of factory*Total area used for manufacturing of PE for Coloreel". This was done for the period April 2021 to Feb 2022 for which 1176 print engines units were produced.

Table 16: Energy use in production of one print engine

Energy type	LCI data representation in ecoinvent 3.8	Amount (kWh per unit)	Certificate?
Electricity	Electricity, medium voltage {SGCC}| market for | Cut-off, U	3.5	No

The energy for the manufacturing of the chassis has been provided by AQ Components Västerås AB. They stated that it takes approximately 71 kWh to manufacture the biggest chassis part (Chassy Y) weighting 15 kg. The reasoning behind the energy consumption is unknown. It is assumed that the same energy demand, converted to per kg, is used for all chassis parts manufactured by AQ Components, see Table 17. All chassis parts are listed in Table 11 having a total weight of 34 kg.

Table 17: Energy use in production of the chassis for one Coloreel unit.

Energy type	LCI data representation in ecoinvent 3.8	Amount (kWh per kg chassis)	Certificate?	Comment
Electricity	[1032] Wind power Electricity, medium	4.86	Yes, electricity from wind	LCI data is a copy and edit of: *Electricity, medium*

[6] Weight EUR pallet: https://www.epal-pallets.org/eu-en/load-carriers/epal-euro-pallet
[7] Suggested by PEFCR: https://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_guidance_v6.3.pdf

	voltage {SE}| market for | Cut-off, U		power. See appendix Figure 28.	*voltage {SE}| market for | Cut-off, U* And does only include wind power. Transmission and distribution losses are modelled and attributed to the SE grid mix.

The final assembly of the Coloreel unit is performed by Scanfil Åtvidaberg AB Sweden. No manufacturing of parts is carried out by Scanfil, only manual assembly and testing. The energy has been reported for the year 2021 for which 400 units were produced. The energy has been allocated based on utilized factory area out of the total area, see Table 18.

Table 18: Energy use for final assembly of one Coloreel unit.

Energy type	LCI data representation in ecoinvent 3.8	Amount (MWh per unit)	Certificate?	Comment
Electricity	[1032] Hydro power Electricity, medium voltage {SE}| market for | Cut-off, U	0,0425*1,05	Yes, renewable electricity. See appendix Figure 29.	LCI data is a copy and edit of: *Electricity, medium voltage {SE}| market for | Cut-off, U* And does only include hydro power. Transmission and distribution losses are modelled and attributed to the SE grid mix.
Heat (onsite wood chip heating)	Heat, district or industrial, other than natural gas {SE}| heat and power co-generation, wood chips, 6667 kW, state-of-the-art 2014 | Cut-off, U	0,235	-	

4.5.2 Direct emissions

Scanfil states that they have no direct emissions.

4.5.3 Consumables

A very small number of consumables has been reported by Scanfil for the assembly of Coloreel, see Table 19. Due to the low weight, the transport has been considered negligible.

Table 19: Consumables used in assembly of one Coloreel unit.

Type of consumable	Material	Amount (kg)	LCI data representation in ecoinvent 3.8
Bostik Silikon Universal	Silicone	Estimated 1 gram	Silicone product {RER}| market for silicone product | Cut-off, U
Universalfog Multi Transparent	Universal sealing	Estimated 1 gram	Silicone product {RER}| market for silicone product | Cut-off, U
Klüberplex AG 11-462	Adhesive lubricant based on mineral oil.	Estimated 1 gram	Lubricating oil {RER}| market for lubricating oil | Cut-off, U
Loctite 2400		Neglectable	
Loctite 496		Neglectable	

4.5.4 Transport of incoming material and components

The raw materials and components come from many suppliers. A transport scenario has been created based on the top 75% raw materials and components based on weight. From the top 75% components, 72% comes from Sweden and 28% comes from China. Hjortkvarn has been used as supplier location in Sweden as it is the demographic center of Sweden[8]. It is rather close to Åtvidaberg, where the assembly is performed. Coloreel has expressed that most components from Sweden is sourced regionally. Dongguan, Guangdong, China is considered as a representative location for the China producers. A newly opened Ricoh factory is in Dongguan[9]. The final transport scenario per kg of incoming material is presented in Table 20.

Table 20: Transport of incoming materials and components per kg.

Supplier location	Road transport type	Road transport distance (km)	Sea transport type	Sea transport distance (km)	Comment
72% come from Sweden	Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U	111	-	0	Hjortkvarn, Örebro County -> Scanfil, Åtvidaberg
28% come from China	Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U	314	Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, U	18730	Åtvidaberg, Sweden -> Gothenburg port, Sweden -> Dongguan,

[8] https://en.wikipedia.org/wiki/Demographic_center_of_Sweden
[9] https://www.therecycler.com/posts/ricoh-starts-production-in-new-factory-in-china/

					Guangdong, China

4.5.5 Internal transports

No internal transport has been reported.

4.5.6 Production waste

The waste in the assembly is presented in Table 21. The data has been reported by the assembly company Scanfil. The waste of raw material and components are low as it is only an assembly factory. It has been estimated to be 0,5% of the total weight of the product.

Table 21: Coloreel assembly waste and treatment

Waste type	Waste transport type	Waste transport distance (km)	Waste quantity (kg)	Waste treatment
Combustible waste for energy recovery	Transport, freight, lorry 16-32 metric ton, EURO5	50	1,14	Municipal solid waste {SE}| treatment of, incineration | Cut-off, U - Content of incinerated waste unknown. Municipal waste used as proxy.
Cardboard for recycling	Transport, freight, lorry 16-32 metric ton, EURO5	50	1,58	Paper (waste treatment) {GLO}| recycling of paper | Cut-off, U
LDPE stretch film for recycling	Transport, freight, lorry 16-32 metric ton, EURO5	50	0,026	Mixed plastics (waste treatment) {GLO}| recycling of mixed plastics | Cut-off, U
Assumed waste factor in assembly	Transport, freight, lorry 16-32 metric ton, EURO5	50	0,5% of total weight of the Coloreel unit	Municipal solid waste (waste scenario) {SE}| Treatment of waste | Cut-off, U - Estimated to 0,5% of total weight by the assembly company Scanfil.

No waste data has been received from Ricoh, the producer of the print engine. Same waste in production as for the Coloreel assembly is assumed, see Table 22. Due to modeling reasons and the low amount of waste generated (approximately 45 grams), a Swedish waste scenario is used as a proxy for the waste treatment.

Table 22: Main part: Print engine assembly waste and treatment

Waste type	Waste transport type	Waste transport distance (km)	Waste quantity (kg)	Waste treatment
Assumed waste factor in assembly	Transport, freight, lorry 16-32 metric ton, EURO5	50	0,5% of total weight of the print engine	Proxy: Municipal solid waste (waste scenario) {SE}| Treatment of waste | Cut-off, U - No waste data has been received from Ricoh, the producer of the print engine. Same amount as for the Coloreel assembly is assumed.

The waste generated during the production of the chassis has been estimated by the producer, AQ Components Västerås AB, to be 20% of the weight of the chassis. All pure materials are sent to material recycling.

Table 23: Main part: Chassis manufacturing waste and treatment

Waste type	Waste transport type	Waste transport distance (km)	Waste quantity (kg)	Waste treatment
Assumed waste factor for production of chassis	Transport, freight, lorry 16-32 metric ton, EURO5	50	20% of total weight of the chassis	Steel and iron (waste treatment) {GLO}| recycling of steel and iron | Cut-off, U - All waste is assumed to be sent to recycling.

4.6 Transport of finished goods (downstream)

A transport scenario has been created based on where the product is sold. 60% is sold to Europe, 30% to the US and 10% to Asia. Google maps has been used to calculate the distances for road transport and searates.com[10] has been used to calculate sea distances. Normally two Coloreel units are loaded onto an EUR pallet and is delivered to distributors at each market. From the distributors the Coloreel units are further transported to the end customer. As presented in the result section, the life cycle impact from transportation to customer is less very small (e.g., less than 1% of the total GWP). Further details of how the transport is carried out would likely not affect the result and was therefore not investigated further.

Table 24: Distribution of products

[10] https://www.searates.com/services/distances-time/

Market	Road transport type	Road transport distance (km)	Sea transport type	Sea transport distance (km)	Comment
Europe 60% market share	Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U	1700	-	0	Approximate distance Åtvidaberg, Sweden to Paris/London. Assumed representative for European market.
United states 30% market share	Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U + Transport, freight, lorry 16-32 metric ton, EURO5 {RoW}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U	300 + 1900	Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, U	6 300	Åtvidaberg, Sweden -> Gothenburg port, Sweden -> New York port, US -> Kansas City, US (Assumed midpoint of continental US)
Asia 10% market share	Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U + Transport, freight, lorry 16-32 metric ton, EURO5 {RoW}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U	300 + 20	Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, U	15 000	Åtvidaberg, Sweden -> Gothenburg port, Sweden -> Dhaka port, BD -> Dhaka city BD

4.7 Usage (downstream)

The energy data has been calculated into energy use per 1000 stiches, see Table 25. It is based on a power rating of 0,290 kW, a machine speed of 800 rpm and an uptime of 75%. Per hour the number of stiches is:

*800 rpm * 60 minutes * 75% = 36 000 stiches.*

The energy consumption thus becomes:

*(0,290 kW / 36 000 stiches per hour) * 1000 stiches = 0,0081 kWh per 1000 stiches.*

The source of electricity is based on the market scenario for Coloreel. As seen in Table 25, ecoinvent market groups has been used to model the electricity use in each market.

Table 25: Energy consumed in the use phase

Quantity (kWh per 1000 stiches)	LCI data representation in Ecoinvent 3.8	Comment
0,0081*60%	Electricity, low voltage {RER}| market group for | Cut-off, U	Market group for Europe.
0,0081*30%	Electricity, low voltage {RNA}| market group for | Cut-off, U	Market group for North America.
0,0081*10%	Electricity, low voltage {RAS}| market group for | Cut-off, U	Market group for Asia.

The consumables used in the use phase is presented in Table 26. It includes thread, washing fluid, lubrication oil, ink, and air filter. The recycled polyester thread is specially developed to be used with the Coloreel unit.

Table 26: Consumables in the use phase

Material	Quantity (per 1000 stitches)	Reference service life	LCI data representation in Ecoinvent 3.8	Comment
Recycled polyester thread	0,0044 km		[1032] fibre, recycled polyester {IN}| recycled polyester fibre production	Weight of thread is 0,025 kg per km. LCI dataset is a copy and edit of: fibre, polyester {IN}| polyester fibre production, finished | Cut-off, U

				The input material has been changed to recycled PET: Polyethylene terephthalate, granulate, amorphous, recycled {Europe without Switzerland}| market for polyethylene terephthalate, granulate, amorphous, recycled | Cut-off, U
Recycled polyester thread (waste)	3,25%		Same as "Recycled polyester thread"	Thread waste during embroidery.
Washing fluid	0,090 grams		1% of Alkyl sulphate (C12-14) {GLO}| market for alkyl sulphate (C12-14) | Cut-off, U + 99% of Tap water {Europe without Switzerland}| market for | Cut-off, U	99% water, 1% Sodium dodecyl sulfate
Lubrication	0,010 grams		Lubricating oil {RER}| production | Cut-off, U	Used lubrication on thread. 5% of thread weight
Ink	0,021 grams		Confidential	Based on confidential recipe by "Sensient Imaging Technologies S.A.". Shared with non-disclosure agreement.
Air filter	0,0029 grams		[1032] Air filter, decentralized unit, 180-250 m3/h {RER}| production | Cut-off, U, converted to kg	Main wash filter 47g; Wash prefilter 22g; Air filter 7g; change every 3 months

A few components are replaced during the lifetime of the unit, see Table 27.

Table 27: Replaced components during the lifetime of the Coloreel unit

Material	Quantity	Reference service life	LCI data representation in Ecoinvent 3.8	Comment
Waste ink tank (WIT)	0,169 kg per WIT.	427 hours	Polystyrene, general purpose {GLO}| market for | Cut-off, U	On an eight hours shift, two ink cleaning processes are carried out. A total of 2,5 ml ink per shift is collected in the WIT. When full, it is disposed of for incineration. A total of 23 WIT is disposed of during the lifetime of 10 000 hours. Transport to waste treatment, lorry 50 km assumed per WIT.
Print engine head	0,055 kg	5000 hours	See Table 13	The print engine heads are replaced after 5000 hours. A transport scenario from customer to Ricoh UK Birmingham was created for refurbish of the print heads. The transport scenario is very similar to the one presented in Table 24.
Cartridge refill	-	328 hours		The ink cartridge is sent to Ricoh UK Birmingham for refilling. A total of 30 cartridges are refilled during the lifetime of 10 000 hours. A transport scenario from customer to Ricoh UK Birmingham was created for the refill of cartridges. The scenario is very similar to the one presented in Table 24.

4.8 End-of-Life (downstream)

The end-of-life phase handles the product and the material it consists of after its use. The final handling includes dismantling of the product, transport to a facility for waste treatment, any energy and materials used for preparation for waste treatment and final waste treatment. If the material is recycled or reused into a new product, the environmental aspects of the processing of the secondary material are allocated to the life cycle of the new product.

The end-of-life treatment depends on the market where the product is used. An end-of-life scenario has been created based on the market shares of each market. The disposal scenario for the Coloreel unit, packaging and the consumables is presented in Table 28. Transport of 50 km by truck is assumed for all waste management. For the separation of materials in the Coloreel unit, disassembly and shredding is needed. The process "*treatment of waste electric and electronic equipment, shredding GLO*" has been added as a proxy for the separation of materials into separate waste streams. Further recycling processes are attributed to the subsequent life cycle.

Table 28: Waste scenario of the Coloreel machine and consumables.

Market	LCI representation	
Europe 60%	Municipal solid waste (waste scenario) {EU27}| Treatment of waste | Cut-off, U, See appendix, Table 40 for details.	The LCI record was created by PRé Sustainability thus not reviewed by ecoinvent.
US 30%	Municipal solid waste (waste scenario) {US}| Treatment of waste | Cut-off, U See appendix, Table 41 for details.	The LCI record was created by PRé Sustainability thus not reviewed by ecoinvent.
Asia 10%	Municipal solid waste (waste scenario) {CN}| Treatment of waste | Cut-off, U See appendix, Table 42 for details.	The LCI record was created by PRé Sustainability thus not reviewed by ecoinvent. China used as proxy for Asia.

The same market scenario is used for the consumables. There are however two differences. Firstly, the Waste ink tank is known to be fully incinerated. The process "*Waste polystyrene {RoW}| treatment of waste polystyrene, municipal incineration | Cut-off, U*" is used for the waste ink tank. Secondly, the washing fluid is treated with the process "*Wastewater, average {Europe without Switzerland}| treatment of wastewater, average, capacity 1E9l/year | Cut-off, U*".

All waste generated during the manufacturing is processed with the waste scenario "*Municipal solid waste (waste scenario) {SE}| Treatment of waste | Cut-off, U*". The dataset has been created by PRé Sustainability and is thus not reviewed by ecoinvent. See appendix, Table 43 for details on recycling, incineration, and land filling rates.

5. Life cycle impact assessment (LCIA)

In this part, the result from the different environmental impact assessment methods will be presented. First the result for the EPD will be presented followed by the single score weighted results according to EF 3.0. Then more details regarding the climate impact (GWP) is presented. Section 5.3 and 5.4 presents additional mandatory information to be presented in the EPD. Section 5.5 presents all the results with the functional unit of 1000 stitches. In the interpretation section, further analysis is made looking at for example the use of renewable electricity in the use phase. 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.

Sankey diagrams are used to display the results as flow diagrams where the thickness of the arrows reflects the relative amount of that flow. All the nodes cannot be displayed simultaneously due to the vast amounts of background data. Therefore, a cut-off to the diagrams has been applied which is specified in the figure text.

5.1 Results to be presented in the EPD

The result for the mandatory impact categories and the optional impact category ODP according to the international EPD system is presented in Table 29. The result is presented for one declared unit and the full use phase, see section 3.3.2 for more information. The Environmental Footprint 3.0 method as implemented in SimaPro has been used to calculate the results.

Table 29: Environmental impact results for one declared unit.

PARAMETER		UNIT	Upstream	Core	Downstream	TOTAL
Global warming potential (GWP)	Fossil	kg CO2 eq.	6,85E+02	3,27E+01	1,76E+03	2,48E+03
	Biogenic	kg CO2 eq.	2,89E+00	3,58E-01	2,39E+01	2,71E+01
	Land use and land transformation	kg CO2 eq.	9,88E-01	1,70E+00	8,45E+00	1,11E+01
	TOTAL	kg CO2 eq.	6,88E+02	3,47E+01	1,79E+03	2,52E+03
Depletion potential of the stratospheric ozone layer (ODP)		kg CFC 11 eq.	1,17E-03	8,45E-06	9,61E-05	1,27E-03
Acidification potential (AP)		kg mol H+ eq.	4,76E+00	3,11E-01	8,43E+00	1,35E+01
Eutrophication potential (EP)	Aquatic freshwater	kg P eq.	6,76E-01	1,32E-02	1,24E+00	1,93E+00
	Aquatic marine	kg N eq.	1,01E+00	7,71E-02	1,71E+00	2,80E+00
	Aquatic terrestrial	mol N eq.	8,61E+00	9,61E-01	1,47E+01	2,42E+01
Photochemical oxidant creation potential (POCP)		kg NMVOC eq.	2,63E+00	2,51E-01	4,39E+00	7,27E+00
Abiotic depletion potential (ADP)	Metals and minerals	kg Sb eq.	1,68E-01	1,10E-03	1,14E-02	1,81E-01
	Fossil resources	MJ, net calorific value	8,54E+03	3,65E+02	2,93E+04	3,82E+04
Water deprivation potential (WDP)		m3 world eq.	2,14E+02	1,31E+01	3,64E+02	5,91E+02

Figure 12 shows what part of the life cycle that is contributing to the overall impact in each category.

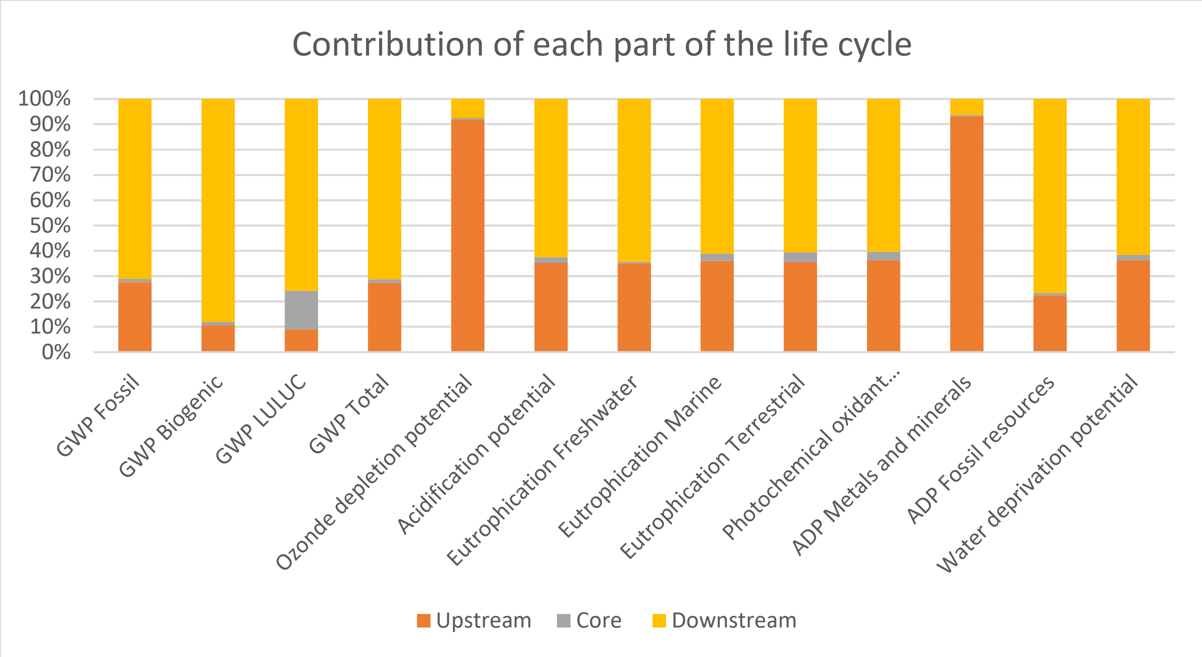

Figure 12: Contributing parts of the lifecycle.

It is mainly Downstream and Upstream that is contributing the most. Figure 13 shows a more granular division of each process in the life cycle. It shows that the electricity in the use phase stands for the biggest parts of the impact in most impact categories, except abiotic depletion, minerals, and ozone layer depletion. The raw materials stand for a relatively large share in most categories and for the biggest share in abiotic depletion, minerals and ozone layer depletion. The ozone layer depletion potential comes mainly from the use of polytetrafluoroethylene in the ”Contact fix concave/convex units”.

The Water deprivation potential mainly comes from the downstream electricity consumption during use and from the upstream production of raw materials. The on-site water consumption used by the Coloreel unit during thread coloring is small. It is only the washing fluid and the ink that is consuming water. For the full lifetime of the unit the total on-site water consumption is 36,2 liters (32,1 liters for the washing fluid and 4,1 liters for the ink).

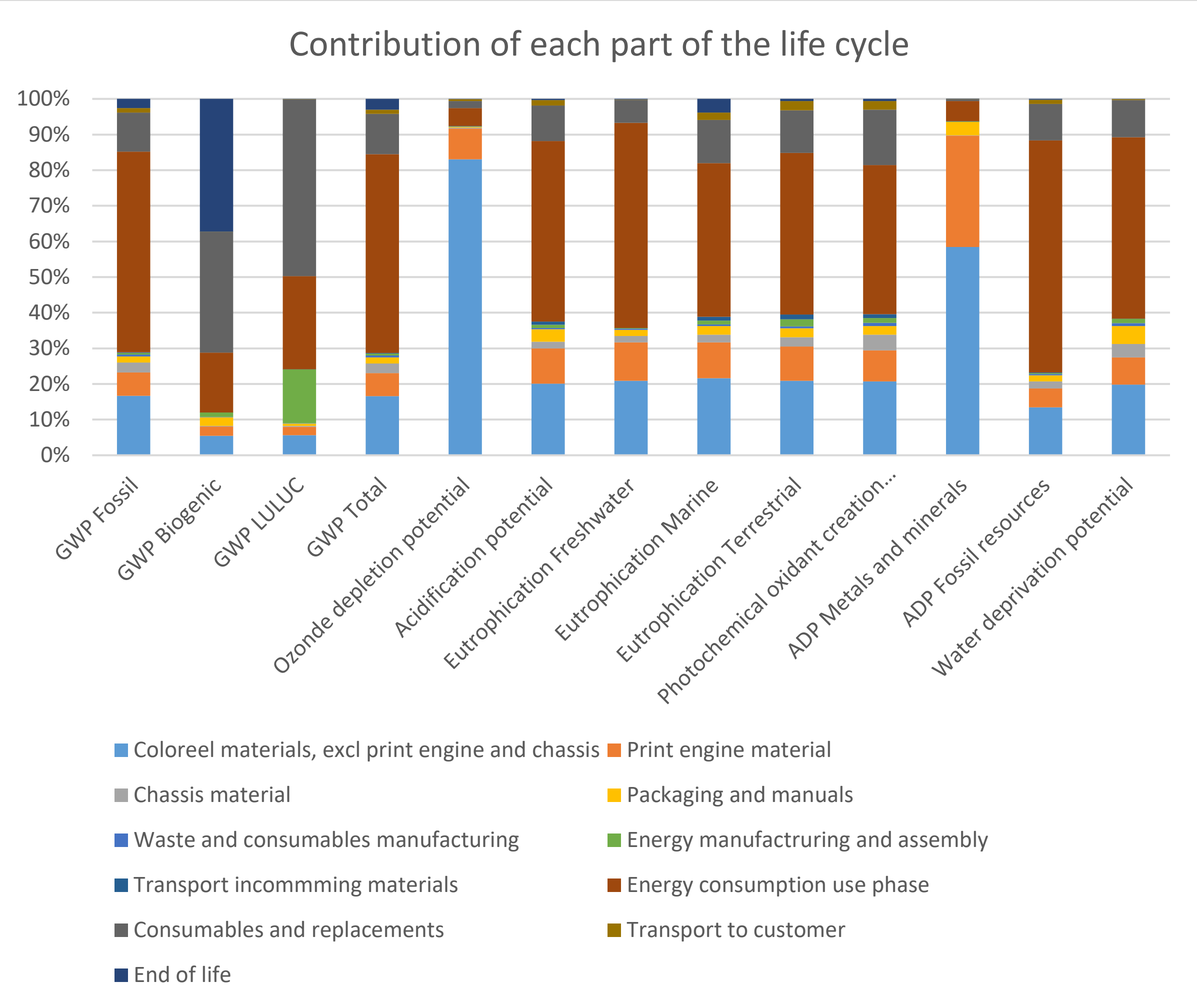

Figure 13: Contributing parts of the lifecycle with more granular division.

5.1.1 Environmental Footprint Endpoint

The environmental footprint endpoint shows the contribution of each environmental impact category to the total environmental weighted impact. The result from this section will not be us in the EPD. It will however bring additional insights into what impact categories that are more important to focus on according to the Environmental footprint 3.0 method. The result is presented in Figure 14.

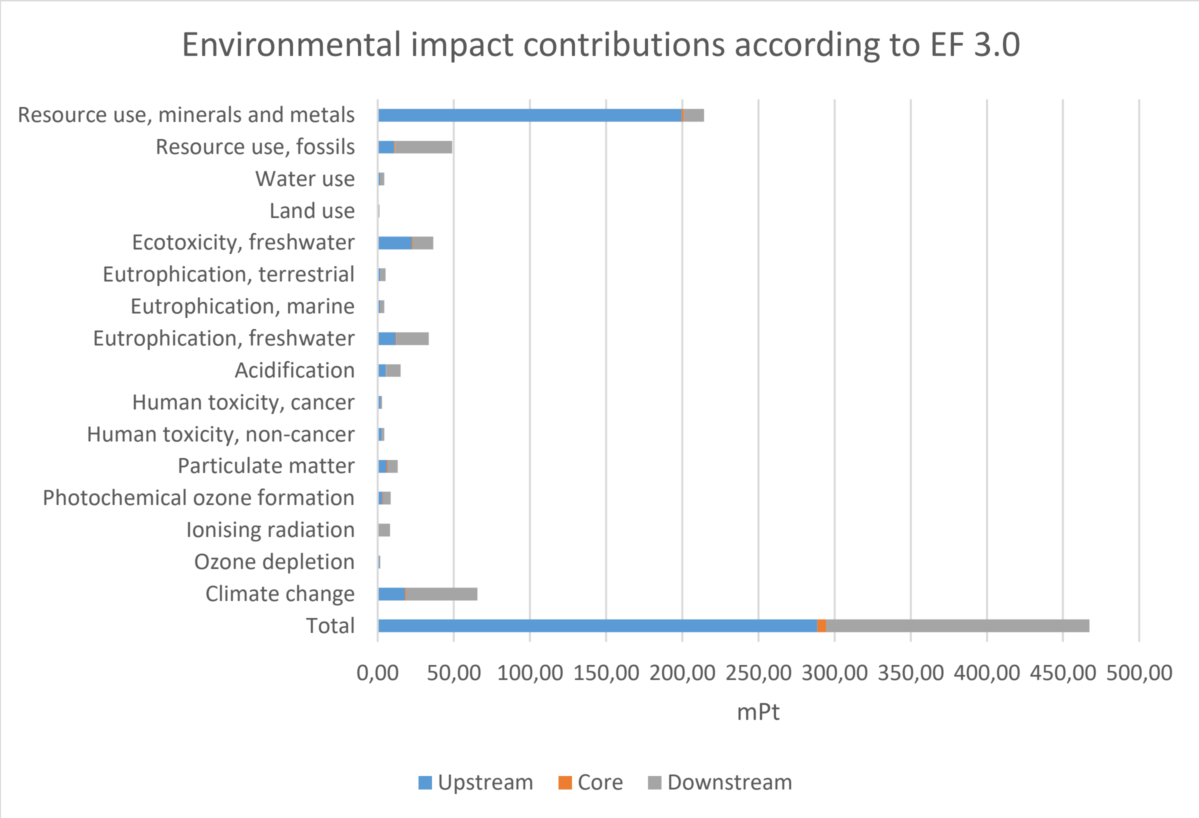

Figure 14: Share of environmental impact per impact category.

The most important impact categories to focus on according to the EF 3.0 method are "*Resource use, minerals and metals*", "*Climate change*" and "*Resource use, fossils*". The upstream life cycle step stands for the largest impact for the "*Resource use, minerals and metals*" category while the downstream step stands for most impact for "*Climate change*" and "*Resource use, fossils*". It is the generation of electricity that is mainly causing the impact for the categories "*Climate change*" and "*Resource use, fossils*". Figure 15 shows what processes that are contributing to the total environmental impact. It shows that it is the printed wiring boards (PCBs) that is having the biggest contribution followed by the electricity consumption in the use phase.

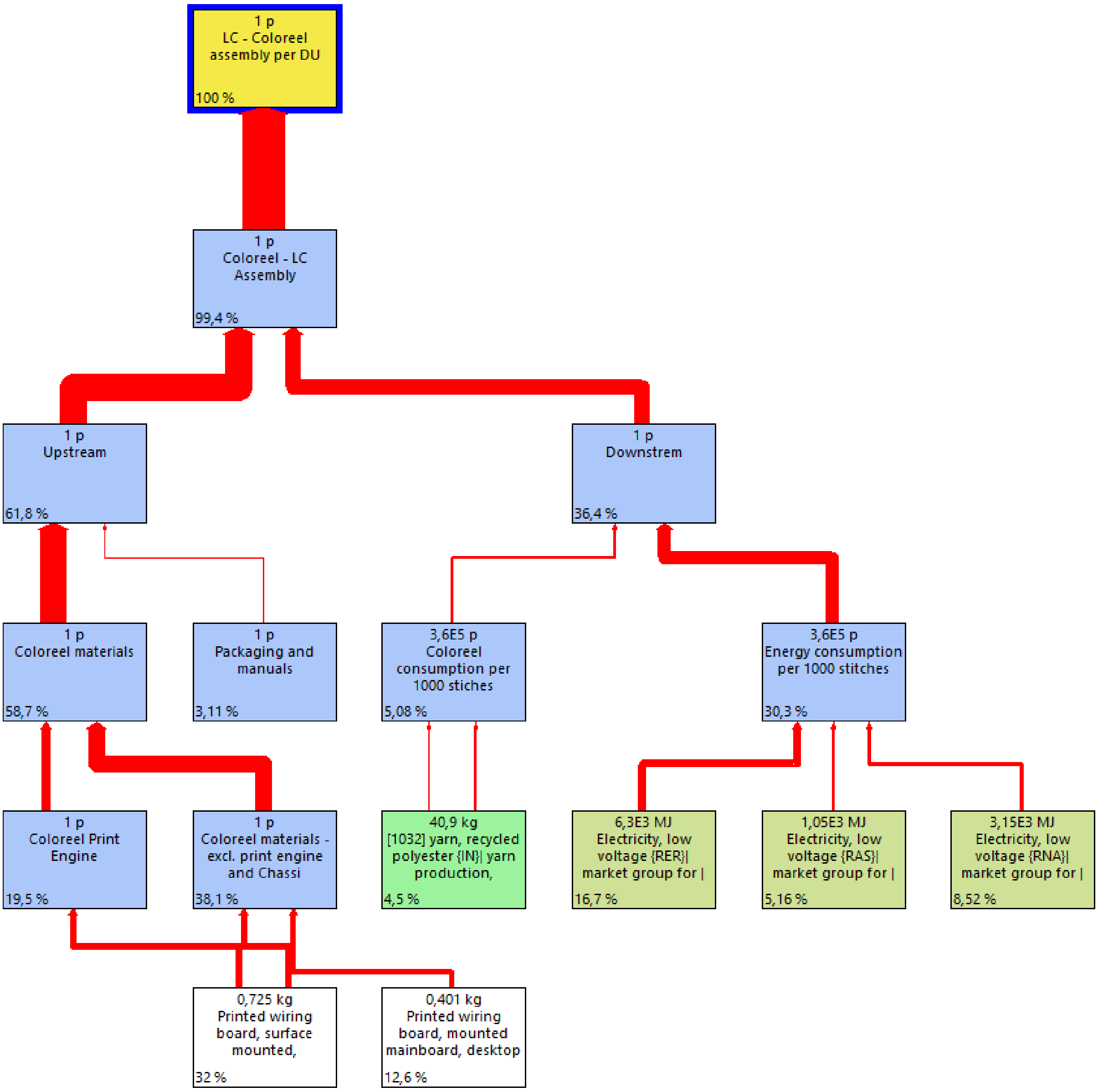

Figure 15: Sankey diagram over share of environmental impact contributions per module (EF 3.0 single score). Cut-off 3%[11].

To dig further Figure 16 shows that it is the use of gold that is having a big impact in the category "Resource use, minerals and metals". The gold and silver are mainly used in the integrated circuits on the PCBs. Tellurium is a by-product in the production of copper.

[11] Showing only processes contributing to more than 3% or the environmental impact.

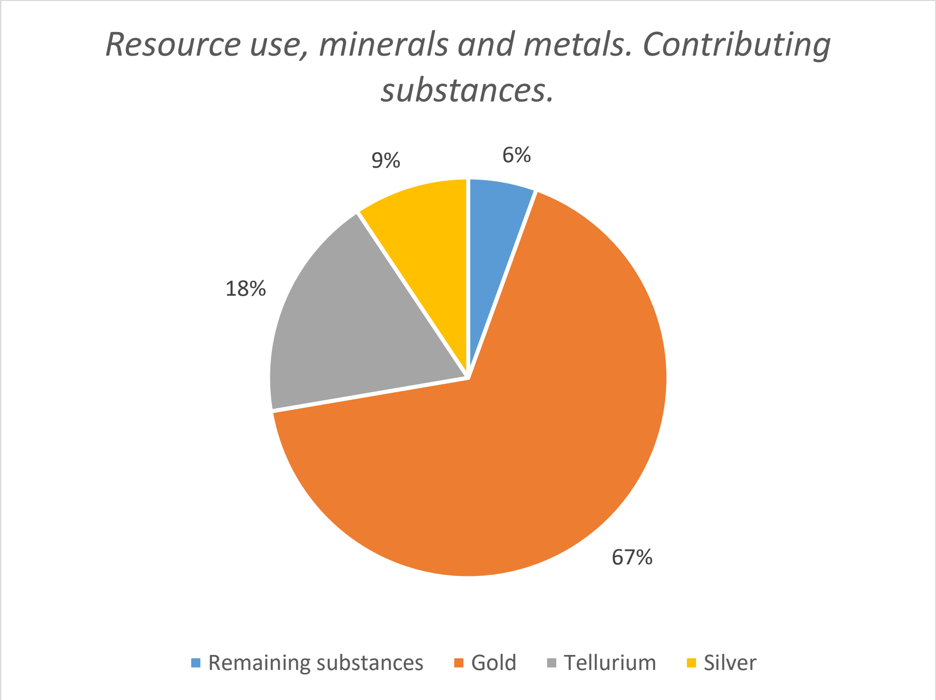

Figure 16: Contribution substances for the impact category “Resource use, minerals and metals”.

5.2 Climate impact (GWP) - IPCC GWP 2013 100

Figure 17 shows a Sankey diagram over climate change impact category. It shows that the electricity in the use phase stands for 56%, the production of raw materials for 26% and the polyester thread for 10%. The IPCC 2013 method as implemented in Environmental Footprint 3.0 has been used to calculate the results.

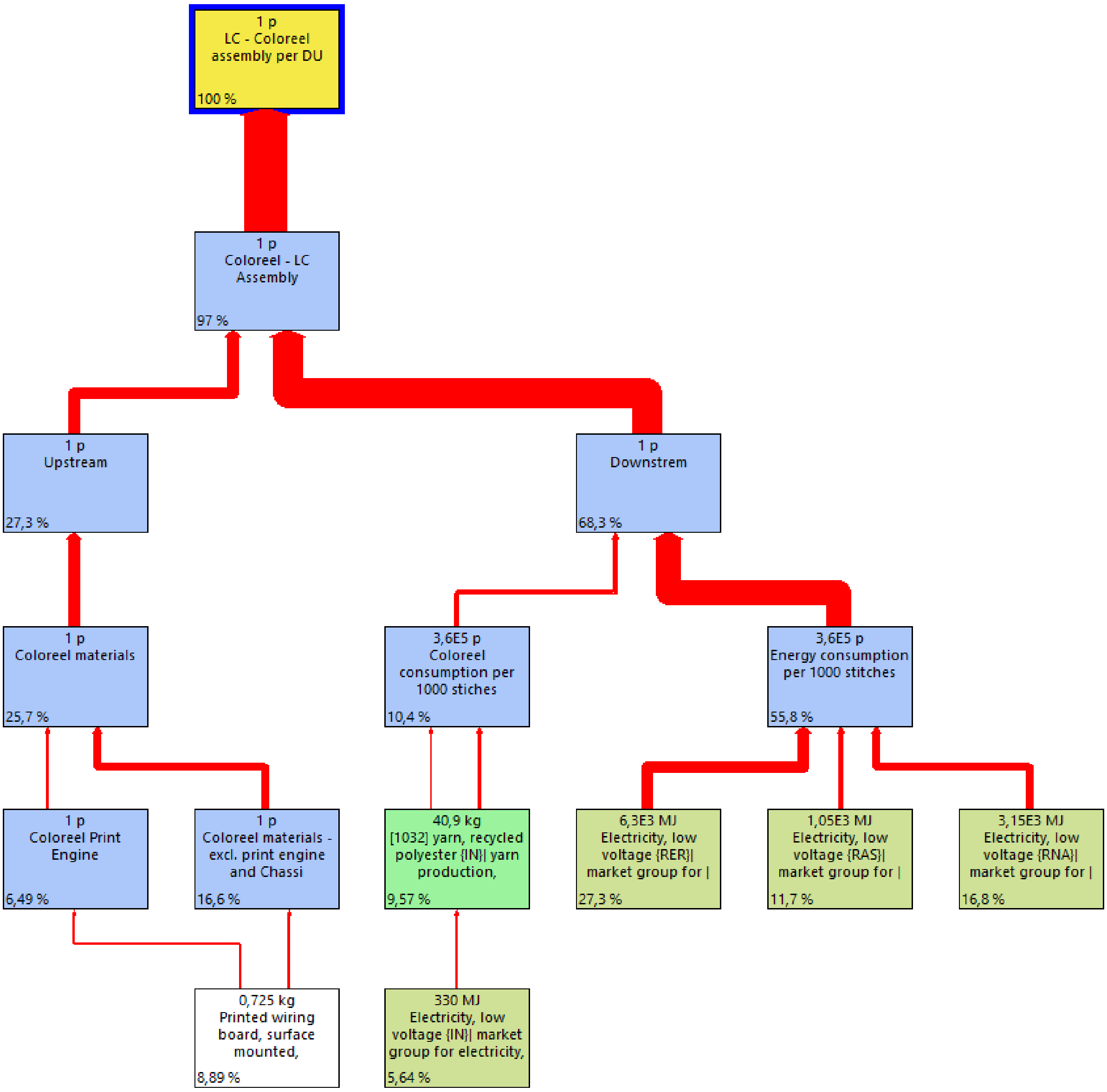

Figure 17: Sankey diagram over share of GWP, IPCC 2013 GWP 100. Cut-off 4%[12].

5.2.1 Cradle to gate

To understand the climate impact from the production of 1 Coloreel unit, the cradle to gate GWP result is presented in Figure 18. The result is presented for one Coloreel unit with the user and end-of-life phase excluded. It shows that it is mainly the electronical components such as the printed circuit boards that is having the biggest impact.

[12] Showing only processes contributing to more than 4% or the GWP.

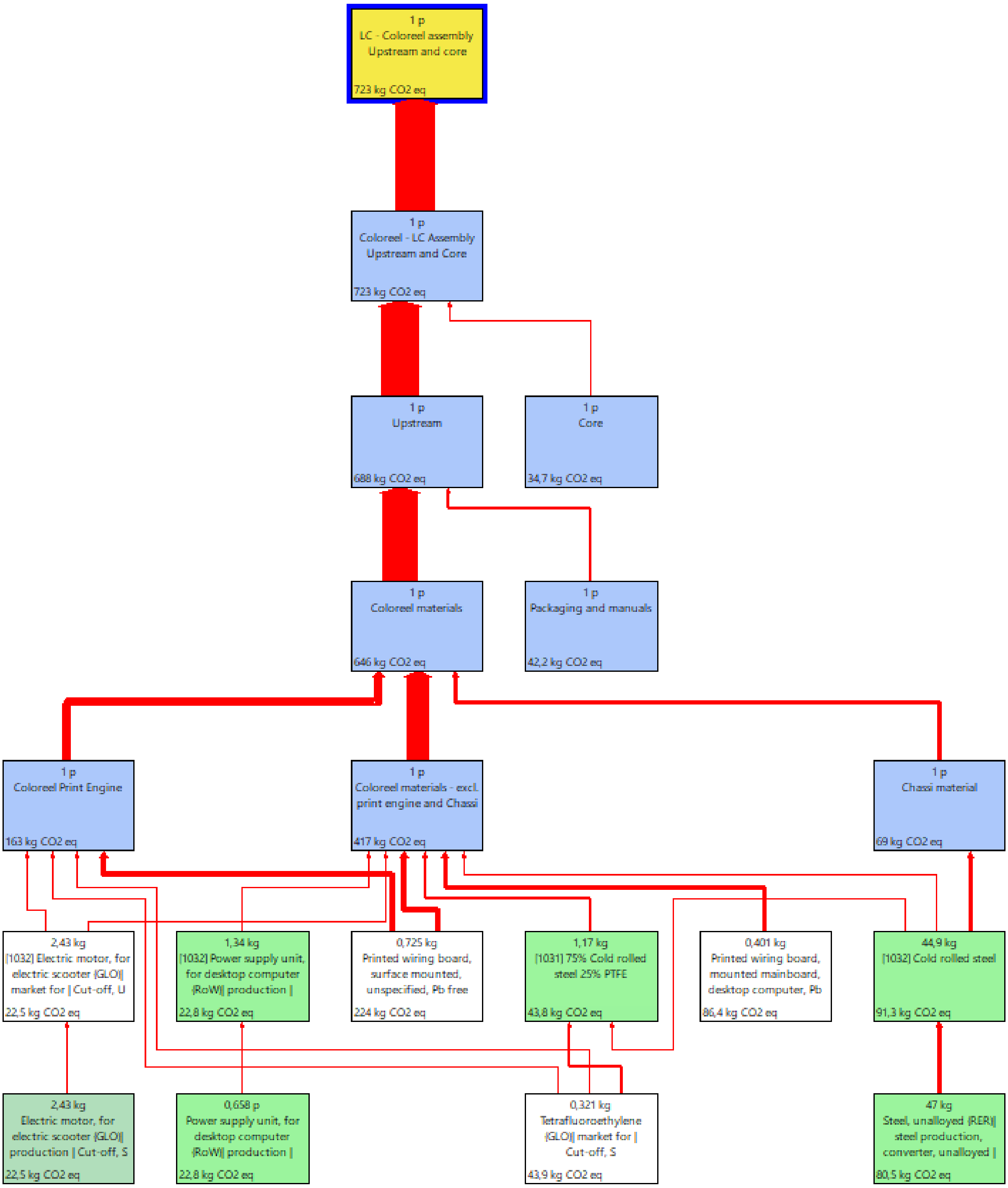

Figure 18: Sankey diagram over cradle to gate results for 1 unit of Coloreel. Cut-off 3%.

5.3 Use of resources and energy CED 1.11

The use of resources and energy should be reported into the EPD. The consumption of resources in terms of energy is measured as primary energy demand with the method Cumulative Energy Demand 1.11 (see Appendix 2). Embodied energy in materials such as plastic, cardboard, and paper has been calculated according to lower heating value from Phyllis2 (TNO Biobased and Circular Technologies, n.d.).

Table 30: Use of resources and energy

PARAMETER		UNIT	Upstream	Core	Downstream	TOTAL
Primary energy resources – Renewable	Use as energy carrier	MJ, net calorific value	8,27E+02	1,24E+03	4,66E+03	6,72E+03
	Used as raw materials	MJ, net calorific value	1,49E+02	0,00E+00	0,00E+00	1,49E+02
	TOTAL	MJ, net calorific value	9,76E+02	1,24E+03	4,66E+03	6,87E+03
Primary energy resources – Non-renewable	Use as energy carrier	MJ, net calorific value	8,35E+03	3,86E+02	3,10E+04	3,97E+04
	Used as raw materials	MJ, net calorific value	7,54E+02	0,00E+00	2,48E-03	7,54E+02
	TOTAL	MJ, net calorific value	9,10E+03	3,86E+02	3,10E+04	4,05E+04
Secondary material[13]		kg	0	0	4,09E+01	4,09E+01
Renewable secondary fuels		MJ, net calorific value	0	0	0	0
Non-renewable secondary fuels		MJ, net calorific value	0	0	0	0
Net use of fresh water[14]		m^3	7,86E+00	1,60E-01	1,18E+01	1,98E+01

5.4 Waste production and output flows

Final waste and output flows, refers to flows that are leaving the system of the LCA. In this LCA only elementary flows (substances) and materials going to recycling are leaving the system. As waste treatment processes are already included within the system boundary, the waste disposed is reported as 0 in accordance to the guidelines from Environdec (EPD International AB, n.d.).

Table 31: Waste production for upstream, core and downstream

PARAMETER	UNIT	Upstream	Core	Downstream	TOTAL
Hazardous waste disposed	kg	0	0	0	0
Non-hazardous waste disposed	kg	0	0	0	0
Radioactive waste disposed	kg	0	0	0	0

Materials sent to recycling is calculated based on the end-of-life scenario as presented in section 4.8.

[13] The secondary materials only include materials reported by Coloreel, more specifically the recycled polyester thread. Secondary materials used within default ecoinvent processes are not included.
[14] Includes "Water, lake", "Water, river", "Water, unspecified origin", and "Water, well".

Table 32: Output flows

PARAMETER	UNIT	Upstream	Core	Downstream	TOTAL
Components for reuse	kg	0	0	0	0
Material for recycling[15]	kg	0	7,55E-02	4,63E+01	4,63E+01
Materials for energy recovery	kg	0	0	0	0
Exported energy, electricity	MJ	0	0	0	0
Exported energy, thermal	MJ	0	0	0	0

5.5 Result presented per functional unit of 1000 stitches

The result as previously presented in section 5 will now be presented per the functional unit of 1000 stitches. To get the impact per 1000 stitches the result is scaled down by dividing by 360 000. The details of the functional unit are explained in section 3.3.2. Table 33 shows the environmental impact per 1000 stitches.

Table 33: Environmental impact results for 1000 stitches.

PARAMETER		UNIT	Upstream	Core	Downstream	TOTAL
Global warming potential (GWP)	Fossil	kg CO2 eq.	1,90E-03	9,07E-05	4,90E-03	6,89E-03
	Biogenic	kg CO2 eq.	8,04E-06	9,94E-07	6,63E-05	7,53E-05
	Land use and land transformation	kg CO2 eq.	2,74E-06	4,73E-06	2,35E-05	3,09E-05
	TOTAL	kg CO2 eq.	1,91E-03	9,64E-05	4,99E-03	6,99E-03
Depletion potential of the stratospheric ozone layer (ODP)		kg CFC 11 eq.	3,25E-09	2,35E-11	2,67E-10	3,54E-09
Acidification potential (AP)		kg mol H+ eq.	1,32E-05	8,64E-07	2,34E-05	3,75E-05
Eutrophication potential (EP)	Aquatic freshwater	kg P eq.	1,88E-06	3,67E-08	3,44E-06	5,35E-06
	Aquatic marine	kg N eq.	2,81E-06	2,14E-07	4,75E-06	7,77E-06
	Aquatic terrestrial	mol N eq.	2,39E-05	2,67E-06	4,07E-05	6,73E-05
Photochemical oxidant creation		kg NMVOC eq.	7,31E-06	6,98E-07	1,22E-05	2,02E-05

[15] Sum of all material entering recycling processes in SimaPro.

potential (POCP)						
Abiotic depletion potential (ADP)	Metals and minerals	kg Sb eq.	4,67E-07	3,07E-09	3,16E-08	5,02E-07
	Fossil resources	MJ, net calorific value	2,37E-02	1,01E-03	8,14E-02	1,06E-01
Water deprivation potential (WDP)		m3 world eq.	5,93E-04	3,65E-05	1,01E-03	1,64E-03

Table 34 shows the use of resources per 1000 stitches. See section 5.3 for more details about the indicator.

Table 34: Use of resources and energy per 1000 stitches

PARAMETER		UNIT	Upstream	Core	Downstream	TOTAL
Primary energy resources – Renewable	Use as energy carrier	MJ, net calorific value	2,30E-03	3,43E-03	1,29E-02	1,87E-02
	Used as raw materials	MJ, net calorific value	4,13E-04	0,00E+00	0,00E+00	4,13E-04
	TOTAL	MJ, net calorific value	2,71E-03	3,43E-03	1,29E-02	1,91E-02
Primary energy resources – Non-renewable	Use as energy carrier	MJ, net calorific value	2,32E-02	1,07E-03	8,60E-02	1,10E-01
	Used as raw materials	MJ, net calorific value	2,09E-03	0,00E+00	6,89E-09	2,09E-03
	TOTAL	MJ, net calorific value	2,53E-02	1,07E-03	8,60E-02	1,12E-01
Secondary material[16]		kg	0	0	1,14E-04	1,136E-04
Renewable secondary fuels		MJ, net calorific value	0	0	0	0
Non-renewable secondary fuels		MJ, net calorific value	0	0	0	0
Net use of fresh water[17]		m^3	2,18E-05	4,44E-07	3,28E-05	5,50E-05

Table 35 shows the output flows per 1000 stitches. See section 5.4 for more details about the indicator.

[16] The secondary materials only include materials reported by Coloreel, more specifically the recycled polyester thread. Secondary materials used within default ecoinvent processes are not included.
[17] Includes “Water, lake”, “Water, river”, “Water, unspecified origin”, and “Water, well”.

Table 35: Output flows per 1000 stitches

PARAMETER	UNIT	Upstream	Core	Downstream	TOTAL
Components for reuse	kg	0	0	0	0
Material for recycling	kg	0	2,10E-07	1,28E-04	1,29E-04
Materials for energy recovery	kg	0	0	0	0
Exported energy, electricity	MJ	0	0	0	0
Exported energy, thermal	MJ	0	0	0	0

6. Interpretation

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

6.1 Key aspects of results

The environmental impact of Coloreel in a lifecycle perspective comes mainly from the electricity consumption in the use phase and the production of raw materials.

For climate change the electricity in the use phase stands for 56%, the production of raw materials for 26% and the polyester thread for 10% of the impact.

The most important impact categories to focus on according to the EF 3.0 method are "*Resource use, minerals and metals*", "*Climate change*" and "*Resource use, fossils*". It is the use of gold and silver in the integrated circuits on the printed circuit boards that is having the biggest impact in the category "*Resource use, minerals and metals*". For "*Climate change*" and "*Resource use, fossils*", it is the electricity consumption in the use phase that is having the biggest impact. The use of water has a non-significant impact.

The most critical components are electronics such as PCBs, power units and motors, followed by the steel in the chassis.

6.2 Sensitivity analysis

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

A few scenarios are evaluated in the sensitivity analysis. The first is the lifetime of the Coloreel unit. The lifetime of the unit has a potential to be prolonged by further replacing certain parts. However, the true lifetime of the unit is uncertain and depends on the customer. Therefore, a sensitivity scenario has been constructed to evaluate the impact of prolonging and shortening the lifetime of the unit. The second aspect to be evaluated is the use of renewable electricity in production. The electricity is purchased with market-based certificates for the assembly of Coloreel and the production of the chassis. The true environmental improvement of the electricity system because of the purchased certificates are hard to evaluate. A scenario has been constructed using Swedish electricity mix instead of renewable electricity for the assembly of Coloreel and the production of the chassis. Similarly, a scenario where all production is performed in China has been created. Lastly, a scenario looking at improving the energy efficiency with half the energy use in the use phase has been evaluated. A summery can be seen in Table 36. The result is presented per the functional unit of 1000 stitches to be able to get meaningful results when altering the lifetime of the unit.

Table 36: Sensitivity analysis scenarios.

Scenario	Comment
Different lifetime	Changing the lifetime to 20 000 h and 5000 h. The default is 10 000 h.
Non-renewable electricity in production	Renewable electricity has been purchased with certificates for the assembly of Coloreel and the production of the chassis. A scenario has been constructed to evaluate the impact if Swedish electricity mix was used instead.
All production in China	All production, including assembly and chassis, is performed in China.
Improved energy efficiency in use	Improved energy efficiency in the use phase by 50% of the original energy use.

The result of the sensitivity analysis is presented in Figure 19.

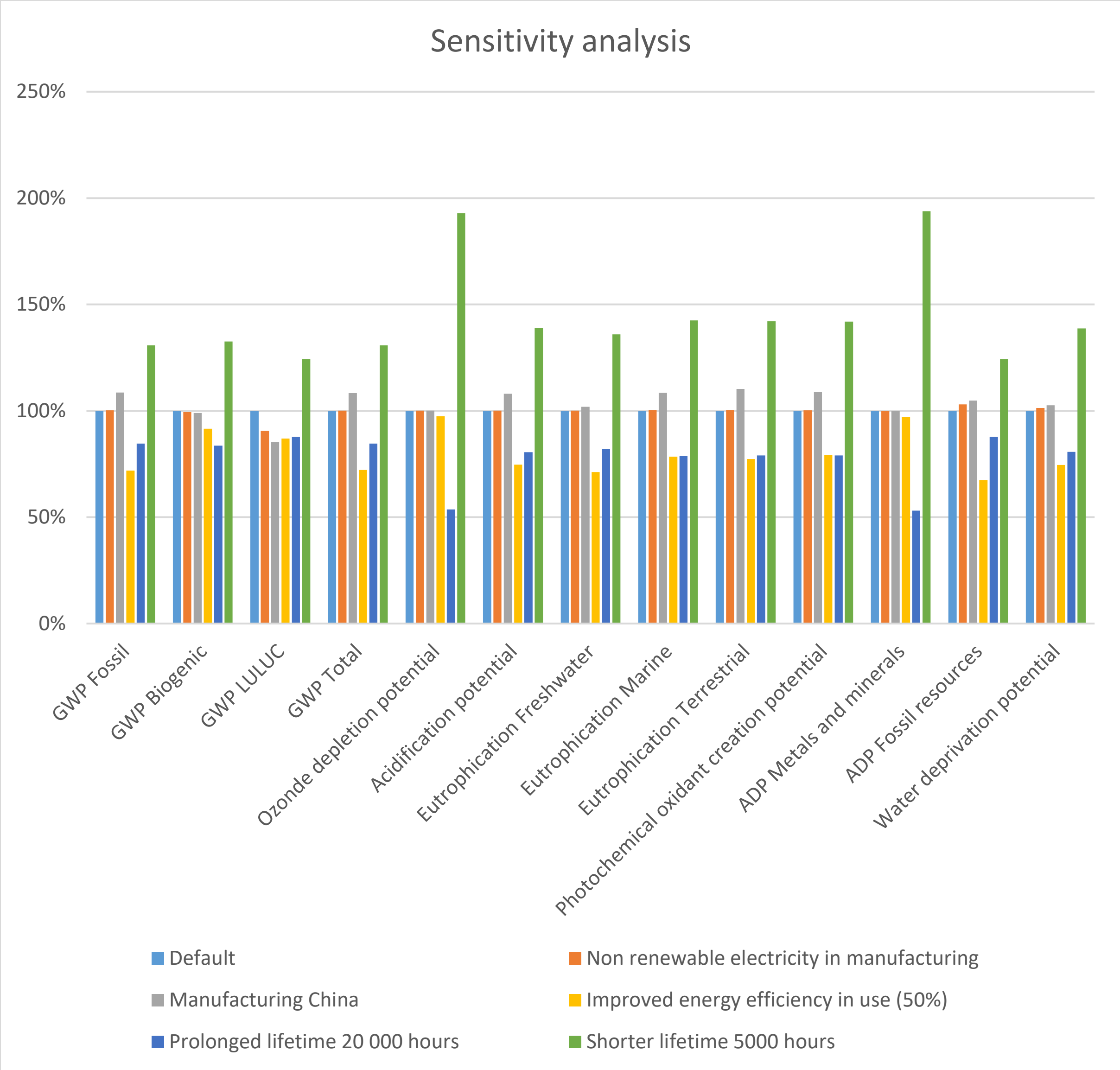

Figure 19: Sensitivity analysis. Functional unit, 1000 stitches.

Depending on the impact category, the environmental impact is rather drastically reduced if the energy efficiency is improved or if the lifetime of the unit is prolonged. A shorter lifetime will lead to a higher result. The energy in the production phase is only slightly affected by changing to non-renewable or China electricity mix.

6.3 Scenario analysis

6.3.1 Renewable electricity in the use phase

The electricity in the use phase stands for a large part of the GWP as seen in Figure 17. A scenario has been constructed to evaluate the impact if the user only purchases electricity from renewable sources. The result of this scenario will be presented as additional information in the EPD. The ecoinvent process "*Electricity, low voltage, renewable energy products {CH}| market for electricity, low voltage, renewable energy products | Cut-off, U*" has been used. It represents the renewable electricity consumption in Switzerland for the year 2019. The main energy source is hydropower followed by smaller shares of wind-, bio- and solar energy. The result will be presented for the full life cycle of one declared unit.

One should be careful when drawing conclusions related to environmental impact and electricity purchased with certificates (Gillenwater, 2013). Renewable electricity certificate (REC) is a market-based instrument. It does not reflect the actual electricity flowing through the grid. Even though you have purchased electricity from renewable sources, the actual electricity used might originate from fossil-based generation. One of the ideas behind REC is that it should lead to an increased amount renewable electricity being produced and more polluting electricity generation being replaced. This might not always be the case. For example, the potential to develop more hydropower is in many places of the world very limited as it is already fully utilized. Purchasing electricity from hydropower with RECs might therefore not lead to an increase of renewable electricity being produced. Market-based instruments for purchasing electricity has a risk of just shuffle numbers around without leading to major improvements of the environmental impact.

The first result of the scenario is presented in Figure 20. It shows that the environmental impact in most categories is drastically reduced if renewable electricity is used. The total GWP has been reduced by 54%.

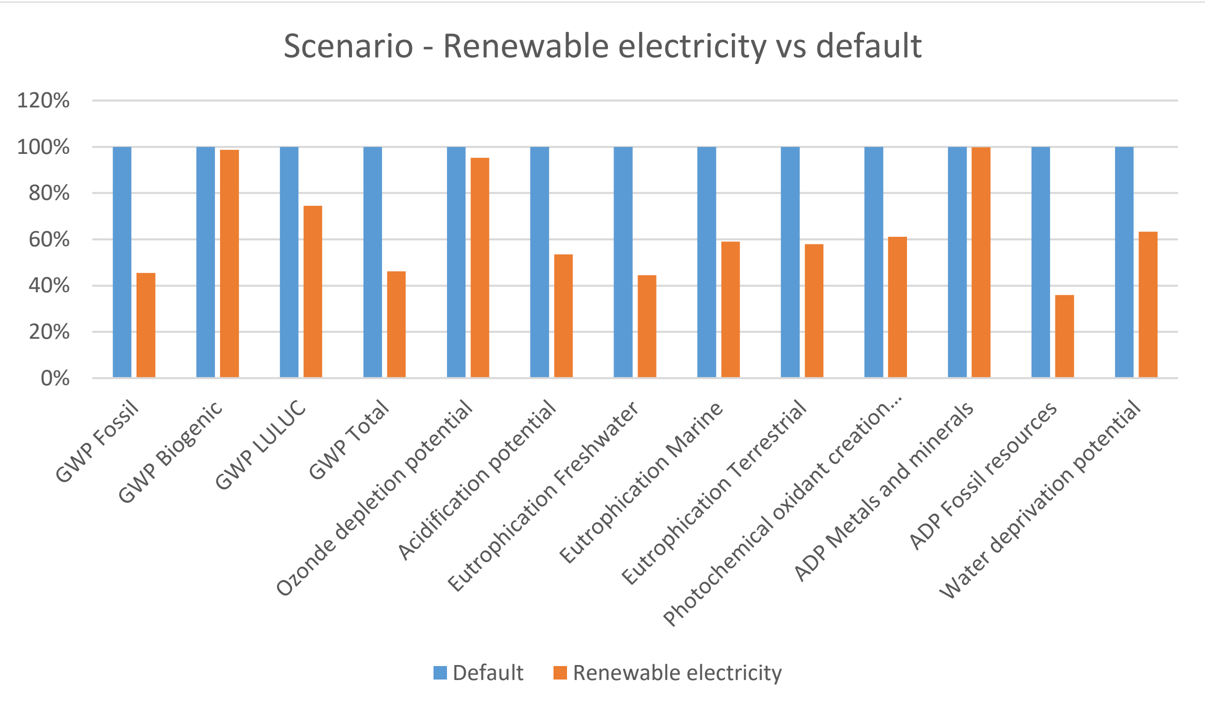

Figure 20: Scenario – renewable electricity in use phase compared to default scenario.

The result table to be presented as additional information in the EPD is shown in Table 37.

Table 37: Scenario – renewable electricity in use phase. Impact categories for EPD.

PARAMETER		UNIT	Upstream	Core	Downstream	Total
Global warming potential (GWP)	Fossil	kg CO2 eq.	6,85E+02	3,27E+01	4,12E+02	1,13E+03

	Biogenic	kg CO2 eq.	2,89E+00	3,58E-01	2,35E+01	2,67E+01
	Land use and land transformation	kg CO2 eq.	9,88E-01	1,70E+00	5,59E+00	8,28E+00
	TOTAL	kg CO2 eq.	6,88E+02	3,47E+01	4,41E+02	1,16E+03
Depletion potential of the stratospheric ozone layer (ODP)		kg CFC 11 eq.	1,17E-03	8,45E-06	3,52E-05	1,21E-03
Acidification potential (AP)		kg mol H+ eq.	4,76E+00	3,11E-01	2,16E+00	7,23E+00
Eutrophication potential (EP)	Aquatic freshwater	kg P eq.	6,76E-01	1,32E-02	1,68E-01	8,57E-01
	Aquatic marine	kg N eq.	1,01E+00	7,71E-02	5,64E-01	1,65E+00
	Aquatic terrestrial	mol N eq.	8,61E+00	9,61E-01	4,47E+00	1,40E+01
Photochemical oxidant creation potential (POCP)		kg NMVOC eq.	2,63E+00	2,51E-01	1,56E+00	4,44E+00
Abiotic depletion potential (ADP)	Metals and minerals	kg Sb eq.	1,68E-01	1,10E-03	1,09E-02	1,80E-01
	Fossil resources	MJ, net calorific value	8,54E+03	3,65E+02	4,82E+03	1,37E+04
Water deprivation potential (WDP)		m3 world eq.	2,14E+02	1,31E+01	1,47E+02	3,74E+02

As seen in Figure 21, it is now the upstream life cycle part that has the biggest contribution in most impact categories. In the default scenario, the downstream had a much higher impact in most categories, see Figure 12.

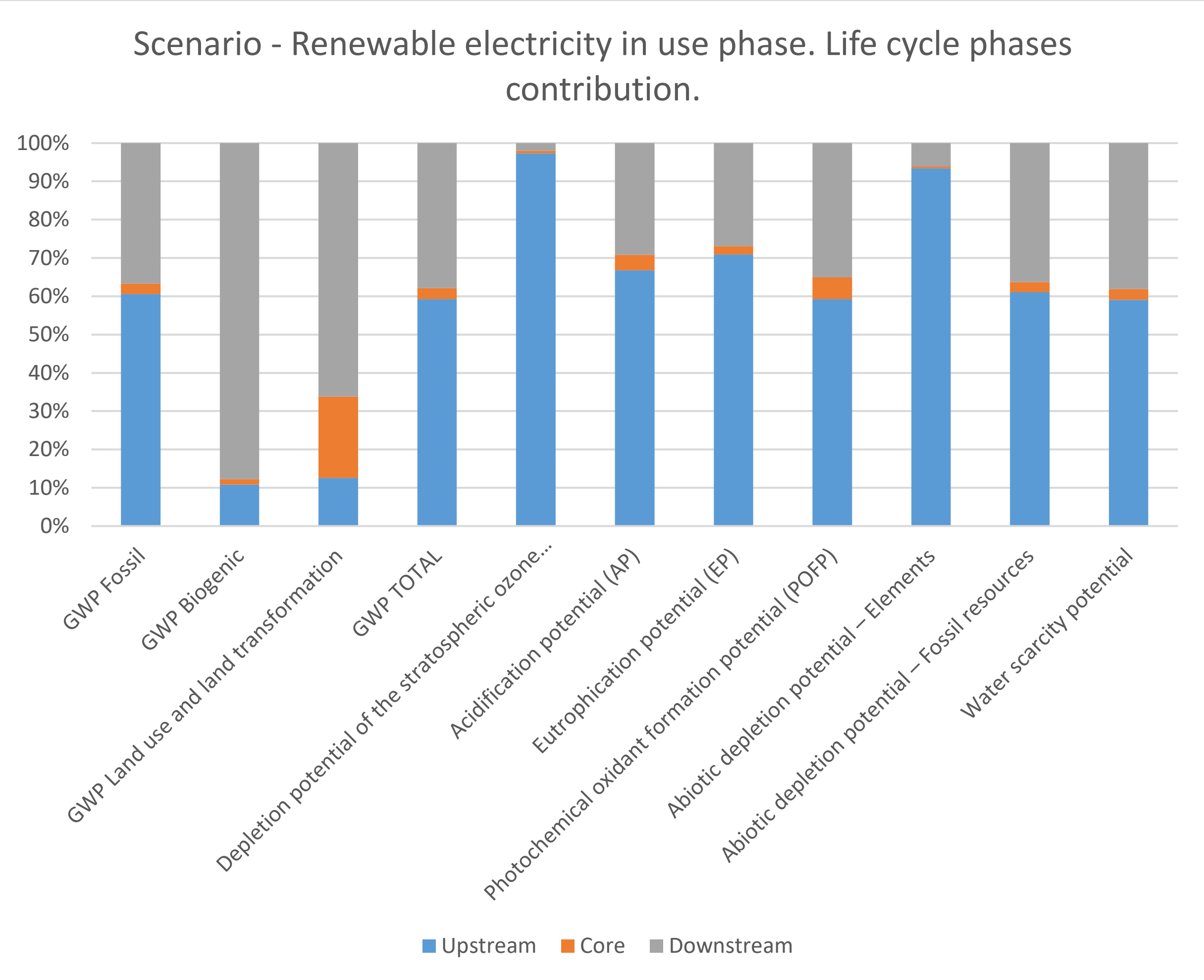

Figure 21: Scenario – renewable electricity in use phase. Contributing parts of the lifecycle.

A Sankey diagram of GWP is shown in Figure 22. It shows that the main impact now comes from the materials (56%), including PCBs (27%), followed by the production of the polyester thread.

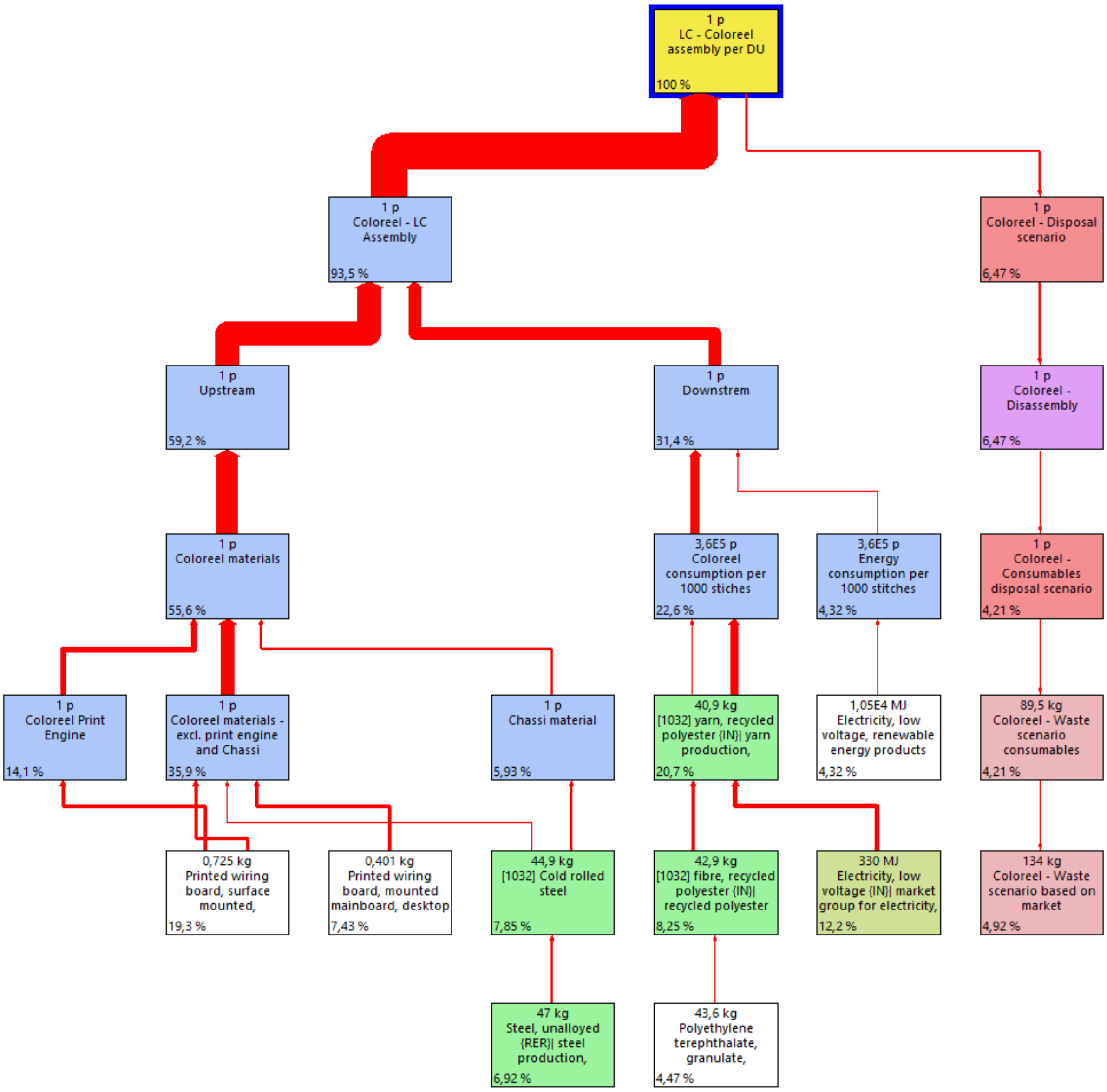

Figure 22: Scenario – renewable electricity in use phase. Sankey diagram showing the GWP. Cut-off 4%.

6.4 Data quality assessment

An evaluation of the data requirements as established in section 3.3.8 is made. The data requirement is separated into upstream, core and downstream.

6.4.1 Upstream processes

The following requirements apply to the upstream processes:

- Data referring to processes and activities upstream in a supply chain over which an organisation has direct management control shall be specific and collected on site.
  - Coloreel has no operational control over upstream processes and activities
- Data referring to contractors that supply main parts, packaging, or main auxiliaries should be requested from the contractor as specific data, as well as infrastructure, where relevant.

- ➢ **The suppliers of the print engine and chassis has been contacted. Data on energy and type of material in the print engine has been received. Data on the energy for the production of the chassis has been received.**
- ❖ The transport of main parts and components along the supply chain to a distribution point (e.g., a stockroom or warehouse) where the final delivery to the manufacturer can take place based on the actual transportation mode, distance from the supplier, and vehicle load.
  - ➢ **The transport distance of incoming materials is based on the originating country of the top 75% components based on weight, see section 4.6.**
- ❖ For the electricity used in the upstream processes, electricity production impacts shall be accounted for in this priority when specific data are used in the upstream processes:
  1. Specific electricity mixes as generated, or purchased, from an electricity supplier.
     a. **Renewable electricity with certificate used for the production of the chassis, see Appendix 3.**
  2. National residual electricity mix or residual electricity mix on the market
  3. National electricity production mix or electricity mix on the market.
     a. **Ecoinvent market process for electricity consumption in the production of the print engine used. Residual mix should preferable be used, however residual electricity data on the Chinese grid is not easily available and the impact very low (0,2% of total climate impact)**
- ❖ Packaging: specific data shall be used for the consumer packaging production if it is under the direct control of the organization or if the environmental impact related to the consumer packaging production is more than 10% of the total product environmental indicators.
  - ➢ **The packaging is not under direct control of Coloreel and stands for less than 10% of the impact in all categories.**

6.4.2 Core processes

The following requirements apply to the core processes:

- ❖ Specific data shall be used for the assembly of the product and for the manufacture of main parts as well as for on-site generation of steam, heat, electricity, etc., where relevant.
  - ➢ **Specific data regarding energy and materials has been received for the assembly of Coloreel (Scanfil), the print engine (Ricoh), the chassis (AQ Components)**
- ❖ For the electricity used in the core processes, electricity production impacts shall be accounted for in this priority:
  1. Specific electricity mixes as generated, or purchased, from an electricity supplier.
     a. **Renewable electricity with certificate used in the assembly of Coloreel and the production of the chassis, see Appendix 3.**
  2. National residual electricity mix or residual electricity mix on the market
  3. National electricity production mix or electricity mix on the market.
- ❖ Transport from the final delivery point of raw materials, chemicals, main parts, and components (see above regarding upstream processes) to the manufacturing plant/place of service provision should be based on the actual transportation mode, distance from the supplier, and vehicle load, if available.
  - ➢ **The transport distance of incoming materials is based on the originating country of the top 75% components based on weight, see section 4.6. Coloreel receives components from a wide range of suppliers. A simplified transport scenario has been created to make it manageable. The impact from transportation is generally small (0,2% of total climate impact).**
- ❖ Waste treatment processes of manufacturing waste should be based on specific data, if available.
  - ➢ **Amount of waste and type of management has been reported for the assembly of Coloreel by Scanfil. Matching processes from ecoinvent has been chosen.**

6.4.3 Downstream processes

The following requirements apply to the downstream processes:

- ❖ Data for the use stage are usually based on scenarios, but specific data should be used when available and relevant.
  - ➢ **A scenario has been created based on a typical use case of the Coloreel unit.**
- ❖ Data on the pollutant emissions from the use stage should be based on documented tests, verified studies in conjunction with average or typical product use, or recommendations concerning suitable product use. Whenever applicable, test methods shall be internationally recognised.
  - ➢ **No direct pollutant emissions occur.**
- ❖ The use of electricity in the region/country where the product is used (as specified in the geographical scope of the EPD) shall be accounted for in the following priority:
  1. National residual electricity mix or residual mix on the market
  2. National electricity production mix or electricity mix on the market
     a. **Global electricity market process has been created based on the markets where the Coloreel units are sold (60% Europe, 30% US and 10% Asia). Residual electricity mix should preferably be used, but no feasible data exists for creating of a global residual electricity mix based on the market share specified. The impact from electricity in the use phase is high for most impact categories (56% of the total climate impact).**
- ❖ The transport of the product to the customer shall be described in the reference PCR, which should reflect the actual situation to the best extent possible. The following priority should be used:
  1. Actual transportation distances and types.
     a. **A transport scenario has been created based on the markets where Coloreel is sold, see section 4.6.**
- ❖ Scenarios for the end-of-life stage shall be technically and economically practicable and compliant with current regulations in the relevant geographical region based on the geographical scope of the EPD.
  - ➢ **Little information is known about the end-of-life management. A scenario has been crated based on the waste management scenarios as implemented by PRé sustainability and the market shares of the product, see section 4.8.**

6.4.4 DQA summary

An overall summary of the DQA as defined in the ISO 14044 standard is shown in Table 38.

Table 38: Data quality assessment for the study.

Aspect	Notes
Data quality assessment scheme	The data quality level and criteria from the product category rules will been applied when final version is released. PCR “Other special-purpose and general-purpose machinery and parts thereof.”
Geographical coverage	Upstream data: Fair (RER) Core module: Very good (site-specific) Downstream: Fair
Technological representativeness	Upstream data: Good (Generic data based on plant averages) Core module: Good (site-specific)

	Downstream: -
Time-related coverage	Upstream data: Good Core module: Very good (Generally 2021 data) Downstream: -
Validity	The technological and geographical coverage of the data chosen reflects the physical reality of the product system modelled.
Plausibility	Based on experience, the electricity in the use phase often stands for a large part of the impact if modelled on a global market. Thereafter, the impact from raw materials tends to have the largest impact.
Precision	Material and energy flow quantified based on generic data from the ecoinvent 3.8 database.
Completeness	Data accounts for all known sub-processes. All upstream processes were modelled using generic data from the ecoinvent 3.8 database, using country-specific datasets whenever available, otherwise using European datasets.
Consistency, allocation method, etc.	There are some differences in how energy has been allocated for the production of components and for the assembly of Coloreel. Generally, the suppliers have provided a number of energy use based on utilized factory space out of the total factory. Another supplier provided data based on the revenue. These are internal calculations performed by the suppliers.
Completeness and treatment of missing data	No data is found missing.
Final result of data quality assessment	The requirements as established in the PCR has been met.

6.4.5 Uncertainty check

Uncertainty of in-data will be checked in two ways. For generic data a quantitively analysis of data variability will be done by a Monte Carlo analysis. Uncertainty concerning specific data and assumptions done are analyzed in a sensitivity analysis described under section 6.2.

A Monte Carlo simulation performs distribution analysis by building models of possible results by substituting a range of values—a probability distribution—for any factor that has inherent uncertainty. It then calculates results over and over, each time using a different set of random values from the probability functions. Depending upon the number of uncertainties and the ranges specified for them, a Monte Carlo simulation involve thousands of recalculations before it is complete. Monte Carlo simulation produces distributions of possible outcome values.

Most generic data from ecoinvent 3.8 have a distribution range for input data and the cumulative effect of these distribution can be quantified with a Monte Carlo analysis.

The result from the Monte Carlo analysis can be seen in Figure 23 and Figure 24. The error bars show the 95% confidential interval. The inherit uncertainty for the water depletion is very high and the result has therefore been extracted to a separate figure. The results shows that the provided inherit uncertainty in the ecoinvent database is very high for water use, relatively high for Eutrophication, freshwater, Climate change – Biogenic and Ozone depletion. It should be noted that the high uncertainty of water use is an artefact of having inputs and outputs in the same method (and not a real uncertainty). The input and output of water flows should be equal but is in the Monte Carlo analysis changed independently of each other, thus showing a higher uncertainty.

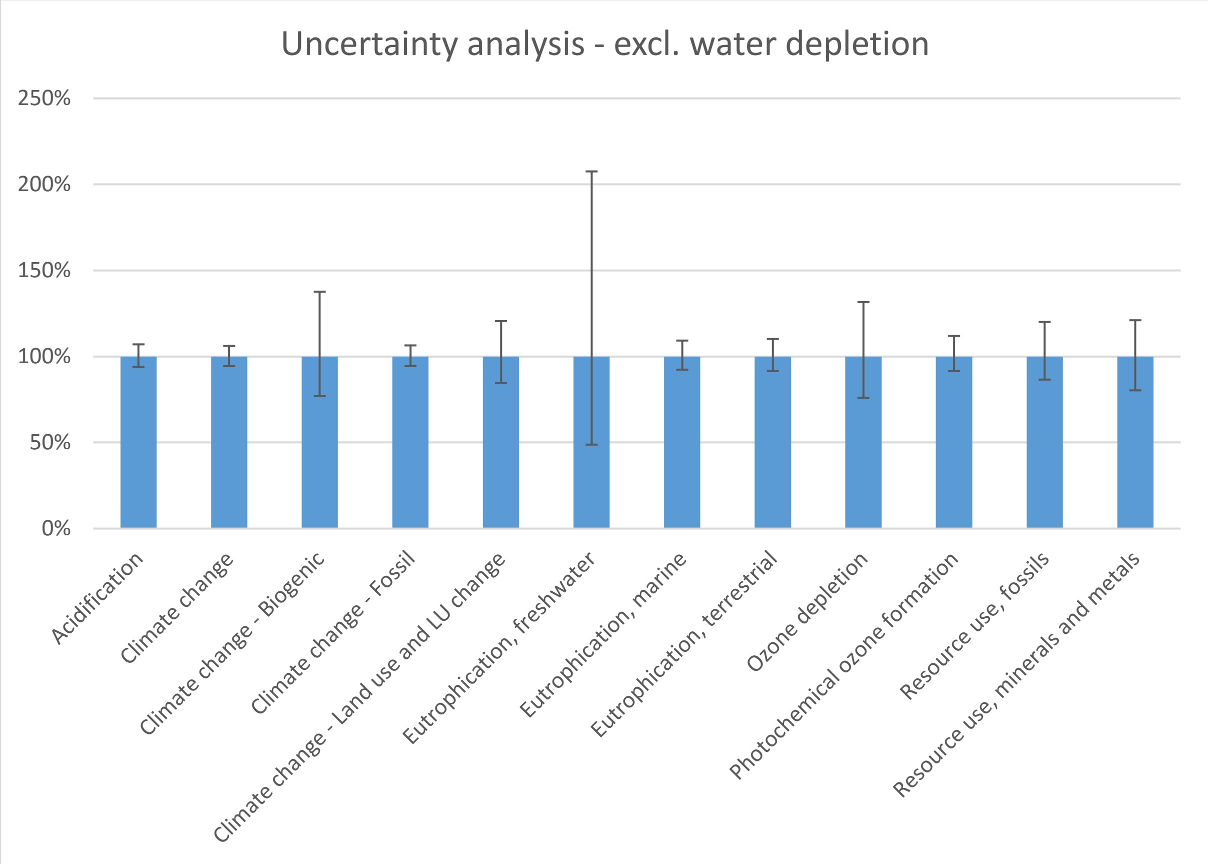

Figure 23: Results of the Monte Carlo analysis, excluding water depletion.

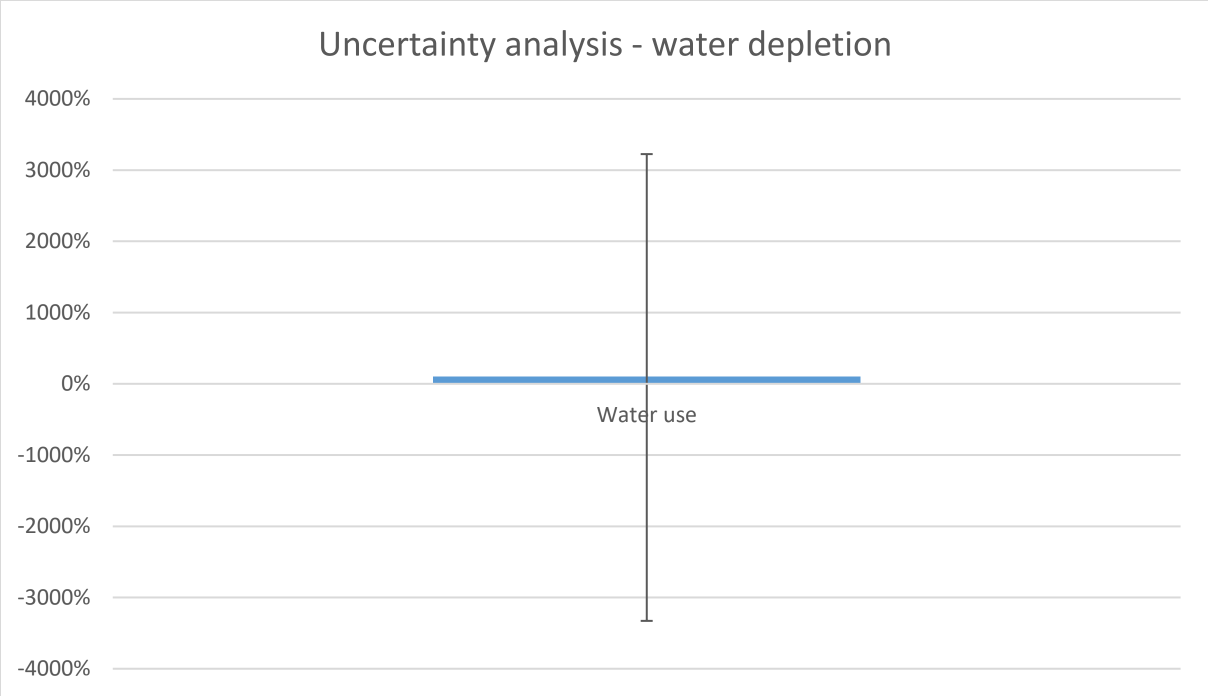

Figure 24: Results of the Monte Carlo analysis, water depletion.

6.5 Limitations

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. The LCA is based on a model of reality and contains assumptions and simplifications which will directly influence the result.

7. Conclusions and recommendations

This section will summarize the conclusions from the study in terms of highlighting the most important aspects from the results and the interpretation. Recommendations will be presented in suggestions of how to mitigate the hot spots, how to communicate the results and how to reduce the uncertainties of the study.

Given the almost water free process, the environmental impact of Coloreel in a cradle-to-grave perspective comes mainly from the use of **electricity in the use phase** followed by the production of **raw materials**. The high impact from electricity comes from the generally high use of fossil fuels for production of electricity on the markets where the Coloreel ITC-U is used. Manufacturing, transportation, and packaging stands for a small part of the overall impact.

The most important impact categories to focus on according to the EF 3.0 method are "*Resource use, minerals and metals*", "*Climate change*" and "*Resource use, fossils*". It is the use of gold and silver in the integrated circuits on the printed circuit boards that is having the biggest impact in the category "*Resource use, minerals and metals*". For "*Climate change*" and "*Resource use, fossils*", it is the electricity consumption in the use phase that is having the biggest impact. The Water deprivation potential, which has a non-significant impact, mainly comes from the downstream electricity consumption during use and from the upstream production of raw materials. The on-site water consumption used by the Coloreel unit during thread coloring is small. It is only the washing fluid and the ink that is consuming water. For the full lifetime of the unit the total on-site water consumption is 36,2 liters (32,1 liters for the washing fluid and 4,1 liters for the ink).

The most critical components are electronics such as PCBs, power units and motors, followed by the steel in the chassis. The impact from the production of the recycled polyester thread do also have a clear impact.

7.1 Recommendation on how to mitigate the hot spots

Several suggestions on how to lower the potential environmental impact is now presented.

7.1.1 Reduce the energy consumption in the use phase

Reducing the energy consumption in the use phase would drastically lower the environmental impact as seen in section 6.2.

7.1.2 Prolong the lifetime of Coloreel

The environmental impact per 1000 stitches is reduced if the lifetime of the Coloreel unit is prolonged as seen in section 6.2. This is especially apparent for the impact categories most relevant to the production of the Coloreel unit, namely the abiotic depletion, minerals, and ozone layer depletion. The global warming potential is slightly reduced but not to the same extent as abiotic depletion and ODP as it is more related to the energy consumption in the use phase.

7.1.3 Replace of reduce the use of high impact materials and components

Electronics such as printed circuit boards show a high environmental impact. Introducing a recycling scheme and increasing the use of recycled materials in the electronics would likely reduce the impact.

The unit contains rather high amount of steel in the chassis. Reducing the amount of steel would lower the impact. However, the overall impact from the chassis is relatively small as seen in Figure 13. The recycled polyester thread does also have a clear impact. Using recycled polyester compared to primary material is lowering the impact. It seems to be the electricity used in the production of the thread that is having the biggest impact. The data on the recycled polyester thread contains high uncertainties as it is modelled based on a generic ecoinvent process and not based on primary data. Placing the production of the polyester thread in country with a less polluting electricity mix would be beneficial.

The polytetrafluoroethylene (PTFE) used in the Contact fix concave/convex units are having most of the impact for the ozone layer depletion potential. It does also have a rather high climate impact potential, around 45 kg CO2-eq for the two components.

7.2 How to communicate the results

An EPD will be created based on the result of the LCA. The result in the EPD can be used for external communication with customers and other interested parties.

7.3 How to reduce uncertainties

Components with high environmental impact such as printed circuit boards have been modelled with generic data from ecoinvent. These has a high degree of uncertainties as the industry of electronics is progressing at a fast pace. It is generally the integrated circuits on the PCBs that is having the biggest contribution. Finding more granular information on what components are assembled on the PCBs would be beneficial. The true environmental impact from electronics might be lower but is still likely to be relevant.

The recycled polyester thread has been modelled with generic LCI data from ecoinvent. Using more site-specific data would give a more accurate result.

7.4 Internal follow-up procedures

For EPDs, internal follow-up procedures shall be established to confirm whether the information in the EPD remains valid or if the EPD needs to be updated during its validity period. The GPI state that the main parameters that may mandate an update shall be identified through a sensitivity analysis. The established procedure may or may not involve a contracted verifier. The follow-up shall be at least annually and should be made with a frequency that will allow for an acceptable coverage of changes that might occur.

The procedure should include how the organization monitors any significant changes that have taken place in the information submitted as input data for the information in the EPD, such as raw material acquisition, transportation modes, manufacturing processes, changes in product design, or updated legislation. The follow-up procedure may be made part of an existing quality or environmental management system.

An EPD shall be updated and re-verified during its validity if changes in technology or other circumstances have led to:

- an increase of 10% or more of any of the indicators listed in Section 9.5.5 as declared in the EPD,
- errors in the declared information, or

- significant changes to the declared product information, content declaration, or additional environmental, social, or economic information.

8. Bibliography

Baumann, H., & Tillman, A.-M. (2004). The Hitch Hiker's Guide to LCA. In *Studentlitteratur Lund*.

Böckin, D., Goffetti, G., Baumann, H., & Zobel, T. (2020). *Environmental assessment of two business models Division of Environmental Systems Analysis*.

Chequer, F., Olivera, G. A. R., Ferraz, E., Cardoso, J., Zanoni, M., & Olivera, D. P. (2013). Textile Dyes: Dyeing Process and Environmental Impact. *Eco-Friendly Textile Dyeing and Finishing*, *6*, 151–176. https://doi.org/10.5772/53659

Coloreel Group AB. (n.d.). *Operator's Manual - Coloreel ITC Unit*. Retrieved March 30, 2022, from https://www.coloreel.com/wp-content/uploads/2021/06/coloreel-operators-manual-en-coloreel.pdf

EPD International. (2021). *General Programme Instructions for the International EPD® System. Version 4.0*.

EPD International. (2022). *PCR: OTHER SPECIAL- AND GENERAL-PURPOSE MACHINERY AND PARTS THEREOF VERSION 4.0*. https://environdec.com/pcr-library

EPD International AB. (n.d.). *Impact Indicators*. Retrieved March 23, 2022, from https://environdec.com/resources/indicators

European Commission. (2012). *Product Environmental Footprint (PEF) Guide*. https://ec.europa.eu/environment/eussd/pdf/footprint/PEF methodology final draft.pdf

Frischknecht, R., Jungbluth, N., Althaus, H. J., Doka, G., Dones, R., Hischier, R., Hellweg, S., Humbert, S., Margni, M., Nemecek, T., & Spielmann, M. (2007). *Implementation of Life Cycle Impact Assessment Methods: Data v2.0. ecoinvent report No. 3*.

Gillenwater, M. W. (2013). *Redefining recs: additionality in the voluntary renewable energy certificate market* [Princeton University]. https://www.proquest.com/dissertations-theses/redefining-recs-additionality-voluntary-renewable/docview/1367619803/se-2?accountid=10041

Goedkoop, M., & Spriensma, R. T. (1999). *The Eco-Indicator 99: A Damage Oriented Method for Life Cycle Impact Assessment Methodology*.

Guinée, J., Gorrée, M., Heijungs, R., Huppes, G., Kleijn, R., Koning, A., Oers, L., Wegener Sleeswijk, A., Suh, S., Haes, H., Bruijn, H., van Duin, R., & Huijbregts, M. (2002). *Handbook on Life Cycle Assessment - Operational Guide to the ISO Standards*.

Hauschild, M. Z., & Huijbregts, M. A. J. (2015). *Life Cycle impact assessment. In series LCA compendium – the complete world of Life Cycle Assessment*.

ISO. (2006a). *ISO 14040:2006, Environmental management — Life cycle assessment — Principles and framework*. 1–28.

ISO. (2006b). *ISO 14044:2006, Environmental management — Life cycle assessment — Requirements and guidelines*. https://doi.org/10.1007/s11367-011-0297-3

Steffen, W., K. Richardson, J. Rockström, S.E. Cornell, et. al. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223), 1259855. https://doi.org/10.1126/science.1259855

Tillman, A.-M., Ljunggren Söderman, M., André, H., Böckin, D., & Willskytt, S. (2020). *Circular economy and its impact on use of natural resources and the environment - Chapter from the upcoming book "Resource-Efficient and Effective Solutions – A handbook on how to develop and provide them."*

TNO Biobased and Circular Technologies. (n.d.). *Phyllis2*. Retrieved March 23, 2022, from https://phyllis.nl/Browse/Standard/ECN-Phyllis#poly

9. Appendix list

Appendix 1 Methods for Impact Assessment

Classification and characterization

Classification means that all categories of data are sorted into different categories of environmental effects (see Figure 25). Readymade methods for this have been used to evaluate environmental effects from a broad perspective and find the categories with the most potential impact. The most commonly used methods include Ecoindicator and EPS. These methods also include characterization (and weighting, described below). In characterization, the aim is to quantify each element's contribution to the different categories of environmental effect, respectively. To do this, each category of environmental effect is multiplied with characterization factors that are specific for the data and the category of environmental effect. The result of the characterization indicates what or which emissions lead to a significant environmental influence. Each of these characteristics represents the potential environmental influence that could arise if an element were released into the environment or if a resource was consumed. Classification and characterization are where all items in the inventory are assigned to the effect it is likely to have on the environment.

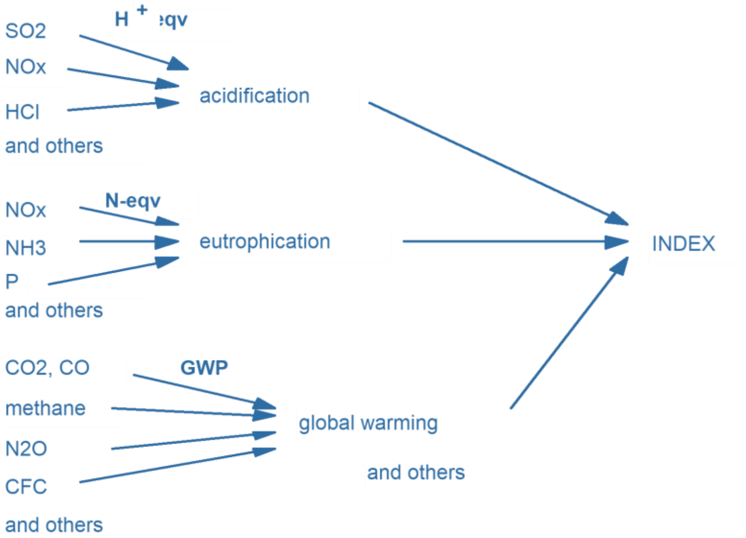

Figure 25: An illustration of the Impact Assessment of an LCA.

When this link is determined, we call it an environmental aspect. This environmental aspect has to be linked between the environment and the process before you can say that it is established and that the process is unsustainable. In the early stages of the Life Cycle Assessment, substances that were found in the inventory are assigned to environmental aspects. In order to contribute to the ultimate goal of sustainability, it is important to also describe the local and global environment. Environmental aspects that may have an impact are located and after that, the link to the inventory and the process path features may be analyzed and established.

LCA impact categories vs planetary boundaries

It can be relevant to note that the impact categories described above do not have a one to one correlation with the planetary boundaries as described by Steffen et al. (Steffen, W., K. Richardson, J. Rockström, S.E. Cornell, 2015). Table 39 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 ILCD indicators of photochemical ozone creation potential and respiratory effects are meant to represent direct human health impacts.

The corresponding planetary boundary is atmospheric aerosol loading, but this is instead mainly meant to represent effects on monsoon rains. Furthermore, acidification in ILCD 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 ILCD standard 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 ILCD, while the planetary boundaries do not include a category for abiotic resource depletion.

Table 39: Planetary boundaries, by Steffen et al. (Steffen, W., K. Richardson, J. Rockström, S.E. Cornell, 2015), and mid-point environmental impact indicators in LCA recommended by ILCD (Hauschild & Huijbregts, 2015). Adapted from (Tillman et al., 2020).

Planetary boundaries	Mid-point indicators in LCA as recommended by ILCD	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 non-cancer)	
Atmospheric aerosol loading	Photochemical ozone creation	Some correspondence
	Respiratory effects, inorganic	
Ocean acidification	Freshwater acidification	
Biospheric integrity (biodiversity loss)	Resources land use	
Land system change	Resources land use	
Freshwater use	Resources dissipated water	
-	Resources minerals and metals	No correspondence
-	Resources fossils	
-	Ionising radiation	

Weighting
The results of an LCA may depend on the method for impact assessment. There are several different models to assist in the assessment of the environmental impacts connected to the life cycle, e.g. ecological scarcity (ECO), the environmental theme method (ET), ECO indicator (EI), ReCiPe and the Environmental Priority Strategies in Product Design (EPS) method.

Using a weighting method implies that all of the data classes are weighted together so that only one number is expressed for the weighting method. The different data categories are weighed from some form of valuation principle. The basis of valuation could be either individual or a community's political and/or morality valuations. The weighting expresses the relation between values in the community and variations in nature. The more effect or deviation an environmental aspect has from the valuations, the higher the weighting value assigned to that environmental aspect.

The basis of the valuations used to develop weighting methods could be; political decisions, technical-financial conditions, nature conditions, health effects, panels or studies of behavioral patterns. In a weighting method, there is either one or a combination of valuation bases. Since the basis of valuations varies for each weighting method, a comparison between different methods will give a corresponding shift in the result.

The most commonly used weighting methods are collected in the book "The Hitch Hiker's Guide to LCA", written by Baumann & Tillman (Baumann & Tillman, 2004), and the most important are presented below:

Ecoindicator'99 is a weighting method based on the distance-to-target principle, and the target is established as environmental critical loads of 5 % ecosystem degeneration, or similar. Ecoindicator'99 weights are determined from three different cultural perspectives; hierarchist, egalitarian and individualist perspectives. Ecoindicator’99 is based on Goedkoop and Spriensma (Goedkoop & Spriensma, 1999).

EPS 2000 is based on the willingness-to-pay for avoiding damages on environmental safeguard subjects. The EPS method is especially suitable for the assessment of global impacts, such as climate change potential and resource depletion. The EPS indices are prepared by a group at the Chalmers University of Technology and a steering committee from the industry in Sweden.

Among the most common methods, however, are EF and ReCiPe and they deserve some more details, which are presented below.

The impact assessment methods EF 3.0 and ReCiPe 2008
While the Environmental Footprint method is used in this report, it is built on the foundation of the ReCiPe 2008 method, which is presented in detail here.

ReCiPe LCIA Methodology is a methodological tool used to quantitatively analyze the life cycle of products/activities. ISO 14040 and 14044 provide a generic framework. After the goal and scope have been determined and data collected, an inventory result is calculated. This inventory result is often a long list of emissions, consumed resources and sometimes other items. The interpretation of this list is difficult. An LCIA procedure, such as the ReCiPe method is designed to help with this interpretation. The primary objective of the ReCiPe method is to transform the long list of inventory results, into a limited number of indicator scores. These indicator scores express the relative severity of an environmental impact category. In ReCiPe indicators are determined on two levels:

- Eighteen midpoint indicators
- Three endpoint indicators

ReCiPe uses an environmental mechanism as the basis for the modelling. An environmental mechanism can be seen as a series of effects that together can create a certain level of damage to, for instance, human health or ecosystems. For climate change, we know that a number of substances increase radiative forcing. This means that heat is prevented from being radiated from Earth to space. As a result, more energy is trapped on Earth and temperature increases. As a result, we can expect changes in habitats for living organisms, resulting in the potential extinction of species. From this example, it is clear that the longer the chains of environmental mechanisms, the higher the uncertainties (see Figure 26). Radiative forcing is a physical parameter that can be relatively easily measured in a laboratory. The resulting temperature increase is less easy to determine, as there are many parallel positive and negative feedback. Our understanding of the expected change in habitat is also not complete, etc.

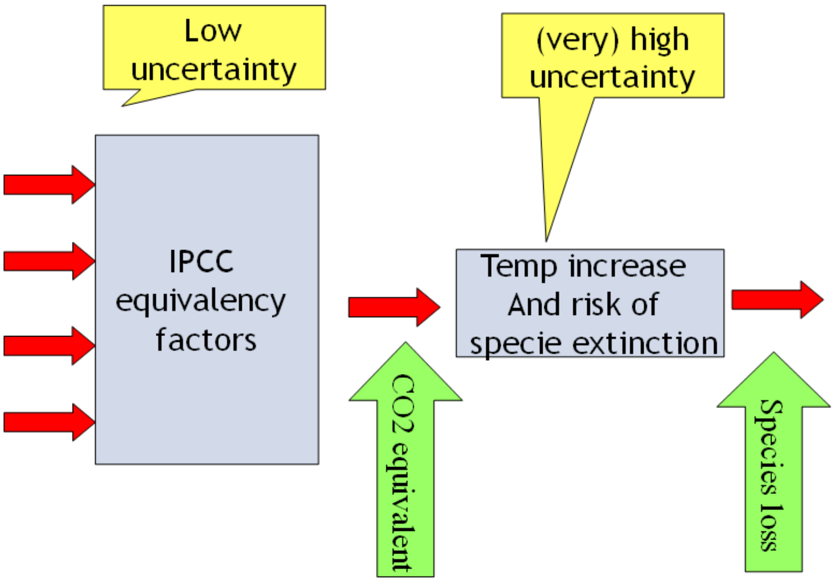

Figure 26: Example of a harmonized midpoint-endpoint model for climate change, linking to human health and ecosystem damage.

Hence, the obvious benefit of only taking the first step is the relatively low uncertainty. However, ReCiPe combines mid- and endpoints. Eighteen midpoint indicators are used, but three much more uncertain endpoint indicators are also calculated. The motivation to calculate the endpoint indicators is that the large number of midpoint indicators is difficult to interpret, partially as there are too many, partially because they have a very abstract meaning. How to compare radiative forcing with base saturation numbers that express acidification? The indicators at the endpoint level are intended to facilitate easier interpretation, as there are only three, and they have a more easily grasped meaning. The idea is that each user can choose at which level they wants to have the result:

- Eighteen robust midpoints, that are relatively robust, but not easy to interpret
- Three easy to understand, but more uncertain endpoints:
  - Damage to Human health
  - Damage to ecosystems
  - Damage to resource availability

The user can thus choose between uncertainty in the indicators on the one hand and uncertainty in the correct interpretation of indicators on the other hand. Figure 27 provides the overall structure of the method.

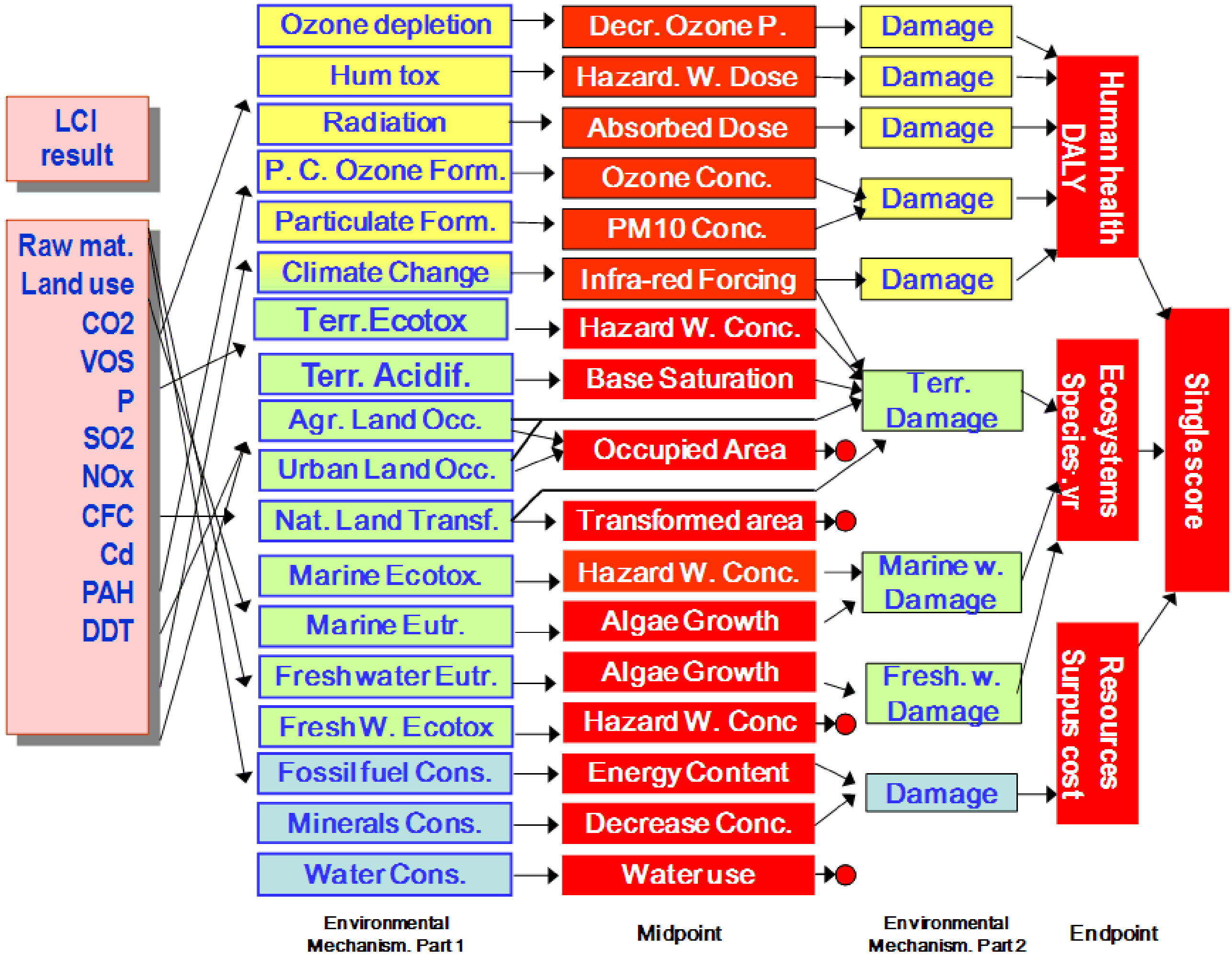

Figure 27: ReCiPe Characterization links.

Appendix 2 Cumulative Energy Demand, CED

Cumulative Energy Demand (CED) is a method to calculate direct and indirect use of energy resources, commonly referred to as *primary energy*. Characterization factors are given for the energy resources divided into five impact categories:

- Non-renewable, fossil
- Non-renewable, nuclear
- Renewable, biomass
- Renewable, wind, solar, geothermal
- Renewable, water

Some studies also add energy from waste as an indicator. This is not done here, since waste is not considered to be primary energy, and thus the input of energy resources may be less than the final energy (heat and electricity) delivered by the system.

Normalization is not a part of this method. To get a total ("cumulative") energy demand, each impact category is given the weighting factor 1 (Frischknecht et al., 2007).

Appendix 3 Energy certificates

Miljöintyg

El från vindkraft

Kungsleden AB

köper förnybar el från urspungsmärkt vindkraft under avtalstiden. På så sätt stödjer ni utbyggnaden av vindkraft och minskar företagets miljöpåverkan.

Vi garanterar att er årsförbrukning framställs i form av vindkraft.

Intyget gäller för 20210101 - 20211231

Bästa hälsningar

Emma Borgström
Head of Energy Sales B2B
E.ON Energilösningar AB

e·on

Figure 28: Electricity certificate for the producer of the chassis. AQ Components Västerås AB. Property owner Kungsleden AB.

Intyg om 100 % förnybar el

Härmed intygas att

Industrigallerian A E AB

556252-6466

köper vattenkraftproducerad el med EPD
från Skånska Energi AB under 2020

EPD-Environmental Product Declaration – är en av AB Svenska Miljöstyrningsrådet
registrerad certifierad miljövarudeklaration med kvalitetssäkrade
uppgifter om exempelvis resursförbrukning, utsläpp, avfall och återvinning.

Södra Sandby den 11 maj 2020

Helena Käll
Skånska Energi AB

skånska energi
100% sol och vatten

Figure 29: Electricity certificate for the assembly factory. Scanfil AB. Property owner Industrigallerian A E AB. The electricity agreement was updated 2020 and runs for 5 years.

Appendix 4 Waste treatment processes

Table 40: Waste treatment process - Municipal solid waste (waste scenario) {EU27}| Treatment of waste | Cut-off, U

Comment		
This waste scenario record links to ecoinvent incineration and landfill waste treatment processes – the recycling waste treatment processes linked to were created by PRé Sustainability. This record was created by PRé Sustainability thus not reviewed by ecoinvent. This datasheet is valid for the municipal solid waste of EU27. Europe without Switzerland incineration and landfill processes were used. The percentages indicate the 'Recycling rate' for the purposes of Article 6(1) of Directive 94/62/EC by which is meant the total quantity of recycled packaging waste, divided by the total quantity of generated packaging waste. Data for European countries were retreived from the Eurostat table 'Packaging waste by waste management operations [env_waspac]', extracted on 27 October 2021. The data are representative for 2019. Percentages of non-recycled material that go to waste incineration and landfill are based on the Eurostat table 'Municipal waste by waste management operations [env_wasmun]', extracted on 27-10-2021. The percentage of composting is based on the later table, assuming 44% of the total waste is compostable waste (based on www.compostnetwork.info).		
Separated waste	Waste type	Percentage
Core board (waste treatment) {GLO}| recycling of core board | Cut-off, U	Cardboard	82,3
Paper (waste treatment) {GLO}| recycling of paper | Cut-off, U	Packaging paper	82,3
Packaging glass, white (waste treatment) {GLO}| recycling of packaging glass, white | Cut-off, U	Glass	76,3
Steel and iron (waste treatment) {GLO}| recycling of steel and iron | Cut-off, U	Ferro metals	78
Aluminium (waste treatment) {GLO}| recycling of aluminium | Cut-off, U	Aluminium	78
Steel and iron (waste treatment) {GLO}| recycling of steel and iron | Cut-off, U	Steel	78
Mixed plastics (waste treatment) {GLO}| recycling of mixed plastics | Cut-off, U	Plastics	41
PE (waste treatment) {GLO}| recycling of PE | Cut-off, U	PE	41
PET (waste treatment) {GLO}| recycling of PET | Cut-off, U	PET	41
PP (waste treatment) {GLO}| recycling of PP | Cut-off, U	PP	41
PS (waste treatment) {GLO}| recycling of PS | Cut-off, U	PS	41
PVC (waste treatment) {GLO}| recycling of PVC | Cut-off, U	PVC	41
Paper (waste treatment) {GLO}| recycling of paper | Cut-off, U	Paper	82,3
Paper (waste treatment) {GLO}| recycling of paper | Cut-off, U	Newspaper	82,3
Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, U	Compost	40,2
Remaining waste		
Municipal solid waste (waste scenario) {Europe without Switzerland}| Treatment of municipal solid waste, landfill | Cut-off, U		47,2

Municipal solid waste (waste scenario) {Europe without Switzerland}| Treatment of municipal solid waste, incineration | Cut-off, U		52,8

Table 41: Waste treatment process - Municipal solid waste (waste scenario) {US}| Treatment of waste | Cut-off, U

Comment		
This waste scenario record links to ecoinvent incineration and landfill waste treatment processes – the recycling waste treatment processes linked to were created by PRé Sustainability. This record was created by PRé Sustainability thus not reviewed by ecoinvent. This datasheet is valid for the municipal solid waste of the Unites States. Swiss incineration and landfill processes were used as proxy for US. The percentages indicate the 'Recycling rate' for the purposes of Article 6(1) of Directive 94/62/EC by which is meant the total quantity of recycled packaging waste, divided by the total quantity of generated packaging waste. Data for US are based on "Advancing Sustainable Materials Management: 2018 Tables and Figures, Assessing Trends in Materials Generation and Management in the United States (December 2020)". These data are representative for 2018.		
Separated waste	Waste type	Percentage
Core board (waste treatment) {GLO}| recycling of core board | Cut-off, U	Cardboard	96,5
Paper (waste treatment) {GLO}| recycling of paper | Cut-off, U	Packaging paper	20,8
Packaging glass, white (waste treatment) {GLO}| recycling of packaging glass, white | Cut-off, U	Glass	31,3
Steel and iron (waste treatment) {GLO}| recycling of steel and iron | Cut-off, U	Ferro metals	33,1
Aluminium (waste treatment) {GLO}| recycling of aluminium | Cut-off, U	Aluminium	34,9
Steel and iron (waste treatment) {GLO}| recycling of steel and iron | Cut-off, U	Steel	74,8
Mixed plastics (waste treatment) {GLO}| recycling of mixed plastics | Cut-off, U	Plastics	13,6
PE (waste treatment) {GLO}| recycling of PE | Cut-off, U	PE	9,9
PET (waste treatment) {GLO}| recycling of PET | Cut-off, U	PET	25,4
PP (waste treatment) {GLO}| recycling of PP | Cut-off, U	PP	2,7
PS (waste treatment) {GLO}| recycling of PS | Cut-off, U	PS	3,6
PVC (waste treatment) {GLO}| recycling of PVC | Cut-off, U	PVC	0
Paper (waste treatment) {GLO}| recycling of paper | Cut-off, U	Paper	0
Paper (waste treatment) {GLO}| recycling of paper | Cut-off, U	Newspaper	0
Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, U	Compost	0
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Aluminium	13
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Coppers	12
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Steel	5
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Tin Sheet	12

Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Glass	13,4
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Paper	15,5
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Cardboard	0,7
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Packaging paper	15,5
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Newspaper	15,5
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Paint	16,9
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Plastics	16,9
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	PE	16,9
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	PET	16,9
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	PP	16,9
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	PS	16,9
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	PUR	16,9
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	PVC	16,9
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Rubber	16,9
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Textile	15,5
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Wood	15,5
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Biopolymers	16,9
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Brick	0
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Cement	0
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Ceramics	0
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Non-ferro	12
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Others	0
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	PVDC	16,9
Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, incineration | Cut-off, U	Zincs	12
Remaining waste		

Municipal solid waste (waste scenario) {CH}| Treatment of municipal solid waste, landfill | Cut-off, U		100

Table 42: Waste treatment process - Municipal solid waste (waste scenario) {CN}| Treatment of waste | Cut-off, U

<table>
<tr><th colspan="3">Comment</th></tr>
<tr><td colspan="3">This waste scenario record links to ecoinvent incineration and landfill waste treatment processes – the recycling waste treatment processes linked to were created by PRé Sustainability. This record was created by PRé Sustainability thus not reviewed by ecoinvent.
This datasheet is valid for the municipal solid waste of China. Rest of the World incineration and landfill processes were used as proxy for China. The percentages indicate the 'Recycling rate' for the purposes of Article 6(1) of Directive 94/62/EC by which is meant the total quantity of recycled packaging waste, divided by the total quantity of generated packaging waste. The data are based on various sources.
Source: http://m.people.cn/n4/2020/1015/c4048-14488350.html
Development Report of China Plastic Recycling Industry published by China Plastic Recylcing Association
These data are representative for 2018.</td></tr>
<tr><td>Separated waste</td><td>Waste type</td><td>Percentage</td></tr>
<tr><td>Core board (waste treatment) {GLO}| recycling of core board | Cut-off, U</td><td>Cardboard</td><td>50</td></tr>
<tr><td>Paper (waste treatment) {GLO}| recycling of paper | Cut-off, U</td><td>Packaging paper</td><td>50</td></tr>
<tr><td>Packaging glass, white (waste treatment) {GLO}| recycling of packaging glass, white | Cut-off, U</td><td>Glass</td><td>14</td></tr>
<tr><td>Steel and iron (waste treatment) {GLO}| recycling of steel and iron | Cut-off, U</td><td>Ferro metals</td><td>85</td></tr>
<tr><td>Aluminium (waste treatment) {GLO}| recycling of aluminium | Cut-off, U</td><td>Aluminium</td><td>85</td></tr>
<tr><td>Steel and iron (waste treatment) {GLO}| recycling of steel and iron | Cut-off, U</td><td>Steel</td><td>85</td></tr>
<tr><td>Mixed plastics (waste treatment) {GLO}| recycling of mixed plastics | Cut-off, U</td><td>Plastics</td><td>30</td></tr>
<tr><td>PE (waste treatment) {GLO}| recycling of PE | Cut-off, U</td><td>PE</td><td>30</td></tr>
<tr><td>PET (waste treatment) {GLO}| recycling of PET | Cut-off, U</td><td>PET</td><td>30</td></tr>
<tr><td>PP (waste treatment) {GLO}| recycling of PP | Cut-off, U</td><td>PP</td><td>30</td></tr>
<tr><td>PS (waste treatment) {GLO}| recycling of PS | Cut-off, U</td><td>PS</td><td>30</td></tr>
<tr><td>PVC (waste treatment) {GLO}| recycling of PVC | Cut-off, U</td><td>PVC</td><td>30</td></tr>
<tr><td>Paper (waste treatment) {GLO}| recycling of paper | Cut-off, U</td><td>Paper</td><td>50</td></tr>
<tr><td>Paper (waste treatment) {GLO}| recycling of paper | Cut-off, U</td><td>Newspaper</td><td>50</td></tr>
<tr><td>Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, U</td><td>Compost</td><td>0</td></tr>
<tr><td>Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U</td><td>Aluminium</td><td>6</td></tr>
<tr><td>Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U</td><td>Coppers</td><td>6</td></tr>
<tr><td>Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U</td><td>Steel</td><td>6</td></tr>
</table>

Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Tin Sheet	6
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Glass	34,4
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Paper	20
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Cardboard	20
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Packaging paper	20
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Newspaper	20
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Paint	30
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Plastics	30
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	PE	30
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	PET	30
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	PP	30
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	PS	30
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	PUR	30
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	PVC	30
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Rubber	30
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Textile	20
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Wood	20
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Biopolymers	30
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Brick	0
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Cement	0
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Ceramics	0
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Non-ferro	6
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Others	0
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	PVDC	30

Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, incineration | Cut-off, U	Zincs	6
Remaining waste		
Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, landfill | Cut-off, U		75
Municipal solid waste (waste scenario) {GLO}| Treatment of municipal solid waste, open dump, wet infiltration class (500mm) | Cut-off, U		25

Table 43: Waste treatment process - Municipal solid waste (waste scenario) {SE}| Treatment of waste | Cut-off, U

Comment		
This waste scenario record links to ecoinvent incineration and landfill waste treatment processes – the recycling waste treatment processes linked to were created by PRé Sustainability. This record was created by PRé Sustainability thus not reviewed by ecoinvent. This datasheet is valid for the municipal solid waste of Sweden. Europe without Switzerland incineration and landfill processes were used. The percentages indicate the 'Recycling rate' for the purposes of Article 6(1) of Directive 94/62/EC by which is meant the total quantity of recycled packaging waste, divided by the total quantity of generated packaging waste. Data for European countries were retreived from the Eurostat table 'Packaging waste by waste management operations [env_waspac]', extracted on 27 October 2021. The data are representative for 2019. Percentages of non-recycled material that go to waste incineration and landfill are based on the Eurostat table 'Municipal waste by waste management operations [env_wasmun]', extracted on 27-10-2021. The percentage of composting is based on the later table, assuming 44% of the total waste is compostable waste (based on www.compostnetwork.info).		
Separated waste	Waste type	Percentage
Core board (waste treatment) {GLO}| recycling of core board | Cut-off, U	Cardboard	75
Paper (waste treatment) {GLO}| recycling of paper | Cut-off, U	Packaging paper	75
Packaging glass, white (waste treatment) {GLO}| recycling of packaging glass, white | Cut-off, U	Glass	93,1
Steel and iron (waste treatment) {GLO}| recycling of steel and iron | Cut-off, U	Ferro metals	81
Aluminium (waste treatment) {GLO}| recycling of aluminium | Cut-off, U	Aluminium	76,2
Steel and iron (waste treatment) {GLO}| recycling of steel and iron | Cut-off, U	Steel	85,8
Mixed plastics (waste treatment) {GLO}| recycling of mixed plastics | Cut-off, U	Plastics	53,2
PE (waste treatment) {GLO}| recycling of PE | Cut-off, U	PE	53,2
PET (waste treatment) {GLO}| recycling of PET | Cut-off, U	PET	53,2
PP (waste treatment) {GLO}| recycling of PP | Cut-off, U	PP	53,2
PS (waste treatment) {GLO}| recycling of PS | Cut-off, U	PS	53,2
PVC (waste treatment) {GLO}| recycling of PVC | Cut-off, U	PVC	53,2
Paper (waste treatment) {GLO}| recycling of paper | Cut-off, U	Paper	75
Paper (waste treatment) {GLO}| recycling of paper | Cut-off, U	Newspaper	75

Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, U	Compost	32,2
Remaining waste		
Municipal solid waste (waste scenario) {Europe without Switzerland}| Treatment of municipal solid waste, landfill | Cut-off, U		1,4
Municipal solid waste (waste scenario) {Europe without Switzerland}| Treatment of municipal solid waste, incineration | Cut-off, U		98,6