# Sustainability assessment of textile reuse and recycling in and outside of Europe

Environmental, economic, and social implications

ivl
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**Photo:** Bales of sorted textiles at Humana's sorting facility in Vilnius, Lithuania. Photo by Maja Nellström (IVL).

*[European textile industry, textile reuse, textile recycling, fibre recycling, waste hierarchy, life cycle assessment, LCA]*

# Preface

This report was produced as part of the co-financed research project *Sustainability assessment of textile reuse and recycling in and outside of Europe*. The project was funded by the Swedish Institute for Water and Air Pollution Research (SIVL), Humana LT, Human Bridge, Björkåfrihet, and Södra.

The report was authored by IVL Swedish Environmental Research Institute and comprises two main chapters: Life cycle assessment (LCA) and an analysis of economic and social effects. The LCA chapter was written by Matilda Lidfeldt, Gustav Sandin, and Maja Nellström, while the analysis of economic and social effects was authored by Amanda Martvall and Simone Andersson.

With kind regards,
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# Summary


## Aim of the study

The waste hierarchy identifies reuse as a more favourable option than recycling (European Parliament and Council, 2008). Several studies have highlighted the environmental benefits of reuse compared to other alternatives in the hierarchy, such as recycling, energy recovery, and disposal (Sandin, et al., 2019). However, the export of textiles for reuse in developing countries has drawn criticism, particularly concerning challenges related to waste management. These critiques have sparked debates about the validity of the waste hierarchy's prioritisation when geographical context is taken into account.

This study aims to support European stakeholders in managing collected textiles in the coming years, as decisions regarding policy, infrastructure, technology, and other factors may influence the focus on reuse or recycling, either within or outside Europe. This aim is pursued through an evaluation of the environmental, social, and economic sustainability of different approaches to managing textiles collected in Sweden.

In terms of environmental sustainability, the study compares reuse with fibre-to-fibre recycling and examines how the location of these options (in or outside of Europe) affects their sustainability. For economic and social sustainability, the effects of textile reuse (in and outside of Europe) are analysed, with a focus on the trade of post-consumer textiles within the second-hand clothing (SHC) market.

## Method and scope

The methods used to fulfil the aim of the study is life cycle assessment (LCA) and an analysis of economic and social effects.

LCA is a method used to assess the environmental impact of a product or service throughout its life cycle. For this study, LCA was used to assess the environmental impact of the following five case studies:

A. Reuse in Europe
B. Reuse outside Europe
C. Recycling in Europe
D. Recycling outside Europe
E. Incineration with energy recovery in Europe

The LCA includes the environmental impact and resource use categories: climate change, eutrophication, water scarcity, and energy consumption, as these represent key environmental challenges within the textile industry.

The analysis of economic and social effects of textile reuse within and outside Europe was conducted through a literature review and an interview study. This analysis complements the LCA of case studies A (reuse in Europe) and B (reuse outside Europe), with a focus on Lithuania and Kenya for reuse within and outside Europe, respectively.

It is important to note that the study does not aim to identify the most common practices for managing post-consumer textiles today, nor to examine the most common fractions of collected textiles. Instead, it focuses on practices considered viable options for improving circularity and reducing the environmental impact of the textile industry in Europe.

# Main results and conclusions

This section includes a summary of the main results and conclusions in relation to the research questions outlined for the environmental impact assessment (using LCA) and the analysis of economic and social effects. In addition, recommendations for future research are provided.

## Environmental impact assessment

1. What's the environmental impact of textile reuse in and outside of Europe compared to textile recycling in and outside of Europe?

- For climate change, eutrophication (freshwater, marine, and terrestrial), and energy use (both renewable and non-renewable), reuse exhibits the lowest environmental impact among the three practices studied (reuse, recycling, and incineration).
- Although case study A (reuse in Europe) shows a lower impact compared to case study B (reuse outside Europe), there is not a big difference in terms of environmental impact if the reuse occurs in or outside of Europe. This is based on a low loss rate for reuse outside Europe. If the loss rate is high, the difference increases (see more below).
- Water deprivation impact is the only indicator that shows the lowest results for the recycling cases, i.e. case study C (recycling in Europe) and D (recycling outside Europe).

- There is minimal difference in the results between case study C (recycling in Europe) and D (recycling outside Europe) for all impact categories, indicating that the recycling processes, and where they are located, have a limited impact on the environmental impact results.
- There is no sizable difference in terms of climate change impact between the recycling case studies (C and D) and the incineration case study (E). That textile recycling does not reduce climate impact substantially compared to incineration is aligned with other studies.
- The results are aligned with the waste hierarchy which indicate the importance of collecting post-consumer textiles and prioritise reuse.

2. What parameters (such as replacement rate) are of great significance for the environmental impact of reuse and recycling in and outside of Europe?

- The loss rate (assumed to be 2%) for reuse outside Europe (Africa) significantly influences the results for all studied impact categories. A higher assumed loss rate leads to a substantial difference between reuse in and outside of Europe, with a considerably lower environmental impact for reuse in Europe. This highlighting the importance of the loss rate in studies of textile reuse.
- For all studied impact categories, the assumed replacement rate (the number of times a garment is reused compared to a new garment) has a big impact on the results. More specifically, the following applies:
  - If the replacement rate is lower than the 50% assumed in the base case, the difference between the reuse and recycling cases becomes smaller. Conversely, a higher replacement rate increases the difference between reuse and recycling. This conclusion holds for all impact categories except water deprivation.
  - For water deprivation, the impact of reuse was initially higher than recycling. A lower replacement rate therefore leads to a larger difference between reuse and recycling. On the contrary, a higher replacement rate result in a smaller difference between reuse and recycling.

Some final conclusions of the LCA, is presented below. These conclusions focus on the employed modelling approach: system expansion. This method involves an expanded functional unit and the addition of compensating processes to ensure that the case studies being compared fulfil the same functional unit.

- The system expansion approach presented challenges in communicating the method and the results, both within this report and during presentations to project partners and other stakeholders. Clear communication is crucial, and efforts should be made to simplify complex concepts.
- Different methods for managing post-consumer materials inherently produce different functions, in our case: direct use of products, feedstock for material recycling, and energy. Our results show that system expansion enabled a comparison of the case studies, with the compensating processes being crucial to the results. We recommend the use of system expansion when comparing the environmental impact of product systems that generate different functions.

# Analysis of economic and social effects

The research question outlined for the analysis of economic and social effects is: What are the important economic and social effects of reuse in and outside of Europe? As mentioned above in Method and Scope, Lithuania and Kenya are the focus of the analysis of reuse in and outside of Europe, respectively.

### Important economic and social effects of reuse in Lithuania

In Lithuania, the SHC trade contributes to opportunities in term of:

- Employment opportunities and generation of income.
- Affordable clothing alternatives, especially beneficial for those with lower incomes.
- Accessible jobs with low entry requirements, improving living standards.

There are also economic and social risks related to the SCH trade in Lithuania:

- Maintaining quality and profitability in the SHC trade is challenging due to the impact of fast fashion, which drives down prices and quality of the textiles.
- The challenges related to quality results in many textiles being unsuitable for resale at the second-hand market.

### Important economic and social effects of reuse in Kenya

In Kenya, the economic and social effects of the SHC trade are significant. Important benefits mentioned in literature and by interview respondents are:

- Employment opportunities and financial stability.
- Accessibility to affordable clothing.
- Skill development in areas such as sorting, repairing, and upcycling.
- Accessible jobs, particularly benefiting marginalized groups and local communities.

The SCH trade in Kenya is also associated with certain risks:

- Financial instability remains a concern since profitability of the SHC trade can be unpredictable.
- Many jobs created in the SHC trade are informal and lack the regulatory frameworks necessary to protect workers and ensure fair labour practices.
- Poorly sorted and low-quality SHC from China presents challenges that negatively impact both profitability and consumer satisfaction.

# Recommendations for future research

Several research needs were identified in the work with this project, prompting recommendations for future research. Based on the findings of the environmental impact assessment, three topics are presented as priorities for future research. Additionally, three further recommendations are proposed based on the analysis of economic and social implication of the SHC trade.

### The loss rate for reuse outside Europe

The loss rate for reuse, representing waste generated during retail of the SHC, outside Europe (Africa), has a significant influence on the results. However, this parameter is highly uncertain due to conflicting sources, with reported loss rates ranging from 1% to 50% (see Section 4.1.8.2 for details). The methods used in the studies vary in quality and transparency, highlighting the need for further research to better understand and quantify this parameter.

### The replacement rate

The replacement rate, referring to how many times SHC are used before disposal compared to newly produced garments, significantly impacts the results. Similar to the loss rate, this parameter is subject to considerable uncertainty, with reported values ranging from 25% to 75% for European countries and from 35% to 63% for African countries. Collecting more data on replacement rates, both in and outside of Europe, would therefore be of great value.

### The end-of-life treatment for reuse outside Europe

The end-of-life treatment after reuse outside Europe is assumed to take place in Kenya, with landfilling being the assumed treatment of the textile waste. However, several sources state that open dumpsites and informal landfills are commonly used in Kenya. Unfortunately, no life cycle inventory (LCI) data was identified for such end-of-life treatments. As a result, the LCA model could not fully capture all potential environmental impacts associated with end-of-life practices for textiles in Africa. For future comparisons of textile reuse within and outside Europe, it is recommended that this aspect be explored in greater detail. If sufficient LCI data is unavailable, methods other than LCA may be necessary to evaluate the environmental impacts of waste management for exported textiles.

### Quality assurance of the SHC

A key challenge in the SHC trade is maintaining both quality and profitability. Future studies could explore how measures to enhance quality assurance for exported SHC might help mitigate the risks associated with improperly sorted textiles. Such measures could help reduce financial risks for stakeholders in the global SHC trade and ensure that SHC exports are reused as intended.

### EU legislation and policy frameworks for the SHC trade

Within Europe, there are conflicting opinions on how used textiles should be handled. Future research could investigate how regulatory frameworks can be optimized to enhance the sustainability and profitability of the SHC market, while balancing these regulatory requirements with market realities, to make sure that SHC companies and European suppliers can continue their reuse operations. Additionally, research could examine how the SHC sector can promote knowledge sharing and training to support efficient operations.

### Regulation and collaboration across the global SHC value chain

Outside Europe, the lack of targeted regulatory frameworks poses a threat to the sustainability of the SHC trade. Addressing this challenge requires greater engagement and collaboration across the SHC value chain that help ensure the delivery of high-quality SHC that meets the demands of African markets. Future research should explore how countries outside Europe can regulate the SHC trade to promote circularity and sustainability. Additionally, strategies to improve information sharing and collaboration across the different stages of the global SHC trade should be explored.

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# 1 Introduction

From January 1, 2025, separate textile collection is required in all EU member states through an update in the EU waste management legislation (European Environment Agency, 2024). Additionally, there is currently a discussion about restricting the export of textile waste to countries outside of the EU (European Environment Agency, 2023). To some extent, separate collection of textiles already occurs in Sweden today. However, large quantities of textiles are not collected and instead end up in household waste. The new legislation is expected to result in larger amounts of textiles being collected and these collected textiles need to be managed in a sustainable way. Currently, there are three main practices of managing textile materials collected in Europe, aside from incineration or landfilling:

- Reuse through sales on the second-hand market (in or outside of Europe).
- Low-value recycling, known as downcycling, for purposes like stuffing or rags.
- High-value fibre-to-fibre recycling.

At present, reuse is the most common option of managing collected textiles, and only a very small proportion (less than 1%) of textiles placed on the market are currently fibre-to-fibre recycled (Textile Exchange, 2023). With increased textile collection, the quantity of textiles to be processed in subsequent stages such as sorting, reuse, and recycling will increase. It is crucial that these processes are energy and resource efficient, and that the new circular value chains cause net positive effects on the environment, human health, and the economy. To achieve this, decision-makers, legislators, collectors, sorters, and recyclers need the necessary knowledge to manage collected textiles in the most sustainable way possible.

According to the waste hierarchy, reuse is preferable to recycling (European Parliament and Council, 2008), and several studies have demonstrated environmental benefits of reuse compared to the other options in the hierarchy: recycling, energy recovery and disposal (Sandin, et al., 2019). However, some criticism has been directed at the specific challenges and problems that may arise when textiles are exported for reuse in developing countries.

One challenge highlighted in the global textile trade is the inadequate waste management in the countries receiving textiles for reuse, which may result in textile waste being burned or disposed of in unregulated landfills (European Environment Agency, 2023). This issue is particularly pressing in the Global South, where concerns have emerged about materials ending up in uncontrolled dumpsites (Sumo, et al., 2023).

Other criticism regarding the environmental sustainability of this trade concerns the replacement rate, i.e., the extent to which textile reuse reduces the need for the production and consumption of new textiles (European Environment Agency, 2023). The replacement rate varies based on factors such as the quality of the garments, changing fashion trends, and consumer preferences. Some critics argue that for certain reused textiles, the replacement rate is very low, resulting in limited environmental benefits. Unless the used textiles exported from the EU reduce the need for new clothing purchases, they may not offset new production or significantly benefit the environment. Instead, such exports risk leading to greater volumes of textile waste, particularly in receiving countries with limited waste management infrastructure (Nageler-Petritz, 2023).

Despite these challenges, the export of post-consumer textiles plays a critical role in providing livelihoods, job creation, and economic activities for populations in the Global South (Sumo, et al., 2023). The second-hand clothing (SHC) trade, known as mitumba[1] in Kenya, serves as a valuable clothing source for people facing economic vulnerability, poverty, and low purchasing power (Sumo, et al., 2023). In countries like Ghana and Kenya, the SHC trade is a crucial part of the economy, supporting up to 2.5 million traders, and a majority of the population consume SHC (Odonkor, 2024; IEA, 2021).

In Europe, collection of used post-consumer textiles is predominantly managed by charities, but profit-driven entities are also involved (Watson, et al., 2020). In these business models, used textiles are collected, and the sale of marketable items, such as high-quality garments, helps finance their operations and is important for sustaining the collection process.

[1] Mitumba is a Kiswahili word that means bale or bundle, but today it is also used synonymously with second-hand clothes.

Depending on decisions taken in the years to come, developments in policy, infrastructure and technology may steer towards more or less of reuse and recycling, in or outside of Europe.

# 2 Aim

This study aims to provide decision support to European actors involved in managing collected textiles in the coming years regarding decisions on policy, infrastructure, technology, and other influencing factors that may steer towards more or less of reuse or recycling, in or outside of Europe. This aim is achieved by investigating the environmental, social, and economic sustainability of various options for managing textiles collected in Sweden.

In terms of environmental sustainability, the study compares reuse and fibre-to-fibre recycling and explores how the sustainability of these two alternatives is influenced by whether they take place in or outside of Europe. For economic and social sustainability, the study analyses the economic and social effects of textile reuse, with a focus on the trade of post-consumer textiles for the second-hand clothing (SHC) market.

The goals and scopes of the study are further described in Sections 4.1 and 5.1, respectively.

# 3 Methodology

Two different methods were used to fulfil the aim presented above: Life cycle assessment (LCA) and an analysis of economic and social effects. These two methods are presented in short below.

## 3.1 Life cycle assessment

LCA is a method used to assess the environmental impact of a product or service throughout its life cycle. The LCA study was conducted following the four steps described in ISO 14040 and 14044 standards: goal and scope definition, life cycle inventory (LCI) analysis, life cycle impact assessment (LCIA), and interpretation. These four steps are briefly described below:

- Goal and scope: The purpose of the study is established, and the indicators to be included in the analysis are determined.
- LCI analysis: Data is collected on materials, energy, and emissions associated with each stage in the life cycle. Also, models and calculations are made.
- LCIA: Collected data is evaluated, and the environmental impact of each stage in the life cycle is analysed.
- Interpretation: Results are compiled, analysed, and interpreted. This may involve identifying factors with the most significant impact on the results and assessing uncertainties.

Further details on the LCA methodology are presented in the Section 4.

## 3.2 Analysis of economic and social effects

An analysis was conducted on the economic and social effects of textile reuse both within and outside Europe. The activities included in this analysis were:

- Literature review: Review of existing literature to search for available data, such as existing public sources, with the aim of identifying relevant economic and social effects within the textile reuse industry.
- Interview study: Semi-structured interviews with relevant stakeholders in the reuse industry, including local actors in countries where textiles are reused.
- Analysis of results: The results from the literature review and the interview study was compiled and analysed.

The activities included in the analysis of economic and social effects is described in more detail in Section 5.2.

# 4 Life cycle assessment

This section presents the LCA. Initially, the goal and scope of the study is presented, followed by the LCI analysis and results and discussion. Lastly, the conclusions of the LCA are presented.

## 4.1 Goal and scope

In this section, the goal and scope of the study is defined and explained. The goal and scope definition acts as a guideline for performing the assessment and helps the reader of the report to understand key assumptions, system boundaries, limitations and other aspects influencing the results.

### 4.1.1 Goal and research questions

The goal of the LCA is to provide decision support to European actors involved in managing collected textiles in the coming years, when decisions on policy, infrastructure, technology, and other influencing factors may steer towards more or less of reuse or recycling, in or outside of Europe. To fulfil this goal, the LCA addresses these research questions:

- What's the environmental impact of textile reuse in and outside of Europe compared to textile recycling in and outside of Europe?
- What parameters (such as replacement rate) are of great significance for the environmental impact of reuse and recycling in and outside of Europe?

Apart from providing the above-described decision support, addressing the second research question provides guidance on structuring and designing future reuse and recycling systems both within and outside of Europe.

### 4.1.2 Case studies

To address the above research questions, the LCA explores the following five case studies:

F. Reuse in Europe
G. Reuse outside Europe
H. Recycling in Europe
I. Recycling outside Europe
J. Incineration with energy recovery in Europe

For all case studies (A-E), the input material is assumed to be 1 tonne of post-consumer T-shirts collected in Sweden. Of the collected T-shirts, we have assumed 60% are made of natural fibres (modelled as cotton) and 40% are made of synthetic fibres (modelled as polyester) based on statistics on fibre composition of textiles in

Europe (Statista, 2015). This distribution of natural and synthetic fibres was confirmed by a random sample test of incoming textile material to Humana's manual sorting facility in Vilnius, Lithuania.

Recycling in case studies C (recycling in Europe) and D (recycling outside Europe) refers to high-value fibre-to-fibre recycling, and not downcycling, as this is the focus of large investments and new legislation in Europe ( (WRAP, 2019; Constantinou & Holmgaard, 2020; European Environment Agency, 2023).

For the recycling case studies (C and D), we assume the T-shirts are made of 100% recycled materials. This is a simplified assumption to facilitate the LCA model, but we acknowledge this is not realistic, especially when mechanically recycled materials are used, as these need to be blended with a high share of primary material for the T-shirts to be functionally equivalent to T-shirts made of primary materials. If a more realistic percentage were assumed, it would mean that production of primary materials would have to be added to the recycling case studies (C and D) and more T-shirt production would take place. Thereby, more T-shirt uses would be generated from these scenarios, and this amount of T-shirt uses would have to be added to the functional unit, leading to the addition of a corresponding amount of primary fibre and T-shirt production also in case studies A, B and E. In the end, the same amount of these processes would be added in all case studies. Thus, a more realistic percentage of recycled material would not change the comparison between the case studies. In other words, it does not matter (from an environmental perspective) whether the recycled material is concentrated in one T-shirt with 100% recycled content or in ten T-shirts with 10% recycled content each, if the functionality is assumed to be identical to T-shirts of 100% primary fibres. Alternatively, one could describe the LCA model as reflecting 10% recycled material in each T-shirt in case studies C and D, but that all identical processes have then been removed.

The case studies A-D were selected as they are viewed as viable options for increasing the circularity and reduce the environmental impact of the textile industry in Europe (European Commission, 2022). It should be noted that reuse (either in or outside of Europe) is currently the most common option, and that only a very small proportion (less than 1%) of the textiles placed on the market are fibre-to-fibre recycled today (Textile Exchange, 2023). One of the main reasons for this is that most post-consumer textiles cannot be recycled due to technical limitations of existing large-scale recycling technologies (Dahlbom, et al., 2023). In particular, there is no existing large-scale textile recycling of polyester today, although there are high ambitions for this in the near future (see, e.g. (Syre, 2024)). With the current economic and technical limitations, the reality is that just a few percentages of collected textiles are possible to fibre-to-fibre recycle. There are reports of increasing challenges also with reuse of collected textiles, due to the low-quality of fast fashion textile products sold on the market (Textile Recycling Association, 2024; WINSS, 2024; Rachel Cernansky, 2024). As such, the studied fraction of 1 tonne of collected T-shirts, that may be either reused or recycled, can be considered an ideal fraction, not representative for the majority of collected textiles today. However, studying this ideal fraction is what allows us to address the research questions and compare reuse with fibre-to-fibre recycling, and depending on policy and technological developments, the fractions suitable for reuse and fibre-to-fibre recycling may increase significantly in a few years.

We assumed collected textiles to be T-shirts because this is a relatively common garment that is relatively suitable for both reuse and recycling (e.g., low quantities of hard parts). Additionally, there is good LCI data availability for the subsequent production of new T-shirts (which is included within the system boundaries, see Section 4.1.4). However, the results are relevant also for other garments, with the main difference being that the subsequent production of more complex garments results in a greater environmental impact. This distinction is reflected in the discussions of results (Section 4.3).

A flowchart providing an overview of the processes involved in the case studies are presented in Figure 4-1. The processes in the figure are so-called foreground processes. There are also background processes included in the case studies, which for example are production of energy and materials used in the foreground processes, the transportation of these materials, and the management of any waste generated in the foreground processes. Note that the use stage has a dashed box which is meant to illustrate that it is not included in the studied cases. It should also be noted that distribution is a process that entail transportation to retailing. However, all arrows in the flowchart represent transportation that are included in the case studies. Flowcharts specific for each case study are presented in Section 4.2 and the geographical system boundaries of each case study are outlined in detail in Section 4.1.4.2.

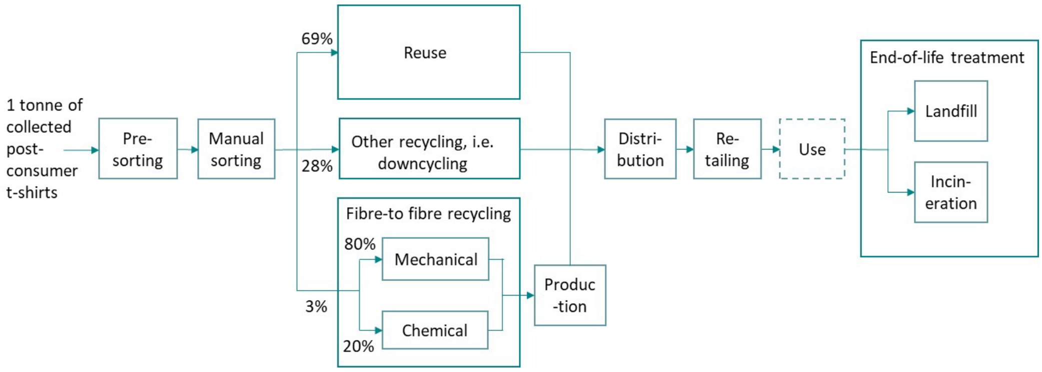


*Figure 4-1. Flowchart representing a generic overview of the processes involved in the studied case studies. Note that "use" has a dashed box to illustrate that it is not included in the studied case studies.*

Figure 4-1 illustrates that most (about 69%) collected textiles are reused and a very small proportion (about 3%) of collected textiles are currently fibre-to-fibre recycled. About a third of collected textiles are subjected to other types of recycling such as downcycling. These numbers are based on an estimate conducted within the project *Does large-scale textile recycling in Europe reduce climate impact*? *A consequential life cycle assessment* (Sandin, et al., 2023).

Two different options for end-of-life treatment are shown in Figure 4-1: Landfill and incineration. The end-of-life treatment for case studies A, C, D and E is assumed to be incineration with energy recovery (Eurostat, 2022; Khan, et al., 2022). For case study B (reuse outside Europe), end-of-life treatment is assumed to take place in Kenya and landfill is the assumed treatment of textile waste. This is based on a report stating that landfill is "the most adopted strategy for disposal of textile waste" (Sumo, 2024). Due to a lack of dataset on African conditions, this was modelled using an LCI dataset on a typical European municipal waste landfill which represent a formal, controlled landfill. Several sources also state that solid waste, including textiles, are commonly disposed of in open dumpsites or informal landfills in Kenya (Fie-Consult, 2023; Kiarie- Kimondo, 2022; Oyake-Ombis, 2017). However, we have not found LCI data of such end-of-life treatments. Therefore, the LCA model could not capture the potential environmental impacts of such end-of-life practices.

### 4.1.3 Functional unit

A functional unit shall reflect the functions of the studied case studies and serves as the unit to which the results are related. Defining the functional unit is what enable us to compare different case studies, as done in this LCA study.

The common function of the case studies we compare is managing 1 tonne collected post-consumer T-shirts. However, the different ways to manage the collected T-shirts in the case studies generate two additional functions (or co-products): T-shirt-uses and energy from incineration of waste with energy recovery. Additionally, the case studies generate different number of T-shirt uses and different amounts of energy.

In LCA, only case studies that have identical functions may be compared. To make the case studies comparable, we therefore expand the case studies so that they include the processes needed to deliver all these functions. In this way, we avoid the need for allocating the environmental impact of each product system to the multiple functions. This approach for avoiding allocation is called "system expansion" in ISO 14044 and is one of the preferred ways of solving such multi-functionality problems according to the standard.

The processes added when expanding the case study, we denote as "compensating processes". When the compensating processes have been added, the five case studies have identical functions, and these functions define the functional unit. This means that the functional unit will include not only the function of managing 1 tonne of post-consumer T-shirts, but also a certain amount of T-shirt uses, and a certain amount of energy (heat and electricity) recovered from waste incineration. The amount of each function included in the functional unit, is defined by the case study that generates the most of each function. In other words, the case study that generates the most T-shirt uses sets the amount of T-shirt uses included in the functional unit, and the case study that generates the most energy sets the amount of energy included in the functional unit. Figure 7-1 in Appendix 1 illustrates how the functional unit was defined based on the functions generated by each case study (before the compensating processes were added).

Based on the above reasoning, the following functional unit was defined: *Managing 1 tonne of collected post-consumer T-shirts and generating: 17 000 MJ energy (4000 MJ electricity and 13 000 MJ heat) and 182 000 number of T-shirt uses.*

Note that the numbers presented for the functional unit are rounded numbers. When calculating the environmental impact of each case study, exact numbers were used.

### 4.1.4 System boundaries

This section specifies the applied system boundaries of the LCA. The following system boundaries are presented: boundaries towards nature, geographical and temporal boundaries, and boundaries towards other technical systems.

#### 4.1.4.1 Boundaries toward nature

This LCA study include environmentally relevant processes within the scope of the study. For each process within the system boundaries, the input flows of natural resources (e.g. crude oil and wood) are followed from where they are extracted from the ground, and emissions are followed to where they are emitted to soil (after human activity has ceased), air (e.g. emissions from combustion of fuels) or water (e.g. water emissions from wastewater treatment).

#### 4.1.4.2 Geographical boundaries

The choice of geographical system boundaries for the case studies included in this LCA are done to best represent the different cases. In Table 4-1 below, the geographical boundaries chosen for the processes involved in each case study are presented. Since not all processes are relevant to every case study, some cells in the table are denoted with "N/A" to indicate that data is non-applicable.

*Table 4-1. The geographical system boundaries for the processes involved in the case studies. Where data is not applicable, the term "N/A" is used.*

| Process | Reuse | | Recycling | | Incineration |
|---|---|---|---|---|---|
| | In Europe (A) | Outside Europe (B) | In Europe (C) | Outside Europe (D) | In Europe (E) |
| Pre-sorting | Sweden | Sweden | Sweden | Sweden | N/A |
| Manual sorting | Lithuania | Lithuania and Pakistan | Lithuania | Lithuania | N/A |
| Recycling | N/A | N/A | Sweden, Germany, and southern Europe | China | N/A |
| T-shirt production* | N/A | N/A | China | China | N/A |
| Retailing | Germany | Kenya | Germany | Germany | N/A |
| End-of-life treatment** | Germany | Kenya | Germany | Germany | Sweden |

*Refers to production of T-shirts from recycled textile fibres.

**The end-of life treatment for case B is landfill. For the other case studies (A, C, D and E) end-of-life treatment is incineration with energy recovery.

As illustrated in Table 4-1, pre-sorting has the same geographical boundary for all case studies where this process is involved, i.e. all case studies except case study E (incineration in Europe). In addition, the manual sorting takes place in Lithuania (specifically Vilnius) for all relevant case studies. However, an extra manual sorting step is assumed in Pakistan for case B (reuse outside Europe).

In Table 4-1, it is also illustrated the recycling processes for case C (recycling in Europe) take place in Sweden, Germany, and southern Europe. The reason for including three different geographical locations is that different recycling techniques have been considered for collecting data on the recycling taking place in Europe. The recycling for case D (recycling outside Europe) is assumed to occur in China. The production of T-shirts from recycled fibres is assumed to take place in China, as China is the leading global producer of textiles (Tugba, 2022).

Retailing of T-shirts is assumed to occur in Germany, specifically Frankfurt, for case A (reuse in Europe), C (recycling in Europe) and D (recycling outside Europe). This location is also assumed for end-of-life treatment (incineration with energy recovery) of the T-shirts in these three case studies. This assumption is chosen since the T-shirts from these three cases are assumed to be used in Germany, and Frankfurt is assumed since it is considered relatively close to the centre of Europe, both geographically and in terms of population. For case study B (reuse outside

Europe) retailing, and end-of-life treatment (landfill) take place in Kenya where the T-shirts are assumed to be reused.

Case study E (incineration in Europe) only involve end-of-life treatment in terms of incineration with energy recovery. As illustrated in Table 4-1, this process occurs in Sweden.

In addition to the processes presented in Table 4-1, two compensating activities are involved in the case studies: T-shirt production and energy production. The processes and geographical boundaries for the compensating T-shirt production is presented in Table 4-2. Note that case C (recycling in Europe) and D (recycling outside Europe) is not included in the table. The reason is the compensating T-shirt production is not needed to generate extra T-shirt uses for these two case studies. The compensating process of energy production, where electricity and steam are generated, takes place in Europe. This compensating activity is relevant for case study A-D. For case E (incineration in Europe), no compensating energy production is needed since the incineration in this case study is assumed to be with energy recovery.

*Table 4-2. The geographical boundaries for the processes involved in the compensating T-shirt production.*

| Process | Reuse | | Incineration |
|---|---|---|---|
| | In Europe (A) | Outside Europe (B) | In Europe (E) |
| Raw material extraction | Global | Global | Global |
| Fibre production | China | China | China |
| Yarn, fabric, wet treatment, and confectioning | China | China | China |
| Retailing | Germany | Kenya | Germany |
| End-of life treatment* | Germany | Kenya | Germany |

*End-of-life treatment is incineration with energy recovery for case study A and E and landfill for case study B.

As illustrated in Table 4-2, fibre production as well as yarn, fabric, wet treatment, and confectioning take place in China for the compensating T-shirt production. China is assumed for these processes since they are the leading global producer of textiles (Tugba, 2022). For the raw material (e.g. cotton fibre, ethylene glycol and purified terephthalic acid) extraction, a global scope is assumed which means that a global average has been used for this process.

Retailing and end-of-life treatment in the compensating t-shirt production takes place in Germany for case A (reuse in Europe) and E (incineration in Europe) and in Kenya for case B (reuse outside Europe). Note that the end-of-life treatment is assumed to be landfill for case B (reuse outside Europe) and incineration with energy recovery for case studies A (reuse in Europe) and E (incineration in Europe).

#### 4.1.4.3 Temporal boundaries

The case studies of all five case studies (A-E) aim to represent the current state of managing textiles collected in Sweden. Therefore, data selection has prioritized the most recent available data while ensuring it accurately reflects the relevant technologies and geographical scope.

#### 4.1.4.4 Boundaries towards other technical systems

As there are inputs from other technical systems in terms of collected post-consumer T-shirts, there is a need to define the boundaries between these systems and the studied system. In this LCA study of the five case studies (A-E), allocation is handled with the cut-off method. This method is further described in Section 4.1.5 below.

### 4.1.5 Allocation method

The input material in each case study is, as previously mentioned, 1 tonne of collected post-consumer T-shirts. This input material is assumed to enter each product system without any environmental burden from previous life cycles. This means that a cut-off allocation method is used which is a common allocation method to use for post-consumer materials. When the cut-off method is used, the collection processes (transports) are often allocated to the product system using the collected material. This is not done in the present study, as the collection of post-consumer T-shirts are assumed to be identical in all case studies and therefore do not influence the comparison made between the case studies (the aim of the study).

In practice, the collection process may differ depending on whether the textiles are destined for reuse, recycling, or incineration. Collection setups, such as transportation methods and distances, can vary significantly between municipalities in Sweden, regardless of the destination of the textiles. Given the absence of a nationally standardized system for addressing the new EU requirements for separate collection, we chose to disregard these differences. In studies of collection in specific municipalities, we recommend to also consider the collection, as previous studies show that collection setups relying on the transports of households can have a substantial environmental impact (Lidfeldt, et al., 2023).

The output flows of energy (heat and electricity generated from incineration of textile waste) that leave each product systems are assumed to exit the product systems without any environmental burden. This means that the cut-off method has been applied for the output flows.

Note that expanding the system boundary to include additional functions is a method to avoid allocation, as described in Section 4.1.3. Without this approach, the environmental impact of each product system would need to be allocated between the multiple functions: management of collected T-shirts, energy generation, and T-shirt use, before comparing the case studies.

### 4.1.6 Environmental impact categories

This LCA study includes the following environmental impact and resource use categories: climate change, eutrophication, water deprivation and energy use. These categories are chosen because they represent important environmental issues of the textile industry.

Two important indicators for the textile industry are not included in this study: land use and toxicity. The reason for excluding them are that the impact assessment methods (e.g., LANCA and USEtox) and the available LCI data are deemed not to be robust enough to provide valuable results for these indicators.

The chosen environmental impact and resource indicators and their characterisation methods are presented in Table 4-3 below. For more information about the impact categories, see Appendix 2: Impact and resource use categories.

*Table 4-3. The environmental impact and resource use categories included in this LCA study, including the characterisation methods used for each category.*

| Environmental impact and resource use category | Method | Unit |
|---|---|---|
| Climate change | Global warming potential (GWP) baseline model of 100 years of the IPCC (based on IPCC 2021), excluding biogenic CO2 | kg CO2 eq. |
| Eutrophication, marine | The EN15804 reference package | kg N eq. |
| Eutrophication, freshwater | The EN15804 reference package | kg P eq. |
| Eutrophication, terrestrial | The EN15804 reference package | Mole of N eq. |
| Primary energy resources (incl. renewable and non-renewable primary energy resources) | The EN15804 reference package | MJ |
| Water deprivation | AWARE, OECD+BRIC average for unspecified water | $m^3$ world eq. |

### 4.1.7 Main assumptions

This section summarises the main assumptions made in the modelling of processes involved in the case studies.

#### Pre-sorting and manual sorting

- Of the collected textiles we have assumed 60% are made of natural fibres (modelled as cotton) and 40% are made of synthetic fibres (modelled as polyester) (Statista, 2015).

#### Recycling and production of T-shirts

- A cotton T-shirt is assumed to weigh 104 grams and a polyester T-shirt 110 grams (Sandin, et al., 2019).
- It is assumed that polyester is not mechanically recycled. This is strengthened by Baloyi et al. (2024) that states there is no way to currently recycle polyester textile waste to new fibres (Baloyi, et al., 2024). At present, the only mechanical recycling of polyester comes from PET-flakes obtained from PET bottles.
- For case studies C (recycling in Europe) and D (recycling outside Europe), we assume the T-shirts are made of 100% recycled materials. The reasoning for this is presented in Section 4.1.2.

#### Use and reuse

- The use stage is not included in the case studies as it is assumed that the choice between the compared options does not significantly affect consumer behaviour. Specifically, whether the T-shirts are second-hand, made from recycled materials, or produced from primary materials is not expected to influence the frequency of washing or ironing.

- It is assumed that 2% of the textiles exported for reuse in Africa is discarded as textile waste. The reasoning behind this assumption is presented in Section 4.1.8.2.
- 50% replacement rate was assumed for a reused T-shirt and 100% replacement rate was assumed for a garment of recycled material. The reasoning behind these assumptions is described in Section 4.1.8.1.
- A T-shirt of primary material is assumed to be worn 30 times before being discarded (Sandin, et al., 2019).

#### End-of-life treatment

- Incineration in Europe is assumed to be done with energy recovery since energy recovery is common in Europe (Eurostat, 2022).
- Incineration in Asia is assumed to be done without energy recovery since incineration is usually conducted without energy in Asia (Khan, et al., 2022).
- The end-of-life treatment of textile waste in Kenya is assumed to be landfill. The reasoning behind this assumption is presented in Section 4.2.2.

#### Transports

- All transports to end-of-life treatment processes are assumed to be 50 km.
- The fuel for the transports is assumed to be diesel with a blend of 6% rapeseed methyl ester, RME.

### 4.1.8 Sensitivity analysis

To expand the scope of the LCA and to test the impact of some key uncertain assumptions or parameters, a sensitivity analysis was conducted. This analysis explored alternative values for the assumed replacement rate of T-shirts in the reuse case studies (A and B) and the assumed loss rate, i.e. the share of waste among the exported T-shirts. The sensitivity analysis for these two parameters is described in more detail below.

#### 4.1.8.1 Replacement rate

The replacement rate indicates how many times a reused garment is worn compared to a newly produced one. In this study, a replacement rate of 50 % was assumed for a reused T-shirt (in case study A and B), while 100% replacement rate was assumed for a T-shirt made from recycled material (in case study C and D). The rationale behind these assumptions is explained below.

The quality of a reused T-shirt is assumed to be reduced by wear and tear, thus having a replacement rate less than 100%. The assumed replacement rate of 50% for a reused T-shirts means that the T-shirt is used 50% fewer times compared to a newly purchased T-shirt made of primary material. Since a new garment is assumed to be worn 30 times before disposal, this means that the reused T-shirt is used 15 times before being discarded.

The assumption of a 50% replacement rate is based on Nørup et al. (2019) which has summarised previously estimated replacement rates for second-hand clothing (SHC) in Europe (spanning from 25% to 75%) and made their own estimates of replacement rates for second-hand clothing for three African countries: Angola, Malawi, and Mozambique (spanning from 35% to 63%). All these numbers were based on questionnaire surveys. A 50% replacement rate, assumed in this LCA study, is in the middle of these ranges. Note that based on this data, it cannot be concluded that the replacement rates for clothing reused in Africa are different from those in Europe. The differences between countries are greater than the differences between the continents.

A T-shirt made of 100% recycled materials is assumed to be functionally and quality-wise identical to a T-shirt made of primary material, see Section 4.1.7. Thus, a replacement rate of 100% was assumed for a T-shirt made of recycled material[2]. This means that the T-shirt of recycled material is used 30 times, i.e. the same number of times as a T-shirt made of primary material.

[2] This can be justified in the present study, in which we assess end-of-life options for one tonne of textiles; however, if the aim was to study large-scale implementation of textile recycling, the increased supply of fibres will probably increase demand of fibres (to an extent depending on the price elasticity of textile fibres) leading to a lower actual replacement rate. We have studied such-large scale implementation of textile recycling, and how the replacement rate influences its climate impact, in a separate study: Sandin et al. (2023).

For the sensitivity analysis, two alternative replacement rates were assumed for the reused T-shirt: 25% and 75%, which roughly reflects the range of replacement rates identified by Nørup et al. (2019).

#### 4.1.8.2 Loss rate

In case study B (reuse outside Europe), a 2% loss for clothing exported to Kenya was assumed. This means that 2% of the clothing exported to Kenya is assumed to be discarded as waste. A description of the rationale for this assumption is provided below.

The management of textile waste is a complex issue often characterised by conflicting information from various sources. A review of several reports shows significant variations in data regarding the amount of textile waste exported. Some sources emphasize that a large portion of the exported textile is reused as second-hand clothing, while others point out that much of it ends up in landfills or is incinerated.

In 2016, a report on textiles used in the Nordics claimed that only 1% of imported textiles ended up as waste in Malawi (Watson, et al., 2016). A 2023 report, *The Quality of Second-Hand Clothes*, states a 2% waste rate (Diamond, 2023). A recent article aligns with these two reports. In this article it is stated that approximately 1–2% of textiles exported to Kenya end up as waste (Ghosh, 2024). Additionally, a report from 2022 estimates a loss rate of 4% for textiles imported to Ghana, specifically to the Kantamanto market in Accra (The OR Foundation for Design for Decomposition, 2022). These reports suggests that most of the imported clothing was either reused or repurposed.

However, other sources provide higher numbers on the loss rate. A recent report exploring reused textiles managed at the Kantamanto market (in Accra, Ghana) suggests that the loss rate ranges from 9% to 18% (Christoph et al., 2024). An even higher numbers on the loss rate is presented in a report from 2023 indicating that anywhere between 20% and 50% of second-hand clothes imported to Kenya is discarded as waste (Urska, et al., 2023). In addition, an article from 2021 include a statement from a waste manager at the Accra, Ghana (Linton, 2021): "Close to 40 per cent of whatever shipments that are coming on a daily basis ends up to be complete chaff of no value." Two additional articles suggest that the loss rate of exported textiles is 40%. These articles are titled *Dead White Man's Clothes clothes* (Ricketts & Skinner, 2019) and *Tunisia's Secondhand Clothes Market, Barometer of Citizen Purchasing Power* (Rihab, 2022). However, these articles do not disclose the sources of these numbers, nor do they provide information on the methods used to estimate the loss rate. Therefore, these two references are not taken into consideration when assuming a loss rate within this study.

The differences in estimated loss rates may reflect variations in methodologies or differing interpretations of waste within the second-hand market. Most of the reports referenced above are based on interview studies. However, many of these reports do not clearly specify the number of interviews conducted or the types of actors interviewed, making it challenging to assess the validity of the reported loss rates.

Of the references identified in this study, three (Watson, et al., 2016; Diamond, 2023; The OR Foundation for Design for Decomposition, 2022) and one article (Ghosh, 2024) suggest a lower range for the loss rate of clothing exported from Europe. In contrast, a higher range is suggested in one report (Urska, et al., 2023) and one article (Linton, 2021). Additionally, one report indicates a middle-range loss rate, specifically from 9% to 18% (Christoph, et al., 2024).

In summary, an evaluation of the references gathered in this study shows that most sources suggest a lower loss rate for clothing exported for reuse from Europe. Based on this, a 2% loss rate was assumed for case B (reuse outside Europe). However, because some sources report much higher loss rates (between 9-50%) for exports to Africa, we included a 40% loss rate in a sensitivity analysis for case B.

### 4.1.9 Data collection

The models are developed based on a combination of primary data, selected generic data from literature and databases, and proxy data derived from various sources. The data is enclosed in detail in Appendix 3: Inventory data. Primary data were collected for the foreground processes of pre-sorting, manual sorting, and retailing, reflecting the actual operations of Humana's sorting facility in Vilnius and their supply chain in 2023.

Selected generic data from literature and databases were used for most of the subsequent life-cycle stages: from recycling to end-of-life treatment. This data is considered technologically, geographically, and temporally representative for the processes examined in the four case studies (A-D). For the recycling processes, most of the data are sourced from a report conducted by IVL Swedish Environmental Research Institute in 2023 (Lidfeldt, et al., 2023). In terms of T-shirt production processes, most foreground data (i.e., in parts of the system that project stakeholders can influence) for these life-cycle stages originate from a report produced under the Mistra Future Fashion research program. This report assessed the environmental impact of Swedish clothing consumption (Sandin, et al., 2019).

The primary source of data for background processes (i.e., parts of the system that cannot be directly influenced by project stakeholders) is the LCA software LCA for experts (formerly known as Gabi) (version 2024.1) provided by Sphera (2024). This data is supplemented by data from the Ecoinvent database when representative data were unavailable in LCA for experts.

## 4.2 Life cycle inventory analysis

This section includes a description of the processes involved in each case study and the collected LCI data for these processes. The data has been collected from project partners and literature. Modelling of the case studies has been conducted using the LCA software LCA for experts (formerly known as GaBi).

### 4.2.1 Processes common to several case studies

Some processes are common for several of the case studies: Pre-sorting, manual sorting, production, distribution, and compensating processes. These processes are described below in Section 4.2.1.1-4.2.1.4.

#### 4.2.1.1 Pre-sorting and manual sorting

Pre-sorting and manual sorting are involved in all case studies, except case study E (incineration in Europe). The pre-sorting of collected T-shirts is assumed to take place in Sweden. After the pre-sorting, the T-shirts are assumed to be transported to Lithuania for manual sorting. This assumption is based on UN Comtrade data, showing that Lithuania was the largest recipient of collected textiles from Sweden in 2022 (United Nations, n.d.). A more detailed description of the data gathered from UN Comtrade is presented in Appendix 4: Data from UN Comtrade.

#### 4.2.1.2 Production

This process refers to production of T-shirts from fibre-to-fibre recycled materials. This process is therefore included in case study C (recycling in Europe) and D (recycling outside Europe). This production of T-shirts involves several key stages: yarn production, fabric formation (e.g., weaving), wet treatment, and garment confectioning (e.g., cutting and sewing). These processes are modelled based on the

LCA method established in the SIPTex project (Lidfeldt, et al., 2023) which in turn was based on a report from the research programme Mistra Future Fashion (Sandin, et al., 2019).

#### 4.2.1.3 Distribution

Distribution is a process involved in all case studies, except case study E (incineration in Europe). This process entail transportation to retailing. However, all arrows in the flowcharts for each case study (see Section 4.2.2-4.2.6) represent transportation included in calculating the environmental impact.

#### 4.2.1.4 Compensating processes

Two compensating processes are included to ensure that all case studies fulfil the functional unit (see Section 4.1.3), which is a prerequisite for comparing the case studies. These compensating processes are described in short below.

##### T-shirt production

The compensating process of T-shirt production is included in case study A (reuse in Europe), B (reuse outside Europe) and E (incineration in Europe). The T-shirt production includes the following processes: processes raw material extraction, production of T-shirt (including fibre and yarn production, wet treatment, and confectioning), distribution, retailing and end-of-life treatment. A flowchart illustrating the processes involved in the T-shirt production is presented in Appendix 5: Compensating T-shirt production.

##### Energy production

A compensating process of energy production is included for all case studies, except case study E (incineration in Europe). The energy production entail production of electricity and heat.

### 4.2.2 Case study A: Reuse in Europe

Case study A is reuse in Europe and the processes included in this case study is presented in Figure 4-2 below.

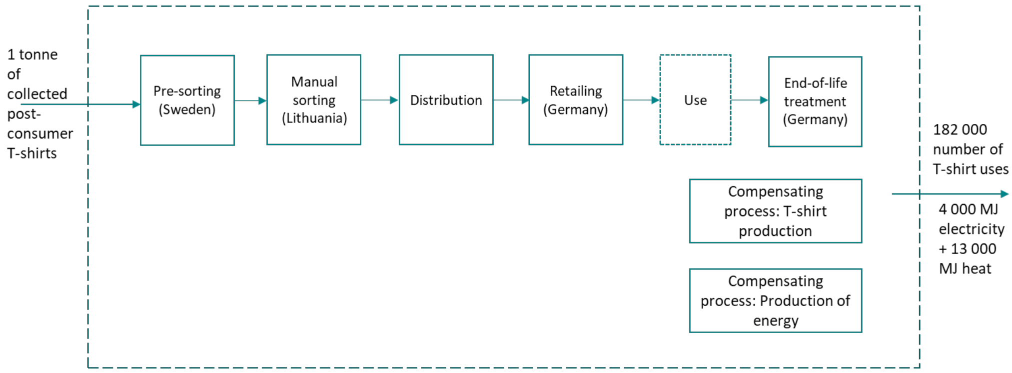


*Figure 4-2. The system boundaries for case study A (reuse in Europe). Included are the compensating processes of T-shirt production and energy (electricity and heat) production required to fulfil the functional unit. Background processes are excluded from the flowchart. "Use" has a dashed box to illustrate that this stage is excluded from case study.*

The initial step for this case study (reuse in Europe) is pre-sorting of 1 tonne of post-consumer T-shirts collected in Sweden, which are subsequently transported from Sweden to Lithuania for manual sorting. Thereafter, the garments are distributed (by truck) for retailing in Germany. Based on data from Humana, it is assumed that about 10% of the T-shirts going to retailing in Europe, will not be sold in Europe. This quantity is therefore transported to Kenya for further retailing. A 2% loss rate is assumed for the T-shirts exported to Kenya, see Section 4.1.8.2. The waste in Kenya is assumed to be sent to landfill (Sumo, 2024).

For this case study (A), the end-of-life treatment of the T-shirts is incineration with energy recovery. This is based on conditions specific to Germany (European Environment Agency, 2022). Additionally, the compensating processes T-shirt production and energy production is added to ensure that the total energy output and t-shirt uses from the system is the same as for all the case studies.

### 4.2.3 Case study B: Reuse outside Europe

Case study B is reuse outside of Europe and the processes involved in this case study is presented in Figure 4-3 below.

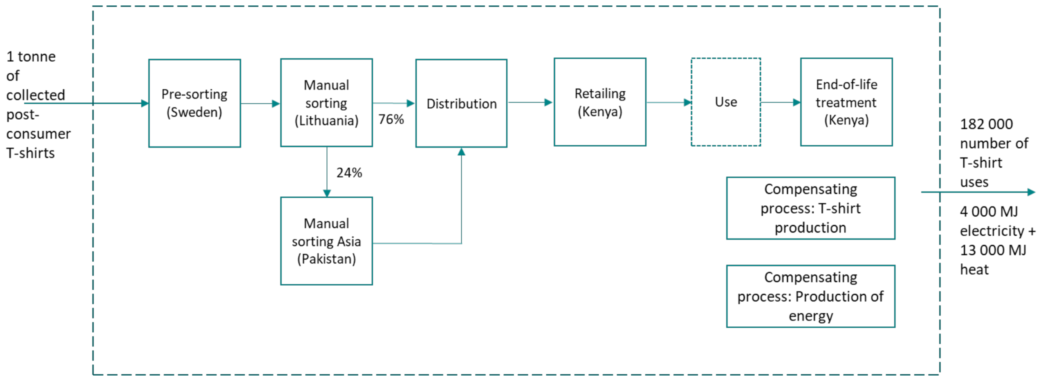


*Figure 4-3. The system boundaries for case study B (reuse outside Europe). Included are the compensating processes of T-shirt production and energy (electricity and heat) production required to fulfil the functional unit. Background processes are excluded from the flowchart. "Use" has a dashed box to illustrate that this stage is excluded from case study.*

This case study (reuse in Europe) is similar to case study A (reuse outside Europe). However, following the manual sorting in Lithuania, 24% of the sorted T-shirts are directed to manual sorting in Pakistan, while the remaining 76% are sent directly to distribution for resale in Kenya. This distribution is partially based on data from Humana (Humana Lt, 2022) and partially on data from UN Comtrade (United Nations, n.d.). According to UN Comtrade, Pakistan is the leading destination for used textiles from Lithuania, and Kenya is the primary recipient of used textiles from Pakistan. The LCI data for the manual sorting in Pakistan is based on data from Humana's sorting facility in Oman.

A 10% loss is assumed during the manual sorting process in Pakistan, based on data from Humana. It is assumed that 20% of this loss is sent to cement production (according to Humana), while the remaining 80% is directed to end-of-life treatment. In Pakistan, end-of-life treatment is assumed to be landfill (Nasir & Melanie, 2022; Safar, et al., 2019). The manually sorted fraction of T-shirts is distributed (by truck and ship) for resale in Kenya, where a 2% loss rate is assumed, see Section 4.1.8.24.1.8.2. After the T-shirts have been used, they are sent to end-of-life treatment in Kenya, which is assumed to be landfill (Sumo, 2024).

To produce the same number of T-shirt uses as the other case studies, the compensating process of T-shirt production was added. Furthermore, the compensating process of energy production is added. This compensating process is added as no incineration with energy recovery is assumed outside of Europe (Khan, et al., 2022).

## 4.2.4 Case study C: Recycling in Europe

The case study C is recycling in Europe and the process involved in this case study is presented in Figure 4-4. The system boundaries for case study C (reuse in Europe). Included are the compensating processes of energy (electricity and heat) production required to fulfil the functional unit.

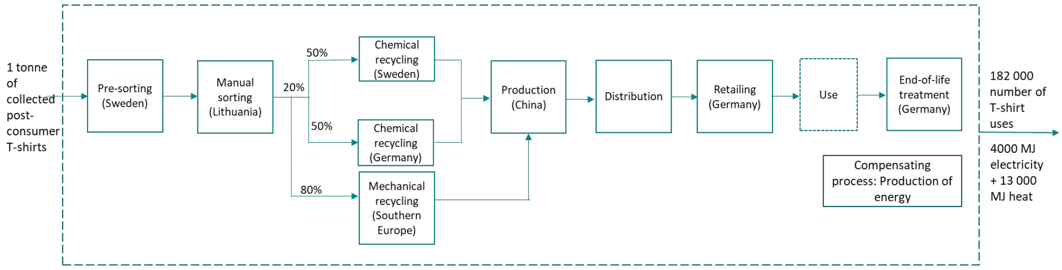


*Figure 4-4. The system boundaries for case study C (reuse in Europe). Included are the compensating processes of energy (electricity and heat) production required to fulfil the functional unit. Background processes are excluded from the flowchart. "Use" has a dashed box to illustrate that this stage is excluded from case study.*

Following pre-sorting and manual sorting, 20% of the T-shirts are assumed to be allocated for chemical recycling (Dahlbom, et al., 2023). Of this portion, 50% is designated for chemical recycling of cotton in Sweden, while the remaining 50% is assigned for polyester recycling in Germany (this assumption was done without any reference). The remaining 80% of T-shirts from the manual sorting process are assumed to undergo mechanical recycling, predominantly in Southern Europe (Dahlbom, et al., 2023).

The recycled fibres produced through recycling (chemical or mechanical) are subsequently transported to China for T-shirt production. The produced T-shirts are distributed to Germany, using truck and ship where they are used. The final process in is the end-of-life treatment in Germany. Germany's landfill rate was reported to be slightly below 1% (European Environment Agency, 2022) and less than 1% of textiles is assumed to be recycled today (Textile Exchange, 2023). The remainder (98%) is therefore assumed to be incinerated with energy recovery.

To ensure comparability among all case studies, the compensating process energy production has been included. Consequently, there is a total output of energy (electricity and heat) from the system equivalent to all case studies.

## 4.2.5 Case study D: Recycling outside Europe

Case study D is recycling outside of Europe and the processes included in this case study is presented in Figure 4-5 below.

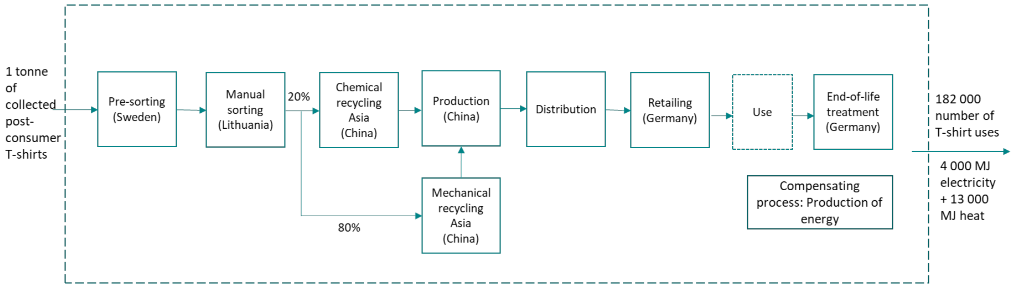


*Figure 4-5. The system boundaries for case study D. Included is the compensating processes of energy production (electricity and heat) required to fulfil the functional unit. Background processes are excluded from the flowchart. "Use" has a dashed box to illustrate that this stage is excluded from case study.*

Pre-sorting and manual sorting for this case study is identical to all case studies that include these processes, i.e. all case studies except E (incineration in Europe). After manual sorting in Lithuania, it is assumed that 20% of the T-shirts are allocated to chemical recycling, with an equal split between cotton and polyester, while the remaining 80% undergo mechanical recycling. Both recycling processes are assumed to take place in China. The proportion of T-shirts allocated to mechanical and chemical recycling is based on the same assumptions used for Europe in case study C (recycling in Europe) (Dahlbom, et al., 2023).

After mechanical recycling and production, the T-shirts are distributed to Germany (by truck and ship) for retailing, use (not included in the analysis) and end-of-life treatment. The end-of-life treatment assumptions for this case study align with those outlined in case study C (recycling in Europe).

To obtain comparability for all case studies, the compensating energy production process has been included. As a result, the system's total energy output (electricity and heat) is consistent with that of all case studies.

### 4.2.6 Case study E: Incineration in Europe

Case study E is incineration in Europe, i.e. incineration with energy recovery, and the processes involved in this case study is presented in Figure 4-6 below.

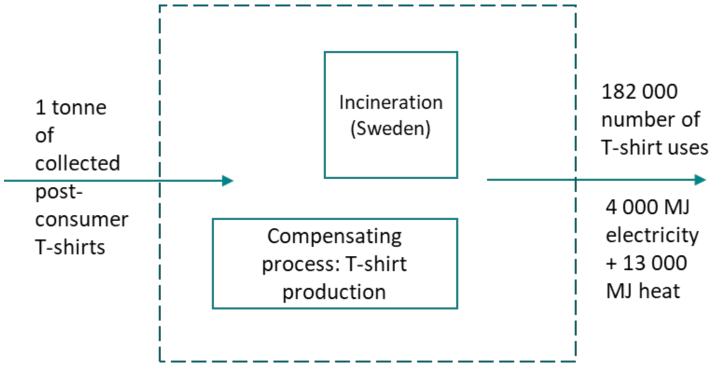


*Figure 4-6. The system boundaries for case study E (incineration in Europe). Included is the compensating process of T-shirt production required to fulfil the functional unit. Background processes are excluded from the flowchart.*

As for all case studies, the input material flow is 1 tonne of collected post-consumer T-shirts. These T-shirts are sent directly to end-of-life treatment in Sweden which is incineration with energy recovery where electricity and heat are generated. Of all case studies. this case study results in the highest energy output. However, the compensating process of T-shirt production is required to generate the same number of T-shirt uses generated from all other case studies.

## 4.3 Results and discussion

This section includes the results and discussion for the selected impact categories. Initially, results for Climate change are presented followed by water deprivation, eutrophication (freshwater, marine, and terrestrial) and primary energy use (non-renewable and renewable). This section also includes the results of the sensitivity analysis on replacement rate and loss rate.

### 4.3.1 Climate change

The results for climate change are presented in Figure 4-7, which provides a comprehensive overview of the hotspots identified in each case study. The results are presented in one bar for each case study, divided in eight processes: sorting, recycling, T-shirt production, distribution, retailing, end-of-life treatment, compensating energy production, and compensating T-shirt production. In the recycling cases (A and B) there is no impact for the compensating T-shirt production, as both recycling cases (in and outside of Europe) yield the highest number of T-shirt uses among all case studies. Consequently, in case study E (incineration in Europe), there is no impact for the compensating energy production since this case has the highest energy output.

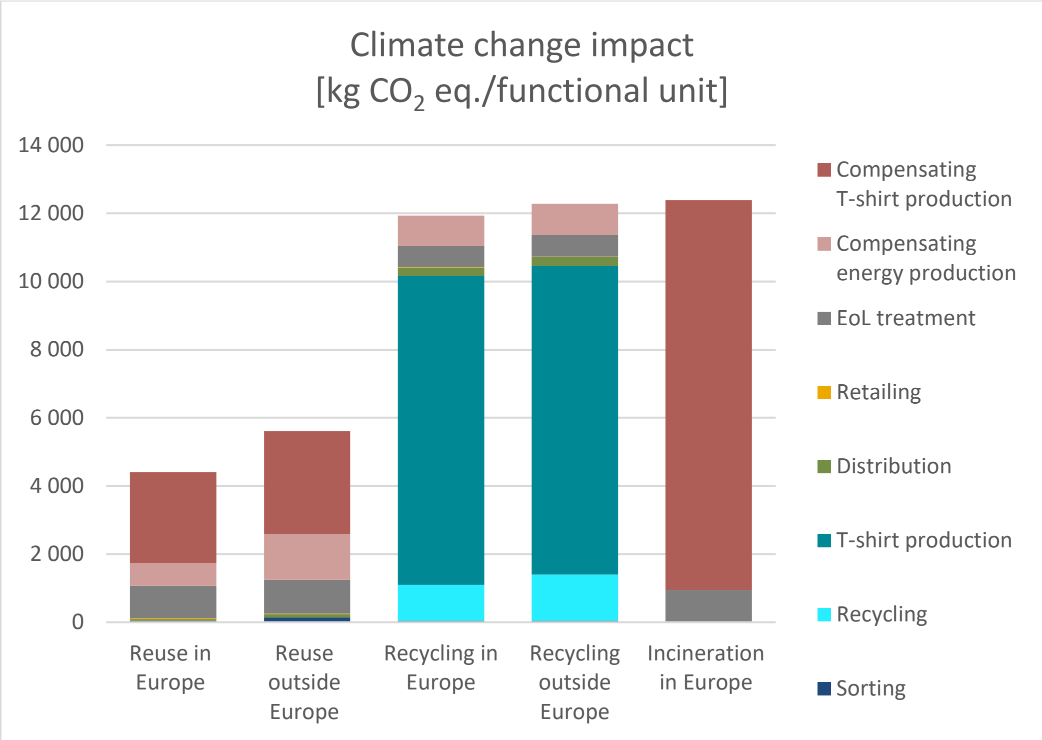


*Figure 4-7: Climate change results for all case studies (A-E). The results are presented for the following processes: Sorting (pre-sorting and manual sorting), recycling, T-shirt production, distribution, retailing, end-of-life (EoL) treatment, compensating energy production, and compensating T-shirt production.*

The results for climate change show that reuse in Europe (case study A) has the lowest impact of the case studies. This is followed by reuse outside Europe (case study B). The primary impact for both cases arises from the compensating T-shirt production, which is influenced by the assumption of a replacement rate of 50%. A sensitivity analysis has been conducted to study the impact of this parameter, see Section 4.3.5.1 for results.

The main difference between the two reuse cases lies in the compensating energy production, where reuse outside Europe (case study B) has a slightly higher impact. This is attributed to the assumption that there is no incineration with energy recovery outside of Europe (Khan, et al., 2022), necessitating greater energy production in case study B to balance the overall system outcome.

The results show that recycling in Europe (case study C) has a slightly lower climate change impact than recycling outside Europe (case study D). The only processes that differ between the two cases are the recycling operations conducted within Europe (case study C) and those conducted outside of Europe (case study D). However, these differences don't have as much impact as the T-shirt production. Note that in both recycling case studies (C and D) we assume that T-shirt production occurs in Asia, for example using the average Chinese electricity mix with a climate impact of 0.8 kg $CO_2$eq. per kWh. If textile recycling in Europe would mean that T-shirt production instead occurs in Europe, using energy with lower climate impact, this would lead to lower climate impact for case study C (recycling in Europe).

The highest impact among all case studies is observed in incineration in Europe (case study E). The primary impact for incineration in Europe stems from the compensating T-shirt production. In other words, when T-shirts are incinerated after being collected from their first users, rather than being reused or recycled, they are no longer available for use or as a raw material for recycling. Therefore, more new T-shirts will have to be produced to satisfy the market demand, compared to if the T-shirts had been reused or recycled. The production of these new T-shirts from primary fibres is what causes the main climate change impact of case study E (incineration in Europe). This shows the importance of adding processes to ensure the compared case studies have identical functions. Without the compensating processes, incineration would have had the lowest results together with the reuse scenarios.

For climate change impact, there is minimal difference in the results between the recycling cases and incineration. This is because the biggest impact in the climate change results don't come from the fibre production, as have been shown in previous studies (Sandin, et al., 2023; Lidfeldt, et al., 2023). Instead, the hotspot lies in the garment production. Garment production is an energy-intensive process, and the energy sourced in China has a high reliance on fossil fuels (IEA, 2023). Consequently, the results indicate a high climate change impact associated with garment production. In general, energy consumption, particularly the use of primary fossil fuels for heat and electricity, is the main driver of environmental impacts in textile production, a trend consistent across all impact categories. It is mainly the electricity from fossil resources, but also some heat from fossil resources, used in the wet treatment processes that dominate. For further details on the factors contributing to the impact of these life-cycle stages, we refer to the modelling source Sandin et al. (2019).

These results are aligned with the waste hierarchy, which implies that reuse have the lowest climate change impact compared to recycling and incineration.

### 4.3.2 Water deprivation

Figure 4-8 illustrates the results for all case studies in terms of water deprivation impact. The results are presented in one bar for each case study, divided in seven processes: recycling, T-shirt production, distribution, retailing, end-of-life treatment, compensating energy production, and compensating T-shirt production.

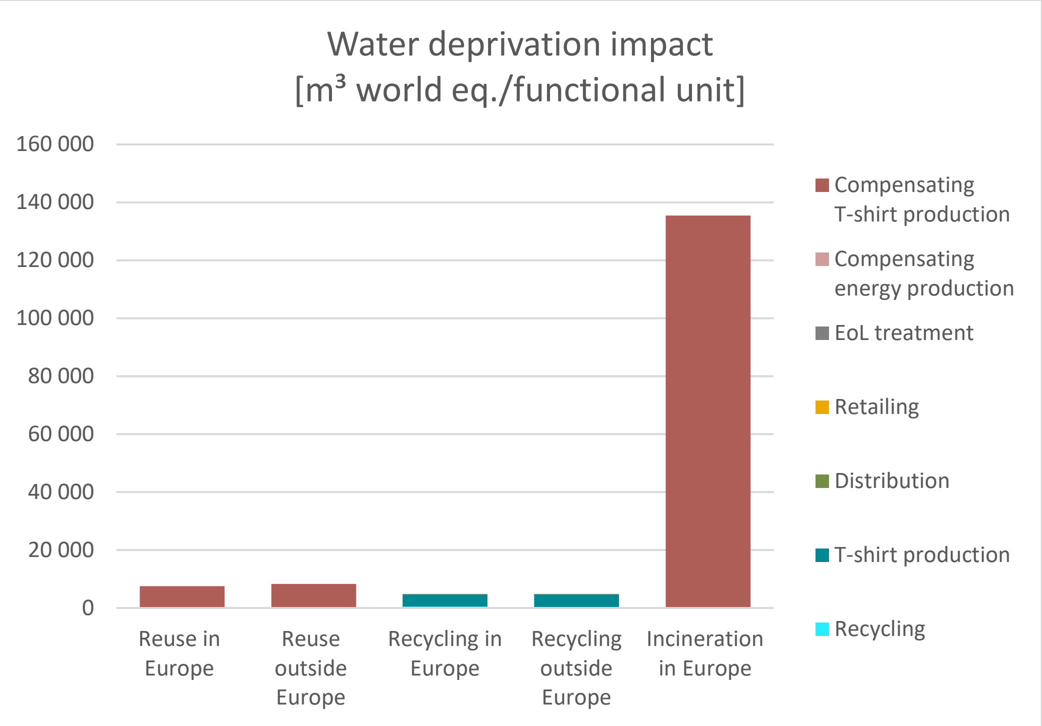


*Figure 4-8: Water deprivation results for all case studies (A-E). The results are presented for the following processes: Recycling, T-shirt production, distribution, retailing, end-of-life (EoL) treatment, compensating energy production, and compensating T-shirt production.*

The result for water deprivation impact clearly shows that case study E (incineration in Europe) has a noticeably higher impact compared to the other case studies (recycling and reuse). Specifically, case study E (incineration in Europe) shows an impact that is 16 to 28 times greater than that of case studies A-D. Almost all the impact for case study E (incineration in Europe) is attributed to the compensating T-shirt production, as was the case for climate change impact. This is explained primarily by fibre production (specifically cotton cultivation) being a main water deprivation hotspot in this compensating process. When the collected T-shirts are incinerated, the fibres are no longer available for T-shirts uses (neither through reuse nor recycling), and therefore new cotton must be cultivated to deliver the T-shirt uses needed to fulfil the functional unit. The avoided water deprivation impact is a key benefit of cotton recycling, which aligns with previous research showing that raw material extraction for fibre production is the most important contributor to water deprivation (Lidfeldt, et al., 2023).

When comparing the results between the reuse case studies (A and B) and the recycling case studies (C and D), the results reveal that the reuse cases have approximately twice the impact of the recycling cases. This difference is because reused T-shirts are assumed to be used half the number of times compared to newly produced T-shirts made of recycled materials, i.e., the replacement rate is 50% for reused T-shirts (alternative replacement rates are analysed in Section 4.3.5.1). Although there are some losses in the recycling processes, the recycling case studies still result in more T-shirt uses than the reuse scenarios. Therefore, the compensating T-shirt production, which includes cotton cultivation that contributes to water deprivation impact, is considered. In other words, the T-shirts produced in the compensating T-shirt production are made from primary fibres, which require considerably more water than T-shirts produced from recycled fibres.

### 4.3.3 Eutrophication

In this section, results for freshwater, marine, and terrestrial eutrophication are shown in Figure 4-9, Figure 4-10 and Figure 4-11, respectively. The results are presented in one bar for each case study, divided in seven processes: recycling, T-shirt production, distribution, retailing, end-of-life treatment, compensating energy production, and compensating T-shirt production. Note that the results for the eutrophication impact categories are expressed in different units and, therefore, cannot be compared.

In Figure 4-9, the results of freshwater eutrophication are shown.

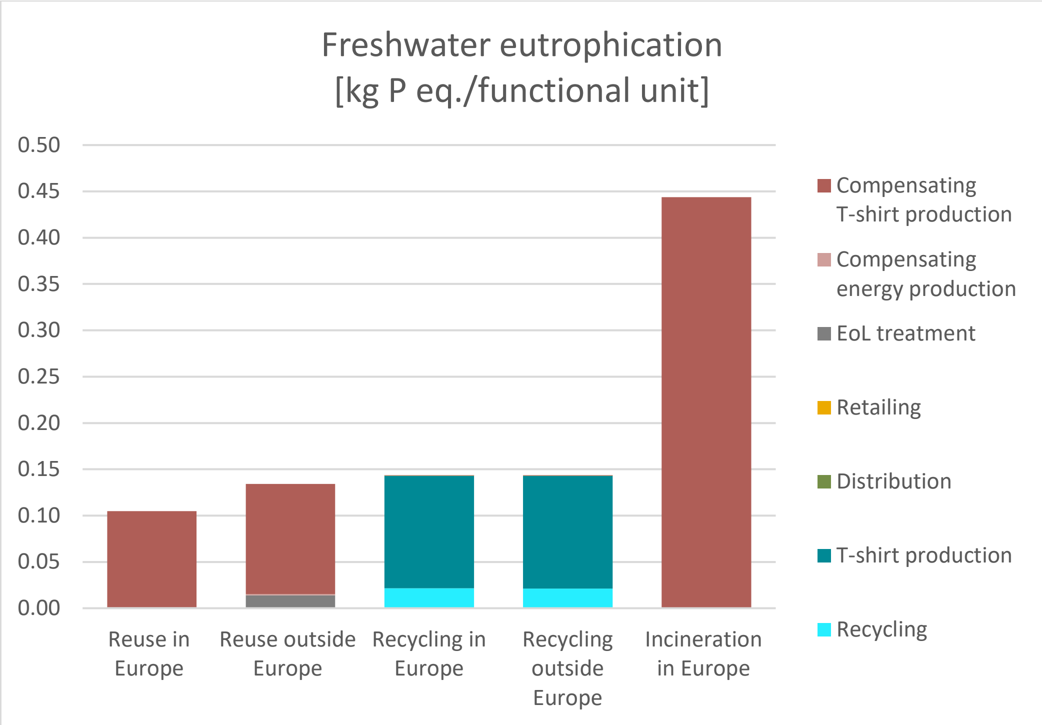


*Figure 4-9: Freshwater eutrophication results for all case studies (A-E). The results are presented for the following processes: Recycling, T-shirt production, distribution, retailing, end-of-life (EoL) treatment, compensating energy production, and compensating T-shirt production.*

The freshwater eutrophication results shows that case study E (incineration Europe) has the highest impact of all. More specifically, the compensating T-shirt production is what contributes to freshwater eutrophication. Within this process, cotton cultivation as well as production of ethylene glycol and purified terephthalic acid (that are used to produce primary polyester) are important contributors to the impact, followed by T-shirt production.

The reuse (A and B) and recycling (C and D) case studies have comparable freshwater eutrophication results. For all case studies, the major contribution comes from T-shirt production, either as T-shirt production from recycled fibres (C and D) or as compensating T-shirt production (A, B and E). For the incineration scenario (E), the compensating T-shirt production includes fibre production, which is the main contributor to the results. The reuse and recycling scenarios require less fibre production to fulfil the functional unit, and therefore the results of these scenarios are considerably lower.

Figure 4-10 presents the results for marine eutrophication.

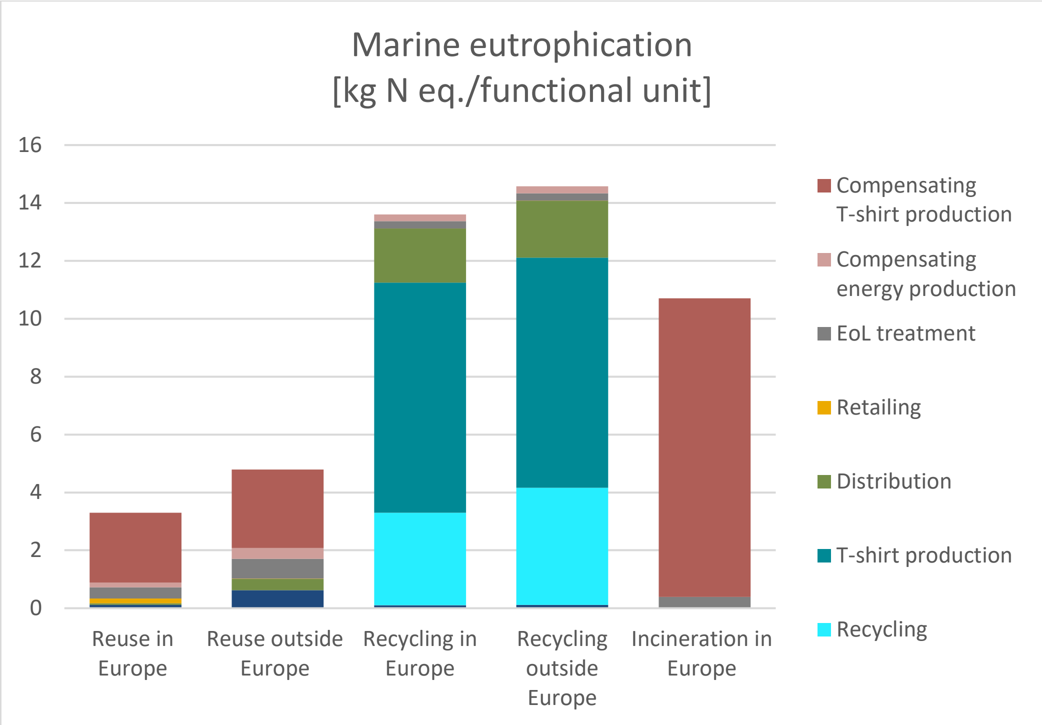


*Figure 4-10: Marine eutrophication results for all case studies (A-E). The results are presented for the following processes: Recycling, T-shirt production, distribution, retailing, end-of-life (EoL) treatment, compensating energy production, and compensating T-shirt production.*

For marine eutrophication, the impacts are similar for the recycling cases (C and D) and the incineration case (E) with the recycling cases having the highest impact. For incineration, it is the compensating T-shirt production that contributes most to the impact, whereas the T-shirt production is the major contributor in the recycling cases. Note that it is the same subprocess that is the main contributor in both these cases, namely the T-shirt production (the compensating T-shirt production includes the entire life cycle of the T-shirt, from raw material extraction to end-of-life treatment). Within this process it is the district heat generated in China that has the biggest impact, which is used in the wet treatment. The results of the reuse cases (A and B) are lower, with reuse in Europe (A) having the lowest results.

In Figure 4-11, the results for terrestrial eutrophication are shown.

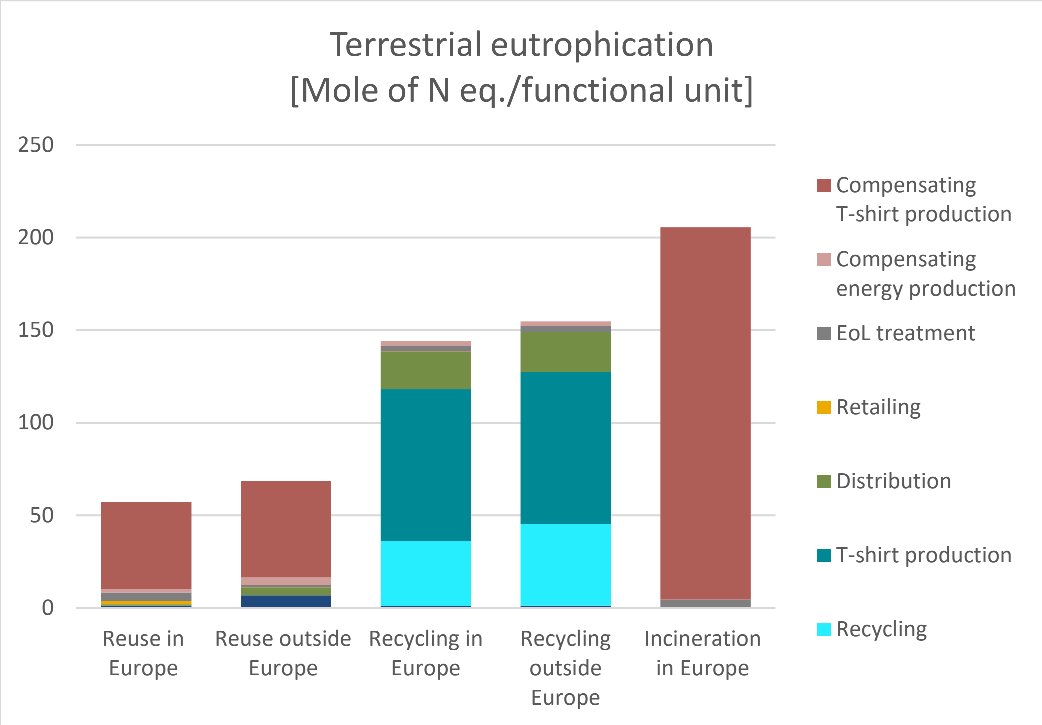


*Figure 4-11: Terrestrial eutrophication results for all case studies (A-E). The results are presented for the following processes: Recycling, T-shirt production, distribution, retailing, end-of-life (EoL) treatment, compensating energy production, and compensating T-shirt production.*

For terrestrial eutrophication, incineration (E) has the highest impact followed by the recycling cases (C and D). The reuse cases (A and B) have the lowest impact when it comes to terrestrial eutrophication.

The biggest impact for the incineration case and the reuse cases comes from the compensating T-shirt production. The main contributor within this process is the cotton fibre cultivation, as was the case for freshwater eutrophication. For the recycling cases it is the T-shirt production that is the most important contributor to the impact, since the impact of fibre production is excluded in the recycling cases. Within the T-shirt production it is the Chinese district heat used in wet treatment that is the main contributor, as was the case for marine eutrophication.

Whether recycling or reuse occurs in or outside of Europe does not affect this impact category significantly. This holds true for all eutrophication results.

### 4.3.4 Primary energy

This section includes the results of non-renewable and renewable primary energy use. The results are presented in one bar for each case study, divided in seven processes: recycling, T-shirt production, distribution, retailing, end-of-life treatment, compensating energy production, and compensating T-shirt production.

Figure 4-12 shows the results for total use of non-renewable primary energy (PENRT).

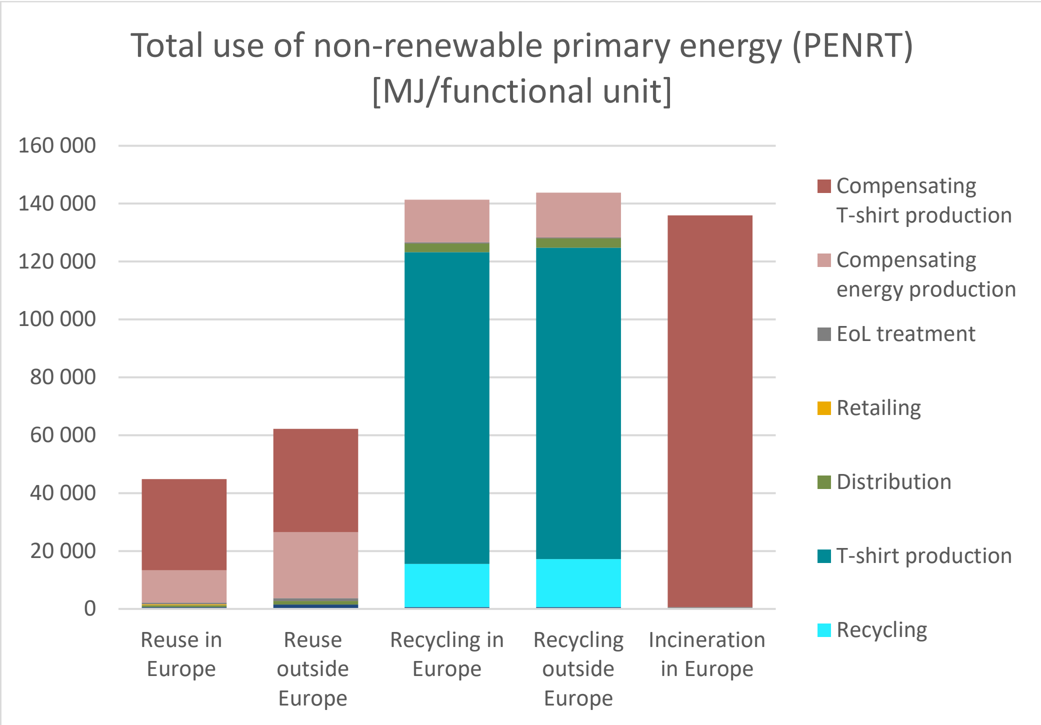


*Figure 4-12: Total use of non-renewable primary energy for all case studies (A-E). The results are presented for the following processes: Recycling, T-shirt production, distribution, retailing, end-of-life (EoL) treatment, compensating energy production, and compensating T-shirt production.*

The results for PENRT indicate that the reuse case studies (A and B) use less non-renewable primary energy, compared to the recycling case studies (C and D) and incineration in Europe (case study E). This is primarily because case studies C, D and E require much more production of new T-shirts to fulfil the functional unit, compared to the reuse case studies, and these processes are highly energy demanding.

The PENRT hotspot for all case studies is the T-shirt production, that is an energy-intense process assumed to occur in China, and the energy sourced in China has a high share of fossil fuels (IEA, 2023), as stated earlier in the report.

Figure 4-13Figure 4-13 shows the result for total use of renewable primary energy resources (PERT).

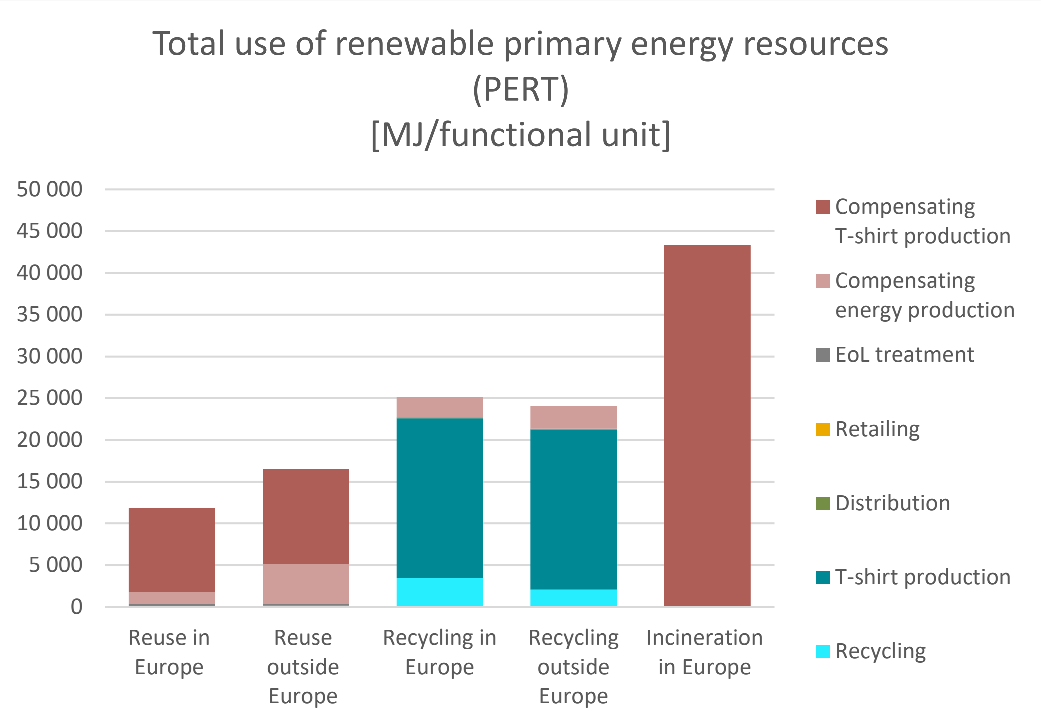


*Figure 4-13: Total use of renewable primary energy resources for all case studies (A-E). The results are presented for the following processes: Recycling, T-shirt production, distribution, retailing, end-of-life (EoL) treatment, compensating energy production, and compensating T-shirt production.*

The results for PERT show that incineration in Europe (case study E) has the highest renewable primary energy use, while the reuse cases (A and B) have the lowest use. The results for the recycling case studies (C and D) are lower compared to incineration (E). Be aware that the y-axis value varies between Figure 4-12 and Figure 4-13.

For all case studies, it is the T-shirt production that is the main PERT hotspot. More specifically, for the reuse cases and the incineration case, most primary renewable energy resources are used in the cotton fibre cultivation. While for the recycling cases, it is the generation of electricity used in the yarn production that is the major user of primary renewable energy resources.

### 4.3.5 Sensitivity analysis

This section includes the results of the sensitivity analysis on replacement rate and loss rate, i.e. the share of exported clothes being discarded as waste.

### 4.3.5.1 Sensitivity analysis of replacement rate

The results of the sensitivity analysis focused on replacement rate for reuse is presented in Figure 4-14Figure 4-14. As was justified in Section 4.1.8.1, the base case assumed a replacement rate of 50%, while the assumed replacement rate for the sensitivity analysis is 25% and 75%.

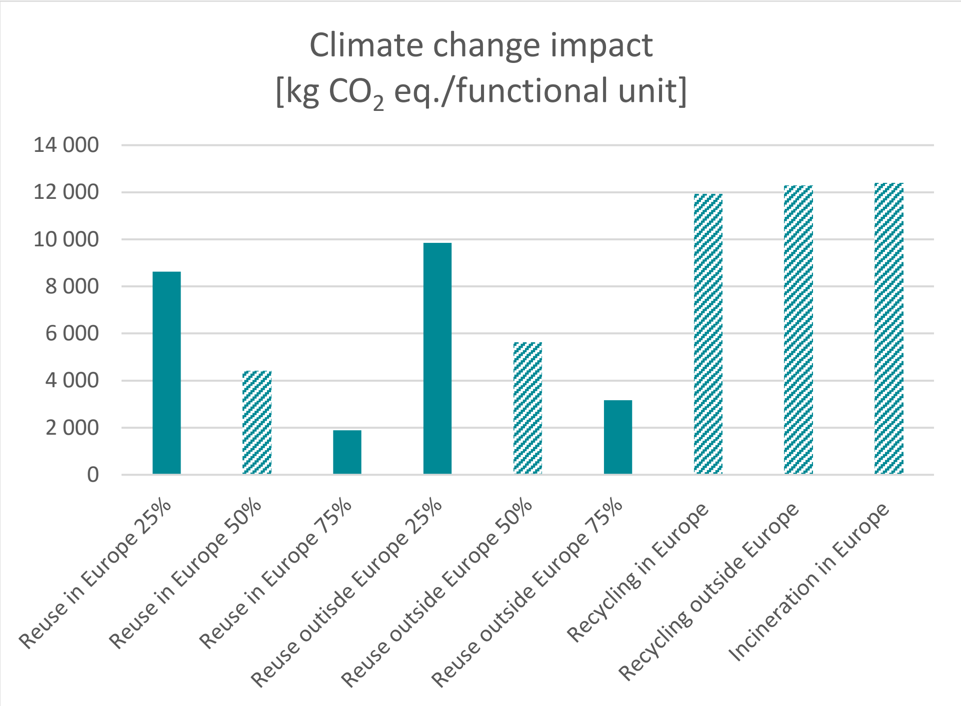


*Figure 4-14: Climate change impact of the sensitivity analysis focusing on replacement rate for case study A (reuse in Europe) and B (reuse outside Europe). The replacement rate is assumed to be 25%, 50% and 75%. The dashed bars represent the base cases, and the fully coloured bars represent the sensitivity analysis.*

The results of the sensitivity analysis on the replacement rate of reused T-shirts indicate that this factor has a considerable effect on the climate change results. Compared to the base case, a 25% replacement rate increases the climate change impact by 76% and 97% for case studies A and B, respectively. Conversely, a 75% replacement rate reduces the impact by 44% and 58% compared to the base case for case studies A and B.

When the replacement rate for reuse is 25% or 50%, case studies C (recycling in Europe) and D (recycling outside Europe) generate the most T-shirt uses from 1 tonne of post-consumer T-shirts. However, with a 75% replacement rate, most T-shirt uses are generated in case study A (reuse in Europe), which therefore does not need compensating T-shirt production. This explains the lower results for the 75% replacement rate for the reuse cases.[3]

The results for the other impact categories (water deprivation, eutrophication, primary energy resources) are presented in Appendix 6: Sensitivity analysis. They follow the same trend as the result for climate change, meaning that the 25% replacement rate increases the impact for the reuse cases while the 75% replacement rate decreases the impact for the reuse cases. However, the results for freshwater eutrophication show that assuming a 25% replacement rate translates to higher impact for the reuse cases compared to the recycling cases. This is the only impact category that shows higher results for reuse than for recycling (except for water deprivation impact, but that impact category already had a higher impact for the reuse cases compared to the recycling cases in the base cases). The main freshwater eutrophication impact comes from the cotton cultivation. With a lower replacement rate, this impact increases due to the need for more compensating T-shirt production.

#### 4.3.5.2 Sensitivity analysis of loss rate

This sensitivity analysis examines the share of garments exported outside of Europe that are discarded as waste, i.e. the loss rate. As was justified in Section 4.1.8.2, the base case assumes a 2% loss rate, while a 40% loss rate is tested in the sensitivity analysis. The results are presented in Figure 4-15.

[3] When case study A generates the most T-shirt uses, the functional unit will also have to include more T-shirt uses. This means that the other scenarios would have to include more compensating T-shirt production to fulfil this new functional unit. This change in functional unit is not reflected in Figure 4-14, which means that it slightly underestimates the climate impact results of the other scenarios when compared with the “Reuse outside Europe 75%” scenario.

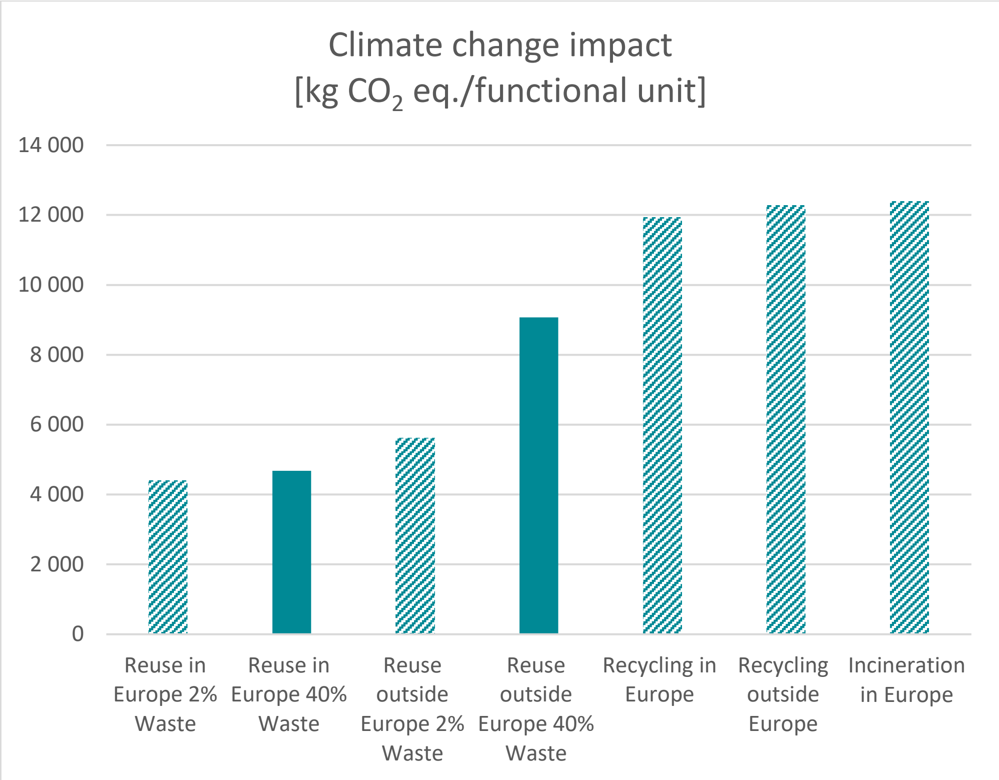


*Figure 4-15: Climate change impact of the sensitivity analysis on loss rate. In the base case, a 2% loss is assumed and in the sensitivity analysis a 40% loss is assumed. The dashed bars represent the base cases and the fully coloured bars the sensitivity analysis.*

The results indicate that a substantially higher loss rate translates to a nearly 60% increase in climate change impacts for reuse outside Europe (case study B). This increase is not surprising, as a higher loss rate means that fewer T-shirt uses are generated from the reused T-shirts. Therefore, more compensating T-shirt production is necessary to fulfilling the functional unit. As shown in Figure 4-7, the main climate impact of case study B is the T-shirt production. A smaller increase is also noted in case study A (reuse in Europe) since the waste generated during retailing in Europe are being sent to Kenya for resale.

Results from the sensitivity analysis for the other impact categories (water deprivation, eutrophication, primary energy resources) are presented in Appendix 6: Sensitivity analysis. The results for those impact categories follow the same trend as for climate change, where the impact for reuse outside Europe increases. The results for freshwater eutrophication show that reuse outside Europe gets a higher impact than the recycling cases when the loss rate is 40% instead of 2%. The above results and discussion highlight the importance of the loss rate when studying reuse. A high loss rate implies an inefficient system, where many of the textile products sent to reuse are never reused and thus never replace production of new textile products. In such a system, the environmental benefit of reuse compared to recycling and incineration are much lower compared to an efficient system with a low loss rate. However, even with a high loss rate (40%) there are clear benefits with reuse for most impact categories. This is a parameter for which we recommend more data to be collected to improve future studies of reuse, especially studies of reuse in outside Europe. As pointed out in Section 4.1.8.2, there are few available reliable data sources, and many of the sources reporting loss rates do not give references or describe how the data were derived.

## 4.4 Conclusions

In this section, the main conclusions of the LCA study are summarised in relation to the outlined research questions. These conclusions are based on the results and discussion presented in the previous Section 4.3.

Before delving into the conclusions, it is important to note that this study does not aim to determine the most common practices for managing post-consumer textiles today, or to study the most common fraction of collected textiles. Instead, it focussed on practices viewed as viable options for increasing the circularity and reduce the environmental impact of the textile industry in Europe. An ideal fraction of collected textiles have been chosen – 1 tonne of T-shirts, that together are made of 60% cotton and 40% polyester –that enabled the comparison of reuse and fibre-to-fibre recycling. Section 4.1.2 further justifies the studied practices.

1. What’s the environmental impact of textile reuse in and outside of Europe compared to textile recycling in and outside of Europe?

The following conclusions are drawn:

- For climate change, eutrophication (freshwater, marine, terrestrial), and energy use (renewable and non-renewable), reuse has the lowest environmental impact of the three practices (reuse, recycling, and incineration), with case study A (reuse in Europe) demonstrating a lower impact compared to case study B (reuse outside Europe).
  - For climate change and energy use (PERT and PENRT), this difference is mainly attributed to the compensating energy production, which is slightly higher for case study B (reuse outside Europe), due to the assumption that there is no incineration with energy recovery outside of Europe.

  - For freshwater and marine eutrophication, it is the end-of-life treatment that has a higher impact for case study B compared to case study A. For terrestrial eutrophication, it is the sorting process that results in a higher impact for case study B compared to case study A.
- Water deprivation impact is the only indicator that shows the lowest results for the recycling cases (C and D). This is because reused T-shirts are assumed to be used half the number of times compared to a newly produced T-shirt made of recycled materials. Thus, the recycling cases (C and D) generate more T-shirt uses than the reuse ones (A and B). The compensating T-shirt production in the reuse cases have water deprivation impact, due to the cotton cultivation.
- There is minimal difference in the results between case study C (recycling in Europe) and D (recycling outside Europe) for all impact categories. This indicate that the recycling processes, and where they are located, have a limited impact on the environmental impact results. The main impact in the recycling case studies is from production (including yarn and fabric production), which is primarily due to its energy-intensive nature.
- There is no substantial difference in climate change impact between the recycling (C and D) and incineration case study (E) which is aligned with previous studies (Lidfeldt, et al., 2023). This is explained by the fact that the production of primary fibres, which decrease because of material recycling, generally contribute with no more than about 10% of the climate impact of textile products. In contrast, reuse (A and B) that decrease the need for additional production processes, leads to greater climate change benefits.
- The results are aligned with the waste hierarchy which indicate the importance of collecting post-consumer textiles and prioritise reuse.
- The results show that there is not a big difference in terms of environmental impact if the T-shirts are reused in or outside of Europe (as was explained in the first conclusion). We expect this conclusion to be valid also for other types of clothing, likely with greater climate impact benefits the more complex the garment is, as production of more complex garments generally yield higher climate impact (Sandin, et al., 2019).
- There is much greater difference between reuse in and outside of Europe (Africa) if we assume a higher loss rate for t-shirts reused outside of Europe, which is an uncertain parameter in our model, see more below.

2. What parameters (such as replacement rate) are of great significance for the environmental impact of reuse and recycling in and outside of Europe?

The following conclusions are drawn:

- The sensitivity analysis on loss rate, i.e. how much of the textiles exported outside of Europe (Africa) is disposed as waste, showed that a high loss rate translates to a substantial difference between reuse in and outside of Europe (Africa), with a substantially lower environmental impact for reuse in Europe. This holds true for all studied impact categories. This shows the importance of the loss rate when studying reuse which is one of the modelling parameters in our study associated with greatest uncertainty. We assumed a 2% loss rate, but there are reports implying a 40% loss rate (see more in Section 4.1.8.2). We recommend future studies to focus on investigating the loss rates in more detail, preferably by collecting primary data.
- If the replacement rate (how many times a T-shirt can be used if it is reused) is lower than assumed in the base case (50%), there is a smaller difference between the reuse cases and recycling cases. In the same way, the difference between the reuse cases and recycling increases with a higher replacement rate. This is accurate for all impact categories except for water deprivation. For water deprivation, the results show an even higher impact for the reuse cases if the replacement rate is low, which means a higher difference between the reuse and recycling cases. When the replacement rate is higher there is instead a lower difference between the reuse and recycling cases, since the results from the beginning had a higher impact for reuse compared to recycling. The conclusion drawn for all impact categories is that the replacement rate has a big impact on the results.

The final reflections and conclusions of the LCA, presented below, focus on the modelling approach employed: system expansion. This approach involves an expanded functional unit and the addition of compensating processes to ensure that the compared case studies fulfil the same functional unit.

- The system expansion approach presented challenges in communicating the method and the results, both within this report and during presentations to project partners and other stakeholders. For example, the functional unit, which involves managing 1 tonne of collected post-consumer T-shirts, generating 17 000 MJ of energy, and facilitating 182 000 T-shirt uses, is not inherently intuitive. Furthermore, it proved difficult to explain that some compensating processes, such as T-shirt production, are identical to other processes within the product system itself. Clear communication is crucial, and efforts should be made to simplify complex concepts. For example, the figure in Appendix 1: Illustration of the functional unit , was included when presenting project results, in an attempt to clarify the functional unit.

- The system expansion approach allowed for a fair comparison of the case studies. Different methods for managing post-consumer materials inherently produce different functions, in our case: direct use of products, feedstock for material recycling, and energy. Our results show that system expansion enabled a comparison of reuse, recycling, and incineration, with the compensating processes being crucial to the results. For example, without the compensating processes, incineration would have been the most preferred option, rather than the least preferred, for all studied indicators. This would have been in direct conflict with the waste hierarchy. Ultimately, the system expansion approach proved useful, and we recommend its use when comparing the environmental impact of product systems that generate different functions.

# 5 Analysis of economic and social effects

This section presents the goal and scope of the analysis of economic and social effects conducted within this project. The method used for the analysis is also presented, followed by results and discussion. Lastly, the conclusions and recommendations based on the analysis is presented.

## 5.1 Goal and scope

This analysis examines the economic and social effects of textile reuse, with a focus on the trade of post-consumer textiles for the second-hand clothing (SHC) market. The emphasis on reuse stems from the fact that recycling used textiles into new materials remains limited. In 2022, only 1% of pre- and post-consumer textiles were recycled into new textiles (Textile Exchange, 2023).

This analysis complements the life cycle assessment (LCA) of case study A (reuse in Europe) and B (reuse outside Europe). For reuse in Europe, this analysis focuses on Lithuania and for reuse outside Europe, Kenya is the focus of the study. These countries represent distinct markets, offering insights into varying conditions, opportunities, and challenges within the textile sector.

This analysis aims to address the following question: What are important economic and social effects of the SHC trade related to reuse in and outside of Europe?

Regarding economic effects, market opportunities, challenges, and dynamics are explored. Social effects that are investigated involve a broader perspective, including the role of the SHC market in community development, while addressing both its potential and its limitations.

### 5.1.1 Limitations

This study has certain limitations, primarily due to its focus on the economic and social effects of textile reuse in two specific markets: Lithuania and Kenya. As a result, the findings are limited to these geographical areas and do not extend to other trade routes or destinations, such as other African countries where collected textiles may be reused.

While this study explores economic and social effects in these regions, it does not encompass all potential opportunities and risks associated with the trade of post-consumer textiles fit for resale on the SHC market. Notably, certain important dimensions such as the indirect social effects of textile reuse in supporting charitable activities, gender-specific advantages and disadvantages, and the occupational risks associated with the informal nature of many jobs created in African countries, are acknowledged. However, these dimensions are not examined in depth. These significant factors require further investigation to achieve a more comprehensive understanding of the subject. Furthermore, a limited number of reports and articles (25 in total) have been included in the literature review to describe and present key economic and social effects of textile reuse. Of these, 13 have been referenced in the literature review, which limits the scope of the analysis and impacts the comprehensiveness of the overall understanding.

Additionally, the study reflects the perspectives of a limited number of participants in each location, meaning it cannot confirm broader generalizations or whether there is widespread agreement on specific issues. The participants also have different personal, and/or professional stakes in the SHC market, which likely influences their view on the subject. Furthermore, given the complexity of the SHC trade as part of a global production system, this research only examines a small segment of the entire system.

## 5.2 Method

The analysis of economic and social effects is based on a literature review combined with semi-structured interviews. In addition to the literature review and the interviews, conversations were held with the project partners, to get their broad, contextual, overview around the trade dynamics for SHC and its economic and social effects. Also, a field visit to Humana sorting centre in Lithuania, was conducted, which enriched the authors' understanding of manual sorting and the handling of collected textile in Europe. This field visit is further detailed in Appendix 7: Field study to Humana´s sorting facility.

### 5.2.1 Literature review

The literature review involved gathering data from academic journals, reports, and relevant publications that focus on textiles suitable for reuse in the global SHC market, emphasizing economic and social effects. Relevant publications were identified using keyword combinations such as: "second-hand clothing market," "SHC trade" "textile reuse," "economic effects," "social effects," "value chain," "business model," "health impacts," and "livelihoods."

The goal of the literature review was to identify results and conclusion from the literature of the opportunities, and risks associated with the SHC trade. It provided knowledge of key economic and social effects, identifying both potential benefits and challenges. Some of the economic and social effects identified in the literature were observed on a global scale, whereas some appeared in a more geographically specific context.

The results and information compiled in the literature review were used to guide the formulation of the interview questions. This was done to investigate whether the economic and social effects identified in the literature review, manifest in the two locations included in this study (Lithuania and Kenya), and how the opportunities and risk plays out on each market.

### 5.2.2 Interview study

The interviews were conducted with key respondents from the two selected locations: Lithuania and Kenya. In total, ten interviews were carried out with stakeholders who are either directly involved in the SHC trade or have the ability to influence national SHC trade and market strategies. Participants were selected based on their roles or organizational involvement within the SHC value chain, ensuring that a range of perspectives was captured. For reuse in Lithuania, this study captured the perspectives of three respondents located in Vilnius, as presented in Table 5-1. For reuse in Kenya, this study captured the perspectives of seven respondents located in Nairobi, as presented in Table 5-2. To ensure anonymity, each respondent has been assigned a reference number (see Table 5-1 and Table 5-2), which will be used throughout the report. A more detailed description of the respondents' roles and involvement in the SHC trade is provided in Appendix 8: Respondents in the interview study.

*Table 5-1. Respondents in Lithuania, including their roles and businesses.*

| No. | Role and involvement in the SHC value chain |
|---|---|
| 1 | Import-Export Manager at a Wholesale Sorting Company<br>*Manage suppliers and customers for SHC operations, overseeing trade and compliance.* |
| 2 | Deputy Manager for Second-hand Shops<br>*Manage retail operations for second-hand shops in Lithuania, Latvia, Estonia, Hungary, Belgium, and Poland.* |
| 3 | Business Developer at a Waste Management Company<br>*Manage and develop the wholesale sorting business.* |

*Table 5-2. Respondents in Kenya, including their roles and businesses.*

| No. | Role and involvement in the SHC value chain |
|---|---|
| 4 | Manager at a Medium SHC Business<br>*Oversees SHC importing, wholesale, retail, and exporting operations.* |
| 5 | Manager at a Small SHC Business<br>*Oversees SHC importing, wholesale and retail.* |
| 6 | Manger at a Small SHC Business<br>*Handles SHC imports and redistributes to wholesalers, retail shops, and open-air markets.* |
| 7 | Co-Founder at a Textile Upcycling Company<br>*Leads textile collection and upcycling into high-end products for local and export markets.* |
| 8 | Wholesale Manager at a SHC Company<br>*Oversees SHC warehousing and distribution operations across multiple branches.* |
| 9 | Business Developer at a SHC Company<br>*Manage and develop the wholesale sorting business.* |
| 10 | CEO at Regional Trade Association<br>*Directs industry initiatives, partnerships, and regional SHC trade development.* |

The interviews, which aimed to explore the lived experiences of those engaged in the SHC trade, were conducted as digital video meetings, mainly using the platform Teams. Additionally, one interview was conducted via Zoom, and another through WhatsApp. The interviews were conducted in August and September of 2024. Each semi-structured interview took approximately 60 minutes and featured open-ended questions to facilitate dynamic and in-depth discussions.

The interview questions focused on the respondent's experience and insights in the SHC business, as well as the economic and social effects associated with it. A sample of the interview questions is included in Appendix 9: Example of interview questions.

## 5.3 Results

The results section for the analysis of economic and social effects is divided into two parts. The first part presents the results from the literature review, which takes a global perspective on the SHC trade. The second part presents the results from interviews conducted with respondents in Lithuania and Kenya.

### 5.3.1 Results from the literature review

The SHC trade has long provided an affordable option for individuals with limited financial resources. It is a value chain connecting developed and developing countries, offering an affordable clothing consumption alternative for people facing economic decline, poverty, and low purchasing power. Traditionally, the trade was dominated by countries in the Global North[4], where charities and other organizations collected textiles and exported them to the Global South[5], which had a demand of affordable clothing (Dissanayake & Pal, 2023; Ellen Macarthur Foundation, 2024; Sumo, 2024).

In recent years, the practice of purchasing clothes second-hand and thereby reusing these items have become widespread. This was driven by increasing sustainability concerns and changing fashion trends (Persson & Hinton, 2023). Nowadays, the SHC trade has evolved into a global and complex network that involves a diverse

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[4] Refers to countries of the world which are characterised by a high level of economic and industrial development and are typically located to the north of less industrialized nations. Refers primarily to countries in the northern hemisphere and includes Europe and North America (Alisdair, et al., 2013).

[5] Refers to countries in the southern hemisphere including Africa, Asia, Latin America, and the Caribbean. Often used in preference to the term "developing countries", characterised by lower income levels and varying degrees of industrialization (Alisdair, et al., 2013).

range of stakeholders and activities (Dissanayake & Pal, 2023; Ellen Macarthur Foundation, 2024; Sumo, 2024).

The SHC value chain encompasses various entities, including charities and social enterprises that collect and sort garments for resale to fund their business models. It also includes commercial waste collectors and wholesale sorters that manage logistics and sort textiles based on quality, type, and fabric to meet global demand (Dissanayake & Pal, 2023). Additionally, exporters and importers facilitate the movement of SHC across borders. When SHC reach their end destination, the clothes can undergo further handling including categorization by wholesalers, retailers, and market traders before reaching the end consumer (Neuhoff, 2024; IEA, 2021). The SHC trade is complex with smaller traders specializing in different types of clothing and targeting different end markets, to larger formal companies (IEA, 2021; USAID East Africa Trade Hub, 2017). Retailers and markets trades can either sell SHC to consumer in formal shop or at information open-air markets, and in Kenya the informal retail market is significant (Neuhoff, 2024).

According to Dissanayake & Pal (2023) and Owino (2021), current trends indicate that some countries in the Global South are becoming significant exporters of SHC themselves, signalling a shift in traditional trade dynamics. In 2020, China emerged as one of the top three global exporters of used clothing (Dissanayake & Pal, 2023). Additionally, countries like Kenya have also become exporters of SHC to other African nations, such as Uganda and Tanzania, to meet rising regional demand (IEA, 2021).

#### 5.3.1.1 Economic and social opportunities

The SHC trade presents significant opportunities that drives both economic activity and social development. Literature highlights its impact on job creation, resulting in new income opportunities and fostering social connections across its value chain (Neuhoff, 2024; Sumo, et al., 2023; Odonkor, 2024; IEA, 2021; Walsh, et al., 2023). From an economic perspective, the SHC trade is a significant driver of employment across its entire value chain, generating jobs in collection, sorting, transportation, repair, washing, and retail. These roles create income opportunities in both exporting and importing countries, fostering economic stability and growth in various regions (Walsh, et al., 2023; Sumo, et al., 2023). Walsh, et al. (2023) further note that more women than men are employed in these roles. In several countries in Sub Saharan Africa, the SHC retailing model, has grown significantly, creating new avenues for employment. Moreover, the SHC trade has a considerable impact on key sectors of these countries´ economy, generating government revenues through import tariffs and the issuance of business licenses, which in turn help fund public services and infrastructure (Walsh, et al., 2023; Sumo, et al., 2023).

The SHC trade operates within a business model based in the principles of the circular economy, aimed at reducing the need for primary textile material and extending the lifecycle of textiles (Persson & Hinton, 2023). The model supports job creation, fosters entrepreneurial opportunities, develops skills in craftsmanship, and generates local employment, leading to both positive economic and social effects (Collacott, 2023; Dissanayake & Pal, 2023; Watson, et al., 2020).

From a social perspective, an effect of the SHC trade is the role and involvement that charity organizations and social enterprises have in this sector. In Europe, the collection of used post-consumer textiles is mainly managed by charities, although profit-driven entities are also involved (Watson, et al., 2020). In these business models, used textiles are collected, and the sale of marketable items helps fund operational costs, sustaining the collection process and raising funds for humanitarian aid (Dissanayake & Pal, 2023; Watson, et al., 2020). Watson et al. (2020) further explain that motivations for collecting used textiles vary where charitable organizations and social enterprises often collect textiles not only to generate revenue but also to provide direct donations to people in need. Furthermore, these organizations also generate employment opportunities within textile collection and processing, especially for individuals facing barriers to entering the traditional job market (Watson, et al., 2020).

In Sub Saharan Africa, the SHC trade plays a significant role in improving livelihoods by providing affordable clothing options, serving as a means of poverty alleviation. The low barriers to entry in the SHC trade allow individuals to support their family income and achieve self-reliance (Dissanayake & Pal, 2023; Odonkor, 2024; IEA, 2021). In many African countries, the SHC trade has grown into a major industry, especially in rural and low-income areas, providing both livelihoods and income (IEA, 2021; Odonkor, 2024). Additionally, this trade democratizes fashion, granting access to styles that might otherwise be financially out of reach, thereby enhancing the quality of life for many (Dissanayake & Pal, 2023; Persson & Hinton, 2023).

#### 5.3.1.2 Economic and social risks

Alongside the economic and social opportunities, literature identify several challenges and risk, where the fragmented SHC value chain and the rise of fast fashion presents economic barriers (Dissanayake & Pal, 2023; Walsh, et al., 2023). Narrow profit margins make it difficult for businesses in the SHC trade to remain viable (Watson, et al., 2016). Additionally, improperly sorted textiles, such as those with poor quality, stains, or damage, can hinder the ability to sell imported bales of clothing, impacting profitability and business sustainability (Walsh, et al., 2023). Furthermore, the lack of feedback loops between exporters, importers, and wholesalers complicates the process of returning unsellable goods, resulting in limited ability to monitor, inspect, and assess the market value of received products (Walsh, et al., 2023). Ellen Macarthur Foundation (2024) further emphasizes that the absence of a standardized framework or common language for sorting processes and outputs, as well as clear definitions of good versus poor quality, diminishes visibility across the supply chain, thereby worsening existing challenges (Ellen Macarthur Foundation, 2024).

Additionally, the SHC trade is often criticized for undermining local textile and apparel industries in African countries, resulting in both economic and social risks (Walsh, et al., 2023; Watson, et al., 2016; USAID East Africa Trade Hub, 2017). Literature highlights the ambiguity surrounding this issue, with some sources arguing that the availability of cheap SHC has negatively impacted domestic manufacturing, by shifting consumer preferences away from locally produced textiles, resulting in job losses and fewer opportunities for local producers (Kiss, 2024; Sumo, et al., 2023). This competition has diminished the market share of local textile manufacturers, threatening their sustainability and employment levels, resulting in both economic and social consequences (Ellen Macarthur Foundation, 2024; Sumo, 2024).

However, others contend that it is inaccurate to only blame the industry’s decline on the trade and market for SHC. Sumo et. al (2023) states that the collapse of the textile and apparel sectors can be attributed to broader factors such as poor leadership, governance issues, infrastructural limitations, outdated technology, lack of skilled labour, and intense competition, primarily from cheap imports from China and other Asian countries (Sumo, et al., 2023). To address the challenges and strengthen the local industry, the Vision 2030 program in Kenya has emphasized the need to ensure a level playing field for the domestic textile industry and for imported goods as part of efforts to further strengthen and revitalize the local textile and garment industry (Republic of Kenya, 2024).

In addition to economic risks, the SHC market and trade presents certain social risks. Despite the SHC trade being vital for local economies, many of the jobs created in African economies are informal (Neuhoff, 2024), leading to challenges related to job security, low wages, and poor working conditions. These issues not only impact individual livelihoods but also contribute to broader economic and social inequalities (Walsh, et al., 2023). Moreover, power inequalities and gender-specific disadvantages are also (Walsh, et al., 2023; Sumo, et al., 2023).

### 5.3.2 Results from interviews

The results from the interviews are presented below for: reuse in Lithuania (based on case study A – reuse in Europe) and reuse in Kenya (based on case study B – reuse outside Europe).

#### 5.3.2.1 Reuse in Lithuania

In this section, economic and social risks and opportunities related to reuse in Lithuania that were identified from the interview study are presented. Based on the interviews, a description of the management of textiles for reuse in Lithuania is presented as well.

##### 5.3.2.1.1 Management of textiles for reuse in Lithuania

*The dynamics of the SCH trade in Lithuania is presented in in Figure 5-1Figure 5-1. A simplified illustration of the SHC trade in Lithuania (illustration by the author).*

below.

The collection and sorting of textiles for reuse are managed by a mix of social enterprises and private companies, reflecting the European model that integrates charitable organizations, social enterprises, and profit-driven companies. Textiles are either collected locally through the municipality system or imported from other European countries such as Sweden, Denmark, the Netherlands, Germany, Austria, Italy, and Belgium for sorting (see Figure 5-1).

Once collected, textiles are manually sorted by wholesale sorters based on whether they are suitable for reuse or recycling. In the reuse segment, textiles are categorized into up to 250 different groups based on their quality and to meet customer orders. All respondents in Lithuania noted that, in addition to sorting, their companies are also involved in charitable efforts, such as donating clothes and partnering with product aid initiatives.

All respondents in Lithuania explained that textiles are manually sorted based on their quality, which is categorized into three grades: A, B, and C. According to the respondents, grade A represents the highest quality, referring to textiles that are in excellent condition—well-shaped, not colour-faded, and free of stains. These garments are fashionable and stylish, often from reputable mid-range to high-end brands, and made from premium fabrics like cotton, linen, viscose, silk, and wool. Grade C garments, while still of good quality and style, are more worn and less fashionable, and may have easily repairable defects. Despite these differences, all grades have a market, as different customer segments are willing to buy based on their specific needs.

In addition to sorting by quality, the textiles are packed according to customer orders. Some bales contain specific garment types, such as women's cotton blouses, while others contain a mix of clothing items. For example, the "tropical mix" includes a variety of seasonal clothing for men, women, and children.

Reusable textiles are then sold to retail shops, such as second-hand clothing stores in Lithuania, or exported (see Figure 5-1). The exported textiles are distributed globally, including to European countries, as well as markets in India, Pakistan, and various African countries. According to respondents, around 35-40% of the exports are directed to the African market.

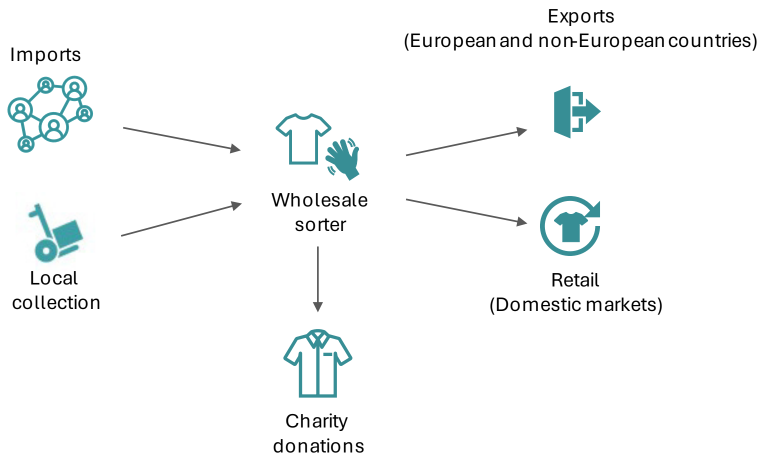


*Figure 5-1. A simplified illustration of the SHC trade in Lithuania (illustration by the author).*

##### 5.3.2.1.2 Economic and social opportunities

**Employment and income from trade**

All respondents confirmed that the increased demand for SHC has led to creation of accessible employment and income opportunities. Respondents 1 and 2 noted that jobs in sorting and retailing do not require specialized education, making these positions more accessible. Respondents 1 and 2 also emphasized that while no formal education is necessary for roles in sorting, retail, or logistics, a strong interest in fashion and a good understanding of clothing materials, quality, and style are highly valued.

When asked about the proportion of women versus men employed in sorting and retail, it was stated that there are significantly more women in these roles. This imbalance is partly attributed to the greater difficulty in recruiting men for these positions, in part due to preconceived gender roles.

**Improving living standards and livelihoods**

Respondents 1 and 2 highlighted the social benefits of the SHC trade, noting that the growth of second-hand stores in Lithuania enhances the livelihoods of individuals with limited financial resources by providing affordable, high-quality second-hand clothing. Respondent 2, Deputy Manager for Second-hand Shops, further explained that there is a demand for lower-grade items in these stores. This demand for more affordable clothing is driven by the low-income levels in small towns, where well-paying job opportunities are scarce.

Moreover, all respondents highlighted their active participation in charitable initiatives, including donating various products, such as textiles, to support local communities. According to the respondents, this involvement not only strengthens community support but also plays an important role in improving living standards and livelihoods for those that are dependent on daily support.

##### 5.3.2.1.3 Economic and social risks

**Narrow profit margins, quality, and feedback challenges**

All respondents expressed concerns about the declining quality of textiles, which is negatively impacting profitability in wholesale sorting and exports. This decline has been particularly noticeable over the past 5 to 10 years, driven by the rise of cheap, low-quality brands and an increase in synthetic materials.

Respondent 1 emphasized that their sorting process prioritizes quality over brand names, stating, "everything is about good quality," highlighting that maintaining high standards is essential for business viability. All respondents attribute this decline to the fast fashion industry's focus on frequent purchases and rapid turnover, which has led to quality problems like wear, discoloration, and pilling. Shein and Temu were cited as brands exemplifying this fast fashion trend. To address the growing volumes of low-cost items, respondent 2, Import-Export Manager at a wholesale sorting company, explained that they have developed a list of brands categorised by fast-fashion quality, which requires special attention from sorters to ensure these items meet the necessary quality standards.

Regarding feedback among stakeholders in the value chain, respondent 1 mentioned that feedback on whether the exported textiles meet the promised quality is gathered to some extent. They explained that they have communication with customers continuously. Respondent 3 noted that manual sorting carries a risk of textiles being incorrectly categorized and mentioned that determining what is and isn't reusable can sometimes be very subjective. However, respondent emphasized the self-regulating nature of the SHC trade, stating, "customers would not pay the money if we were bringing trash". If the textiles do not meet the promised quality, negative feedback can spread quickly. Customers dissatisfied with the quality of textiles in a bale are likely to stop purchasing from that supplier, which can significantly impact the supplier's business. Further, respondent 3 explained the high costs associated with exporting SHC, all of which are borne by the customers. In addition to the cost of second-hand textiles, the customer also pays for duties of around EUR 10,000 and shipping fees ranging from EUR 3,000 to EUR 4,000 per container.

Additionally, respondent 2, the deputy manager for second-hand shops, noted that consumers in the second-hand shops are becoming more aware about the materials they purchase. There is a growing preference for natural materials such as cotton, wool, and silk over synthetic fabrics, reflecting a shift in consumer awareness and demand for higher-quality textiles.

#### Working conditions

Throughout the interviews, respondents were asked about social, health, and safety risks related to working conditions associated with the SHC trade. However, no such risks were mentioned during the interviews.

**Identified risks with imports of second-hand clothing to Lithuania**

During the interviews, several indirect business risks associated with the import of SHC in Lithuania were highlighted, particularly in relation to existing and new EU legislation. This section aims to provide a more nuanced understanding of these issues, specifically focusing on the challenges connected to the "imports" arrow in Figure 5-1.

Both respondent 1 and 3 emphasized the difficulties of sorting clothes in Lithuania due to ongoing uncertainties in managing the collection, sorting, and disposal of large volumes of used clothing. They both highlighted the complexities of EU regulations concerning whether textiles are classified as "waste" or "product". Respondent 3 explained that although their company handles municipal and plastic waste and is equipped to manage textiles, there is ambiguity in how textiles should be treated. While used clothing is collected as waste, these materials are ultimately sold as second-hand products (not waste), creating some regulatory confusion in terms of reporting and categorization towards authorities.

Additionally, respondent 1 discussed how their business is affected by Sweden's interpretation of waste shipment regulations. The requirement to pre-sort textiles before exporting from Sweden adds extra work for Swedish operators, impacting the financial viability of their businesses and aid activities. As a result, the sorting company incurs higher costs due to the additional pre-sorting steps, making the clothes harder to manage and sort.

Beyond the extra costs of pre-sorting, additional risks have emerged. The requirement on pre-sorting increases the likelihood of shoes being separated and exposes clothing and textiles to moisture and dirt, as they must be removed from their plastic bags. As a result, Swedish collectors now need to invest in solutions to address these issues to ensure the viability of their operations.

## 5.3.2.2 Reuse in Kenya

This section provides a description of how textiles are managed for reuse in Kenya followed by the economic and social risks and opportunities related to textile reuse.

### 5.3.2.2.1 Management of textiles for reuse in Kenya

In Kenya, the SHC trade encompasses both formal and informal traders, as well as businesses of varying sizes. Some respondents specialize in specific types of clothing, such as baby clothes, while others offer a mix of textiles. Respondents in Kenya emphasized the diverse range of jobs created by this trade and provided detailed insights into its various stages and activities. They also described the distribution routes that imported bales follow before reaching consumers. These findings, along with supporting literature, are summarized in Figure 5-2 which illustrates the dynamics of the SHC trade in Kenya.

*Textiles in Kenya are imported from a variety of countries. Respondents explained that SHC businesses source textiles from locations such as the UK, Pakistan, China, Canada, the US, and Australia. Depending on the country where the suppliers are located, delivery times vary. Suppliers in China are advantageous as their delivery times are relatively short. The process of textile reuse in Kenya typically starts with an importer who brings in containers of SHC bales (see Figure 5-2Figure 5-2. A simplified illustration of the SHC trade in Kenya (illustration by the authors).*

) covering costs such as the container, transportation, and duties. These costs are then added to the price of the bales. The importer can either sell the bales in bulk to a wholesaler or directly sell the SHC items through their own business (see Retail in Figure 5-2).

Wholesalers or brokers operate in different ways. Some businesses act as broker services, reselling bales to other wholesalers while others store them in warehouses that serve as showrooms, where traders can inspect and purchase SHC items. These warehouses often open early, around 6 AM, for a process known as "camera", where buyers arrive at staggered times to select the best items. Higher-quality items are picked first, while lower-quality SHC is sold later, often in rural areas. It's also common for SHC businesses to export bales to meet demand in other African countries such as Tanzania, South Africa, and the Democratic Republic of Congo. Retailers, on the other hand, purchase bales in smaller quantities and sell individual SHC items rather than full bales.

The SHC items are usually sold in retail shops or by independent traders at open-air markets like the Gikomba Market, or Toy Market. Additionally, some businesses have begun collecting worn-out or unwanted SHC and upcycling them into higher-value products, which are then sold in high-end retail stores or exported.

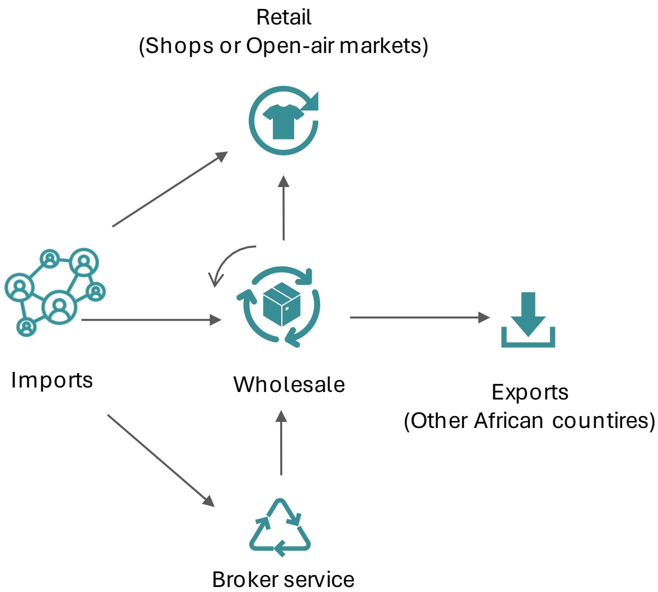


*Figure 5-2. A simplified illustration of the SHC trade in Kenya (illustration by the authors).*

Respondents in Kenya noted that the quality of purchased SHC varies by supplier and bale. Quality is categorized into three grades: A, B, and C. From the interviews, it was evident that respondents have different approaches, with some primarily purchasing grade A and B items due to the challenges of selling grade C, which offers lower profit margins. Respondent 6 explained that the ease of selling SHC is closely tied to its grade. Approximately 80% of grade A garments sell quickly without discounts, while about 60% of grade B items are sellable at full price. In contrast, grade C is much harder to sell, yielding minimal profits and often sold at open-air markets. However, some respondents explained that they also sell grade C items, since these are often more affordable for lower-income consumers. The three grades and their estimated saleability are outlined in Table 5-3.

*Table 5-3. The three grades and their estimated ease of sale according to respondent 6 in interview study.*

| Grade | Description |
|---|---|
| A | High quality (premium), with approximately 80% of items selling quickly without price reductions. |
| B | Moderate quality, with around 60% of items selling quickly without price reductions. |
| C | Low quality, yielding minimal profit and sometimes requiring price reductions, primarily sold at open-air markets. |

##### 5.3.2.2.2 Economic and social opportunities

**Employment and income from trade**

All respondents involved in SHC trading highlighted the diverse employment opportunities created by the industry. They emphasized that the trade offers easily accessible jobs with low barriers to entry, making it simple for individuals to generate income. There are many different roles in the supply chain, and those at the end of the chain can start small-scale businesses. This trade also provides job opportunities, often for self-employed individuals, not only in major cities but also in towns and secondary cities.

Depending on whether they sell bales or individual garments and the quality of the textiles, profit margins and income vary. Respondent 4 highlights how quality differs between suppliers, noting that the quality from suppliers in the UK is consistently guaranteed and very high. They also noted that the trade is market-driven, with success relying on accurately meeting customer demand and avoiding unsellable items to safeguard profits. Respondent 8, who represents a larger company, elaborates on this approach. In their company, if clothing does not sell within one to two days, its price is progressively lowered until it finds a buyer. The same strategy is used by respondent 5.

**Circular business models**

Respondent 7, co-founder, and manager at a company collecting used textiles in Nairobi, highlighted how their circular business model creates employment, currently employing 60 full-time staff and generating approximately 120 jobs per month. Most production roles are held by women, particularly in rural areas, while men dominate management positions. The company is working to increase female representation, especially in leadership roles.

Respondent 7 further explained that establishing a circular business model comes with significant challenges, as it demands considerable resources and specialized skills. Another difficulty lies in consumer perception and the valuation of products made from waste materials, which are often undervalued. Additionally, respondent 5 emphasized the importance of regulatory tools, such as an extended producer responsibility (EPR), to support businesses like theirs. Such measures would help cover the costs of textile collection and reduce the prevalence of mixed materials and low-cost synthetic brands in the market.

Respondent 9 also observed changes in the SHC trade in recent years. While much of the trade still occurs in open-air markets, there is a growing shift toward selling in shops, boutiques, and through personal trading methods like backpack-to-backpack sales. Furthermore, respondent 9 explained how this change is driven by technological advancements that allow traders to market themselves and adopt successful sales strategies, which is important to remain competitive at the SHC market.

**Improving living standards and livelihoods**

In terms of social benefits, all the respondents in Kenya confirmed that the SHC trade *(*mitumba*)* trade, has positively impacted their income and livelihoods by creating new income and business opportunities. They also noted that these benefits extend to a broader societal level by providing affordable clothing to those on tight budgets. Respondent 4, who is expanding the business model, explains how starting as a trader in the open-air market and gradually learning the business has contributed to finance their college studies. Further adding that: "This business has given me the confidence to start a family."

Respondent 6 highlights the social benefits of being a wholesaler, noting that wholesalers have more control over earnings, can negotiate better deals, and choose higher-quality items. Furthermore, respondent 6 explains that retailers, on the other hand, lack bargaining power and face limitations in profitability. However, over the past 10 years, respondent 6 explains that there has been a decline in income generated from second-hand sales, making it insufficient to sustain a livelihood. As a result, respondent 6 is now working part-time at another businesses, helping to sell bales at the market, in addition to running their own business. Respondent 5 further explains that initially, it was not possible to support oneself, but the business has been developed step by step and is now their main source of income, stating: "I don't make millions, but the bills get paid on time."

Respondents 4 and 6 explain that while the mitumba trade requires low initial skills, individuals often develop expertise in accounting and business strategies through hands-on experience and advice from others. Success in the trade however depends on acquiring knowledge about different garment grades, understanding profit margins, and having a strong financial mindset.

#### 5.3.2.2.3 Economic and social risks

**Narrow profit margins, quality, and feedback challenges**

Concerns regarding the quality of imported SHC were a recurring concern throughout the interviews. Respondent 6 highlighted the impact of export restrictions from Europe, which have led to a greater reliance on SHC suppliers from Pakistan and China. This shift has affected earnings, as the SHC from these sources are often of lower quality. SHC originating from China was frequently mentioned as a particular risk. Respondent 4, who imports SHC from a Chinese supplier, noted that while these clothes are more affordable and the cost of bales is cheaper, they often consist of smaller sizes. Respondents 5, 6, and 9 further confirmed the increasing volume of SHC from China, describing these clothes as being of poor quality, predominantly synthetic, and often in very small sizes, which frequently end up as waste. Additionally, respondents expressed concerns about the growing influence of Chinese textiles on the SHC market, emphasizing that a significant portion of imported SHC now comes from China.

Respondent 4 also highlighted that SHC bales can sometimes contain new garments, stating: "I can confidently say that we often receive factory rejects in the bales from China, which are new, unused clothing." This observation is also confirmed by respondent 6.

Regarding challenges with improperly sorted textiles, respondents 4, 5, and 6 state that SHC items do not always meet the desired quality standards, posing challenges and results in financial losses in their business. Occasionally, they open a bale to find items that are oversized (e.g., XXL), stained, or of poor quality. In such cases, they may lower prices to sell the items, give them away, or sell them as cleaning rags for about EUR 0.13 per kg (KSH 20 per kg). Due to these efforts, all items are sold in some manner.

Once a bale is opened, it is generally non-returnable due to the fragmented nature of the supply chain. Freight distances vary depending on the supplier's location, with shipping times ranging from 16 days (from Pakistan) to up to 2 months (from the UK) for a container. These factors contribute to the high cost of returns. Respondents 4 and 6 describe that they often try to negotiate prices instead of returning the bales or SHC items. Additionally, respondents 4, 5 and 6 mention that their customers sometimes complain about the quality of the SHC. They address these complaints in various ways, primarily by offering alternative garments as compensation, and in some cases offering price reductions.

#### Impact on domestic textile production

Respondent 10, representing an economic authority, highlights the risks associated with SHC imports, particularly its impact on domestic textile production. They explain that Kenya's textile industry once thrived through extensive cotton cultivation and manufacturing. However, since the 1990s, the focus has shifted toward becoming a trade hub, heavily dependent on importing secondary products, which has weakened the domestic manufacturing sector.

Respondent 10 also notes that banning import of SHC to Kenya could have a negative impact on employment as the SHC trade remains a significant sector in Kenya, a concern also shared by respondents 5 and 9. To promote local textile production and ensure long-term job security, respondent 10 emphasizes the need to carefully sort SHC so that only sellable items are imported. Respondent 10 stated that currently a significant portion of imported clothing ends up as waste. Furthermore, respondent 10 suggests reviving domestic industries, including cotton cultivation, through a balanced approach, such as raising tariffs on second-hand imports while investing in local textile production.

When discussing tariffs and increased taxes on imported SHC, respondents 4, 5, 6, and 9 explain that the Kenyan government has raised import taxes, making it more costly to bring in bales. Respondent 6 specifies that around six years ago, a bale of grade A items cost approximately EUR 170 (KES 25,000), but today, the price has risen to between EUR 270 (KES 40,000) and EUR 320 (KES 46,000). Despite these increased import costs, all respondents stated that the volume of imported SHC continues to grow.

### Working conditions

Social risks highlighted throughout the interviews are closely linked, ensuring that earnings cover expenses, including the potential for sudden changes in government regulations. Additionally, all respondents expressed concerns about the unhealthy work environments at open-air markets due to inadequate infrastructure. While these markets provide basic services such as water and electricity, they often lack essential infrastructure and proper planning, making them vulnerable to flooding. Furthermore, the markets are often overcrowded, with large numbers of people, making them very congested. This frequent congestion increases the risk of fires and highlights the urgent need for improved safety measures. Respondent 5 elaborated that, despite extensive discussions about formalizing the markets, no concrete actions have yet been taken. This lack of progress has, according to respondent 5, resulted in growing mistrust towards those in positions of authority.

## 5.4 Discussion

The discussion is based on the literature review and interviews to economic and social effects identified in Lithuania and Kenya, and how these opportunities and risks appear on respective market. The economic and social effects are interconnected and are addressed collectively and further discussed below as (i) effects related to employment, working conditions, and improving livelihood and (ii) markets dynamics and risks in the SHC trade.

### 5.4.1 Reuse in Lithuania

#### Employment, working conditions and improving livelihoods

The economic and social opportunities related to employment, working conditions, and improving livelihoods, are evident in the SHC trade, as highlighted in both the literature and interviews conducted within this study. The literature emphasizes that the SHC trade creates employment opportunities across the value chain and all respondents in Lithuania confirmed the variety of jobs created in collection, logistics, sorting, and retail. Respondents also noted that, in addition to creating job and income opportunities, work in sorting, retail, and logistics does not require specific academic qualifications, making these jobs accessible to individuals with distance to other employment sectors. This has both economic and social effects, which are also supported by literature (Watson, et al., 2020).

Regarding employment opportunities, a study by Walsh, et al. (2023) notes that women are more likely than men to be employed in SHC value chain. This gender disparity was also confirmed in interviews from Lithuania, where respondents observed that women dominate the roles in sorting and retail. However, this has not been further explored quantitatively. In terms of social risks connected to improving livelihoods, employment and working conditions, no concerns were raised by the respondents, even though the question was brought up during the interviews.

Additionally, the SHC trade generates indirect social benefits by raising funds for charity organizations and social enterprises to support humanitarian aid, a connection highlighted in the literature (Dissanayake & Pal, 2023) and corroborated by project partners. For example, importing post-consumer textiles for sorting in Lithuania supports charitable organizations’ collection processes, enabling them to fund operations that provide essential resources to those in need. This highlights how the SHC trade not only supports the economy but also promotes social welfare through resource redistribution.

#### Market dynamics and risks in the SHC Trade

Although the SHC trade in Europe is often linked to charitable organizations and social enterprises, all respondents in Lithuania highlighted that the trade is still strongly market driven. SHC is sold where it commands the best price, with the price of textiles closely related to their quality. Respondents mentioned a system for categorizing SHC, classifying textiles into grade A, B, or C. This categorization framework challenges existing literature, which suggests a lack of universally accepted definitions for what constitutes good or poor quality (Ellen Macarthur Foundation, 2024). Further investigation into this system could enhance transparency within the value chain and facilitate the development of a common language for exporters and importers, potentially minimizing the risk of improperly sorted clothing being exported.

Fast fashion poses significant risks to the SHC trade, as stated in the literature (Dissanayake & Pal, 2023; Walsh, et al., 2023) and by respondents. The rapid turnover of garments and declining textile quality from low-cost brands have increased consumption rates, reduced the potential for extending garment lifespans, and lowered resale value. To address this decline in quality, one respondent stated that garments fit for reuse are sorted more rigorously, reflecting an attempt to mitigate the impact of fast fashion on the viability of second-hand retailing models. There are other possible indirect effects of this fast fashion trend, such as reduced quality and availability of clothing for donation, and lowering the resale value, which could undermine the sustainability of charitable initiatives tied to the SHC trade. While this aspect was not deeply explored in this study, it is important to recognize its potential impact on maintaining aid efforts. Since only one social organization’s perspective was interviewed, future research should explore a broader range of viewpoints to better understand the social impact of these organizations´ work.

### 5.4.2 Reuse in Kenya

#### Employment, working conditions and improving livelihoods

In Kenya, there are several economic and social opportunities related to the SHC market and trade, confirmed both by literature (Neuhoff, 2024; Sumo, et al., 2023; Odonkor, 2024; IEA, 2021; Walsh, et al., 2023) and by all respondents. The SHC trade not only generates employment but also provides affordable clothing and improves livelihoods. This contributes to a higher standard of living, with many respondents noting how the SHC trade has helped them support their families, achieve financial stability, and invest in education. Additionally, the SHC market is viewed as an accessible way to earn money, offering a viable path out of poverty.

While several respondents highlighted the economic security that the SHC trade has provided, others pointed out that the business is not always as straightforward as it seems. In certain circumstances, the trade may not deliver the expected returns, leading to financial uncertainties. This reflects the dual nature of the SHC trade, offering both opportunities and risks for those involved, which is frequently mentioned in literature (Dissanayake & Pal, 2023; Walsh, et al., 2023).

Furthermore, respondents highlighted several risks associated with the informal nature of the SHC trade, a concern also discussed in the literature (Walsh, et al., 2023). While the trade offers accessible employment opportunities, particularly in informal settings, it often lacks the regulatory frameworks that could safeguard workers and ensure fair labour practices. Respondents emphasized the social risks, particularly regarding working conditions and the uncertainty created by sudden regulatory changes that affect trade dynamics. The inadequate infrastructure in open-air markets leads to unsafe working conditions, along with ongoing discussions about potentially banning SHC imports, creating instability for traders who rely on the SHC trade for their livelihoods. However, this study did not thoroughly examine the distinction between formal and informal sectors. Further research could provide valuable insights by exploring the differences between these sectors and the unique challenges that they face.

#### Market dynamics and risks in the SHC trade

The market of SHC in Kenya is strongly market driven. Several respondents from both Lithuania and Kenya emphasized this, highlighting that the export of SHC is demand-driven. They also noted that no one would invest in SHC, including transportation costs, without expecting a return on their investment. While much of the literature tends to focus on negative aspects, such as the perceived dumping of used textiles in Africa, the SHC trade has demonstrated its role in providing affordable and appealing textile products to the Kenyan market. This dynamic is shaped not only by local policies and regulations in Kenya but also by international frameworks, such as those in the EU, that govern the flow of second-hand textiles across borders.

According to respondents, sorting is done based on three different grades depending on their quality, and these grading standards are recognized in both Lithuania and Kenya. This suggests that there is some form of informal product standardization or quality labeling for SHC that are fit for reuse. However, literature and several respondents in Kenya, state that there are challenges with improperly sorted clothing. Some respondents mentioned that they occasionally purchase bales of textiles that do not meet the promised quality. The literature also indicates that there are poor feedback opportunities upstream in the value chain, which complicates the process of returning unsellable goods. Several respondents state that returning items is difficult due to long transport distances, which contributes to high costs.

Similarly observed in Lithuania, where the presence of low-quality fast fashion garments contributes to declining quality, respondents in Kenya reported that low-quality clothing from Chinese suppliers have impacted the profitability in the SHC market. These garments are cheaper, but of inferior quality and have shorter lifespans. Additionally, two respondents noted the presence of unused clothing, such as factory rejects or unsold stock, in SHC bales. This statement points to the inclusion of pre-consumer clothing in the SHC value chain.

Another risk highlighted in the literature is the SHC trade's potential to undermine local apparel industries, a concern articulated by one respondent who stated that the SHC trade has significantly contributed to the decline of local textile production, particularly since the 1990s. The widespread availability of cheap second-hand clothing has shifted consumer demand away from domestic products, creating challenges for local manufacturers to remain competitive (Kiss, 2024). However, the literature also attributes this decline to broader factors like poor infrastructure, outdated technology, and lack of investment (Sumo, et al., 2023). It is important to critically examine both systems, as each presents its own set of advantages and disadvantages. While the local textile industry has suffered, the SHC market has introduced an alternative economic model, creating opportunities for resale, recycling and exports which contribute to the local economy in different ways.

The Vision 2030 program for Kenya to bring further economic development highlight some aspects of the need to regulate the SHC imports in order to support a local textile and garment industry (Republic of Kenya, 2024). However, for local economies that rely heavily on SHC, there may be an overdependence on imported SHC, which could limit the development of domestic manufacturing industries.

The question on regulating the trade and markets for SHC in Kenya is not easy, probably there is a need to regulate some parts of it, but also support and try to identify potential synergies with a local textile and garment industry. Upcycling, recycling, and other circular solutions can be integrated parts of a local textile market. As of now the SHC trade as represented by the mitumba trade is put against a local textile market. In the new circular economic model these two textile sectors could both be part of building and strengthening the textile sector in Kenya. Currently, there are many highly skilled people involved in the trade and markets of textiles and garments who could also work on other textile supply chains.

## 5.5 Conclusions

This section includes the main conclusions of the analysis of economic and social effects in relation to the outlined research question: What are the important economic and social effects of reuse in and outside of Europe? As previously stated in Section 5.1, Lithuania and Kenya are the focus of the study of reuse in and outside of Europe, respectively. The conclusions presented below are based on the results from the literature review and the interview study conducted within the analysis of economic and social effects.

#### Important economic and social effects of reuse in Lithuania

In Lithuania, the SHC trade contributes to employment opportunities and generation of income. Furthermore, the accessibility of SHC provides affordable clothing alternatives, which is especially beneficial for those with lower incomes. The SHC industry creates accessible jobs with low entry requirements, which can improve living standards. Additionally, it plays an important role in charitable work.

There are also economic and social risks related to the SCH trade in Lithuania. These risks are mainly related to maintaining quality and profitability in the SHC trade, as fast fashion's focus on new purchases drives down prices and quality of the textiles. This results in many textiles being unsuitable for resale on the second hand-market.

#### Important economic and social effects of reuse in Kenya

In Kenya, the economic and social effects of the SHC trade are significant. According to respondents, reuse of clothing creates employment opportunities, financial stability, and accessibility to affordable clothing. Respondents also stated that the trade is primarily market-driven, with importers covering transportation costs, and local economies are highly dependent on this trade. Additionally, the trade contributes to skill development in areas such as sorting, repairing, and upcycling. Socially, it offers accessible jobs, particularly benefiting marginalized groups and local communities. These opportunities help improve livelihoods and support families, offering a pathway out of poverty.

The SCH trade in Kenya is also associated with certain risks. One such risk is financial instability that remains a concern for some respondents, stating that profitability of the SHC trade can be unpredictable. Another risk is that many jobs created in informal settings lack the regulatory frameworks needed to protect workers and ensure fair labour practices. Furthermore, there are challenges associated with the inflow of improperly sorted SHC, which affects the profitability of many traders. SHC originating from China is a particular concern, as they are predominantly made from synthetic materials and often come in very small sizes, negatively impacting both profitability and consumer satisfaction.

# 6 Recommendations for future research

This section provides recommendations for future research based on the conclusions of the sustainability assessment including environmental, economic, and social implications. Based on the findings of the environmental impact assessment, three topics are presented as priorities for future research. Additionally, three further recommendations are proposed based on the analysis of economic and social implication of the second-hand clothing (SHC) trade.

### The loss rate for reuse outside of Europe

The sensitivity analysis showed that the waste generated in the retailing outside of Europe (in Kenya, Africa) greatly influence the results. However, this is an uncertain parameter as the sources we found had conflicting information, ranging from a loss rate of 1% to 50% (see more in Section 4.1.8.2). The methods reported vary in quality and transparency. Therefore, it would be of great value to study this parameter more.

### The replacement rate

In this report we chose a 50% replacement rate in the base case. This was based on (Nørup, et al., 2019), which, however, showed that for second-hand clothing in Europe, the replacement rate spans from 25% to 75% and in African countries from

35% to 63%, indicating a high uncertainty. As the sensitivity analysis showed that the replacement rate has an important impact on the results, it would be of great value to have more data on the replacement rate, both in Europe and outside of Europe.

#### End-of-life treatment of textile waste outside of Europe

An additional uncertainty is the assumed end-of-life treatment for reuse outside Europe. As was described in Section 4.1.2, this was assumed to occur in Kenya, but it was modelled using European LCI data on a municipal landfill. Furthermore, several sources indicate that open dumpsites and informal landfills are commonly used, but we found no LCI data of such end-of-life treatments (Fie-Consult, 2023; Kiarie- Kimondo, 2022; Oyake-Ombis, 2017). Also, the selected impact categories may not capture all the relevant impacts of such informal end-of-life practices. Therefore, the LCA model could not adequately capture all the potential environmental impacts of the end-of-life practices of textiles in Africa. This aspect is relevant to assess in greater detail in future comparisons of reuse in and outside of Europe. If sufficient LCI data is not available, further research may need to assess the environmental impacts of waste management of exported textiles using methods other than LCA. However, it is important to note that Kenya's challenges with poor waste management are not specific to SHC and that new garments are as likely to face the same treatment upon disposal.

#### Quality assurance of the SHC

A key challenge in the SHC trade is maintaining both quality and profitability. Future studies could explore how measures to enhance quality assurance for exported SHC might help mitigate the risks associated with improperly sorted textiles. One potential approach could involve clarifying the definitions of grades A, B, and C, which have become standard terms in both Lithuania and Kenya. Such measures could help reduce financial risks for stakeholders in the global SHC trade and ensure that SHC exports are reused as intended.

#### EU legislation and policy frameworks for the SHC trade

Within Europe, there are conflicting opinions on how used textiles should be handled. This relates to challenges of managing textiles collected as “waste” and later sold as ”products”. In this context, regulatory frameworks will be important in providing clear guidelines for how the SHC business should operate. The EU Strategy for sustainable and circular textiles, the proposal to revise the Waste framework directive, and the coming Extended producer responsibility (EPR) will all play important roles in shaping how textiles are produced, consumed, and managed at the end-of-life stage. Future research could investigate how the regulatory landscape can be optimised to enhance the sustainability and profitability of the SHC market, while balancing these regulatory requirements with market realities to enable continued reuse operations. Additionally, research could examine how the SHC sector can promote knowledge sharing and training to support efficient operations.

#### Regulation and collaboration across the global SHC value chain

Outside Europe, the lack of targeted regulatory frameworks poses a threat to the sustainability of the SHC trade, partly due to the impact of the fast fashion industry. While the SHC trade is crucial for many local communities, it is heavily influenced by global markets, where factors like price volatility and inconsistent quality often lie beyond the control of domestic traders, especially in countries such as Kenya. To address these challenges, greater collaboration across the SHC value chain is needed. Future research should explore how countries outside Europe can regulate the SHC trade to promote circularity and sustainability Additionally, studies should focus on improving information sharing and collaboration between exporters and importers to ensure the delivery of high-quality SHC. This would help reduce the volume of unsellable items in exported bales and better meet the demands of African markets.

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# 7 Appendices

## Appendix 1: Illustration of the functional unit

Figure 7-1 provides an overview of the functions (in terms of T-shirt uses and energy) generated for each case study (A-E). The figure illustrates that each option for managing collected post-consumer T-shirts (reuse, recycling, and incineration) generates different functions. As a result, compensating processes (in terms of T-shirt production and energy production) are required to achieve the same function for each case study, enabling comparability.

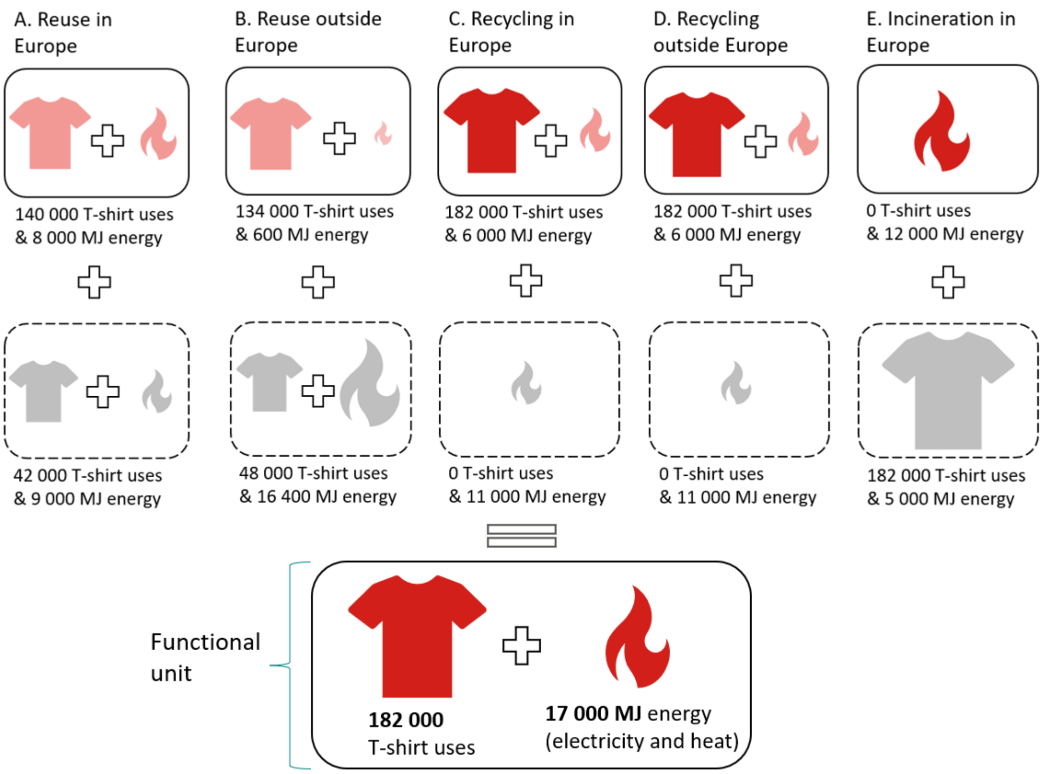


*Figure 7-1: Overview of all case studies with their respective functional unit. Red symbols illustrate the original processes generated in the case studies, and grey symbols are the compensating processes. Dark red symbolises the processes with the most T-shirt uses or energy.*

From Figure 7-1 we can see that recycling in and outside of Europe generate the most T-shirt uses (182 000 T-shirt uses), and the most energy (12 000 MJ) is generated from incineration in Europe. It is also clear that without the compensating processes (in grey) the functions generated would not be equal for each case study and thus they would not be comparable. When the compensating processes have been added to the case studies, all five case studies fulfil the functional unit of managing 1 tonne post-consumer T-shirts and generating 182 000 T-shirt uses and 17 000 MJ energy.

# Appendix 2: Impact and resource use categories

The impact and resource use categories studied in the present study are described below.

## Climate change

Global warming is caused by increases in the atmospheric concentration of chemical substances that absorb infrared radiation. These substances reduce the energy flow from Earth in a way that is similar to the radiative functions of a glass greenhouse. The category indicator is the degree to which the substances emitted from the system investigated contribute to the increased radiative forcing. The characterisation factor stands for the extent to which an emitted mass unit of a given substance can absorb infrared radiation compared to a mass unit of $CO_2$. As the degree of persistence of these substances is different, their global warming potential (GWP) will depend on the time horizon considered, such as 20, 100 and 500 years. In this study, a time horizon of 100 years has been applied.

## Eutrophication (nutrient enrichment)

When the nutritional balance in the soil and waters is disturbed, it is called eutrophication (when the amount of nutrition is increased). In aquatic systems, this leads to increased production of biomass, which may lead to oxygen deficiency when the biomass is subsequently decomposed. The oxygen deficiency, in turn, kills organisms that live in or near the bottom of the lakes or coastal waters. It also makes the reproduction of fish more difficult. In terrestrial systems, deposition of nitrogen compounds leads to increased concentrations of nitrogen, which in turn leads to a change in the growing conditions. The nitrogen may leak into water systems and cause increased levels of nitrogen in the aquatic systems. The effects in aquatic systems depend on the recipient. Different terrestrial and aquatic systems have different sensitivity to eutrophying and oxygen depleting substances. Phosphorous-containing substances increase.

## Total use of primary energy resources

The category reflects the use of renewable and non-renewable primary energy resources. Renewable primary energy resources are, for example, biomass, wind power and hydropower. Non-renewable primary energy resources are, for example, crude oil, coal, and natural gas.

## Water deprivation

Freshwater resources, among others including surface water flows and groundwater flows and stocks, are increasingly under stress due to human interventions. This has consequences for humans (e.g., through less water available for agriculture) and for ecosystems. Water stress also makes society and ecosystems less resilient to other environmental impacts. For example, resilience to changed weather patterns is reduced due to climate change (e.g., less rainfall) and nutrient pollutants. In this study, water deprivation is considered by using the AWARE method for water deprivation (Boulay, et al., 2023).

In the AWARE method, the freshwater removed from a catchment is considered, and this water use is then multiplied by a factor between 0.1 and 100 that reflects the scarcity of water in that catchment. If the exact catchment area is unknown or not specified, an average AWARE factor for the considered region is used (this may be a country or a larger area).

# Appendix 3: Inventory data

Link to the data collection file is found here.

# Appendix 4: Data from UN Comtrade

The UN Comtrade database compiles detailed global annual and monthly trade statistics by product and trading partner (United Nations, n.d.). This database allows for the tracing of trade flows and the identification of how collected textiles move across borders.

Country selection for reuse case studies, in and outside of Europe, was based on export flows of HS 6309 "Worn textiles and clothing" from Sweden in 2022, as recorded in the UN Comtrade database. Lithuania emerged as the top destination for these exports, leading to its selection for case study A (reuse in Europe).

From Lithuania, most of the sorted textiles were exported to Pakistan. However, Pakistan is not considered the end destination for reuse, but rather an intermediate country where textiles are sorted and re-exported (Walsh, et al., 2023). It was therefore assumed that all textiles imported to Pakistan are re-exported. In 2022, Kenya was the top recipient of these re-exports, leading to its selection for case study B (reuse outside Europe).

It is important to acknowledge potential limitations in the UN Comtrade database, which may include data gaps and inaccuracies. Furthermore, used textiles can be exported under two main product codes in the Combined Nomenclature (CN) classification system: HS 6309 is used for "worn textiles and clothing", and HS 6310 for "sorted and unsorted used rags and textile scraps" (European Environment Agency, 2024; European Environment Agency, 2023).

Generally, code 6309 is assigned to textiles fit for reuse (second-hand products), while code 6310 is used for textiles unfit for reuse, such as shredded textiles for recycling or industrial rags. The EU has over the past two decades, primarily exported used textiles under code 6309 (worn textiles and clothing), with only small amounts under code 6310 (sorted and unsorted rags and scraps). As a result, exported textiles, known as "originals", contain both reusable and non-reusable items of varying quality. These mixed batches are often classified under code 6309, even if they include rags and waste, leading to inaccurate classification. The limited use of code 6310 is also due to stricter regulations on waste exports (Walsh, et al., 2023; European Environment Agency, 2023; European Environment Agency, 2024).

Additionally, assumptions were made about intermediary countries, where it was presumed that imported textiles were re-exported rather than sold in local second-hand markets. These assumptions may not accurately represent the actual quantities of textiles imported and exported. As a result, the assumed pathways for used textiles exported from Sweden may not fully reflect the actual pathway for exported second-hand clothing.

The three five receiving countries of exported textiles under the classification 6309 from Sweden, Lithuania and Pakistan is presented in Table 4-Table 6 below.

*Table 4. Export of HS 6309 "Worn textiles and clothing" from Sweden 2022.*

| Ranking | Destination | Amount (tonne) |
|---|---|---|
| 1 | Lithuania | 9 763 |
| 2 | Germany | 7 473 |
| 3 | Poland | 5 609 |

*Table 5. Export of HS 6309 "Worn textiles and clothing" from Lithuania 2022.*

| Ranking | Destination | Amount (tonne) |
|---|---|---|
| 1 | Pakistan | 8 566 |
| 2 | Belarus | 5 119 |
| 3 | Togo | 4 594 |

*Table 6. Export of HS 6309 "Worn textiles and clothing" from Pakistan 2022.*

| Ranking | Destination | Amount (tonne) |
|---|---|---|
| 1 | Kenya | 49 655 |
| 2 | Mozambique | 42 655 |
| 3 | United Rep. of Tanzania | 40 414 |

# Appendix 5: Compensating T-shirt production

Figure 7-2 shows the processes involved in the compensating T-shirt production, from cradle-to-grave.

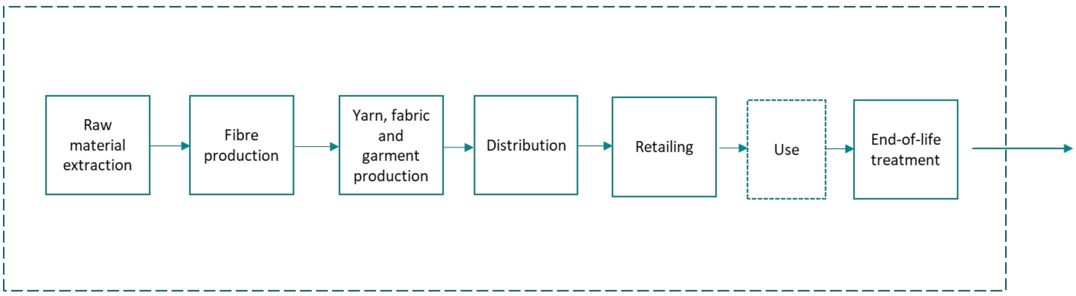


*Figure 7-2. Flowchart of the compensating T-shirt production, from cradle-to-grave.*

# Appendix 6: Sensitivity analysis

The sensitivity analysis results for the impact categories: water deprivation impact, eutrophication (freshwater, marine, terrestrial), and energy use (renewable and non-renewable) are presented below.

Results for sensitivity analysis on replacement rate are presented in Figure 7-3 - Figure 7-8. The replacement rate is 25% and 75% for the sensitivity analysis, while the base case is 50%.

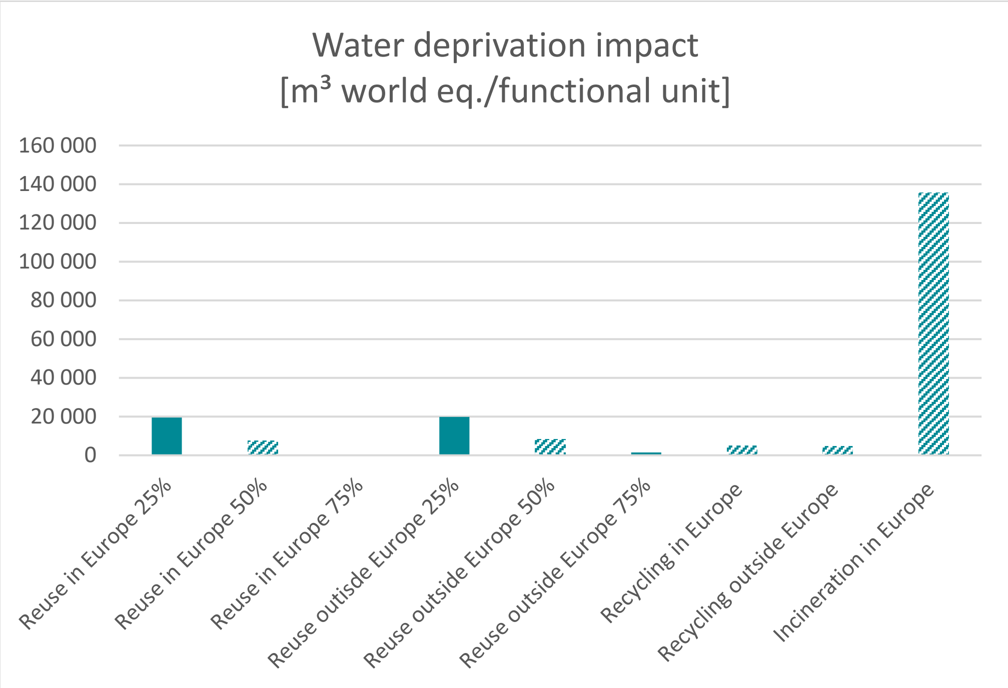


*Figure 7-3: Results for water deprivation impact for the sensitivity analysis on replacement rate. Dashed bars represent the base case, and the fully coloured bars represent the case studies affected by the sensitivity analysis.*

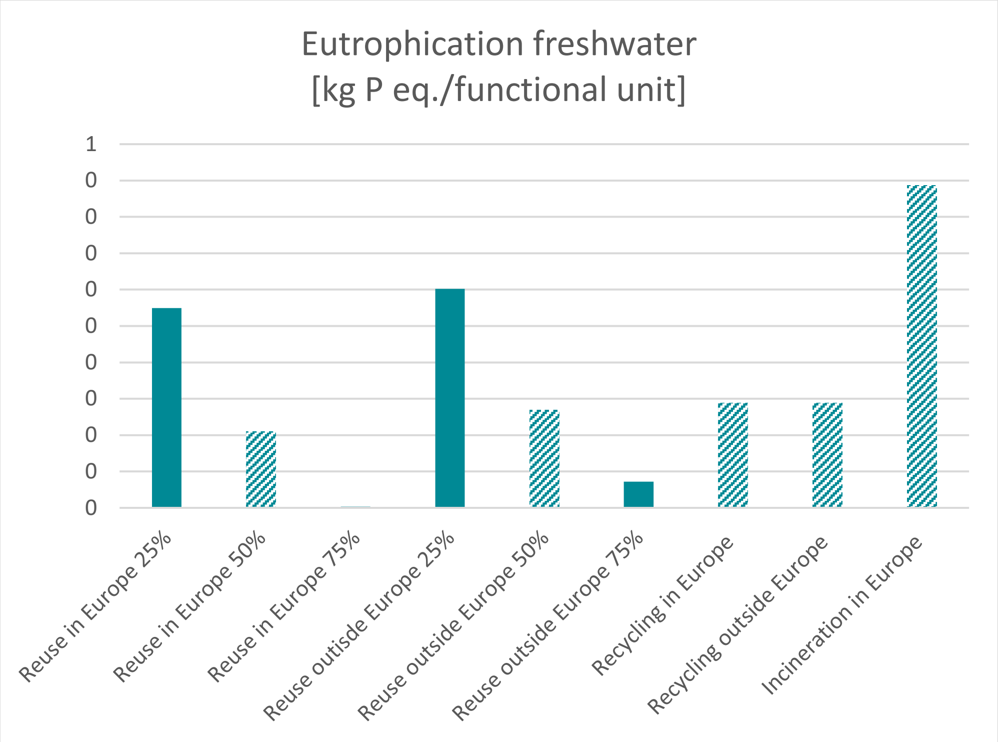


*Figure 7-4: Results for freshwater eutrophication for the sensitivity analysis on replacement rate. Dashed bars represent the base case, and the fully coloured bars represent the case studies affected by the sensitivity analysis.*

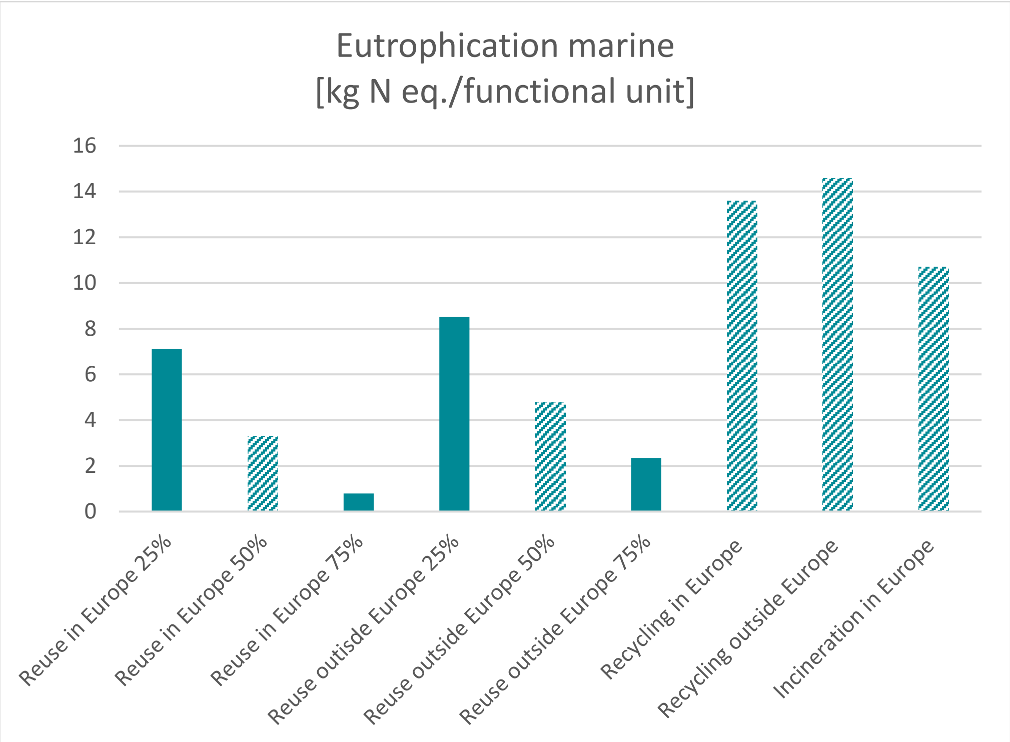


*Figure 7-5: Results for marine eutrophication for the sensitivity analysis on replacement rate. Dashed bars represent the base case, and the fully coloured bars represent the case studies affected by the sensitivity analysis.*

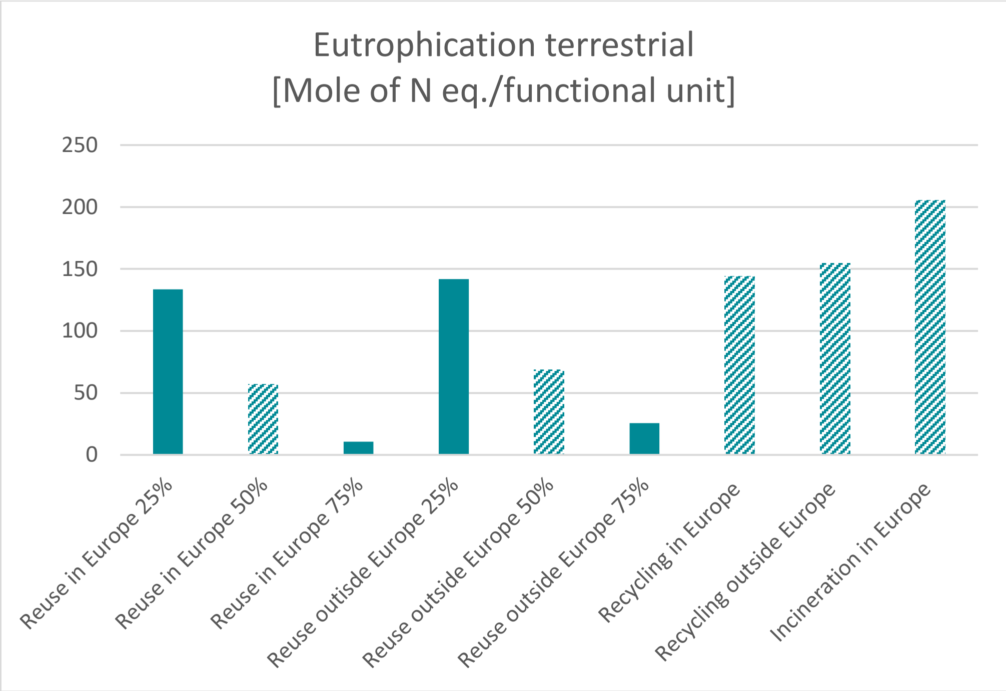


*Figure 7-6: Results for terrestrial eutrophication for the sensitivity analysis on replacement rate. Dashed bars represent the base case, and the fully coloured bars represent the case studies affected by the sensitivity analysis.*

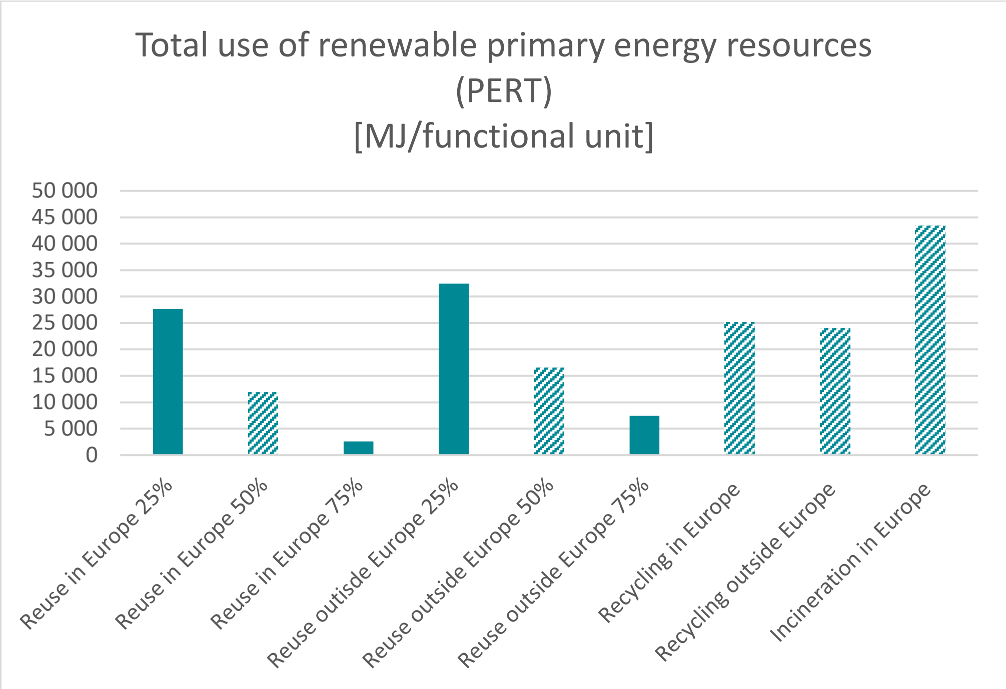


*Figure 7-7: Results for total use of renewable primary energy resources (PERT) for the sensitivity analysis on replacement rate. Dashed bars represent the base case, and the fully coloured bars represent the case studies affected by the sensitivity analysis.*

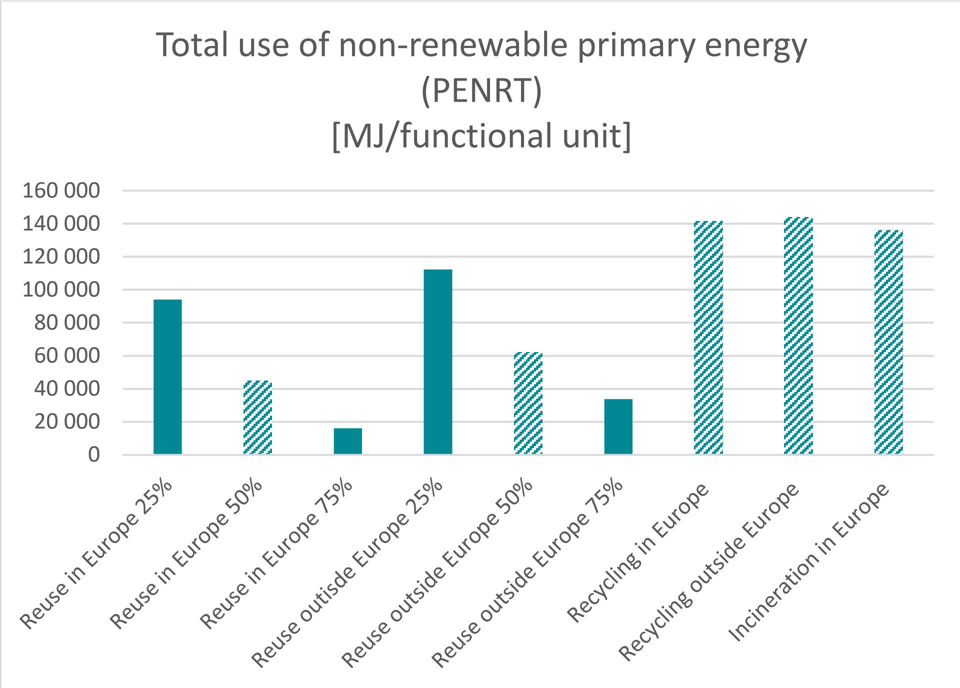


*Figure 7-8: Results for total use of non-renewable primary energy resources (PENRT) for the sensitivity analysis on replacement rate. Dashed bars represent the base case, and the fully coloured bars represent the case studies affected by the sensitivity analysis.*

In Figure 7-9 – Figure 7-14 the sensitivity analysis on loss rate, i.e. waste generated in the retailing process, in Kenya is presented. For the sensitivity analysis the waste generated in the retailing process in Kenya is 40%, while for the base case is 2%.

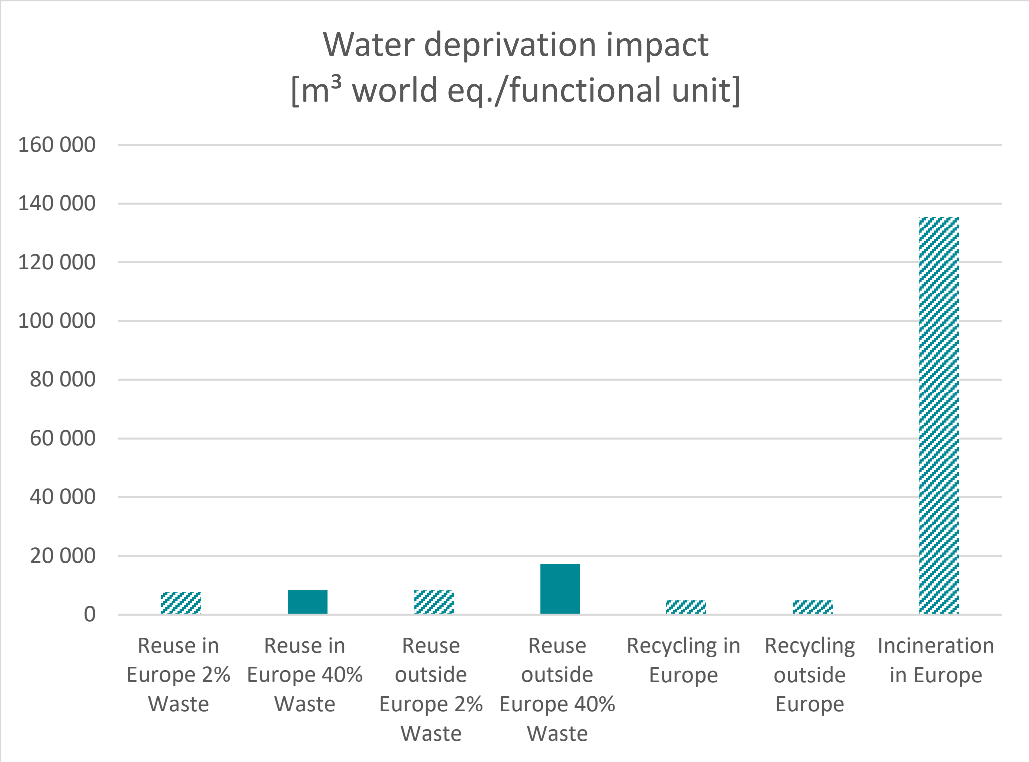


*Figure 7-9: Results for water deprivation impact for the sensitivity analysis on loss rate. Dashed bars represent the base case, and the fully coloured bars represent the case studies affected by the sensitivity analysis.*

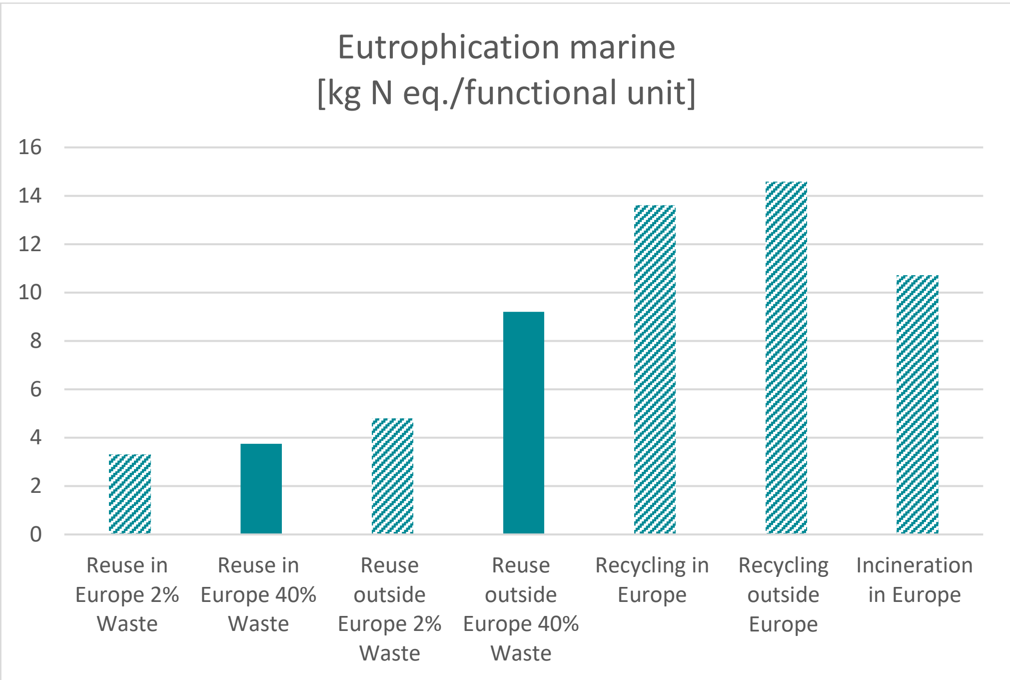


*Figure 7-10: Results for marine eutrophication for the sensitivity analysis on loss rate. Dashed bars represent the base case, and the fully coloured bars represent the case studies affected by the sensitivity analysis.*

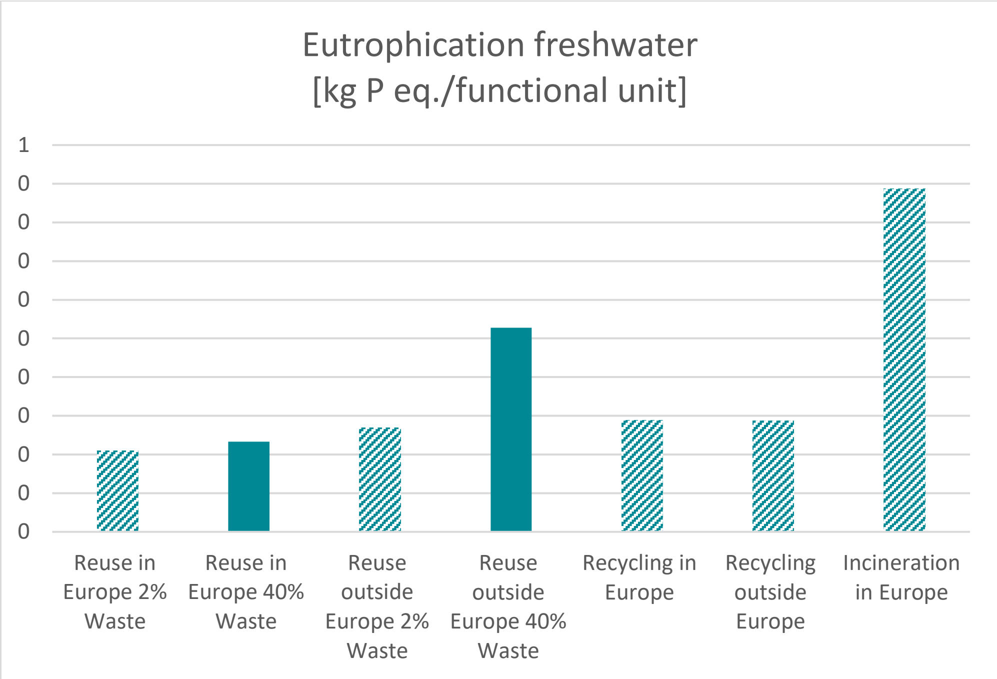


*Figure 7-11: Results for freshwater eutrophication for the sensitivity analysis on loss rate. Dashed bars represent the base case, and the fully coloured bars represent the case studies affected by the sensitivity analysis.*

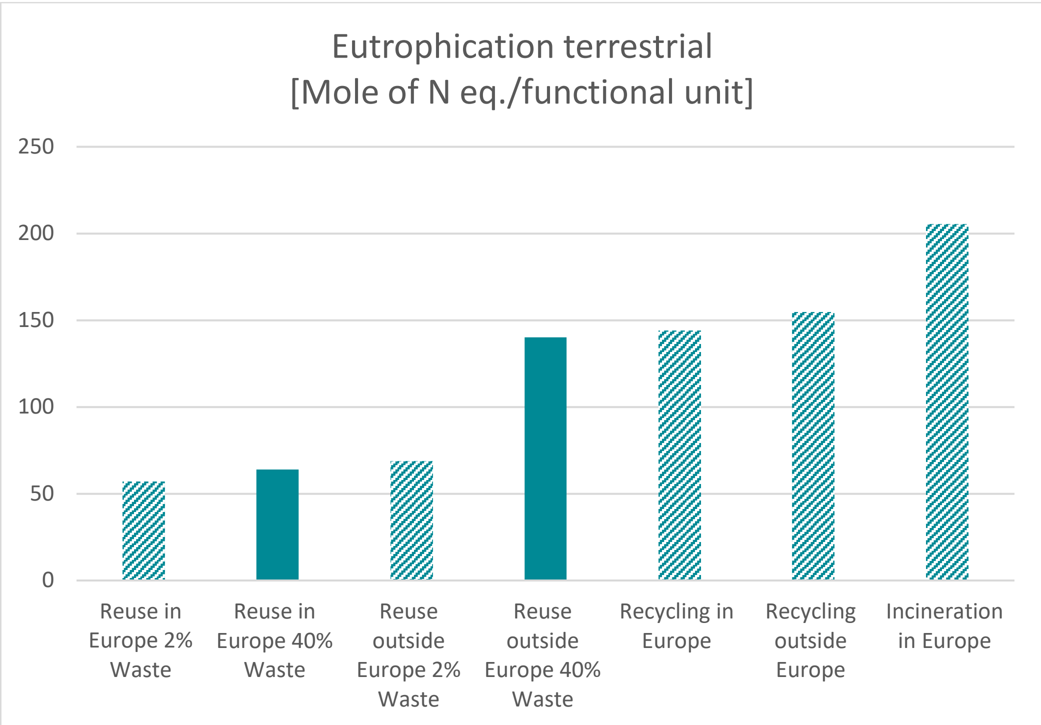


*Figure 7-12: Results for terrestrial eutrophication for the sensitivity analysis on loss rate. Dashed bars represent the base case, and the fully coloured bars represent the case studies affected by the sensitivity analysis.*

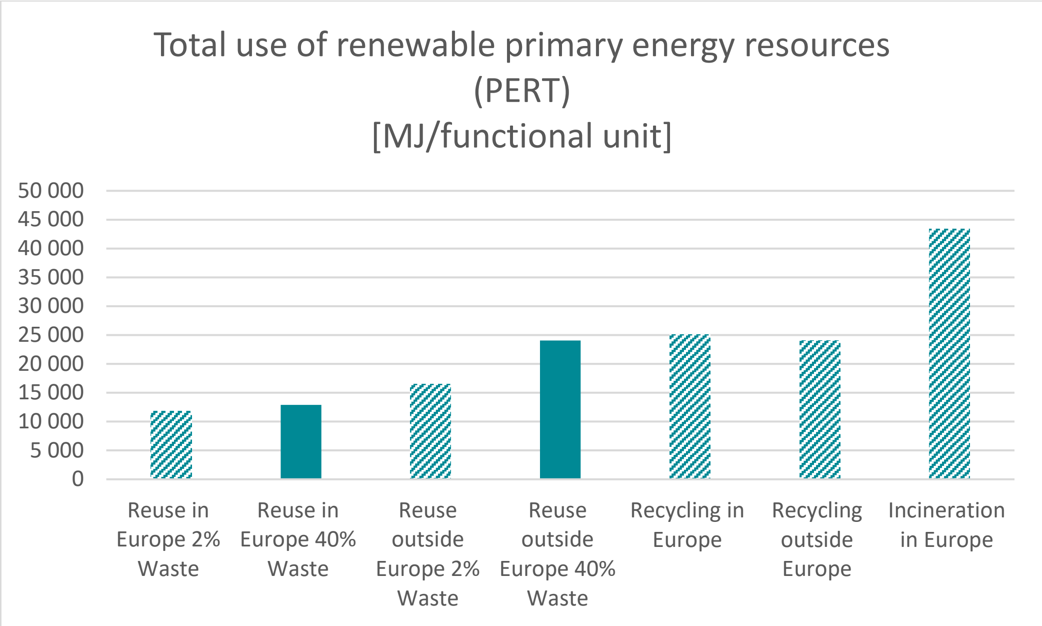


*Figure 7-13: Results for total use of renewable primary energy resources (PERT) for the sensitivity analysis on loss rate. Dashed bars represent the base case, and the fully coloured bars represent the case studies affected by the sensitivity analysis.*

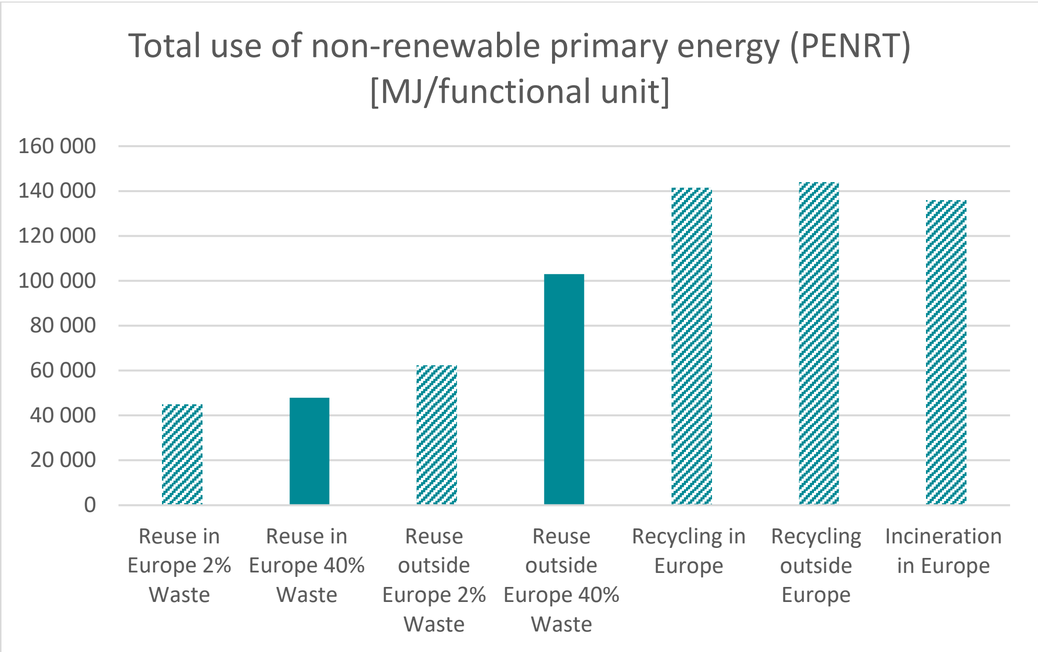


*Figure 7-14: Results for total use of non-renewable primary energy resources (PENRT) for the sensitivity analysis on loss rate. Dashed bars represent the base case, and the fully coloured bars represent the case studies affected by the sensitivity analysis.*

# Appendix 7: Field study to Humana´s sorting facility

At Humana's sorting facility in Vilnius, Lithuania, used clothing is sorted manually. The facility also handles bales of shoes and other type of accessories, which are washed and refurbished if needed. On average, 140 to 160 tons of textiles are sorted daily, with a maximum capacity of 200 tons per day across two shifts. Experienced sorters can process up to 800 kg of textiles daily, with a minimum requirement of 650 kg. Those who do not meet this minimum receive additional training, while high performers can earn bonuses.

To enter the profession, workers undergo a three-month training program supported by the company. This training covers sorting criteria and visual inspection techniques to determine whether items should be categorized for reuse, recycling, or disposal. The sorting center uses up to 250 categories, developed to meet customer demand for both export and local second-hand shops.

In addition to sorting for reuse, textiles are categorized for recycling (downcycling). This includes sorting materials for wipers, separating knitted textiles for use in producing carpets and cushions, and sorting 100% wool bodies for sale. Stuffed textiles are sorted for reuse in stuffing materials.

The sorted textiles are subject to audits to ensure they meet sorting specifications, with a 5% allowance rate. Discrepancies identified during audits may result in salary deductions. Finally, the sorted textiles are baled, with each large bale weighing approximately 45 kg.

# Appendix 8: Respondents in the interview study

### Respondent 1 – Import-export manager at a wholesale sorting company

Respondent 1 is responsible for sourcing customers, suppliers, and buyers, and that the textiles purchased meet customer requirements and are suitable for resale. Reusable textiles are sorted and sold locally in second-hand stores in Lithuania, as well as across Europe. The company also exports textiles to international markets, including India, Pakistan, and Africa, with 35% of clients based in Africa.

### Respondent 2 – Deputy manager for Second-Hand Shops

Respondent 2 manages second-hand retail operations across multiple countries, including Lithuania, Latvia, Estonia, Hungary, Belgium, and Poland. Is responsible for coordinating store operations, ensuring efficient inventory management, maintaining relationships with suppliers and customers, and works with charity projects.

#### Respondent 3 – Business developer at a waste management company

Respondent 3 manages a wholesale sorting business as part of a company responsible for collecting 70% of Lithuania's used textiles through municipal and national collection points. Collected textiles are sorted manually into about 100 categories, separating high-quality garments from damaged or unclean ones. Reusable items are sold in bales to local and international clients, with 40% of exports going to Africa. Items unsuitable for reuse or recycling are incinerated. The company also engages in charitable activities, such as clothing donations and aid collaborations.

#### Respondent 4 – Manager at a medium SHC business

Respondent 4 oversees importing, wholesaling, retailing, and exporting second-hand clothing (SHC) in Kenya. The business sources containers with SHC textile bales from the UK, Pakistan, and China, operates warehouses for repacking and distribution, and manages retail shops. They are planning regional expansion into countries such as Tanzania and South Africa.

#### Respondent 5 – Manager at a small SHC business

Respondent 5 handles importing, wholesale and retail of SHC in retail shops. SHC is sourced from suppliers in Canada, the US, the UK, and Australia. The business focuses on sourcing high-quality textiles and catering to local market demands.

#### Respondent 6 – Manager at a small SHC business

Respondent 6 manages SHC imports and sells them to wholesalers, retail shops, and open-air markets. Sourcing from Canada and the UK, the business prioritizes high-quality textiles that align with local consumer preferences.

#### Respondent 7 – Co-founder and general manager

Respondent 7 is a co-founder of a business focused on collecting and upcycling textiles into high-end products like carpets and baskets. The operation integrates collection, sorting, and production, with unsellable textiles either repurposed as filler for rural areas or disposed of in landfills. High-end products are marketed locally and exported, particularly to the UK, while involving local communities in the production process.

#### Respondent 8 – Wholesale manager at a SHC company

Respondent 8 manages SHC warehousing and distribution across multiple branches in

Kenya. Bales, sourced from suppliers in Lithuania, Estonia, Oman, and Türkiye, are inspected and distributed to retail shops and wholesalers.

### Respondent 9 – Business developer at a SHC company

Respondent 9 develops the wholesale sorting business for a large SHC company, focusing on operational efficiency and market expansion.

### Respondents 10 - CEO at regional trade association

Respondent 10 leads industry initiatives, partnerships, and the regional development of the SHC trade. Currently, they are focused on formalizing the mitumba trade in Kenya, with the goal of creating long-term, safe working conditions for traders.

# Appendix 9: Example of interview questions

Could you please describe your (your organization's) role in the second-hand clothing (SHC) trade?

What type of second-hand textiles (product categories) do you sort and/or sell?

How do you perceive the overall quality of bought textiles?

Do you receive feedback on the quality of exported textiles from your customers? What happens if a customer is unhappy with the quality of their purchase?

What is your opinion on the level of knowledge required to work in this sector?

How do you perceive the working conditions in the SHC trade compared to other types of jobs?

How has the second-hand trade impacted your income and livelihood?

Has the market for the SHC trade changed over time, for example over the last 10 years?  In what way?

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*This report has been reviewed and approved in accordance with IVL's audit and approval management system.*