Master's Thesis– Master Sustainable Business and Innovation

Towards a circular textile industry

A study to design a more inclusive Dutch EPR system for textiles

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Abstract

Introduction
The world's population has been rapidly expanding, and with that, the resource use has grown exponentially. This has led to an immense amount of waste, which is generally not managed in a sustainable manner, creating significant societal challenges. One way to limit this waste is by implementing the concept of a circular economy (CE). An important policy that could help in achieving this CE goal in that of extended producer responsibility (EPR). EPR is a governmental policy that adds external costs associated with the processing of products after their use phase to the market price of these products, paid for by the producers. The Dutch government has set CE goals for its textile industry and is currently in the process of implementing an EPR legislation. However, past EPR legislations have generally not been effective in transforming an industry towards circularity. Therefore, the research question is as follows:

How can the upcoming Dutch EPR for textiles be structured to accelerate progress towards the circularity goals?

Theoretical framework
This study uses a systems thinking approach. Within this approach a combination of value chain mapping, material flow analysis, and cost-benefit analysis is made as a framework to understand the textile industry. Recent findings on EPR improvements are then integrated into this framework.

Methods
The research was in part qualitative and in part quantitative in nature. Data for this research was acquired through 18 semi-structured interviews with experts from inside the textile value chain or linked to it, in combination with data from literature.

Results
The results first give an overview of the current textile value chain in the Netherlands and its waste flows. Following this, drivers and barriers are discussed for transparency in the supply chain, reusing of textiles, recycling of textiles, other VROs, and supply chain management responsibilities. Finally, a model based approach for EPR cost calculations is presented. The results show that collaboration and transparency are both essential for progress. Furthermore, it is crucial that the fee of an EPR is substantial and that fee reductions are implemented for well performing producers, in order to incentivise change towards circularity.

Discussion/Conclusion
The findings shed a new light on the creation of an EPR structure and the potential possibilities within such legislation. It provides valuable insights for policy-makers involved in the development of new regulations and helps to further a way of thinking that links economic and sustainability incentives for producers.

Keywords: *circular economy, textile industry, extended producer responsibility, waste management, sustainability, value retention options, r-ladder, recycling, reuse, clothing*

Executive Summary

The current ways of doing business are unsustainable and create immense pressures on the planet and its resources. Waste production has been exponential over the past decades, most of which is incinerated or landfilled. The textile industry is seen as one of the industries with the highest negative impacts along the supply chain. Circular economy (CE) is a concept that gives a framework on how to combat these negative consequences. In the CE, materials keep their value for multiple use phases, and waste does no longer exist, as the materials are seen as resources.

To get closer to a CE, governments have started to implement policies relating to waste management. One such policy is the extended producer responsibility (EPR). In EPR legislation, producers are held responsible for the processing of their products after their use phase. However, current EPR policies have shown little effectiveness in progressing towards a CE, and research has shown new possibilities in shaping EPR.

The Dutch government has an extended CE action plan, with the textile industry being an important part, and is currently in the process of implementing an EPR for textiles. This leads to the following research question:

How can the upcoming Dutch EPR for textiles be structured to accelerate progress towards the circularity goals?

The research was performed by interviewing 18 experts from the textile industry, including producers, processors, and experts from outside the supply chain. In the end, the research lead to several policy recommendations, which are shown below.

Recommendations
• It is essential to keep in mind all the different value retention options along the value chain in the creation of EPR legislation
• Collaboration and partnerships between different actors in the value chain are crucial when striving for sustainability
• The creation a circular value chain organisation, next to the PRO, would be very valuable in EPR legislation
• Making the responsibility for the producers as far-reaching as possible has the largest circularity outcomes
• A strong economic incentive, via the EPR fee, is essential in changing the way products are manufactured and processed
• It is crucial that there are fee modulations, or discounts. This is the most important way in which such a legislation can steer producers towards a more sustainable way of doing business
• Implementing an EPR has more impact if done on a supranational level

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1. Introduction

1.1 Background

In 1972, a group of leading scientists from the Club of Rome published a report called 'The Limit to Growth'. It augmented the idea that resources on earth are not inexhaustible and infinite and that something needs to be done to limit the number of resources humanity uses (Meadows et al., 1972). Since the report came out, resource use has still kept exponentially growing, as shown in Figure 1 (United Nations Environmental Panel[UNEP], 2016). Most of these resources are not managed sustainably, and this linear take-make-waste pattern of global growth creates over 2 billion tonnes of waste annually. Most of the waste ends up in landfills and incineration, meaning reusing the resources is almost impossible (Kaza et al., 2018). Not only does this create excessive strain on the world's resources, it also causes sizeable environmental damage.

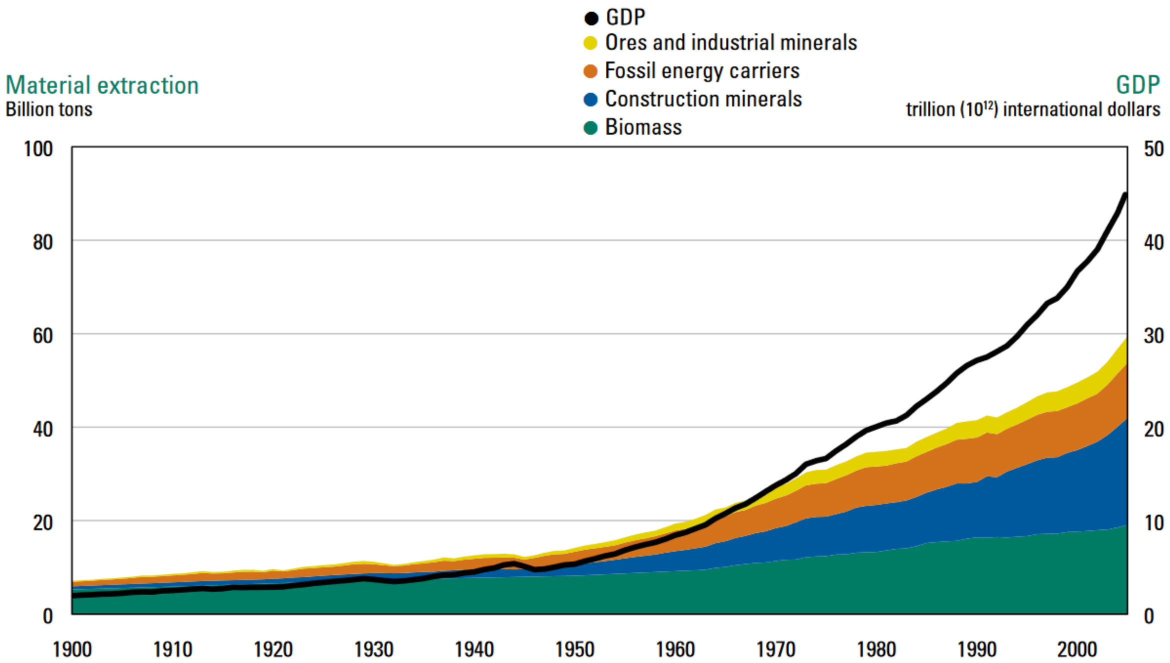

Figure 1. Worldwide material extraction over the years (UNEP, 2016)

Resource use happens because, currently, the use of resources is closely linked to economic growth and human well-being—this link between the two needs to be undone to guarantee human well-being without exhausting the planet's resources. One framework to achieve this is that of the Circular Economy (CE). CE is defined as "*an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes*" (Kirchherr et al., 2017).

The aim is to accomplish sustainable development, enabling ‘decoupling’ of resource use from economic growth (Geissdoerfer et al.,2017). This process is shown in Figure 2.

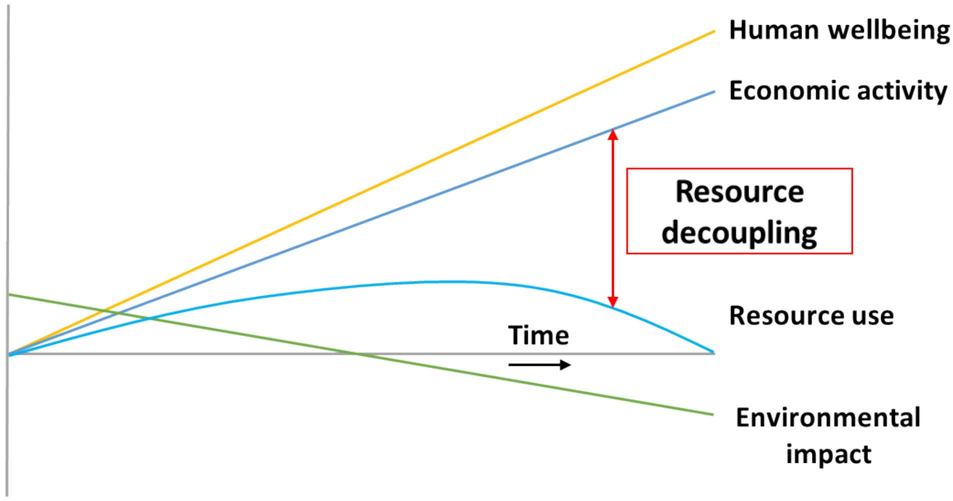

Figure 2. The concept of resource decoupling visualised. Adapted from UNEP (2016)

Multiple political bodies have recently released plans to grow towards a CE, such as China’s “Made-in-China 2025” and the European Union’s “Circular Economy Action Plan” (Chen et al.,2021; Calisto Friant et al., 2021). Within the scope of this European action plan, one of the frontrunners is the Netherlands. The Dutch government has set clear goals of 50% fewer resources used in 2030 and the ambition to be fully circular in 2050 (Rijksoverheid, 2016).

1.2 Problem definition

The textile industry is one of the highest-impact industries worldwide. It used 80 billion cubic meters of water in 2015, is estimated to be responsible for up to 10% of global carbon emissions, and 100 million tons of textile waste is created annually (Global Fashion Agenda, 2018). Despite this, textile consumption in the Netherlands is only increasing, with most of it being incinerated when thrown away (CBS, 2021). The government has calculated that the environmental impacts of this were 7634 megatons of CO_2, 53370 megajoules of energy, and 5618 Mm^3 of water in 2019.

Because of this, the textile industry is one of the key focus areas in the European and Dutch CE plans, with the Dutch government setting a goal of 50% sustainable or recycled content in 2030 (van Veldhoven-van der Meer, 2020). The primary waste management policy tool the Dutch government will use to reach its goals is Extended Producer Responsibility (EPR). Within an EPR, producers become responsible for organising the take-back, treatment and recycling of their products' waste (Mayers, 2007). This legislation already exists for several product categories.

1.3 Scientific & practical relevance

Currently, EPR legislation is not always as effective as expected. The focus of most practices or proposals for EPR implementation tends to be only on the disposal phase, and, particularly, on promoting waste collection rates. In contrast, the design, manufacturing and use phases generally do not receive sufficient attention (Gu et al., 2019). Based on a recent Delphi study, a recently published whitepaper by the Utrecht University’s Circular Economy and Society Hub shows seven limitations to current Dutch EPR practices and presents three pathways for improving EPR (Vermeulen et al., 2021). The Dutch government is currently developing an EPR for the textiles industry, which will take effect in 2023 (Rijksoverheid, 2022). Considering that the government’s goals are structured around the input side, and EPRs typically focus on the output side, this is an interesting contrast. That makes this research a unique opportunity to overhaul the Dutch EPR system through holistic CE strategies, leading to both improved human well-being and system functioning.

1.4 Aim & Research question

With this in mind, the main aim of this research is to find out what is necessary to create a more inclusive textiles EPR that accelerates progress towards the government's circularity goals. This leads to the following research questions:
Main RQ: How can the upcoming Dutch EPR for textiles be structured to accelerate progress towards the circularity goals?

- *RQ1: What is the current state of the Dutch textile value chain and its waste flows?*
- *RQ2: What are the drivers and barriers for circularity along the Dutch circular textile value chain?*
- *RQ3: What value retention options are the most promising, and how could they be stimulated via an EPR structure?*
- *RQ4: How can these findings be used in the design of a circularity-oriented Textile EPR conform to the pathways outlined in Vermeulen et al. 2021?*

To accomplish the aim of this study, the research outline is as follows. First, the current state of the Dutch textile value chain and its waste flows needs to be investigated. Following this, the network of the most critical value retention options needs to be analysed and mapped. Then, the drivers and barriers need to be considered for these different options. Following this, the established data is used to form recommendations for a new EPR. The scope of this research will be inside the Netherlands since this is where an EPR is currently being developed. The final design can help the Dutch government in this transition towards its goals.

2. Background and policy

This chapter describes fundamental background information necessary for the understanding of this study and current policy implementation. It first describes the global textile industry and the different fibres used in the industry. Following that, recycling and other sustainability options within the industry are mentioned. Finally, the 10implementation of EPR policies is discussed.

2.1 The textile industry and its complexities

2.1.1 The global industry

The textile industry is one of the largest and most global industries and is a fundamental part of most human beings' everyday life (Hansen & Schaltegger, 2013). The industry's total worth is estimated to be over US$1 trillion worldwide, contributing 7% of the world's total exports and employing approximately 35 million people worldwide (Global Market Report on Sustainable Textile, 2019). Besides being one of the largest industries, the textile industry is considered one of the primary reasons for pollution worldwide. The process of textile manufacturing is known for consuming valuable resources like water and fuel while using a variety of chemicals on a large scale (Desore & Narula, 2018). The supply chain for textiles is a very international one and has different impacts during the different stages, as is visualised in Figure 3.

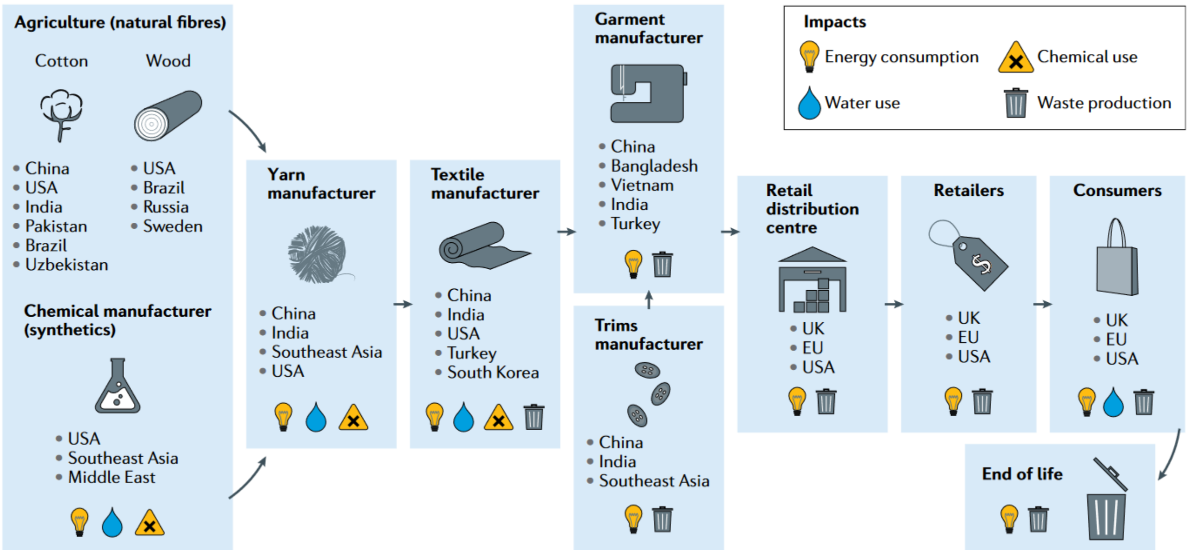

Figure 3. The worldwide textile industry and its impacts per location (Niinimäki et al., 2020)

The Dutch government and the textile industry have previously stated their goals for a circular textile industry and have worked together to achieve this. The most important document, in this case, is the sector plan of both branch organisations, Modint and INretail. The plan is called "the road towards a sustainable clothing- and textile industry in 2050", and was released in 2019. It outlines how the branch organisations have helped the industry become more sustainable since 2012. An overview of the initiatives is given in Appendix A. However, all of these agreements have been voluntary, and while they were widely adopted, their effects are still unclear. Furthermore, the focus of the agreements have generally been on the social side of sustainability, such as supply chain management and better worker conditions.

In the policy program for circular textiles 2020-2025, the national government has explained what the transition towards a circular textile chain looks like. The policy program sets intermediate targets for 2025, 2030 and 2035 to eventually achieve a fully circular economy by 2050 (Rijksoverheid, 2022).

The introduction of an EPR system for textiles is, co-initiated by Europe, an important means of achieving these objectives.

2.1.2. Characteristics of different fibres used in the textile industry

There are many different types of fibres used in textiles products, which is important to understand before looking at the processing of their waste products. Fibres used in textile products are selected based on various characteristics, such as how they feel, their breathability, and their strength. Textiles can be woven or knitted from two types of fibres: natural or synthetic (Schwartz, 2019).

Natural fibres include fibres that consist of cellulose, such as cotton, linen and hemp, as well as fibres that consist of proteins, such as silk and wool. Generally, during the growth of natural fibres, there is significant use of land, water, and chemicals. While natural fibres are relatively biodegradable, chemicals used during processing and dying can still negatively impact soil and water when disposed of unsustainably (Harmsen et al., 2021).

Synthetic fibres include those made on a petrochemical basis, such as polyesters, of which the most common is polyethylene terephthalate (PET). Other manufactured fibres include nylon, elastane, or regenerated cellulosic fibres such as bamboo and viscose. Synthetic fibres are made by putting a liquefied feedstock through a spinneret to form a fibre that can then be spun into yarn for weaving or knitting into textiles (Muthu, 2017). Synthetic fibres need a significant amount of energy for production, and those made on a petrochemical basis are made from non-renewable resources. Furthermore, they are not generally biodegradable and will persist in the environment for millennia when disposed of (Muthu et al.,2012).

Where cotton used to be the largest share of all different fibre sorts, it has now been overtaken by the decennia of growth in synthetic fibre usage. Synthetic fibres account for over 60% of all fibres, while cotton stands at just over 30%. This growth has been facilitated by the variety of different synthetic fibres and the possibilities in characteristics (Hou et al., 2018). For the same reasons, there has been a significant increase in mixing different materials to create specific characteristics. For example, a blend of cotton and polyester has the same breathability and strength as cotton while creasing less. Moreover, a small percentage of elastane is often added to the fibre mix to create extra stretch. These blends of different textiles do make it harder to recycle because of the difficulty of separating the different fibres from one another (Okafor et al, 2021).

2.1.3 Mechanical and chemical textile recycling

Recycling (R7) is one of the most promising ways to reduce the textile industry’s impact. Recycling refers to the breakdown of a product into its raw materials in order for the raw material to be reclaimed and used in new products (Leal et al., 2019). In the clothing industry, there are two different moments where waste is created to be recycled, namely post-production (pre-consumer) and post-consumer. Post-production waste is generally the wasted textiles that remain during cutting and sewing (Sandin & Peters, 2018). While companies have made progress in limiting this waste flow during recent years, it can still be up to 15% off all materials. Post-consumer textile waste is all the apparel that gets discarded after its use phase. This either gets into the general waste streams or is collected via charitable organisations, municipalities, or in (second-hand) clothing stores (Vajnhandl & Valh, 2014).

After the raw material is recycled, it can be further classified according to the new product stream it enters. These two classifications are open-loop recycling and closed-loop recycling (Curran, 2012). Open loop recycling refers to recycling where the recycled materials enter a different product’s life cycle, as shown in Figure 4. Often, these are products of a lower quality or value, which might therefore be seen as ‘downcycling’. Generally, the second product is not recycled again after its life cycle is complete because there are limits to the number of times materials can be reused. Open-loop recycling does not decrease the amount of virgin materials necessary for the initial product (Payne, 2015). However, it does decrease the amount of needed virgin materials in the second product life cycle. It can therefore be seen as a form of ‘slowing the loop’.

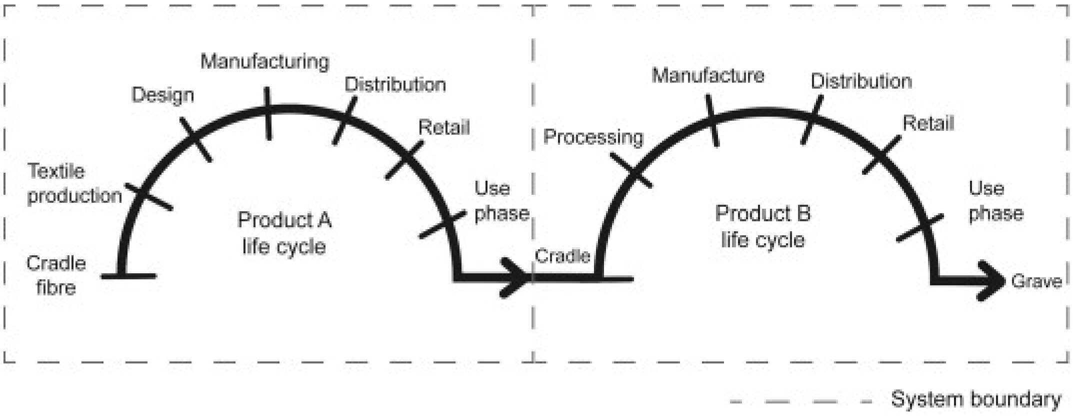

Figure 4. The concept of open-loop recycling visualised (Payne, 2015)

On the other hand, closed-loop recycling can be seen as the most important form of ‘closing the loop’. It refers to the breaking down of materials, which are then used for the same purpose as they were before (Klöpffer & Grahl, 2014). This way, the material can stay in the same product loop multiple times, as shown in Figure 5.

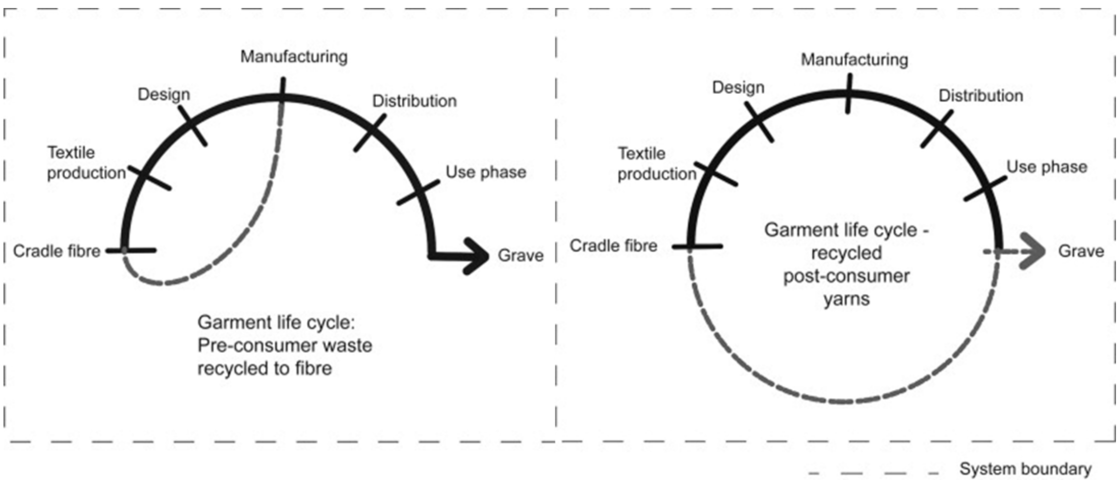

Figure 5. The concept of closed-loop recycling visualised for pre- and post-consumer yarns (Payne, 2015)

There are many different possible classifications of textile recycling, as shown by Ribul et al. (Ribul et al., 2019). However, to keep it simple, only the most common ones are used here. Generally speaking, there are three main classifications for the recycling of textiles, namely mechanical and chemical, and, less frequently, thermal (Sandvik & Stubbs, 2019).

Mechanical recycling converts a textile material into a new material using mechanical processes and machines. The textile waste is first sorted by fibre category, with the non-fibre parts, such as zippers and buttons, being removed, and then the fibres being pressed into a bale. Mechanical recycling consists of cutting textiles into smaller pieces, which then get progressively shredded until the fabric is in a suitable fibrous state, ready to use for other processes, such as re-spinning (Damayanti et al., 2021).

Chemical recycling is a way to break down cellulose- and polymer-based fibres using chemical reactions. First, the fibres are depolymerised into their monomers, which can then be repolymerised into new fibres. The chemically recycled fibres can have the same quality as virgin materials, as there is no loss in physical properties through the recycling process (Pensupa, 2017). Thermal recycling is the melting of synthetic fibres before these are re-spun into new fibres or reshaped into other forms (Juanga-Labayen et al., 2022). Since this also follows a chemical process, it will be categorised under chemical recycling.

2.1.4 Other relevant VROs and sustainability options

While recycling is often seen as the main opportunity for sustainable development of the textile industry and the only one to "close the loop", it is certainly not the only necessary VRO. The most considerable other option for textile waste is the reuse (R2) of the textiles. Textile reuse refers to various means for prolonging the practical service life of textile products by transferring them to new owners with or without prior modification (e.g. mending). This can, for example, be done through trading, swapping, or borrowing, facilitated by, for example, second-hand shops, online marketplaces, and clothing libraries. The reuse of textiles can have even more significant environmental benefits than the recycling of textiles because of the energy and chemicals necessary for recycling (Sandin & Peters, 2018).

Another important part in the value retention of textile products is the separate collection of textile waste products, and sorting them in different categories for further processing. Globally, only 20% of textile waste is separately collected for reuse or recycling. The remaining 80% is landfilled or incinerated (Lewis, 2015). Textile waste can be separately collected via charity organisations, retail take-back programs, second-hand stores, or in public containers. The majority of rewearable textile items collected are exported for reuse (Bartlett et al., 2013). After the collection of textile waste, it needs to be sorted. This is an activity requiring skilled workers to identify and separate wearable textiles from unwearable textiles, which are ready for recycling. This sorting is mainly done by hand, but there are more and more possibilities in mechanical sorting, making the process significantly cheaper (Nørup et al., 2019).

Another way to make the textile industry more sustainable is that of redesigning clothing (R1) so that they last longer. This form of life time extension could be amplified via repair possibilities (R3). Finally, there are opportunities for new circular business models in the industry (Pal, 2017).

2.2 Governance in the circular economy: Extended producer responsibility

2.2.1 Implementation of EPR

It has been 30 years since the introduction of the first EPR legislation, and especially since the 2000s, the number of governments choosing to implement it has grown immensely. Globally, EPR is predominantly applied in high-income countries, with the most common product groups being electronics, tires, vehicles and packaging (Kaffine and O'Reilly, 2013). 90% of the EPR schemes are applied in Europe, North America, and Oceania, with uptake being far more limited in Asia and Africa, although there are a few examples (Peng et al., 2018).

The European Union (EU) sees EPR as one of the main policy instruments to manage waste, and it is an integral part of its Waste Framework Directive (Pouikli, 2020). The Waste Framework Directive establishes basic concepts and definitions pertaining to waste management, including definitions of 'waste', 'recycling', and 'recovery'. In article 8 is laid out that member states can take legislative measures to implement EPR, in order to strengthen reuse, prevention, recycling and other recovery of waste. Article 8a stipulates some general minimum requirements (Steenmans, 2019), namely:

”EPR schemes are in line with the waste hierarchy and financial contributions paid by the producers in a collective EPR scheme to comply with their EPR obligations *“are modulated, where possible, for individual products or groups of similar products, notably by taking into account their durability, reparability, re-usability and recyclability and the presence of hazardous substances, thereby taking a life-cycle approach*.””

The EU has mandated EPR schemes for packaging (94/62/EC; 2018/852), Vehicles (2000/53/EC), electronic waste (2002/96/EC; 2012/19/EU), batteries (2006/66/EC) and, most recently, single-use plastic products, e.g., food containers (EU2019/904). Beyond the mandated schemes, member states have deployed EPR for other products, including tires, used oils, textiles, graphic paper, medicines, mobile homes and others (Backes, 2020). France is the member state that has used the instrument most frequently, with over 20 schemes (Leal Filho et al., 2019).

For years, France was the only European nation to have implemented an EPR framework in the textiles sector, having introduced it in 2007 with *Article L-541-10-3 of the Code de l’Environnement*. The responsibility of this obligation has been collectively filled in via the not-for-profit PRO called Refashion, which collects members’ fees for collection and further processing (Leal Filho et al., 2019). As of January 2022, Sweden has also introduced its own EPR, with licensed textile collections starting in January 2024. In the Netherlands, an EPR structure has been set up for six distinct product groups, including batteries, cars and electronics (Leal Filho et al., 2019). A new EPR is currently being developed for textiles, with the start date of the legislation being January 2023(Rijksoverheid, 2022).

More countries are to follow, since starting in 2025, EU member states will be mandated to collect textiles separately(WFD, Article 12b DIRECTIVE (EU) 2018/851). Furthermore, the European Commission will propose harmonised EU EPR rules for textiles, including eco-modulation of fees, as part of the forthcoming revision of the Waste Framework Directive in 2023.

2.2.2 The Dutch context of EPR

Dutch waste management policy targets a wider set of 85 waste sectors in the Dutch industry. For these 85 sectors, the policy waste management plans are defined and elaborated upon in the National Waste Management Plan (Landelijk Afvalbeheerplan (LAP)). Currently, the third LAP is in effect, which is for 2017-2029. In 2020, the Dutch government published their Regulation on EPR (Besluit regeling voor uitgebreide producentenverantwoordelijkheid), trying to set general minimum requirements for existing and future EPR legislation schemes, following Article 8a of the European Waste Framework Directive. For textiles, the Dutch government has set goals that set the boundaries for producers in the upcoming EPR legislation. These goals are shown in Table 1. Moreover, an additional goal is that all textiles contain 50% sustainable materials in 2030. This fits the overall national goal, which is to reduce resource consumption by 50% in 2030.

Table 1. Textile reuse and recycling goals set by the Dutch government, per year.

Year	Reuse & Recycling	Reuse	Reuse in the Netherlands	Recycling	Fibre-to-fibre recycling (% of recycling)
2025	50%	20%	10%	30%	7,5% (25%)

2026	55%	21%	11%	34%	9,18% (27%)
2027	60%	22%	12%	38%	11,2% (29%
2028	65%	23%	13%	42%	13,2% (31%)
2029	70%	24%	14%	46%	14,72% (32%)
2030	75%	25%	15%	50%	16,5% (33%)

3. Theoretical Framework

There are many ideas for arriving at a more effective implementation of EPR with the goal of getting closer towards achieving set objectives. This chapter goes into the scientific knowledge necessary to develop such policies. It starts with the fundamental idea of systems thinking, including the concept of Circular Economy. Then a combination of value chain mapping, material flow analysis, and cost-benefit analysis is made as a framework. Following this, the most recent developments in EPR science are discussed.

3.1 Systems thinking

As shown before, there is no denying the rapid development of complex systems that constantly emerge in the environment around us. International trade creates strong economic feedback loops between countries. Changes in policy in one country eventually have repercussions in another. Rittel and Webber (1973) describe these kinds of issues as 'wicked' problems in that they have "*no definitive formulation, no stopping rules, no ultimate test of a solution*" and, because every such problem is unique, "*few precedent solutions*" (Crowley & Head, 2017).
The properties of complex systems include the nonlinear and random nature of many of the relationships; the high number and varied nature of feedback loops; the interconnectedness of risk factors, environmental conditions and policy or practice interventions; the heterogeneity of individuals; and the resultant stress on the capacity of systems to adapt and self-organize (Meadows, 2008). Complex problems require deliberately coordinated sets of interventions and creative efforts at many jurisdictional levels (e.g. regional, provincial, national, international) and system levels (e.g. paradigm, goals, organizational structures).
With the use of a skill set called 'systems thinking', one can hope to better comprehend the underlying causes of complicated behaviours in order to more accurately forecast them and, to ultimately change their outcomes. With the exponential growth of systems in our world comes a growing need for systems thinking to tackle these complex problems. System thinking has been hard to define, but recent research defines it as: "*Systems thinking is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications to them in order to produce desired effects. These skills work together as a system*." (Arnold & Wade, 2015).
According to Arnold and Wade (2015), there are 8 necessary elements in systems thinking:

1. Recognizing interconnections
2. Identifying and understanding feedback
3. Understanding system structure
4. Differentiating types of stocks, flows, variables
5. Identifying and understanding non-linear relationships
6. Understanding dynamic behaviour
7. Reducing complexity by modelling systems conceptually
8. Understanding systems at different scales

In this thesis, a systems thinking approach is taken and these 8 elements are taken into account for the system that is the Dutch textile industry.

3.1.1 The Circular Economy & 10R framework

One concept that applies systems thinking is that of the Circular Economy (CE). The CE is a trending but contentious topic, critics sometimes claim that it means many different things to different people. For this reason, recent literature has been trying to conceptualise a commonly accepted definition. Kirchherr et al. performed one such attempt at a systemic analysis. They examined 114 definitions in literature and contributed towards the coherence of the CE concept. They stated that the aim is to accomplish sustainable development. This means creating environmental quality, economic prosperity, and social equity, the three pillars of sustainability, now and for the future (Kirchherr et al., 2017). To accomplish this, it is necessary to take a systems perspective at the micro-, meso-, and macro levels. In the CE, waste no longer exists and is seen as a raw material for new products. This definition signifies the importance of a waste hierarchy in the CE, certain value retention options are preferred over others.

Still, a hierarchy of different options generally exists. This hierarchy is commonly operationalised in the form of an 'R-ladder'. 'R' stands for various terms starting with 're-', such as 're-use' and 're-cycle'. The most extensive and nuanced one is the 10R framework (Reike et al., 2018), depicted in Table 2. These are called Value Retention Options (VROs) since they enable value retention of products and materials, with options higher on the ladder retaining more value.

Table 2. The 10R framework (Reike et al., 2018).

Increasing Circularity ↑

Category	R#	Strategy	Concept Explanation
Smarter product use and manufacturing	R0	Refuse	Make product redundant by abandoning its function or by offering the same function with a radically different product
	R1	Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
Extending lifespan of products and their parts	R2	Re-sell/Re-use	Reuse by another consumer of discarded product which is still in good condition and fulfils its original function
	R3	Repair	Repair and maintenance of defective product so it can be used with its original function
	R4	Re-furbish	Restore an old product and bring it up to date
	R5	Re-manufacture	Use parts of discarded product in a new product with the same function
	R6	Re-purpose (Re-Think)	Use discarded products or its parts in a new product with a different function
Useful application of materials	R7	Re-cycle	Process materials to obtain the same (high grade) or lower (low grade) quality
	R8	Recover (Energy)	Incineration of materials with energy recovery
	R9	Re-mine	Scrapping valuable materials and items from landfills

The emergence of CE is not just a recent phenomenon, but more an upgrade to older theories, beliefs, and practises around consumption and waste that date back to the 1970s. CE has been categorised as an evolving concept that happened in three successive phases and these phases were classified as CE 1.0, CE 2.0 and CE 3.0. Broadly, CE 1.0 (0 (1970-1990) relates to dealing with waste, the output and end-of-life (EoL) stage, and was the phase in which the 3R model was introduced. CE 2.0 (1990-2010) relates to connecting output and input strategies and increasing material efficiency. Environmental problems were also framed as potential opportunities, and concepts such as industrial ecology took off. This phase saw the emergence of eco-design and waste management policies such as EPR. CE 3.0 (2010-present) started when discussions of the concept of CE became more widespread and began to be framed against encroaching societal threats, including planetary limits, resource depletion, biodiversity loss, excessive waste generation and others. This has led to a more integrated and holistic understanding of material use, which aims to slow down, reduce, narrow and close resource cycles in a systemic manner through changes of consumption and production structures and patterns.

3.2 Value chain mapping, material flow analysis, and cost-benefit analysis

One way of visualising such a system and its elements is through value chain mapping. Mapping systems is especially important in the CE. One extensive overview of what this could look like for different systems in a CE was given by Reike et al (2018), and is shown in Figure 6. This map of circular economy retention options shows the different actors within a system and the different VROs in a products lifecycle.

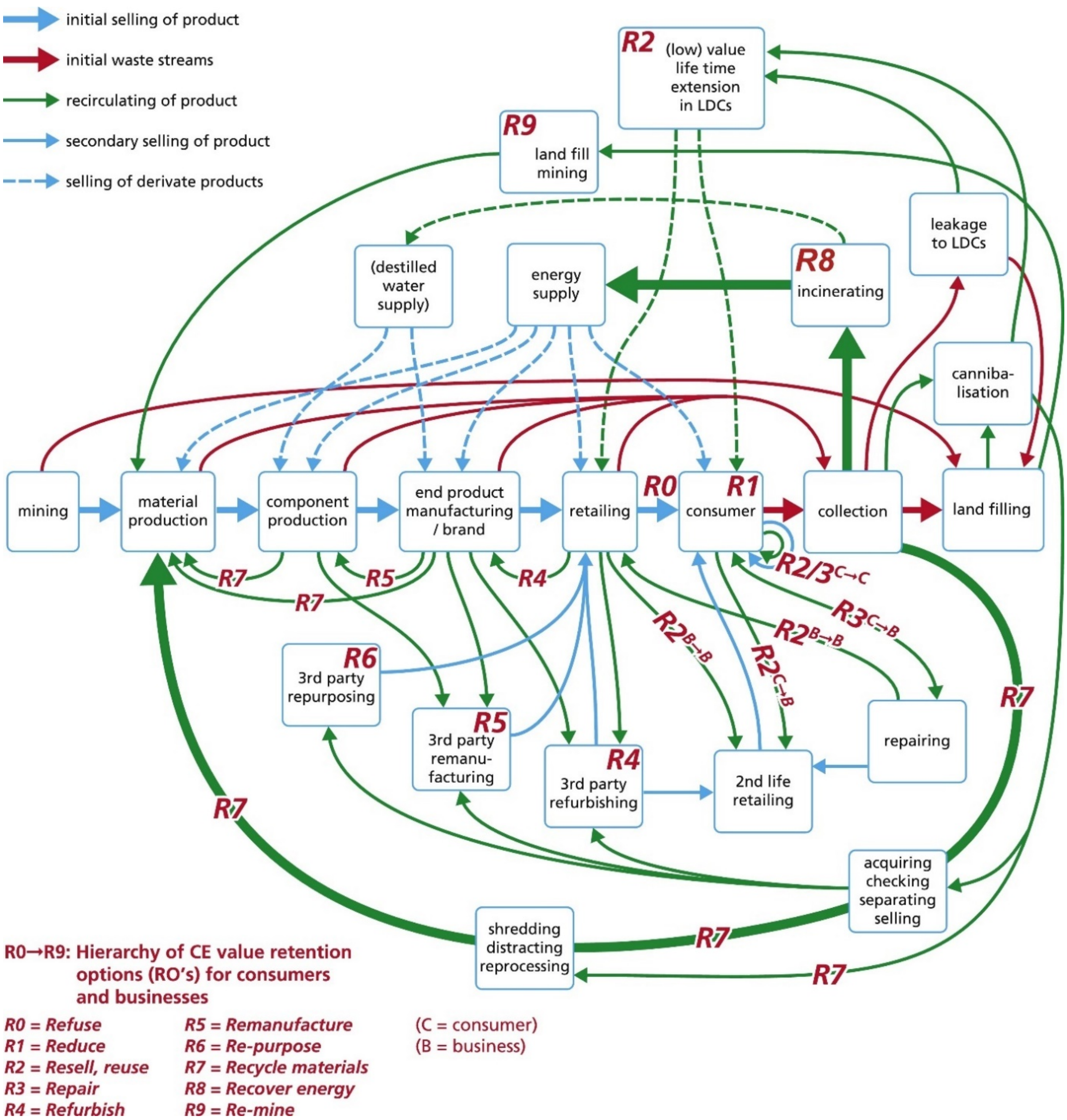

Figure 6. Value chain map of VROs. From Reike et al. (2018)

To achieve such a conceptual map for the textile industry in the Netherlands, it is necessary to map the different stakeholders and their actions within the Dutch textile system. Next to that, the different VROs need to be considered. This thesis is a first start to achieving this complete value chain map.

Another important part in the mapping of a system for circularity is the material flows within such a system. Material flow analysis an analytical method to quantify flows and stocks of materials or substances in a well-defined system (Bringezu & Moriguchi, 2018). This information is important for policy makers to design their waste management systems. This thesis adds a material flow analysis of textiles to the value chain mapping of the Dutch textile industry, in order to give an overview of the system, which is necessary to make the right choices for the implementation of EPR.

A final part of information that is important in the mapping of the system is that of the costs and benefits of the different processes in the system. Cost-benefit analysis is a systematic approach to estimating the strengths and weaknesses of specific processes. It is used to determine options which provide the best approach to achieving benefits with lowest possible costs in, for example, transactions, activities, and functional business requirements (Calthrop et al., 2010). A cost-benefit analysis can be used to compare completed or potential courses of action, and to estimate or evaluate the value against the cost of a decision, project, or policy. It is commonly used to evaluate business or policy decisions, commercial transactions, and project investments (Hirst, 2018). In this thesis, a cost benefit analysis is performed in order to calculate the necessary EPR fee to achieve circularity goals, since the basic idea is that circularity initiatives will not get off the ground as long as the necessary options are more expensive than what is available on the market when they are left to the free market.

3.3 Scientific perspectives of Extended Producer Responsibility

3.3.1 Overview of EPR

Both policymakers and scholars generally regard governmental interventions as an increasingly important factor in realising the CE transition (Kirchherr et al., 2018). Governments have adopted policies in their plans that explicitly try to influence developments to contribute towards specific transitions, such as the one from a linear to a circular economy. However, it is still unclear what the best way is for governments to contribute to transitions or transformative change. Herein lies the barrier that the CE inherently conflicts with norms that underly current policies and regulations (Korhonen et al., 2018; Kirchherr et al., 2017). To tackle this barrier, scientific literature has given governments a wide variety of intervention strategies to follow. These include eliminating subsidies that favour linear products (Kirchherr et al., 2018), shifting towards circular public procurement (Stahel, 2016), raising awareness through communication programs (Rizos et al., 2015), or extending consumer and producer responsibility.

One policy instrument incorporating these strategies is the extended producer responsibility (EPR). EPR is a governmental policy that adds external costs associated with processing of products after their use phase to the market price of these products, paid for by the producers (Lindhqvist, 2000). Thomas Lindhqvist presented the idea for the first time in a report to the Swedish Ministry of the Environment in 1990. The fundamental idea is to hold producers responsible for the costs of managing their products at the end of their life, in an effort to relieve local governments of the expenditures associated with waste managing (Gupt & Sahay, 2015). EPR can take many forms, such as a reuse, buyback, or recycling programs. EPR as a concept contains two main interrelated elements. The first is that producers should bear the financial burden of processing their products in the post-use phase. The second is that this financial burden stimulates producers to minimalise their waste, and therefore their costs, thereby aiding in the process of achieving a more circular economy

(Cai & Choi, 2019). This creates an economic incentive and links the input and output phase of the value chain, which fits the governmental model that has been growing in Europe since the 1990 introduction. In this model, responsibility for problems in the commons is shifted towards market actors, with governments setting the rules and boundaries (Driessen & Glasbergen, 2002).

Responsibility can include multiple mechanisms (Campbell-Johnston, 2022), such as:

- Liability for (environmental) damages caused by the product during its life cycle
- Utilizing their financial resources for the costs of processing a product after its use phase
- Legal responsibility and ownership of the product during the complete life cycle
- Obligation to provide and share information about the product’s properties

Generally, in the legal sense, all producers are individually responsible for their products in EPR legislation. However, to lower the burden of the organisation and registration of such a system, it is typically chosen to do this collectively as a sector (Gottberg et al., 2006). This responsibility usually is taken over from the producers by a third party via creation of a producer responsibility organisation (PRO). After establishing a PRO, PROs are paid by all producers for the management of used-product waste (Gupt & Sahay, 2015). How exactly this is all organised and how the roles of public and private actors are defined varies significantly between countries and between waste categories.

For example, ‘Stichting OPEN’ is the producer responsibility organisation (PRO) that organises electronic waste recycling in the Netherlands. A recycling fee is charged to those who purchase a new electronic device, and that money is used to fund recycling at the end of its useful life (Driessen et al., 2012). An EPR has been introduced in many different countries for many different product groups, and there has been an increase in the number of legislations and policies surrounding EPR systems (Cai & Choi, 2019).

EPR can be implemented via administrative, economic and informative instruments. The precise composition of these instruments forms the EPR structure. This means ERP can entail more than only shifting the financial burden of waste processing to the producers.

The Organisation for Economic Co-operation and Development (OECD) also includes the following in their EPR definition (OECD, 2016):

- Economic and market-based instruments, such as deposit funds, virgin material taxes, or landfill taxes
- Regulation and performance standards, such as a minimum recycled content in products or landfill bans
- Information-based instruments, such as reporting or product labelling requirements

3.3.2 The effectiveness of EPR

The effectiveness of EPR is something no clear cut statements can be made about. This is because efficacy of EPR must take into account the enormous range of its applications worldwide (Tasaki et al., 2019). This is especially true considering the different scopes of the instrument. On the one hand, the goal is to efficiently organise the recycling at the end of the value chain, on the other hand, it is meant to stimulate the redesign of products toward more sustainable and circular versions (Huang et al., 2019). Most studies on the effectiveness of EPR consider specific EPR structures, for specific product streams, in specific countries, making it difficult to generalise conclusions. Therefore, assessing and comparing EPR systems between product categories and countries is difficult, owing to the differences in definitions, reporting and monitoring requirements and data quality (Ongondo et al., 2011). However, an overview of the current strengths and weaknesses found in recent literature is given by Campbell-Johnston, as shown in Table 3.

Table 3. The strengths and weaknesses of global EPR systems (Campbell-Johnston, 2022)

	Strengths	Weaknesses
Organising waste processing	• EPR schemes do divert waste streams from landfilling or incineration to forms of material recycling, which leads to environmental benefits • National (or in Europe EU-) targets are met in frontrunning countries • It uses industry's managerial capacity to organise recycling markets	• Targets and standards are not harmonized and weakly enforced and are not met everywhere • Lack of harmonized definitions • Responsibility for recycling beyond the targeted collection rates is not taken • Recycling process choices need to be based on better assessments • EPR promotes material recycling over re-use and other R-options • Exports of waste to low-income countries prevail
Efficiency	• Low operation costs • Higher volume of materials collected in collective EPRs enable more efficient recycling technology	• Voluntary PROs face freeriding • The level of costs of recycling allocated to producers differs strongly between countries • Data collection and sharing is weak due to cost avoidance • In case recycling is profitable, recycling processers compete with collective systems, cherry-picking the easy gains
Stimulating eco-design	• Being responsible for the end- of-life is assumed to stimulate redesign of products by producers	• Low impact on eco-design • Weak incentives on eco-design, fee systems ignore eco-design efforts • The lack of harmonized legislation hinders impacts on product design

In organising the collection and processing of products, EPR has generally been an effective tool. For example, in Germany and Sweden, both early movers in implementing EPR systems, saw recycling rates for glass packaging above 80% of the quantities collected. EPR for tires has resulted in collection rates of 95% or more and recycling rates of up to 80- 95% in various European countries (Winternitz et al., 2019; Sakai et al., 2019). The effectiveness of the processing methods used, however, is a crucial factor in gauging EPR's circularity performance. In most circumstances, the regulations don't include a mandate for the best technologies to be used. Lower-level processing methods, such as incineration with energy recovery, frequently predominate (Turner and Nugent, 2016). Furthermore, when decision-making is left to market actors, cost-effectiveness considerations may lead to recycling practices that are less expensive, such as recycling textiles into cheap isolating material for the automotive sector (Hawley, 2014). This downcycling does not lead to lower material use in the original product cycle, which means that it does not progress the industry towards achieving the material reduction goals set by organisations such as the EU. Higher prices of recycled materials and quality concerns form barriers to replacing virgin materials for recycled materials, meaning markets for recycled materials are frequently underdeveloped. Currently, EPR schemes do not play an active role in improving the functioning of markets for secondary materials.

It is important to asses EPR systems in their own context. To achieve this for the Dutch context, Campbell-Johnston et al. have recently performed a policy Delphi to explore perspectives on improving EPR policies to further contribute to the CE goals of the Netherlands. This led to a white paper by the Utrecht University Circular Economy and Society Hub, based on a literature review and the results of that Delphi study (Vermeulen et al., 2021). The whitepaper gives the current strengths and limitations of EPR in the Netherlands, and proposes pathways to improve the effectiveness towards the governments CE goals. These strengths and limitations are shown in Table 4 and labelled for later reference as S# for strengths and L# for limitations.

Table 4. The strengths and limitations of Dutch EPR systems (Vermeulen et al., 2021)

Strengths	**Limitations**
(S1) - Applied to relatively many product categories	(L1) - Often EPR schemes do not cover the full waste stream
(S2) - Successful in organising collection for recycling	(L2) - What is collected is not recycled at the highest level
(S3) - Legal targets mostly met and exceeded	(L3) - Economic considerations cast a shadow over sustainability criteria
(S4) - Landfilling and incineration of resources prevented	(L4) - Markets for secondary materials are not being actively strengthened
(S5) - Cost of collection and recycling covered by producers	(L5) - Monitoring and transparency are limited
(S6) - These achievements are created very efficiently	(L6) - There is no assumed stimulus for eco-design
	(L7) - Intended financial incentive for re-design is not targeted, is too weak and is only partial

The whitepaper then presents three pathways around which future EPRs need to be structured to increase their positive impact. These pathways will be cited here as in Vermeulen et al., 2021.

Pathway 1: *Optimizing EPR as an instrument mainly for post-user circularity*

- The first pathway takes EPR in its current form, focusing on efficiently organising collection and recycling, and enhances its effectiveness in contributing to the new CE policy goals. All economic actors related to R3-R8 (repair, refurbishment, remanufacturing, material recycling and energy recovery) need to be represented in an additional *'circular value chain management organisation'* that decides on the *'circular transition strategy'* for the product group.

Pathway 2: *Re-designing EPR as an instrument for the transformation to CE 3.0*

- This pathway focuses on enabling the assumed – but so far in practice weak – incentive for producers to sustainably design more circular products. Circular product design aspects should be addressed in the formulation of *targets*, and more substantial and more direct connections are needed in the *financial mechanisms.*

Pathway 3: Beyond EPR: how other instruments can support EPR and CE

- This pathway gives recommendations for institutional arrangements and further options to support the EPR instrument. These include increased eco-design and design-for-sustainability regulations, eco-taxation options, and the essential roles of consumers and municipalities.

3.4 Scientific perspectives necessary for EPR policy design

In the end, several forms of information are important in the design of a new policy that is more effective. First, a value chain map needs to be made. This requires the actors and processes within the system. Adding to this, the flows of textile materials are put into this map. Finally, the costs and benefits of the processes are calculated and mapped. With all this information a full cost calculation can be made to achieve the policy objectives. Furthermore, an analysis is made on the progress and extent of application of the VROs and the problems they encounter, including financial implications. The necessity of these forms of information show the importance of transparency along the value chain. Finally, the recent perspectives on the effectiveness of EPR are added to create policy recommendations. All of this is necessary to design a modern more inclusive form of EPR for the Dutch textile industry. This framework is visualised in Figure 7.

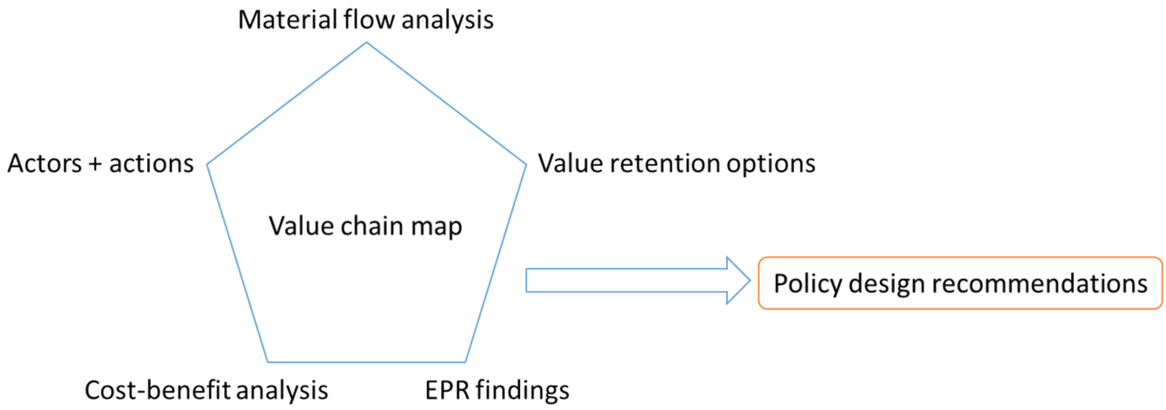

Figure 7. Theoretical framework.

4. Methodology

Within this section of the report, an outline of the research methods will be given. This section first provides information on the research design and why this specific design and scope has been chosen. Following this, the data collection and analysis are discussed.

4.1 Research design

This study aims to answer the research questions and develop recommendations for an inclusive EPR structure for the textile sector that stimulates circularity more than current models. In order to answer the research question of this study, a qualitative research approach has been applied, in two distinct steps, as explained below. This is not a theory-building or theory testing type of research, it is a combination of explorative and evaluative research, leading to recommendations. The scope of the research is the Netherlands for two main reasons. Firstly, the Netherlands has an extensive history in the textile industry and aspires to be a frontrunner in circularity. Secondly, the Netherlands is currently in the process of implementing an EPR for textiles, creating an opportunity to implement these findings.

The research can be categorised into three distinct phases generally following the research questions, visualized in Figure 8. The first phase (RQ1) is a literature review. In this phase, the knowledge to systematically form a value chain map is acquired. Adding to this, information to create a mass flow analysis is found. Finally, the French EPR system for textiles is assessed to see what lessons can be learned to help with the Dutch policy.

The second phase (RQ2 & RQ3) was collecting as much information as possible about the Dutch textile industry and the VROs that exist in the Netherlands. This was the exploratory part of the research. During this phase, an iterative analysis was made of all the relevant actors in the textile value chain. This leads to certain drivers and barriers along this value chain.

In the final phase (RQ4), the findings of the previous steps were applied in a policy design. This was the evaluative part of the research. The findings of the first two phases were combined with other relevant data from literature leading to a value chain map. This value chain map is combined with a material flow analysis and a cost benefit analysis. These are then used to form five different scenarios. The rationale behind these scenarios is that the mass flow through the entire system is followed and that different policy choices can be shown for different applications of VROs in an EPR system. Furthermore, the cost implications for the conditions existing in that scenario are calculated. Finally, these scenarios form the basis for recommendations on how an EPR for textiles could be designed.

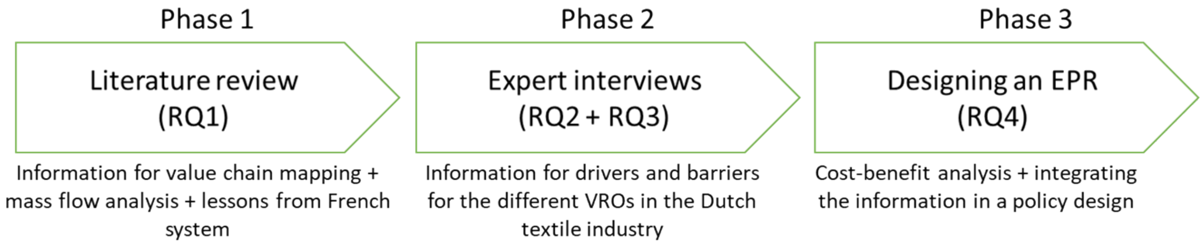

Figure 8. Research design

4.2 Data collection & analysis

The data in this study is a combination of literature and expert opinions. The data in this study has been collected through an iterative process of desk research and interviews. The desk research includes scientific literature and grey literature such as policy documents and governmental reports. This was necessary to gain expertise in subjects relevant to the interviews. Moreover, the grey literature contextualised the Dutch government's textile strategy and the EPR policy plans. The interviews also led to new literature, which was subsequently read and added to the review, and helped in further interviews.

For interviewee selection, a purposive sampling strategy was chosen. In essence, this type of sampling is about the selection of units (persons, organisations, documents, departments, et cetera) in direct reference to the research questions being asked (Bryman, 2012). Furthermore, a snowballing method was used, where the experts were asked for information on other experts to be interviewed. The selection of the interviewees was based on the textiles supply chain, so they were stakeholders in a textiles EPR. At least one interview was held for every step along the supply chain, complemented by experts related to the process, as shown in Figure 9. The interviewees can be grouped into 3 different categories that have different interests and expertise. The first group is at the front of the supply chain, namely the producers and their branch organisations, shown in blue. The second group is the back of the supply chain, the textile waste processors, shown in green. The final group comprises stakeholders and experts from outside the supply chain, shown in orange. Their names and organisations were anonymised for privacy purposes, and the groups are categorised. These categories were given a code P for producers (before the use phase), T for processers (after the use phase), or E for experts (outside the supply chain). One interviewee was both a producer and a recycler, and was given code PT. However, different interviewees' characteristics are mentioned to present the differences among interviewees. The complete list of interviewees and their relevance can be found in Appendix B.

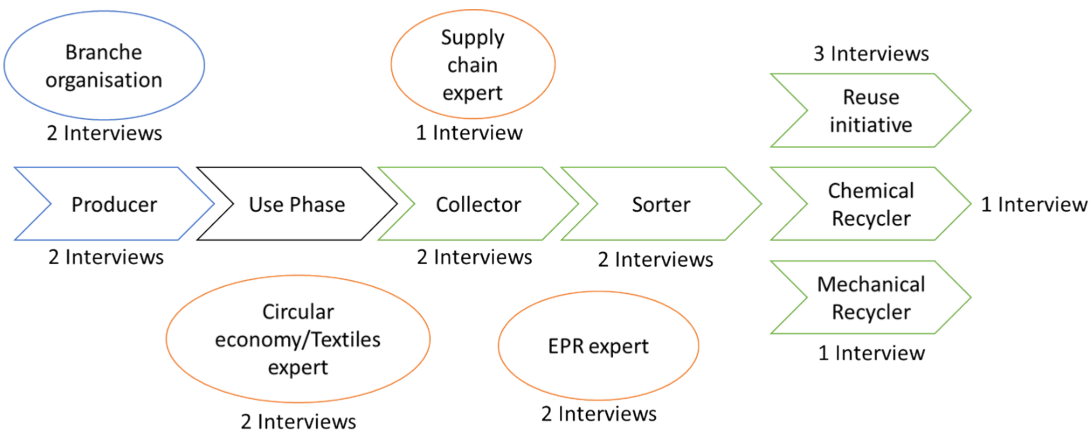

Figure 9. Interviewees along the textile value chain. Blue circles are producers before the use phase (P) and green circles are processors after the use phase (R). Orange circles are the experts (E) from outside the supply chain.

In the end, 18 interviews were held that ranged from 40 minutes to 71 minutes. Semi-structured interviews were chosen, in which the researcher had a list of questions about quite specific topics to be covered, while the interviewee still had a great deal of leeway in how to reply (Bryman, 2012). This was chosen so they can expand on any given topic, following the exploratory design. All interviews were held online via Microsoft Teams or over the phone, and all were recorded. All interviewees were asked questions following the research questions of this study, as shown in the introduction. First, they were asked about the textile industry as a whole to contextualise their coming answers. Following this, they were asked about their specific area of expertise to find drivers and barriers. Finally, they were asked about EPR and how it could affect their area of expertise. The interview guide can be found in Appendix C. However, many more questions were asked, and for every interviewee, a specific list of questions was created based on literature and their area of expertise.

Each interview was recorded, transcribed, and coded. The data analysis process involved generating codes at different levels and identifying common themes, such as drivers and barriers, challenges and opportunities and current and coming developments. A good 'feel' for the data needed to be developed to identify these common themes. To accomplish this, the data has been individually processed many times. Notes were taken during the interviews and then the interviews were listened to a second time while taking more notes. Following this, the interviews were listened to again during transcription, and then the transcripts were read for spelling mistakes. Based on this and earlier research, a coding scheme was developed. The interviews were reread during the coding and then once more while re-coding. All these steps ensure that all spoken words were carefully considered.

The interviews were transcribed by hand using InqScribe (v 2.2.5.264) software. Following this, the transcripts of the interviews were coded using QSR International's NVivo software (release 1.7). The first coding round was based on a literature review and a general concept for what categories could be necessary and the coding scheme was revised during the second round of coding.

5. Results

The results shared here will be a culmination of the insights gathered during the literature review in combination with the expert interviews. The results will be shared following the first two phases that were mentioned in the methods section. First, the results of the literature review are shown. Following that, the results of the expert interviews are given.

5.1 The current state of the Dutch textile industry and its waste flows

The Netherlands has a rich history in textile production, starting in the 17th century. In the early years of textile production, mainly woollen fabric was produced. At the beginning of the 18th century, almost a third of the labour force worked in the textile industry. Industrialisation in the 19th century meant that large textile factories started appearing, which could also produce linen and cotton. However, in the 20th century, the importance of textile production quickly dropped due to the shift towards production in lower-income countries (Textielnet, n.d.). Today, the only type of textile that is still mass-produced in the Netherlands is carpet, in which the Netherlands is the 4th largest manufacturer worldwide (Modint & INretail, 2019).

Because of this, registration of domestic production of textiles does not take place centrally. Statistics Netherlands registers the production of textiles on a more aggregated level, which means that no clear statements can be made on Dutch production. However, since it is relatively limited, almost all textiles are imported into the country (CBS, 2021).

For monitoring purposes, the Dutch government uses three categories of textiles:

- Consumer clothing (clothing, underwear, stockings and socks)
- Workwear (clothing, stockings and socks for business purposes)
- BBK linen bed, bath and kitchen linen and curtains/curtains for private and commercial purposes (sheets, blankets, pillowcases, duvet covers, towels, tea towels, tablecloths, napkins, washcloths, etc.)

Table 5 shows the amounts that were put on the market in 2019 for these different flows, together with the amount of second-hand textiles that were put on the market. This gives a total of 362 kilotons that was put on the market in 2019. Of these textiles, the most common materials are cotton and polyester. This makes the Netherlands one of the highest textiles per capita countries.

Table 5. The total mass of textiles put on the market in the Netherlands in 2019 (Royal HaskoningDHV, 2021)

Type of textile	Size of flow	Per resident
Consumer clothing	248 kiloton	14,5 kg
Workwear	67 kiloton	3,9 kg
BBK linen	28 kiloton	1,6 kg
Second-hand	19 kiloton	1,1 kg

After the use phase, textiles get discarded. In the Netherlands, 305,1 kiloton of household textiles were discarded in 2018, which amounts to 17,7kg per resident (FFact, 2020). Of this discarded amount, 44,6% was collected separately, which means that more than half of the textile waste still ended up in residual waste and got incinerated. What happens to the textiles that are collected separately can be seen in Figure 10. A large part (~55%) of the collected textiles gets processed outside of the country. From the textiles that get processed in the country, a large part (~72%) still ends up being sent abroad. In the end, 81% of all separately collected textiles ends up in a different country.

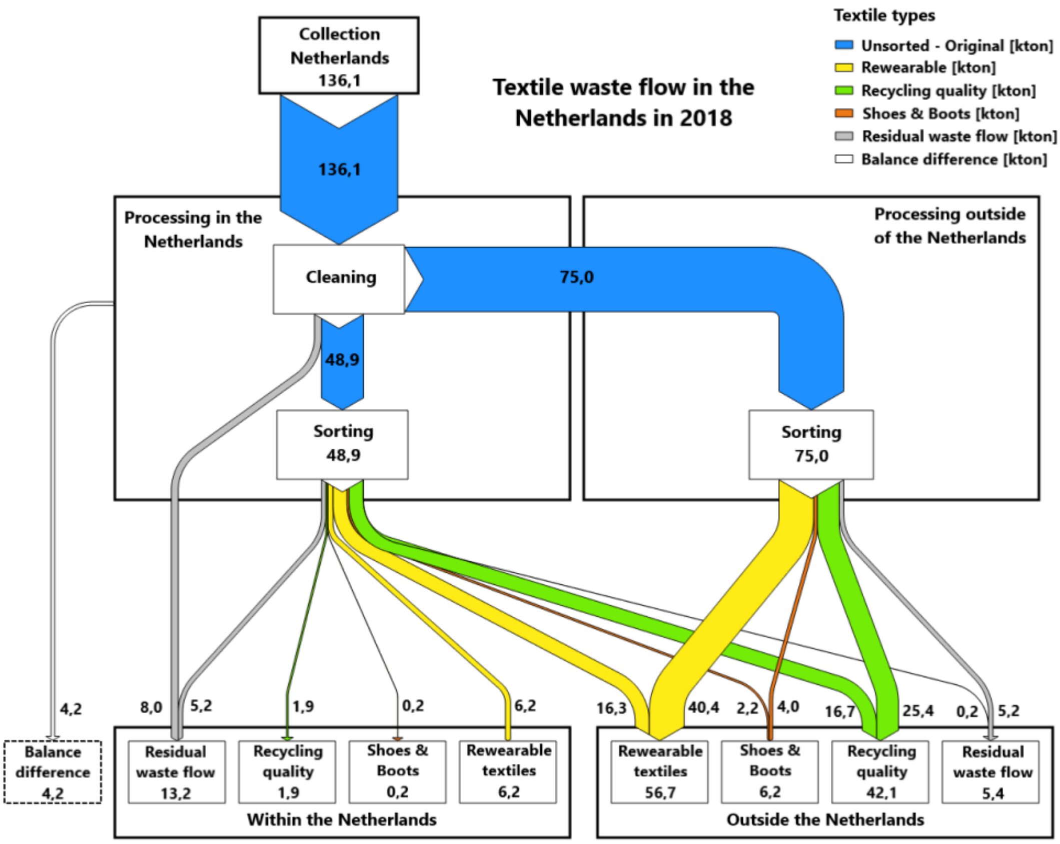

Figure 10. The flow of separately collected textile waste in the Netherlands in 2018. Adapted from (FFact, 2020)

The Dutch system of textile processing is shown in Figure 11. The Netherlands has a very advanced collection and sorting ecosystem, which will be discussed in chapter 5.4. Additionally, there is a very large second-hand market, which is discussed in chapter 5.5. The recycling industry in the Netherlands is still reasonably small and upcoming, and needs more investment to grow, as will be discussed in chapter 5.6.

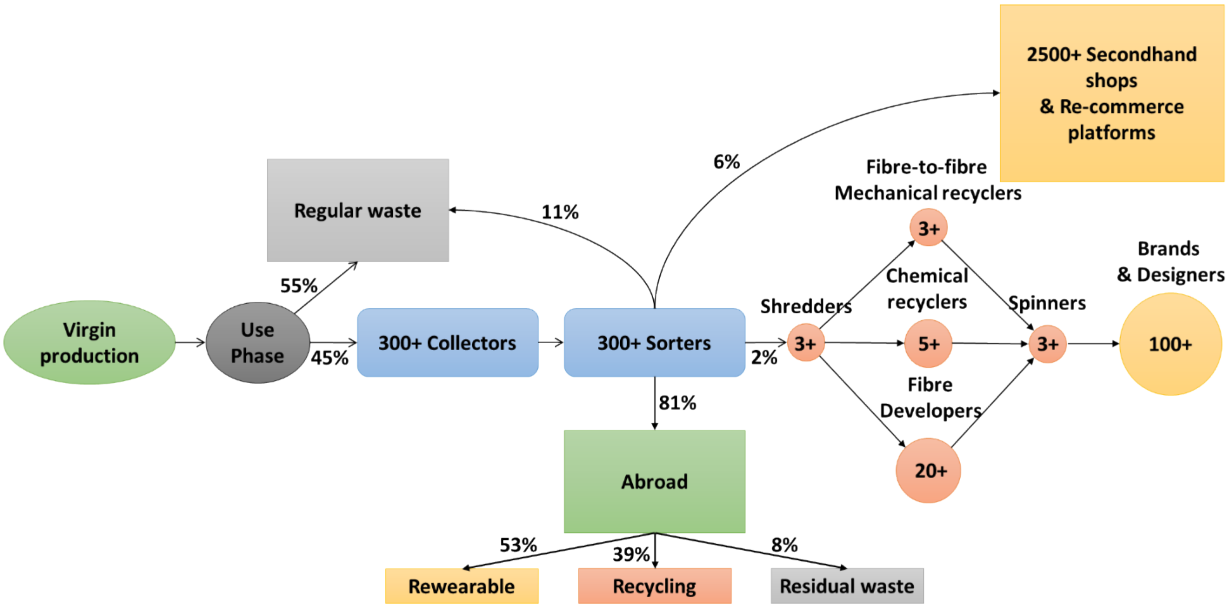

Figure 3. The current system of textile waste processing in the Netherlands. Percentages are from the total flow of mass coming out of a specific step in the value chain. Adapted from (Reike et al., 2022)

As shown in Figure 10 & 11, a significant part of the textile waste gets exported abroad. The Central Bureau of Statistics from the Netherlands has performed a study on this textile export (CBS, 2021). The results are shown in Table 6. Firstly, this shows that over 50% of (the value of) textile exports are staying within Europe. This could be of significance if the EU were to implement an EU wide EPR scheme for textiles, as it is easier to keep an eye on these textiles within the system and then process them in a more circular manner. A large part, however, is sent to other continents; most notably Africa. In this process, control is lost over what happens after the use phase in these countries. This control is discussed in chapter 5.8 and 7.1.

Table 6. The value and destinations of exported second-hand textiles from the Netherlands in 2021 (CBS, 2021).

Destination of second-hand textiles	*Value of export in €1000 (% of total)*
Europe	82445 (55%)
Central-, East-, Southern Africa	27849 (19%)
West Africa	18491 (12%)
Near-, Middle East	7666 (5%)
Central-, South America	6379 (4%)
North Africa	3249 (2%)
Asia, other	3022 (2%)
Oceania	125 (~0%)
North America	58 (~0%)
Total	**149315**

5.2 Lessons from the French system

To create a more inclusive EPR for textiles, it is necessary to take both the global theoretical insights and the expert observations specified on the Dutch textile situation. First, a look will be given to the French system and the insights that can be gained from it, since it has had an EPR structure for textiles since 2007. The EPR in France is not legally mandatory for all producers, but still 95% of the

French industry is currently represented. The goals the government set are found below, compared to the current state of the Dutch industry before implementing an EPR.

- At least 50% collection of all discarded textiles (45% in the Netherlands)
- At least 95% product or material reuse of the collected textiles (93% in the Netherlands)
- A maximum of 2 % residual waste from the collected textiles (7% in the Netherlands)

This shows that the starting position of the Netherlands is already almost at the goals that the French industry has set. The results of the EPR so far are generally seen as mixed. For example, during the EPR, the number of collection points increased from approximately 16 thousand in 2011 to approximately 46 thousand in 2019 and collection per person increased from 2.7 kg in 2014 to 9.7 kg in 2019 (Refashion, 2021). However, these results are generally only in the collection and sorting part, and have not led to a more sustainable production or processing. Furthermore, collection and sorting has increased less rapidly in France over the past 10 years than in a number of countries where no EPR for textiles has been introduced, such as Germany, the Netherlands and Belgium.

One of the reasons can be found in the collected fees. In 2020, the PRO Refashion collected €34.5 million in fees from producers (Refashion, 2021). However, the industry's revenues grew to over €23 billion in 2020 alone (Statista, 2021), which means the EPR fee comes to 0,15% of the industry. This can be explained when looking at the prices per item the PRO has set, as shown in the table below.

Table 7. PRO collected by Refashion fees in France for different item categories (Sachdeva et al., 2021)

Item category	Very small	Small	Medium	Large
Standard fee (€)	0,002	0,009	0,020	0,063

It might be concluded that these fees are not large enough to actively stimulate change in the value chain. This explains why the results of the EPR are not as successful as they could have been. Adding to this fact is that France has recently included eco-modulation (25%-50% discount) in their system, based on durability or recycled content. However, this discount has only been used for 0,5% of all products (Refashion, 2021). The first reason for that is that the registration for discount is difficult, and the administrative costs that come with it too high (Centraal Planbureau, 2019). The PRO requires the producer to perform certain tests. This is complemented by the low standard fee not incentivising the administration. These administrative costs and tests could be included in the fee all producers pay to the PRO. The costs of accessing eco-modulation would therefore be subsidised by all producers.

The eco-modulation of the fees in France does give an example of the possibilities of eco-modulation. It shows that a discount for durability is possible, which they base on different ISO standards and lab tests. The discounts for recycled content are based on certifications, namely the Global Recycling Standard (GRS), the Recycled Content Standard (RCS), or the Recycled Content Certification.

In general, the lessons learned from Refashion are that the fee needs to be high enough to incentivise change, and that eco-modulation needs to be easy and accessible, which could be achieved by more harmonised registration standards.

5.3 Transparency and information exchange along the supply chain

The first thing to be discussed will be information and transparency. This is because transparency is important for the whole supply chain, and while it does not fit inside the R options hierarchy, it can enhance or diminish all the other options.

To achieve faster and cheaper production, production is generally outsourced to countries with cheap labour. Only a few brands retained their own manufacturing facilities. Because of this, the textile industry is complex with a global supply chain, as shown in Figure 3. Furthermore, as interviewee E3 states, the number of suppliers involved in the value chain has grown exponentially during the last decades, resulting in an intricate value network with a low degree of control. This stratified system creates a chain of interdependent companies with various specialisations: farms that grow fibres, petrochemical industries, facilities that make and dye yarns, others that knit or weave yarns into fabrics, others that print fabrics, tanneries that transform hide into leather, factories that cut, sew, assemble garments, logistics, retail (ElMessiry & ElMessiry, 2018). Thus, transparency and trust have become more challenging to acquire in current operating practices and have been a genuine concern for the textile industry. This problem with transparency is stated by interviewee E1:

"Because what's missing in every chain, whether it is linear or circular, is transparency. They don't want to start with it, because if you cannot hide anything, your greenwashing will be exposed."

Another problem with these complex and untransparent supply chains is that traceability of materials is very low. Interviewees T6 and E8 both give examples of recent scandals where this went wrong. First, randomly selected garments from a range of fashion brands were found to contain zero or very little recycled polyester – despite label claims to the contrary (Papú Carrone, 2020). Second, The Global Organic Textile Standard (GOTS) has found proof of organic cotton fraud in India following an investigation, uncovering 20,000 metric tons of fake organic cotton (Partzsch & Kemper, 2019). They both state that there are many other examples since making textiles appear more sustainable has a financial incentive. Since 2015, Fashion Revolution has published an annual report of the Fashion Transparency Index (Fashion Revolution, 2020). In 2020, they reviewed 250 of the world's largest fashion brands and retailers and ranked them according to how much they disclosed about their social and environmental policies, practices, and impacts. Despite progress, most of them still lack transparency: the best brand tops at 73%, and the average score is 23%.

A similar problem that the current textile industry faces is that labelling is often wrong. Interviewees E1, E3, E5, and E8 all mention this problem. Recently, Circle Economy has done a study on the accuracy of labels in Dutch post-consumer clothing commissioned by the government (Circle Economy, 2019). With the introduction of the European Textile Regulation (1007/2011) in 2011, harmonised conditions were imposed on communicating the fibre composition of textile products on the European market. This regulation aimed to provide consumers with information about the composition of textile products at the time of purchase. The study found that only 59% of tested labels were correct in the textile composition. Furthermore, for 20% of the labels, the deviation was found to be very large. Labels of mono-materials were correct 77% of the time, while textiles with fibre blends only 41% were correct. This problem with labels is currently not a high priority for both the Dutch Food Safety Authority (NVWA) or the customs authority, since it is not seen as a big risk for health or safety reasons. Hence, there is also a problem with monitoring, which was also mentioned by interviewees E5 and T2.

All in all, if information of the materials in textile products is not available, it is not possible for consumers to make sustainable decisions. On top of that, as stated by interviewees E3, T1, T2, T3, T5 and T6, it also makes it harder for sorters to sort textiles, and it limits recyclers in the recycling of the textiles. This creates a large barrier for circularity and sustainability. Furthermore, if there is no transparency along the value chain, it will be impossible for the government to actually monitor progress towards its goals.

Recently, producers have started looking more upstream in their supply chain. Interviewees P1 and T3 states that the Dutch industry has had multiple agreements meant to improve social conditions in their supply chain. Furthermore, they state that new regulations on due diligence are supposed to be coming from the EU. However, it has not been enough to fix the problems, and it has only focused on one side of the value chain.

There are multiple solutions to increase transparency along the value chain. For instance, partnerships can be an important part of creating more transparency. If different companies decide to become more closely connected along their supply chain, there is an incentive for both of them to share data transparently. Gaining visibility into the realities of the different processes enables the improvement of work ethics as well as enabling work towards more responsible business conduct (Joy & Peña, 2017). Additionally, traceability can assist the advancement of product quality and adequate delivery times (Kumar et al., 2016). Transparency can therefore be part of circular business models and it gives a reason for companies to care. The importance of this shared value is stated by interviewee E7:

"And it actually starts with the farmer who grows the cotton. And all the steps that come after that should actually be a cooperative chain that jointly share in the value creation it does."

Another factor that has a lot of potential for improvement is traceability. Multiple interviewees mentioned ways to improve traceability, and this is also found in literature. The first solution mentioned is to put QR codes in textiles, as said by interviewees E1, T4, and E8. This gives producers the possibility to show a lot more information to consumers than what would fit on a label. Furthermore, the online information is widely available, making it easier to be checked. Adding to that, it means that the physical labels might no longer be necessary, as the QR code can be printed onto the material itself, which makes it both easier to recycle and cheap. Literature has also found that a security code can be integrated into the design of the QR code (Agrawal et al., 2018). This security code could be scanned by partners along the supply chain, creating a form of checks and balances.

A second solution to improve traceability is to actually include tracers in the materials. This was mentioned by interviewees T1 and E8, and already part of the business practices for interviewee P3. Tracers can be a multitude of different particles, dyes, and proteins that can be embedded in the materials. These tracers contain a code that provides information of the material. This information could then be secured via blockchain, for example. Using blockchain technology, it can be verified that the recycled yarn entering the supply chain is the same yarn that ends up in clothing. This creates secure information along the supply chain, and it is relatively easy to adopt. It is however quite new and still needs to be developed further (Ahmed & MacCarthy, 2021). How this could look in the future is pictured by interviewee T1:

"Then you have a tracer in it and then you know exactly the content, so that you can have it recycled completely automatically [...] that is of course the ideal image."

A final solution that was mentioned, is that of certification and standardisation. As stated in chapter 2.1.1, there are multiple agreements made by the industry to become more sustainable and transparent. Interviewees T1 and E8 mentioned that the Global Recycling Standard (GRS) is the most important certification for recycled content in textiles. Next to that, there are other certification schemes, and there are organisations that exist to improve transparency. These include the Fair Wear Foundation or the Transparency pledge, among many others. These voluntary agreements are a way for textile companies to include third-party monitoring in their business operations, together with a way to show the outside world that they are doing well. Another way to create standardisation, which is important in information sharing, is via norms. In June of 2020, a new standard was released to the public by the Nederlandse Norm (NEN), the Dutch authority on norms and standards. This standard, Nederlandse Technische Afspraak (NTA) 8195, sets standards for circular textile products. It has three parts:

- Demonstrable use of recycled yarns, which can be divided into various categories.
- Demonstrable supply chain management systems, in line with ISO 22095 and BS 8001
- Set up design according to the rules of Design for Circularity

Governmental regulations could be of help here. One example is given by interviewee T2:

"Reporting obligations that involve fees so that you are triggered to be transparent about what you do. With 2 checkpoints, just as with other EPRs. We report what we collected, and the recipient reports what they have received. You have to be able to match them."

These obligations could be set as rules by the government. However, they could also be part of the structure of an EPR system. In such an EPR system, you would be able to get a discount on the fees you have to pay, based on if you follow certain reporting standards, or other guidelines or certifications. For example, if you are GRS certified, and NTA 8195 certified, the fee to put a T-shirt on the market might be lowered by 10%. This creates financial incentive to become more transparent. Next to this, in other EPRs there is the possibility that producers (through the PRO) request the *Inspectie Leefomgeving en Transport* (ILT) to take enforcing action if it is suspected that a company does not contribute (sufficiently) to achieving its objectives. This could give a form of self-authority to the producers.

Clear and transparent information along the supply chain is a catalyst for better circularity outcomes. If it is clear what a certain textile is made of, it will be easier to sort, and that means it is easier to recycle or reuse.

5.4 Collection and sorting of textiles

The collection and sorting of textile waste plays a critical and undervalued role in reaching the circularity goals the government has set. The Netherlands has a strong textile sorting sector, and is a frontrunner in the separate collection of textiles. In the Netherlands, separate collection of textiles is the legal responsibility of the municipality, which places certain types of containers for this purpose. This is outsourced to third parties for a certain fee, since the textile waste has a certain value. However, this is something interviewees did not fully agree on. Interviewee P1 stated that municipalities make a significant amount of money from these fees, selling the rights to collect textile waste. This fee is then used to lower waste collection charges/taxes. Interviewee T2 states that this situation has completely changed over the past few years:

“That situation has completely turned around in [Region] in the last 3 years. And that is also happening nationally at a very rapid pace. It used to be the case in the past, up to hundreds of euros per ton. But that changed very quickly.”

The situation T2 outlines is that in more and more municipalities in the Netherlands, the municipality actually has to put extra money on the table for third parties to collect the waste. This view is shared by interviewee R5. Some municipalities still have old contracts that make them money, but every new contract agreement will be cost negative. The consequences of this is that local waste taxes actually increase because of separate collection. The main reason interviewee R2 gives is that the quality of the collected textiles has decreased rapidly. More and more textiles are low quality cheap fibre blends that are not rewearable and hard to recycle. This problem with textile quality decreasing was also explicitly mentioned by interviewees P1, E2, T1, E5, E6, PT1, R3, T5, and T6. Another explanation for the decrease in quality of textiles is that consumer to consumer textile reuse has grown substantially, which will be discussed in chapter 5.5. Therefore, people might be more likely to resell rewearable clothing. Consequently, the quality of textiles that are discarded at the end of their life could be more worn out and of a lower quality.

Next to the quality of the textiles, the quality of the collection method is also a point of contention. As stated in 2.2.3, there are multiple ways of collecting textile waste. The manner in which it is collected, also affects the quality of the textiles. If textiles are collected in a (second-hand) store, the quality is generally higher, and there is very little contamination of residual trash. As interviewee T4 mentions, this is because there is a form of social control in the form of a shopkeeper. However, people are not likely to go out and hand a shopkeeper in a store a bag of trash. That is a problem, since there is no control with outside containers, making it easy for people to anonymously throw thrash in open containers. There is a difference between above ground and below ground collection containers, though. Interviewee T3 strongly opposes below ground containers:

“But underground, it's such a terrible mess that comes out of there, compared to above ground anyway. [...] The moment you open the container with the crane, it falls into a large collection bin on the truck, and then you only know what's inside it when you sort it. If you really want to kill recycling, you have to collect underground.”

Interviewee T3 gives multiple reasons for this statement. Firstly, below ground containers are often grouped with other trash collection containers that look very similar, especially if they are older or full of graffiti. Above ground containers do not have this problem, since they can be placed wherever necessary, and they can look very distinct from other containers. An added benefit is that they can be easily replaced with a new container, and they can easily be moved to a different location if there is frequent contamination. Secondly, above ground containers can be checked for contamination before loading unto the trucks, unlike below ground containers. If there is contamination, below ground containers immediately contaminate a whole truck load of textile, which could render the whole truck load ready for incineration. Interviewee T3 mentions that this difference can get contamination rates down from over 20% to less than 10%. This preference for above ground collecting is further emphasized by interviewee T5.

Next to the fact that the quality of what is collected is important, it is also important to realise how much is collected. As stated in 4.1, only 45% of all textile waste is collected separately. IntervieweeS T1, T2, T5, T6, E8 all state that they are actively running awareness and behaviour changing campaigns, inside their value chain or outside it. For interviewee T2, a collector that works closely with municipalities, this includes things such as waste coaches, making brochure material, transferring knowledge at schools, or doing projects at schools. Doing these sorts of things cost the tax payer money. Following *pathway 2*, these costs need to be accounted for via an EPR, as informing the public would be part of the responsibility of the producer.

After collection, textile waste gets brought to a sorting facility and put on transport belts. The Netherlands has over 300 sorters, and they play an important role in the processing of textiles. The sorting is generally done in two distinct steps. The first step is choosing whether textiles are still of a quality for them to be reworn. These get separated from the rest, and get sorted on what market they can be sold to. The rest gets sorted again, based on what recycling stream it can enter, which is in turn based on the characteristics of the textile. As stated by interviewee T1, sorting is still mostly a manual task, performed by a human worker, especially the first step, since machines cannot judge whether textiles are rewearable.
From the answers in the interviews, a rough estimate can be made on the percentages for the different flows. Interviewee T1 and T5 both agree that around 15% to 20% of the collected textiles can be reused locally in the Netherlands. Then 35% to 50% is generally sold to Eastern Europe or Africa. A further 20% to 25% is sorted for recycling, and the rest is waste that goes to be incinerated.

An important idea to keep in mind for sorting textiles is that selling textiles for reuse is the main way sorters make their money. Sorters buy textile waste from collectors, and sell rewearable clothes to second hand stores. This needs to compensate for the parts that are not rewearable, such as waste and recyclable fibres. Sorting and selling textiles for recycling actually has a large negative cost for them, since the value of recyclable fibre is very low at the moment. This will be discussed further in chapter 5.5. It is stated succinctly by interviewee T1:

"For us, there need to be clothes that we can simply sell again. Because that pays for everything. The value of recyclable fabric is really just pennies on the dollar."

Since this is the case, there is little incentive for sorters to sort recyclable fabrics thoroughly. Interviewee E5 states that that is a reason large commercial sorters do not really sort for recycling. However, there is a development in this regards, as stated by interviewee T1:

"All the little things that remained were pressed into 1 bale by us, made of all kinds of materials. And the recyclers now say they don't want that anymore, otherwise they have to sort it again, and that is much too expensive, because we [sorters] *already have it in hand, so it's better to do it right away."*

Next to that, sorters face exactly the same problem as collectors, in that the quality of textiles is decreasing, and therefore the value. Sorters also face the problem that they do not know exactly what is in certain fabrics, as stated here by interviewee E3:

"Clothing is very diverse, so even if you're talking about a certain type of polyester, it can still be made up of hundreds of thousands of fabrics and other things, so you don't really know what's in it. And that is important when processing the waste, then you want to know exactly what it is."

There are developments in this regard, as well. NIR spectroscopy technology can help the recognition of textile materials by studying the effects of structural fabric properties on the recognition (Cura et al., 2021). It tells the user the components of fabric, making it easier to sort. On the one hand, this makes sorting cheaper by needing fewer personnel. On the other hand, it is a large investment for smaller sorters, that they might not be able to make. Interviewee R1 stated that they were only able to buy such a machine for their sorting centre using subsidies. This makes it an excellent contender for the use of the money generated in an EPR system.

Properly sorting clothes, by their characteristics and specifications, is essential for efficient further recycling. This is agreed upon by interviewees E3, T1, T2, T11, T3, and T6. A harmonised, standardised system needs to be created for different waste flows. If sorters all sort their textiles within the same categories, with the same specifications, the bulk necessary for recycling is created, lowering the price. Furthermore, such a system would mean that specific recyclers could specialise on specific waste streams. One example of this could be a specific recycler for down feathers, one for linen blouses, one for mattresses, et cetera. These do not have to be in the Netherlands only, it can be a broader range. These ideas fit with the vision of EURATEX ReHubs, which plans to create hubs in specific places in Europe, specialised for specific waste streams (Riemens et al., 2021)

Interviewee T3 states that they already sort 350 different categories. However, as said before, most of this is currently for the reuse market and not yet for recycling. Furthermore, there is no common standard for every sorter, as others sort in 20 categories. Interviewee T5 states that they have started to partner with other second-hand stores, to create a standard for sorting. Again, norms and standards are of great importance for circularity. These might be part of EPR regulations, EPR fee discounts, or they might be separate from the EPR structure. EPR fees can also be a driver for sorting and collection, by controlling the financial flow of the system. As stated by interviewee E3, it is important how EPR financial possibilities that could facilitate circular options along the value chain. Currently this burden falls on the second-hand sales, as that is the only profitable end product in the value chain. However, if this financial burden shifts to EPR fees, there is less incentive to ship lower quality clothing abroad, creating more opportunities for local circularity.

5.5 R2: Reuse of textiles

The reuse of textiles is very important in circularity, and is one of the two main goals the Dutch government has set itself. Reuse can be consumer to consumer, or after the use phase, following collection and sorting to be resold. Research by McKinsey suggests that the second-hand market has doubled during the corona crisis (Goddevrind et al., 2021). Denise et al. state that it is the dominant and most starkly growing circular textile trajectory in the Netherlands and globally (Denise et al., 2018). Respondents stated the main reasons they bought second-hand clothing were either to save money, or to reduce waste (Goddevrind et al, 2021). This shows that consumer demand is shifting towards more sustainable consumerism, as stated by interviewee T2:

"The timing is helping on our side, vintage and second-hand is very hip and cool nowadays."

The main market share (~60%) is currently held by non-commercial second-hand shops (kringloopwinkels), which have been a well-known concept for many years. However, the market growth has mostly been induced via online recommerce platforms, where consumers can sell their clothing to others. Interviewee E2 states there is no exact information on how large this recommerce sector is, and it is unclear how this change in dynamic will influence other parts of the textile system. One the one hand, it is a good sign that there is growth in reuse, as this means clothing is more frequently worn until the end of its lifetime. On the other hand, the sales of new textiles have not decreased, indicating a form of substitution or rebound effect, as people just buy more clothes. Furthermore, this is also an indication of the decrease in quality lifetime of textiles, as touched upon in chapter 5.4. Interviewee E6 also mentions that this increase in recommerce lowers the total amount of rewearable textiles that get brought directly to second-hand stores, as people start to see their financial value, making it harder for them to survive.

The most contentious point of the reuse market is the selling of textiles to lower-income countries. As shown in chapter 5.1, the largest part of all separately collected textiles is sold to be resold outside of the Netherlands. One of the problems with that is that there are very few regulations of what is sent to where, and it is often unknown where it ends up, since there are multiple distributors after the textile waste is sold in bulk. As interviewee R3 states:

"You should prevent warm winter coats from going to Africa and little polo shirts and spaghetti shirts to Siberia. But of course that still happens a lot."

Interviewee P1 states that resellers need to have accountability for where textile waste gets sent and that they need to think about it. Their example is Dutch women's blouses, which only women from very few other countries would wear. Next to that, interviewee E2 states there have been a few recent scandals where textiles meant to be reworn ended up on landfills in places such as Ghana. This raises the question whether sending rewearable textiles to such places should happen at all. And even if they are reworn for a small period, and then and up in landfills, whether that is better for circularity than local recycling. Furthermore, interviewee E3 states that so much is sent to these places, that they do not need it anymore. Worldwide, more than 70% of textiles collected were sent to Africa (Kubania, 2015). This has impacted their local textile industry in a negative way. Therefore, multiple countries are considering banning these sorts of imports (Bukhari et al., 2018). Interviewee E3 gives an argument in favour of keeping textiles locally:

"If you lump it together on a pile somewhere here, and leave it there for a while, at least you retain control and responsibility."

As interviewee T1 states, keeping textiles locally and recycling a larger percentage also creates a larger bulk, which is necessary to increase recycling possibilities, discussed in chapter 5.6. Currently, this is not financially possible, as recycling is still too expensive. As stated in chapter 5.1, over half of the textile waste is exported to countries in Europe. Since the EU has a CE plan that includes a textiles EPR, this focus might be beneficial, and keeping textile waste in Europe will be local enough to be able to keep control and know what happens with it. In any case, the most important thing is that it is clear what happens to the textiles after their use phase, wherever that may be. This is something that has to be included in an EPR, or via other regulations. As interviewee E6 states:

"Europe still does not feel so responsible for this. I think an EPR that doesn't cover this, to look abroad as well, is a bad EPR. It's an EPR from yesterday."

As stated before, reuse after the use phase is currently what finances the post-consumer textile waste processing system. With the growth of the recommerce sector, there is a danger for this money flow. As mentioned in 5.5, the textiles that are separately collected are lowering in quality, and therefore in value. This creates an incentive for cheaper forms of processing, such as incineration. Furthermore, it incentivises selling low quality textiles to lower-income countries, where there is lower quality demand, but also worse value retention processes after the use phase, causing the textiles to often end up on a landfill. The financial flows that an EPR creates could help with the functioning of this system, creating less of a burden on the selling of second-hand clothing to countries with low quality further processing.

In the end, reuse is a very important factor in lowering resources needed for new textile products. Recent research shows that reusing textiles is better at reducing environmental impact than recycling (Sandin & Peters, 2018). As interviewee PT1 states, textiles should be reused if they can be reused. However, there are still a variety of problems to consider, and it is far from the only option, as a wide variety of VROs are necessary. Furthermore, the reuse is textiles is still not a form of closing the material loop. Interviewee E3 states that after however many lifecycles, there is still waste that needs to be processed. Interviewee P1 captures this feeling:

"Second-hand is postponed waste. It's great if it lasts longer, but ultimately the goal is that we start producing in a different way and that raw materials retain their value."

5.6 R7: Recycling of textiles

As shown in 4.1, there are currently only a few recyclers in the Netherlands. However, they are very important for the growth in circularity in the Dutch textile sector. At the moment, only a very small percentage of the recovered textiles are recycled, and most of them into lower grade products. However, the Dutch government has set goals for recycling, including fibre-to-fibre, or closed loop recycling. That means recycling is one of the industries that is supposed to grow a lot in the coming years. However, there are still a few barriers before that can be achieved.

Interviewees P1 and E1 both state that one of the larger barriers in the current textile industry is that it lacks the scale, and it lacks bulk or mass. This is a problem from two sides. On the one hand, there is very low demand for recyclable or recycled fibres, since they are more expensive than virgin fibres. On the other hand, there is not enough supply of recyclable fibres, since the value of these textiles is so low. Recycling is currently still a rather expensive way of processing textile materials, and more innovation and scale is necessary to get these costs down. To create bulk for recycling, there are some important factors. First of all, more textiles need to be separately collected, which is covered in chapter 5.4. Second, normalisation of the waste streams is necessary, also covered in chapter 5.5. Finally, as stated in chapter 5.6, as stricter regulations come into effect, less textile waste will probably be shipped abroad, increasing the bulk needed for recycling to improve and grow competitive.

Another barrier for larger scale recycling is that the technology is just not ready yet for a lot of different options. This is why sorting is so important in this process to get the right waste streams to the right specialised recyclers. However, a lot of things, even when sorted properly, are just not able to be recycled at the moment. One example that interviewee T1 gives is winter coats. That is because they consist of multiple layers, often with multiple types of fibres. This creates an argument for eco-design. Interviewees PT1 and T6 state that an important part in the solution is to go back to mono-materials, instead of all these fibre blends. Once more, these could be in the form of industry standards, or governmental regulations. In order to overcome this problem, investments are needed. This is necessary for innovative solutions, but even more importantly, to scale up. As interviewee E3 states, the government, via EPR, could play a role here:

"So the moment a money flow gets freed up, you could look at where the high costs of recycling are, you could focus more on that as a government, to get more subsidy on it."

These investments are currently lacking in the industry, as stated by interviewee E8. One of the reasons for this is that textiles are a commodity product, which does not have a very high value. Moreover, when applying to growth funds to increase sustainability, normally it is reviewed whether a project lowers CO_2 on a national level. The production and shipping of textiles happens almost strictly abroad. When the recycling of textiles happens in the Netherlands, there might be a decrease in CO_2 emissions worldwide, but an increase on the national level. Furthermore, interviewee P1 states that getting one type of funding often cascades into getting other types of funding, because of the financial assurance. This "starting cash" is something an innovation fund, sourced from EPR funds, could provide.

One point of discussion for the interviewees is the use of PET plastics in textiles. Currently, PET from bottles and other plastic is recycled to create recycled polyester. This PET is very easily recyclable, and can keep its characteristics for multiple cycles (Sarioğlu & Kaynak, 2017). One thing to keep in mind is that one reason PET is easily recyclable is that it is a clearly defined mono-material, and it counts as a sustainable material following the government's definitions. Using PET means fewer virgin materials are necessary in the clothing industry. That is a circularity win in the textile loop, and could be seen as upcycling. However, it is also a form of open loop recycling, since it leaves the plastic cycle. If the demand for plastic does not decrease, that could mean that the demand for new plastic increases, which increases the demand for oil extraction. As interviewee T2 states, the PET is needed in the plastic cycle. On the other hand, if the plastic would otherwise be landfilled or incinerated, it is clearly a better option to include it in textiles. The view on this is also something that changes over time; as interviewee P1 states:

"That was top of the bill 10 years ago, companies that did that were great, while now people are critical of the recycling of PET bottles. And I think that's also because there has been a scandal where PET bottles were produced just to include in textiles."

In mechanical recycling, interviewee PT1 states that they have seen a lot of recent developments, although they are slow. Most of the cases in mechanical recycling have historically been open loop downcycling. Shorter fibre lengths result in poorer quality textiles and it is necessary to combine the recycled fibres with new to achieve the required properties. This is slowly changing, as they state the developments as follows:

"It has become cheaper, and the techniques to do the fiberisation as gently as possible, so that you break down as little fibre as possible, those techniques have improved. And slowly you also see more and more, to a limited extent, that progress is being made, with mixing in post-consumer material."

However, mechanical recycling currently still needs very specific high quality waste streams for any fibre to fibre recycling. Interviewee PR1 describes that this is most useful in pre-consumer waste, as these are well defined streams. Furthermore, interviewee T6 mentions that mechanical recycling has been used for the last 30 years, without making many improvements, mostly recycling into low quality isolation material for the automotive industry. Only recently change has started to come, and the techniques have gotten more developed.

Where mechanical recycling has existed since the start of the industrial age, chemical recycling is a relatively new form of recycling. At the end of a textile product's use phase, the fibres are generally shortened significantly, both because of the normal wear and tear, and the washing. Interviewee PT1 states this can be overcome with chemical recycling, since it rebuilds fibres independent of the quality. Because of that, it is necessary for lower quality post-consumer textile waste processing. However, there are currently a few barriers to this solution. First of all, chemical recycling currently only happens at a small scale. More funding is needed to scale up the solutions that exist. Scaling up can also help lower the costs, since it is still a lot more expensive than all other processing options. Next to that, since chemical recycling is still in the developmental phase, it is not precisely clear what the future capabilities are going to be. A lot of experiments are still being run. Part of these experiments is testing on what fibres and fibre blends the technology works, since that is still unknown. This again shows the need for explicit material compositions and mono materials.

5.7 Other R options and business models

While reuse and recycling are the most commonly mentioned value retention options, both in literature and by the interviewees, and the government's goals are structured around the two, other value retention options are very important to complement these. One commonly mentioned development in recent years is that people have generally gotten more sustainability conscious. This is nicely stated by interviewee T1:

"A lot has happened in the past 2 years. More than the last 30 years combined I think. Well for everyone it is the awareness process, everyone is working on innovations, everyone is now looking at how we can tackle the problems. And years ago that wasn't talked about at all."

This includes consumers, as interviewee T2 mentions, otherwise large fashion retailers would not choose for marketing of sustainability and green labels. Interviewee PT1 agrees, as their corporate clients have also started "*sticking their necks out and initiating change*". Interviewee T4, a second hand initiative, sees this happening in public tenders, as well as in the amount of subsidies they get granted. Even producers in developing countries such as Bangladesh are trying to make a change, according to interviewee E7. They are also working hard to instigate changes in mindset in their own value chain. Interviewee T6 intensively includes their clients in the recycling process, interviewee P3 lets their whole value chain sign their code of conduct, and interviewee E8 sees a big role in sustainability labels on products to inform and influence consumers.

This change in mindset is an important thing to keep in mind, because one way towards circularity is using different business models. If new business models are to be viable, different players in the value chain need to be on board with the changes. This is especially important in the textile industry, which is, as interviewee T5 describes it, a very conservative one. This is because the current way of doing business has been a very successful one. Adding to that, the textile industry has always been incentivised to sell more, faster, creating the problem of fast fashion. New businesses models are a way to combat and change these incentives. They were mentioned and described by interviewees E6, T4, P2, and E7. In the Netherlands, circular business models are still very small, and larger brands have only recently started to experiment with them. The most important one is the rental of clothes, whether that is done through a fashion library, a leasing model, or otherwise. Clothing rental is the fastest growing part of the fashion sector, according to research by research firm GlobalData (2020). A rental model keeps the ownership and the responsibility at the producer level. The consequence is incentive for good quality, long life time, and repairability, as that means it can be worn for longer periods of time, or by multiple people, creating a larger cash flow. This shift of responsibility and incentives can also be achieved using EPR legislation. However, for this incentive to be big enough, the fee needs to be larger than it is in current systems.

The next two value retention options to be discussed are redesign (R1) and repair (R3). The redesign of products has been mentioned in earlier chapters as well, since it is so intertwined with other value retention options. Redesign can be structured around two main components. Firstly, the design could support life time extension, through better quality or repairability. Secondly, the design could enable further recycling possibilities. That steps need to be made at the front of the supply chain was explicitly mentioned by interviewees P1, E3, E4, T1, E6, PT1, E7 and P3. Again, this could be via eco-design norms or regulations, in EPR or outside of it. If the fee is high enough, and there are ways to lower the fee via eco-design, this is the way EPR can stimulate a change in design.

Generally, repair was not mentioned extensively by interviewees. This is probably because it is not part of their business or knowledge. Interviewee E4 did strongly recommend repair shops as being part of the solution. In the Netherlands, repair cafés have started becoming more common; places where people can repair their possessions. In 2017, the Repair Café Foundation developed an online tool, the repair monitor, that enables volunteers to collect and share repair data via a central database. In this way, repairers can learn from each other's experiences and strengthen each other. The Repair Café Foundation uses the collected data, among other things, to argue with manufacturers for products that can be repaired more easily (Repair Monitor, 2022). This also something that has yet to be implemented in the core business by larger companies, which have only recently started with pilots in repairing their own brands apparel. Repair of clothing is also something that is quite difficult to make a business case for, and consumers need to be open for this change in their behaviour as well. In any case, these sorts of initiatives could be stimulated by the money that is collected through an EPR structure as well.

5.8 Who is in charge; the interplay along the supply chain

Since the textile industry is such a complex and global one, decisions made on one side of the value chain have certain effects on the other side of the value chain. This creates an interesting interplay of responsibilities which has certain circularity consequences. For example, if producers were to use mono-materials for their products, they would be easier to recycle. The consequence would be that the responsibility would be with the producer to innovate. This would lower the incentive for recyclers to innovate, which would then mean recyclers would need less investment. However, another situation could be that there is more investment for recyclers, and therefore recycling techniques improved. This would then mean that it would no longer be necessary for producers to innovate towards easier-to-recycle textiles. This interplay of responsibilities leads to finger pointing between different parts of the value chain and corporations being hesitant in taking the next step towards circularity. To achieve circularity there is a need for common goals and shared incentives in those goals. This is another argument for more, and tighter, collaboration along the value chain.

Respondents agree that more control and direction along the supply chain is necessary. However, it is difficult to say who exactly needs to take control in the current system. This is also shown by the responses from the interviewees. Interviewees E2, E3 and E7 agree that the government should play a more guiding role in this problem. The government could set boundaries and regulations, such as banning certain materials because of safety concerns, mentioned by interviewees E7, E3. However, E3 also states that if the government's role gets too big, it might stifle development and innovation.

interviewees P1, E1 and P3 all see a large role for the producers. P1 states that producers want to know the risks along the supply chain, because malpractices in the supply chain are also a risk for the producer. This has improved at the front end of the supply chain, and now producers also want to know where their textiles end up at the end of the chain. Interviewee P1 states that producers can have a helicopter view to make control along the value chain possible. Interviewees E1 and P3 call this a 'circular value chain', which includes all the partners in the supply chain. Interviewee PT1 states the importance of such a value chain:

"The entire chain must be connected. In the circular chain, it is even more important to properly coordinate the supply chain. And then transparency is also very important."

Interviewee E1 states that to make this a possibility it is necessary for business to make control and supply chain management part of their core business activities. Interviewee P3, a corporate fashion producer, has taken this step in their own value chain. They meet with stakeholders from the complete value chain, including recyclers, and they even go so far as to let every company involved in the value chain sign their code of conduct. However, interviewee E1 states that this is currently a voluntary way of doing business for producers, and they are not sure most producers want to change their way of business. It is also something that will be hard to enforce, if possible at all.

To include this control and create this shared responsibility, the organisation of EPR could be part of the solution. In current EPR structures, the government sets goals for the producers. These goals can be seen as setting the boundaries. Furthermore, these goals are structured around the end of the supply chain, after the use phase. In this way, the processing after the use phase also becomes the responsibility of the producers. This linking of before and after the use phase creates a stronger sense of shared responsibility.

Adding to this, interviewee E2 states that a current problem for the circular effectiveness of EPR structures is that producers are generally the party that is involved the most in the creation of an EPR and its goals. In addition, the PRO organisations consist of just producers. Interviewee E2 states this means PROs play the role of representatives of the producers, a role normally reserved for branch organisations, as shown in the quote below:

"We see that those PROs actually act more and more as representatives of the producers who are affiliated with that PRO. Since we just want an EPR to function as effectively as possible from an environmental perspective, we think the role of PROs currently hinders that effectiveness."

This means that the producers fill in how to achieve the goals set by the government. The result of this dynamic is that producers have a unevenly distributed amount of power compared to those at the back end of the supply chain. It makes sense that producers are the ones that decide how the money from an EPR system gets spent, since the goals are for them to achieve, and it is their responsibility. However, when creating shared responsibility, there should also be a shared power dynamic. Moreover, producers do not have all the necessary knowledge to spend the money in a way that retains the most value.

To combat this, and also to create a stronger sense of co-operation between producers and processers, a management organization could be created. This follows the advice given in the whitepaper by Vermeulen et al. Such an organisation could consist of all economic actors related to the value retention options after the use phase, potentially supported by experts outside the supply chain and scientists. This advice is also part of recommendations given by Rebel Group in their EPR advice report to the government (Rebel Group, 2021). What role this organisation is to play and what power it will have is still to be decided. Since it makes sense for the producers to burden the financial responsibility, it could take an advisory role with key tasks such as assessment, strategic decision making, and monitoring transparency. This involvement of multiple stakeholders was also mentioned by interviewees E2, E5, E6, T3 and P2.

6. Designing a more inclusive EPR

6.1 EPR related findings

In the following paragraphs, the ideas considering EPR found in the chapters 5.2-5.7 are shared, following the limitations shown in Table 4, which need to be accounted for in a more impactful EPR structure. First of all, limitation 1 is the fact that EPR structures frequently do not take the whole waste stream into account. The producers generally have to pay only for the processing of the waste that is separately collected. This does not create incentive to lower the waste. To combat this, an EPR for textiles could include a fee that is high enough to process the complete waste stream. For the Netherlands, that means a fee that includes processing and recycling for the 362 kilotons that were put on the market in 2019.

Limitation 2 is that of lower quality processing of waste. There is not enough incentive to recycle at the highest level. In the case of textiles, this means an incentive to recycle fibre-to-fibre. Firstly, this could be combatted by mandatory recycled content regulations. However, as interviewee R1 states, there is not yet enough recycled content to fulfil these regulations, as very little textiles are currently being recycled. So these regulations have to be low, but could slowly increase over time. The currently proposed model does not set recycled content regulations but does set goals to be reached for a percentage of fibre-to-fibre recycling. Next to this, eco-modulation could create incentives for higher quality waste processing. These considerations also help in strengthening markets for secondary materials, combating limitation 4. Likewise, redesign and eco-design (L6 & L7) can be stimulated in this way.

The third limitation states that economic considerations are more important than sustainability considerations. For example, in the textile industry this means that very little waste gets recycled fibre-to-fibre, since it is too expensive. This limitation also shows in the necessity of selling as much textile waste abroad as possible. Next to this, the fee in EPR structures is generally not high enough to actually cover for high quality recycling. An effective EPR needs to combine economic and sustainability considerations. To link these considerations it is necessary to have a fee that is high enough to actually incentivise producers to change. This only works if there are discounts possible for producers that perform better. These considerations follow the advice given in *pathway 2*.

To increase monitoring and transparency, limitation 5, there are also a few conditions. As stated before in *pathway 1*, to create the highest circularity impact, a circular value chain organisation could be created, which would entail an organisation with spokespersons from the different steps along the supply chain and complementary experts. Next to that, fee discounts could be given based on following certain reporting standards.

All in all, there are a lot of possibilities of what could be included in the EPR, or the fee, to create different incentives for producers. An overview of all the costs that could be covered is given in Table 8. This shows the breadth of possibilities that an EPR could cover. Taking these costs into account would create a more fair system where responsibility for a larger area is with the producer. This responsibility also creates the possibility of a fee that is higher than classic EPR systems, and is therefore more likely to stimulate change, especially when there are discounts for performing well.

Table 8. The possibilities that could be included in an EPR fee.

• The development and management of the collection • The development and management of the sorting • The development and management of information sharing, including harmonisation of registration and monitoring of the system and its players • A fund for sustainable innovations • Transport costs within the value chain • Implementation and running costs of an EPR organisation (PRO) • Implementation and running costs of an circular value chain organisation • The development and management of recycling and other value retention options, such as reuse initiatives and repair cafés • Information campaigns for consumers on behavioural requirements and recycling practices

6.2 Modelling costs and benefits in an EPR system: 5 scenarios

To create a new cost structure for an EPR legislation, it is important to keep an overview of the whole textile system and model where exactly costs and benefits exist. An approximation of this system is shown in Figure 12. This model shows the different process steps textile waste goes through, following the arrows. Shown in this value chain are costs made for processing the textile waste during that specific step (in red) and benefits made from selling the processed goods at the end of the chain (in green). All the mass values are taken from the baseline measurements commissioned by the Dutch government, with reference year 2018. Since this is a different source that used different measuring systems, the numbers differ slightly from other sources, such as the one in chapter 5.1. This source is chosen because they are the government's official numbers that are going to be used to measure the progress. The financial values are based on multiple sources, an overview of which can be found in appendix D. It is important to acknowledge that these costs are generally fluctuating, and the model is an approximation and generalisation of a complex reality. Next to that, there are a lot of unknowns in the system, which is continuously changing. The following calculations are therefore more a proof of concept than a concrete number. All the different VROs are shown along the value chain, from R2 to R8. Note that R5 and R6 are not measured by the government, as they are generally seen to fit in recycling, which is why there are no values for those flows.

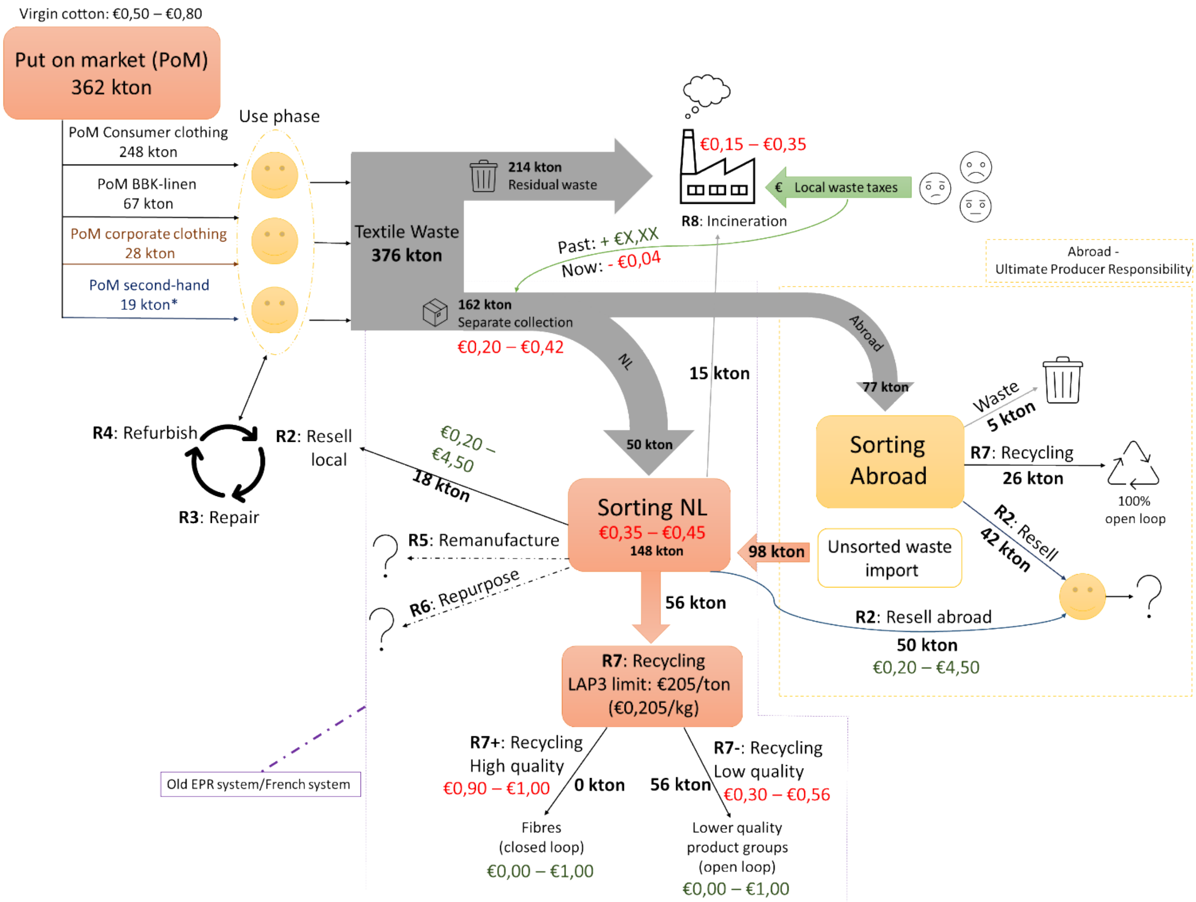

Figure 4. The state of the Dutch textile waste value chain in 2018. Values in red are costs made during a process step, while green values are benefits at the end of the chain. Costs and benefits are shown per kilogram. The part in the purple area is what is classically considered in an EPR system and the part in the yellow area is outside of the Netherlands.

Now that an overview of the costs, benefits, and masses have been given, calculations can be made to see total costs for specific parts of the system. This is important when deciding the fee for an EPR, because it is essential to keep in mind which costs the EPR has to cover. Since the given costs show a range of possibilities, certain choices are made on what value to use, which impacts the final values. In these calculations, it was chosen not to include costs for parts outside of the processing steps (monitoring, organisational, educational, etc.), since these costs are hard to estimate and also depend on what choices are made in including or excluding certain costs. However, a mention of them is given at the end. Five different situations are calculated based on certain assumptions. These assumptions are based on both the mass flows that is accounted for in an EPR and on the prices for certain steps in the system.

6.2.1 Current system deficit

The first calculation is based on the current state of the system, and therefore the current system deficit. The values are those given in Figure 12. The chosen values for costs and benefits are chosen to be in the middle of the range of possibilities. These calculations are shown in Table 9.

Table 9. A calculation of the current costs and benefits within the textile waste value chain, giving the total system deficit.

Costs						
Process step	Price/kg (€)	*	Total mass (kg)	=	Total Value	
Incineration	-€0,25	*	229.000.000	=	€ -57.250.000	
Separate collection	-€0,31	*	162.000.000	=	€ -50.220.000	
Sorting	-€0,40	*	148.000.000	=	€ -59.200.000	
Recycling$^-$ low quality	-€0,43	*	56.000.000	=	€ -24.080.000	
Recycling$^+$ high quality	-€0,95	*	0	=	€ -0	+
Total system costs (a)					€ -190.750.000	
Benefits						
Process step	Price/kg (€)	*	Total mass (kg)	=	Total Value	
Resell local	€ +2,00	*	18.000.000	=	€ +36.000.000	
Resell abroad	€ +1,00	*	50.000.000	=	€ +50.000.000	
Recycling$^-$ low quality	€ +0,20	*	56.000.000	=	€ +11.200.000	
Recycling$^+$ high quality	€ +0,60	*	0	=	€ +0	+
Total system benefits (b)					€ +97.200.000	
Total system costs + benefits (a+b)					€ -93.550.000	

These calculations show that there might be a significant market deficit in the system, which is why there is not enough incentive to become more circular. Currently, a large part of the costs from this market deficit is borne by tax payers, since they pay (214kton x €0,25 = 53.500.000) for incineration of the waste that is not separately collected via local municipal waste taxes.

6.2.2 Scenario 1: Classical EPR

In this scenario, a classical approach was taken in the EPR assumptions, such as in the French system. When deciding on a fee for an EPR system, choices are made on what to include in this fee, as shown in chapter 6.1. In the classic EPR system, the fee is based on the costs of collecting/sorting/recycling of the separately collected waste stream (Walter Vermeulen, personal communication, August 1, 2022). In this case that would be 162 kton. The prices for these steps are again taken to be in the middle of the range of possibilities. Furthermore, according to the LAP3 regulations, if recycling costs are higher than €205 per ton (€0,205/kg), a lower form of recycling is accepted, such as incineration (Vermeulen et al., 2021). Looking at the current costs of recycling, they are all higher than that, creating incentive to incinerate waste or sell low quality textiles abroad. The costs for the producer can be calculated, assuming they are to pay a certain fee per kilogram for specific steps in the system. Calculating the costs included in a classic EPR in such a system is done in Table 10.

Table 10. Calculation of costs and benefits within a classic EPR system.

Costs						
Process step	Price/kg (€)	*	Total mass (kg)	=	Total Value	
Incineration	-€0,25	*	15.000.000	=	€ -3.750.000	
Separate collection	-€0,31	*	162.000.000	=	€ -50.220.000	
Sorting	-€0,40	*	148.000.000	=	€ -59.200.000	
Recycling$^-$ low quality	-€0,205	*	56.000.000	=	€ -11.480.000	
Recycling$^+$ high quality	-€0,95	*	0	=	€ -0	+

Total system costs (a)					€ -124.650.000	
Benefits						
Process step	Price/kg (€)	*	Total mass (kg)	=	Total Value	
Resell local	€ +2,00	*	18.000.000	=	€ +36.000.000	
Resell abroad	€ +1,00	*	50.000.000	=	€ +50.000.000	
Recycling^{-} low quality	€ +0,20	*	56.000.000	=	€ +11.200.000	
Recycling^{+} high quality	€ +0,60	*	0	=	€ +0	+
Total system benefits (b)					€ +97.200.000	
Total system costs + benefits (a+b)					**€ -27.450.000**	
Fee/kg	Total costs / total mass put on market = fee per kilogram € -27.450.000 / 343.000.000 kg = **€0,08/kg**					

In the calculations in Table 10, a very favourable assumption is made that recycling costs are exactly the LAP3 limit, while the benefits stay the same. The final costs in the system are then divided by the total amount of new textiles put on the market (362 – 19 (second-hand) = 343kton). This gives a fee of €0,08 per kilogram. Modint has estimated the value of the textile industry in the Netherlands to be around €10 billion. This fee would be 0,2745% of the total industry. These fees are reasonably similar to those in the French system, and other EPR systems in the Netherlands (Vermeulen et al., 2021). However, as stated before, these fees are not enough to actively stimulate circularity. Furthermore, tax payers still foot the bill for the part that is not separately collected and incinerated.

6.2.2 Scenario 2: A fairer EPR

A more fair system would include the costs made for the part that is not separately collected (15+214 kton), since this is now a burden of the tax payer, and beyond the LAP3 limitations (0,205€/kg), since textile recycling currently costs more than the limit, while recycling is an important part of the government's goals. Assuming this system, as shown in Table 11, would mean the deficit that producers would need to close is €91.050.000. This creates a fee of €0,27 per kilogram.

Table 11. Calculation of costs and benefits within a fairer EPR system.

Costs						
Process step	Price/kg (€)	*	Total mass (kg)	=	Total Value	
Incineration	-€0,25	*	219.000.000	=	€ -54.750.000	
Separate collection	-€0,31	*	162.000.000	=	€ -50.220.000	
Sorting	-€0,40	*	148.000.000	=	€ -59.200.000	
Recycling^{-} low quality	-€0,43	*	56.000.000	=	€ -24.080.000	
Recycling^{+} high quality	-€0,95	*	0	=	€ -0	+
Total system costs (a)					€ -188.250.000	
Benefits						
Process step	Price/kg (€)	*	Total mass (kg)	=	Total Value	
Resell local	€ +2,00	*	18.000.000	=	€ +36.000.000	
Resell abroad	€ +1,00	*	50.000.000	=	€ +50.000.000	
Recycling^{-} low quality	€ +0,20	*	56.000.000	=	€ +11.200.000	
Recycling^{+} high quality	€ +0,60	*	0	=	€ +0	+

Total system benefits (b)	€ +97.200.000
Total system costs + benefits (a+b)	**€ -91.050.000**
Fee/kg	Total costs / total mass put on market = fee per kilogram € -27.450.000 / 343.000.000 kg = **€0,27/kg**

These calculations show a fee that is more than 3 times that of the normally assumed classical system. Even so, these fees are still minimal compared to the value of one kilogram of put on market materials. For example, one kilogram of jeans costs €76,86 on average in the Netherlands (Numbeo, 2022). Adding €0,27 would add 0,3% to the price of a pair of jeans, giving €77,13.

6.2.3 Scenario 3: Highest circularity

This scenario shows the highest possible costs for the producers within the current system, while creating the highest possible circularity outcomes. First of all, the system that would have the highest circularity outcomes would assume that a fee is paid that is high enough to process every new kilogram of textiles put on the market(343 kton) with a high quality. Because of this, everything is assumed to be collected and sorted in the Netherlands, while nothing is incinerated. Furthermore, all the costs are assumed to be at the highest possibility within their range. Next to this, the assumed benefits of every step in the value chain are assumed to be €0,00.

Table 12. Calculation of highest possible EPR costs.

Costs						
Process step	Price/kg (€)	*	Total mass (kg)	=	Total Value	
Incineration	-€0,35	*	0	=	€ -0	
Separate collection	-€0,42	*	343.000.000	=	€ -144.060.000	
Sorting	-€0,45	*	343.000.000	=	€ -154.350.000	
Recycling⁻ low quality	-€0,56	*	0	=	€ -0	
Recycling⁺ high quality	-€1,00	*	343.000.000	=	€ -343.000.000	+
Total system costs (a)					€ -641.410.000	
Benefits						
Process step	Price/kg (€)	*	Total mass (kg)	=	Total Value	
Resell local	€ +2,00	*	0	=	€ +0	
Resell abroad	€ +1,00	*	0	=	€ +0	
Recycling⁻ low quality	€ +0,00	*	0	=	€ +0	
Recycling⁺ high quality	€ +0,00	*	343.000.000	=	€ +0	+
Total system benefits (b)					€ +0	
Total system costs + benefits (a+b)					**€ -641.410.000**	
Fee/kg	Total costs / total mass put on market = fee per kilogram € -641.410.000 / 343.000.000 kg = **€1,87/kg**					

While these costs are massively higher than those shown before, they still only come to about 6% of the total industry's value. Next to this, if this much is high quality recycled, the costs of the process would drop while the demand for recycled materials would go up, changing the dynamics of the system.

6.2.4 Scenario 4: Highest circularity (lower cost assumptions)

A more realistic and fair, but circularity minded scenario will be discussed here. The chosen prices are set at 75% of their maximum, and the benefits are assumed to be the same as in the current system. Table 13 shows that this means that the fee ends up at €1,50 per kilogram.

Table 13. Calculation of a more realistic high EPR cost.

Costs						
Process step	Price/kg (€)	*	Total mass (kg)	=	Total Value	
Incineration	-€0,30	*	0	=	€ -0	
Separate collection	-€0,37	*	343.000.000	=	€ -126.910.000	
Sorting	-€0,43	*	343.000.000	=	€ -147.490.000	
Recycling- low quality	-€0,50	*	0	=	€ -0	
Recycling+ high quality	-€0,98	*	343.000.000	=	€ -336.140.000	+
Total system costs (a)					€ -610.540.000	
Benefits						
Process step	Price/kg (€)	*	Total mass (kg)	=	Total Value	
Resell local	€ +2,00	*	18.000.000	=	€ +36.000.000	
Resell abroad	€ +1,00	*	50.000.000	=	€ +50.000.000	
Recycling- low quality	€ +0,20	*	56.000.000	=	€ +11.200.000	
Recycling+ high quality	€ +0,60	*	0	=	€ +0	+
Total system benefits (b)					€ +97.200.000	
Total system costs + benefits (a+b)					**€ -513.340.000**	
Fee/kg	Total costs / total mass put on market = fee per kilogram € -513.340.000 / 343.000.000 kg = **€1,50/kg**					

Since this fee is higher than the current costs in the system, part of it could be used for other possibilities, such as those shown in chapter 6.1. Furthermore, these investments would lower the price of recycling, and the benefits of the recycling would go up as well.

6.2.5 Scenario 5: 2030 goals achieved

Since the government has set certain goals, it is possible to look at what the system would look like if these goals are to be met. The assumed year is 2030, where the flows of textile waste are supposed to be as shown below. The percentages are of the total amount put on the market (343.000.000kg).

Year	Reuse & Recycling	Reuse	Reuse NL	Recycling-	Recycling+
2030	75%	25%	15%	50%	16,5% (33%)

It is assumed the total amount of textile waste is the same and that after collection there is no waste created, with the costs and benefits staying the same. That means 75% of 376.000.000kg is collected separately, and 25% is incinerated. The same amount of the collected unsorted waste is sold abroad, so 77.000.000kg, and the same amount of unsorted waste is imported, 98.000.000kg. The final results are shown in Table 14.

Table 14. Calculation of costs and benefits in 2030, following the proposed goals set by the Dutch government.

Costs						
Process step	Price/kg (€)	*	Total mass (kg)	=	Total Value	
Incineration	-€0,25	*	94.000.000	=	€ -23.500.000	
Separate collection	-€0,31	*	282.000.000	=	€ -87.420.000	
Sorting	-€0,40	*	303.000.000	=	€ -121.200.000	
Recycling$^-$ low quality	-€0,43	*	114.905.000	=	€ -49.409.150	
Recycling$^+$ high quality	-€0,95	*	56.595.000	=	€ -53.765.250	+
Total system costs (a)					€ -335.294.400	
Benefits						
Process step	Price/kg (€)	*	Total mass (kg)	=	Total Value	
Resell local	€ +2,00	*	51.450.000	=	€ +102.900.000	
Resell abroad	€ +1,00	*	34.300.000	=	€ +34.300.000	
Recycling$^-$ low quality	€ +0,20	*	114.905.000	=	€ +22.981.000	
Recycling$^+$ high quality	€ +0,60	*	56.595.000	=	€ +33.957.000	+
Total system benefits (b)					€ +194.138.000	
Total system costs + benefits (a+b)					**€ -141.156.400**	

This calculation shows that with current (assumed) prices there could still be a large market deficit after achieving the government's goals, larger than the one today. This shows the necessity of developing the different methods to incentivise markets within this system and bring costs and benefits close together.

Finally, the costs mentioned in the calculations are just the costs of the processes along the supply chain. There are more costs that come with an EPR system, depending on what is seen as the responsibility of the producers. As shown in Table 8, these include thing such as information campaigns and the organisational costs of a PRO. These costs are difficult to estimate, however, Rebel Group states that organisational costs for the EPR in France and other EPR systems is around €5 million to €15 million per year. Furthermore, financing needs for circular textile projects are stated to be around €10 million to €160 million per year, depending on different factors. As shown, these costs could be a significant contribution to the total costs of the system, increasing the fee. But they are important in increasing circularity outcomes.

In conclusion, these calculations show that different fees based on different costs can have differing circularity implications. While these calculations are just general assumptions, they show how a fee could be modelled while taking a larger part of the textile waste system into account. The most important factor in these calculations is that the value chain is very complex and the associated material and data flow is still insufficiently mapped. Complete, reliable and verifiable data is crucial to have a reliable EPR that is usable for a larger group of chain partners.

7. Discussion

7.1 Avenues for future research

During this study, multiple avenues for future research were found. One large point of contention among the interviewees was the impact of export of rewearable textiles versus local recycling. It is currently unclear where exactly textile waste is shipped, and even more unclear what the following processing steps are after their life cycle. These transboundary movements are currently not effectively addressed in most national CE policies and practices (Thapa et al., 2022). It is therefore impossible to precisely calculate the environmental benefits of a changing system. Therefore, more research is necessary on what countries the textiles end up and how they are processed in these countries.

If true circularity is the goal, as it is for the EU and the Dutch government, it is necessary to more closely follow these textiles, and to take responsibility further than just (supra)national level. A new concept has recently been proposed to tackle these challenges, called the ultimate producer responsibility (UPR). In principle, this concept is an extension of EPR, with the addition of transboundary responsibility. UPR advises that producers set up infrastructure and pay a fair share to ensure waste collection and management for their discarded products on a global level (Thapa et al., 2022). However, for this to be a possibility, a lot still has to be changed, including transparency, regulations and transnational agreements.

A further avenue for research is the Dutch consumer-to-consumer market. It has been stated this market has been continuously growing over the last few years. However, the Dutch government has stated that is has no clear view of how big this industry exactly is and what the effects are on the lifetime or use phase of different textiles. Furthermore, the effects of reuse and recommerce in general on consumer buying behaviour are unclear. Since reuse is a significant part of the goals the government has set, it would be important to get a clear view of this market, and the effects on both quality and consumer behaviour.

Another interesting idea was shared by interviewee E7. They state that an EPR fee structure could also be based on including the external costs of products, which is called true pricing. The concept of true pricing is based on putting the economic, environmental and social impacts of products into their price. The underlying idea is that all negative impacts can be coupled to a certain financial cost. In this model, negative impacts, such as CO^2 emissions, energy use, water and land use, underpayment, child labour and worker health, of a certain product are measured. Then the costs for these impacts are calculated, which creates the price of a product. However, the focus in true pricing often lies on the production phase. Coupling this with an EPR structure could mean that not just waste management costs, but all costs are covered in the EPR fee, all along the value chain. This idea fits with the Product Environmental Footprint (PEF) initiative. This is an initiative started by the European Commission to help measure environmental performance of any product throughout its life cycle. If these sorts of measurements become more common, or even mandatory, they could help consumers make better choices. Furthermore, governments could tax higher based on worse performance.

Finally, the suggestions made in this study can have certain legal implications. The recommendations that are given present a form of EPR that is more extensive than current models. Furthermore, everything is recommended to be included in such an EPR legislation. However, this is not a study from a lawmaker’s perspective. The recommendations given might therefore not fit within the current laws. For example, the fact that the limitations of €205 per ton for recycling included in the

LAP3 could be removed. Or, as interviewee E5 mentioned, certain recommendations might fit more in a different type of legislation. This corresponds with the views given in *pathway* 3, which suggests instruments next to EPR legislation. It is therefore important to research what changes in EPR laws are necessary and what other types of legislation could be used or created.

7.2 Limitations

During the study, certain limitations were encountered. Firstly, there is a lack of registered quality data available, and financial data was frequently locked behind paywalls. Adding to that, some data was mismatched, with for example different sources show differing number of textile waste in the Netherlands. This can be partly explained by the fact that different sources use different measuring systems. Another reason is that these data are not yet systematically measured and structurally written down. The ultimate challenge is that cooperation in the chain is organized in such a way that essential information is brought to the table and shared. Finally, there is a lack of transparency in the textile value chain, which also led to increased difficulty in finding interviewees. It was also the reason that most interviewees wanted to be anonymised, which led to anonymisation of all interviewees, and therefore limited information for readers. This lack of concrete data registration and openness fits with the conclusions that were reached by KplusV, Rebel Group, and FFact (KplusV, 2020; Rebel Group, 2021; FFact, 2020).

Secondly, a large part of the research was qualitative in nature, which always faces certain limitations. This study was performed by a single individual, creating the possibility of bias, one of the greatest concerns of qualitative research. Because the qualitative analysis required coding, the analysis could have been slightly different if the research had been conducted by another researcher. However, through multiple rounds of coding, supervisor feedback, and iterative discussions with all the experts, it has been tried to keep bias at a minimum level. Furthermore, the data from the interviews have been thoroughly sourced throughout the study.

Finally, the scope and breadth of the research might be a limitation. The 18 interviewees means that the sample for every individual step along the supply chain is rather small. However, the sample is still a clear distinction of producers, expert and processors. Next to that, the research had a more exploratory purpose, getting an overview instead of specifics. Furthermore, the theme of the research was not necessarily the individual steps along the value chain, but a comprehensive overview of EPR possibilities. According to Baker & Edwards (2012), 15 to 20 interviews are a satisfactory amount in obtaining an adequate sample size for reaching ‘thematic saturation’. The term ‘thematic saturation’ describes a situation in which additional interviews yield no new insights. Therefore, considering EPR the theme, the research could be seen as thematically saturated. The scope of the research was an individual industry in an individual country. However, this does not have to be a limitation. The results have been made to be generalisable to all future EPR legislations, and the EU’s vision has been followed throughout.

8. Conclusion & Recommendations

8.1 Summary of the research

The current worldwide model of take-make-waste does not sustainably fulfil the needs of the planet's population and creates a significant amount of waste. To combat this, governments have started to implement legislation that tries to stimulate a more sustainable way of resource use, such as EPR. However, these legislations have not been effective in combating these problems and leading to a more circular economy. Therefore, the goal of this study was to conceptualise a modern form of EPR that fits with the current model of CE 3.0. This was specified on the Dutch textile industry, as the Dutch government has set the industry clear goals, and is currently implementing an EPR for textiles, creating the opportunity to implement these findings to create a more sustainable form of EPR. This was done by first analysing the Dutch textile industry and how its waste flows. This gave an overview of the system in which the EPR is to make a difference, and what waste flows need to be accounted for. Then, the drivers and barriers along the value chain of the textile industry where considered, which creates opportunities for EPR to stimulate the drivers along the value chain, while trying to take away the barriers. Following this, a model-based approach is taken to analyse the costs and benefits within the textile system, to show a new way of calculating the fees associated with an EPR. All in all, the following research question is answered:

How can the upcoming Dutch EPR for textiles be structured to accelerate progress towards the circularity goals?

This research question has been answered through a qualitative study, using insights from experts along the supply chain. For this purpose, 18 semi-structured interviews were held. These data were combined with findings from scientific and grey literature.

8.2 EPR Conclusions

The first barrier that spans the whole value chain is that of information. There is a lack of transparency in business operations, leading to a lack of information registration, creating a lack of traceability of the textiles, enhanced by a lack of monitoring. The main way any EPR legislation combats these barriers is by creating a necessity of registering information. However, this could be strongly enhanced if there were economic incentives for producers to increase transparency. The main manner is which that could be done is through EPR fee discounts for following standards or joining in industry agreements.

For collection and for sorting, the most important barrier is the lowering quality of textiles that are collected, with an unknown blend of fibres, making them harder to sort. Furthermore, only 45% of textiles are currently separately collected. It is crucial that the money collected through an EPR system increases this percentage. First, research needs to be done on how to improve the collection, such as information campaigns, and then these findings need to be implemented. To improve the quality of textiles, it is essential that there are economic incentives for producers to produce a high quality. The first part of this would be an EPR fee that is high enough to make it attractive to sell fewer products of high quality, opposed to many products of low quality, since the fee is paid per item. Adding to this, if the fee is high enough, there could be an opportunity for getting discounts based on following certain quality norms.

The reuse (R2) market has recently grown significantly in the Netherlands. However, a significant part of this growth stems from the consumer-to-consumer market, which could actually have a negative effect on quality of the separately collected textiles, which already have a lowering quality to begin with. In the current system, the reselling of textiles creates the financial flow for other VROs. Combined with the lowering quality of textiles, this creates significant barriers. Furthermore, it creates an incentive to sell textile waste abroad, where control over the end-of-life processing is lost. Since half of the value is sent to the rest Europe, the control over this part could be reinstated through a EU-wide EPR legislation. The broad outlines and opportunities to achieve this have already been instigated by the EU. Furthermore, it is important that the processing of textiles that are sent further abroad is taken into account when deciding on the EPR fee. This part of the fee creates the possibility to then be used to research where exactly the textiles end up, and what happens to them after their use phase. Even further, this part of the fee could then be used to improve the collection, sorting, and recycling facilities in these other countries.

For recycling (R7), the most important barrier was the fact that it is currently almost never economically viable. In part, that is because the technology is not ready yet, and in part because there is little demand for recycled fibres. This combination leads to fibres that are more expensive than their virgin counterparts. A large reason for this is the lack of investment in recycling technologies, making it harder to scale up and create efficiencies to become cheaper. It is central to an EPR that stimulates circularity to cover for the difference in costs between recycled and virgin materials. These differences are therefore essential to take into account when calculating the EPR fee. Furthermore, EPR can help in the creation of viable markets in some ways. Firstly, this lack of investment could be resolved by creating an investment fund with the fees collected. This fund is used to create financing possibilities for sustainable innovations, such as the scaling up of recycling facilities. Secondly, demand could be created by either adding slowly increasing recycled material requirements, or by creating eco-modulation of the EPR fees, through discounts for recycled material contents.

For other R options, the largest barriers are that economic incentives are not linked to circularity outcomes. Adding to that, other VROs are generally not considered in EPR legislation at all. The outcome is that smaller circular initiatives are often not able to be economically independent, and often require subsidies, even though they are important in increasing circularity. Some examples include clothing repair shops (R3) or clothing libraries (R2). A more inclusive EPR with the goal of circularity would take these different possibilities into account. Firstly, the money collected through the EPR could take away the necessity of subsidies for these initiatives, therefore taking away the burden of the tax payer. An investment fund that would help in financing store locations, machinery, or personnel for these different VROs is a possibility. Furthermore, these initiatives might get a fee for every piece of clothing that is repaired or borrowed, just as recyclers get for recycling. This makes sense for producers as both these options also lower the amount of waste, which helps them reach their goals.

Finally, a new model based approach of coming to an EPR fee was suggested. It is important to take the complete system into account when calculating this fee. This was achieved through modelling the system and calculating the costs and benefits along the supply chain. These calculations are important since they are the way to show where investment is necessary, and where there are market deficits. Furthermore, to create a functional roadmap towards the future goals, it is important to model the changes in the system.

8.3 Recommendations

Finally, some policy recommendations can be made based on these findings. First, it is essential to keep in mind all the different VROs along the value chain in the creation of an EPR legislation. EPR generally focusses too much on just recycling, while a specific mix of different R strategies is necessary to become a more circular economy. Redesign, repair, reuse, and, are all essential to reach the government's goals. Additionally, other opportunities outside the R-ladder, such as transparency, are significant in enhancing the VROs.

Next, collaboration and partnerships between different actors in the value chain is crucial when striving for sustainability. These partnerships help creating transparency and link incentives along the value chain. In general, to achieve all these goals for a new and better form of EPR, the most important is that complete, reliable and verifiable data are tracked and shared between different actors along the value chain.

Following this, the creation a circular value chain organisation would be valuable in EPR legislation. Not only does this lead to more collaboration and information sharing along the value chain, it also helps in linking the producer side to the processors side of the chain.In addition to this, making the responsibility for the producers as wide as possible has the largest circularity outcomes. If producers have a larger role to play, there is a larger incentive for change. This includes being responsible for all the different VROs, an innovation fund, monitoring and transparency,

Furthermore, an economic incentive is crucial in changing the way products are manufactured and processed. To achieve a strong enough incentive, the fee has to be high enough to make a difference. Therefore, the calculations for an EPR fee have to include the whole system around textile waste.Moreover, if the fee is high enough, it is crucial there are fee modulations, or discounts. This is the most important way in which such a legislation can steer producers towards a more sustainable way of doing business. These can include discounts based on quality of the product, the use of sustainable materials, the implementation of standards, or for following industry agreements.

Finally, implementing an EPR has more impact if done on a supranational level, such as EU-wide. This is both a win for producers as well as for circularity. It creates a level playing field for the producers, instead of having different regulations per country. It also creates a harmonised system of registration, making information sharing easier, and therefore making monitoring and traceability better. Besides that, it makes it easier to keep control over the processing of materials that are exported.

All in all, the results of this study show that many different improvements can be made in creating a more inclusive EPR structure for textiles. It is necessary to have more collaboration and transparency, but the only way to reach a circular economy is by linking circularity outcomes and economic incentives.

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10. Appendix

10.1 Appendix A: Dutch textile industry sustainability initiatives (Modint & INretail, 2019)

Initatief	Jaar	Thema											
		Due Diligence & inkoopraktijk	Communicatie	Innovatie	Gebonden arbeid	Kinderarbeid	Leefbaar loon	Veilige werkplek	Vakbondsvrijheid	Grondstoffen	water, chemicaliën en energie	Dierenwelzijn	Circulaire economie
Green deal Textielinzameling	2012		■										■
Plan van aanpak: groen is de rode draad	2013	■			■	■	■	■	■	■	■		■
Convenant Duurzame Kleding en Textiel	2016	■			■	■	■	■	■	■	■	■	
Roadmap Circulair Textiel	2017									■	■		■
Dutch Circular Textile Valley	2019			■						■	■		■
Sectorplan Kleding en Textiel	2019		■	■						■	■		■
Nederlands Duurzaam Textiel Pact	2020	■	■	■	■	■	■	■	■	■	■	■	■

10.2 Appendix B: List of interviewees

Interview number	Function	Organisation	Relevance	Length
P1	CSR Manager	Branche organisation retail non-food industry	Involved in development of the textiles EPR	42m
E1	Lecturer-researcher	University of applied sciences	Performed research on the logistics and supply chain of textiles	58m
E2	EPR researcher	Environmental organisation	Performed research on EPR systems	44m
E3	Sustainability advisor	Consultancy organisation	Conducting an LCA on textile processing options	47m
E4	Strategic advisor	University	Board member of textile network organisation	39m
R1	Director	2nd hand store chain/sorter	Expert in collection/sorting/reuse of textiles	51m
E5	Senior Consultant	Sustainable consultancy firm	Performed research and advised on Dutch textiles EPR	51m
E6	Junior Assistant Professor	University	Performed research on current state of Dutch textile industry	71m
R2	Strategy Manager	Waste collection company	Collects textile waste for municipalities	45m
PR1	Finance Manager/Managing Director	Textile producer/Chemical recycler	Expert in producing and recycling textiles	52m
R3	Sales manager	Textile waste collecting and sorting firm	Expert in collection/sorting	59m
R4	Co-founder	2nd hand initiative	Expert in collection/sorting/reuse of textiles	44m
P2	Innovation and sustainability manager	Branche organisation fashion	Involved in development of the textiles EPR	52m

R5	Innovation and sustainability manager	2nd hand store chain/sorter	Expert in collection/sorting/reuse of textiles	39m
E6	Board Member	Textile network organisation	Long career in circularity in fashion	46m
R6	R&D Lead	Mechanical recycler	Expert in recycling of textiles	48m
E7	CTO	Textile labelling and transparency firm	Expert in information and transparency along the supply chain	60m
P3	CEO	Corporate fashion producer	Expert in sustainable production of workwear	52m

10.3 Appendix C: Interview guide

Interview guide research phase 1: Orientation

I. General introduction:

1. Explain purpose and topic of the research
2. Discuss data handling & confirm permission for recording the interview
    a. The personal data of the interview will be anonymized
    b. The transcript will be sent to the participant
3. Ask the participant to give a short introduction about him- or herself (Name, function in the organisation and what this function entails)

II. General textile industry:

1. What are the largest challenges/goals?
    a. How do you view the governments goals?
2. What are the most important drivers/barriers?
3. What are recent/future developments?

III. Specific area of expertise:

1. What are the largest challenges/goals?
2. What are the most important drivers/barriers?
3. What are recent/future developments?

IV. Extended Producer Responsibility:

1. What do you know of EPR systems?
2. What do you think of the coming EPR for textiles?
3. How could [area of expertise] be stimulated via an EPR?

V. Further information:

1. Do you know someone that would be interesting for me to speak to?
    a. Are you willing to share the contact information of these people?
2. Do you know what other places I can find information?
    a. Do you have any relevant reports/documents you can share?

VI. Concluding questions:

1. Are there any questions you would like to come back to?
2. Do you have any other comments or issues you want to share?
3. If I still have some questions afterwards, can I contact you?

10.4 Appendix D: Sources of costs and benefits

Type of costs & benefits	Values per kilogram	Source
Benefits		
Second-hand clothing in NL	€4,50 - €5,00	Interviewee R1 & R5
Second-hand clothing	€0,20 - €4,50	Rebel Group, 2021
Recycling textiles	€0,00 – €1,00	Rebel Group, 2021
Recyclable fibres	€0,07	Interviewee R1
Costs		
Incineration	€0,35	Interviewee R1
Incineration	€0,15 – €0,30	Rebel Group, 2021
Municipality extra collection	€0,04	Interviewee R2
Mechanical recycling cotton	€0,56 - €2,50	European Commission, 2021
Global market price cotton	€0,50 – €0,80	European Commission, 2021
Import price cotton yarns	€1,46 - €1,71	European Commission, 2021
Chemical recycling cotton	€0,90	European Commission, 2021
Mechanical recycling polycotton/polyamide	€0,18 - €0,50	European Commission, 2021
Chemical recycling polycotton	€1,95	European Commission, 2021
Separate collection	€0,20 – €0,42	Rebel Group, 2021
Sorting	€0,35 - €0,45	Rebel Group, 2021
Chemical recycling cotton	€1,00	Interviewee PR1
Recycling	€0,30	Interviewee P1