SYSTEMIC VALUE CHAIN TRANSFORMATION IN THE TEXTILE CLOTHING LEATHER AND FOOTWEAR (TCLF) SECTOR

The potential Impact of Upcoming Legislations and Digitalization Trends

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1. Introduction

"If Europe cannot become more productive, we will be forced to choose. We will not be able to become, at once, ***a leader in new technologies****, a* ***beacon of climate responsibility****, and an* ***independent player on the world stage****. We will not be able to finance our social model. We will have to scale back some, if not all, of our ambitions.*
This is an existential challenge."

- The Future of European Competitiveness (aka. The Draghi Report), Sept. 2024

Most economic sectors are undergoing a fast-paced transition with the emergence of sustainability imperatives and ground-breaking technologies. With a focus on the Textiles, Clothing, Leather, and Footwear (TCLF) sector, we look for direction in the upcoming legislative changes by analyzing the current state of affairs, recalling the motives that led to globalized value chains. There is a need in the Netherlands and other EU countries to clarify the conditions that will pave the way in creating a safe and sustainable Europe through changing legislation and new trajectories in digital technologies and data science. The EU promises to be a leading figure in this transition, having adopted legislation in the 2025 Omnibus Package, and through initiatives like the Textiles of the Future Partnership (2025), the Circular Economy Action Plan (CEAP, 2020), and the Twin Green & Digital Transitions (2022). In this paper, we summarize the challenges faced by all stakeholders in the textile ecosystem, highlighting opportunities and challenges surrounding new policy implementations and digitalization trends.

Climate imperatives demand that the TCLF sector consider not only economic competitiveness but also the hidden costs stemming from the manufacturing, use, and disposal of products. To move towards a European Union that is Safe and Sustainable by design (SSbD), along with the climate goals of Europe, a series of EU legislation proposals have been passed into law, attempting to **increase transparency on the environmental, economic, and social impacts of all the "things" made, used, and recycled in Europe.** According to the European Environmental Agency, the TCLF sector is the third highest for water and land use pressure, and the fifth for material use and greenhouse gas emissions[1]. The same source also expresses concern about water contamination risks associated with PFAS and the enormous amount of waste generated - often ending up in landfills or incinerated and missing out on value recovery of materials addressed in the SSbD framework[2].

There are growing concerns about the social dimension too, with the TCLF industry employing more than 1.3 million workers in the EU and 60 million workers around the world[3]. The TCLF sector often pays an inferior living wage in extra-EU "developing countries", where workers are required to perform excessively long shifts[4]. While **"offshoring" and "cost minimization" economic strategies** have brought affordable fashion to most of the world population, they have directly contributed to the **loss of crucial skills in European countries[5], and excessive**

1 From the EEA, What are the environmental impacts of the textile industry?
2 EU Safe and Sustainable by Design Framework
3 Fashion United Statistics (link), source ILO
4 International Labour Organisation (2014), Wages and Working Hours in the Textiles, Clothing, Leather and Footwear Industries.
5 In the ETP Strategic R&I Agenda, it is shown that the EU workforce aged 50 years or older is increasing and it is now close to 42% of the total. The skills shortage concern material knowledge,

shopping behaviors, a pattern of under-use and overconsumption. Cheap, lower-quality, and easily damaged clothing is contributing to a growing amount of textile waste that is extremely difficult to recycle. EU households have reached a new record high of 19 kg per capita of textile products, including clothing, footwear, and household textiles bought in 2022[6]. At the same time, the recycling infrastructure for textiles is still far from being capable of dealing with those volumes and it is struggling to deliver recycled materials appreciated by the sector, due to high cost and uncertainty regarding the quality.

Recent EU Legislative reforms aim to increase competitiveness and sustainability through digitalization, transparency, monitoring, information sharing, and research actions through the Extended Producer Responsibility (EPR, or UPV in the Netherlands) and the Ecodesign for Sustainable Product Regulations (ESPR) which includes the Digital Product Passport (DPP), Market Surveillance Regulation (MSR), and Waste Framework Directive (WFD). However, **it is still unclear how the data disclosure requirements will be implemented and federated in EU member states and how the actions will affect the sector's operations and economics.**[7] As the implementation of ESPR and EPR comes into focus, **all stakeholders in the ecosystem (including users) seek involvement and higher levels of collaboration**. This is often made more difficult by the different size of companies and the influence that they can exert.

In Figure 1, we illustrate the stakeholder classes operating within or in support of the textile value chain. Within the **NewTexEco** research community, our goal is to **facilitate cooperation among the various actors in the ecosystem and to share research outcomes that improve the economic and environmental performance of the TCLF sector in the Netherlands.** Importantly, as the Dutch textile ecosystem is deeply embedded within the EU context through trade, both in terms of regulation and industrial relationships, we zoom out to discuss dependencies with Europe and global value chains affecting the resiliency of the sector.

manufacturing, and digital and sustainability-related skills.

6 According to the EEA, the export of used textiles from Europe has tripled since 2000 despite the population not having increased much in the same time period.

7 Different national organizations are working to achieve the most effective policy implementation, like the Center of Excellence for Digital Product Passports in the Netherlands launched in October 2025, with implementation of DPPs for clothing and interior textiles required by July 2026 and footwear in late 2029. https://coe-dpp.nl/

Ecosystem definitions and stakeholder classes

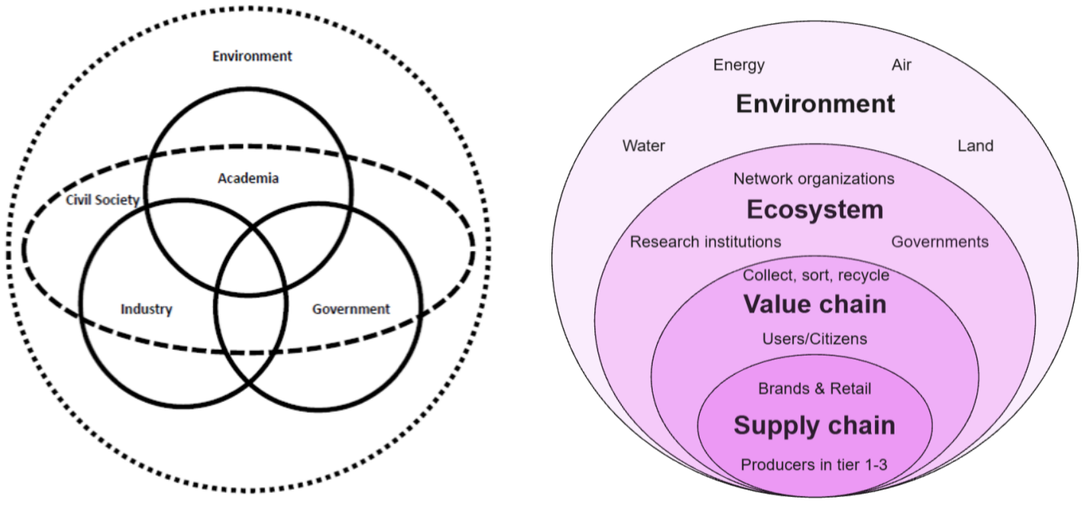


Figure 1: Ecosystem representation (self-produced on the right-hand side) with all "actors" of the Quintuple Helix (left-hand side) and their order of relationship.

The white paper is broken down into three sections. In the **first**, we look at the **current state of the TCLF sector, introducing the variety of challenges that businesses face within the (linear) economic system, and discussing the implications of the transition towards a circular value chain.** All actors in the TCLF value chain have a role to play in the formation and retention of value, including textile users[8] who can actively participate in the re-circulation of used products and materials.

In the **second section, we dive deeper into legislative proposals**, particularly those dealing with **information sharing and data compliance that constitute an important lever to achieve higher levels of transparency and accountability**. This legislation aims to regulate the behavior of businesses and citizens dealing with textile products in the European Economic Region and, indirectly, their suppliers offshore, potentially giving shape to new system of incentives and disincentives ("the carrots and the sticks") especially through EPR schemes and DPP.

In the **third section, we explore the avenues from increased digital information sharing,** looking at use cases across three levels:
1) macro-level applications, potentially useful for government monitoring and regulation,
2) meso-level applications, focusing on business collaboration to progress on circularity goals, and
3) micro applications for individuals to make eco-conscious decisions.

For each of the aforementioned use cases we highlight risks and opportunities, and provide recommendations to policy-makers, businesses, and textile users on how to enhance the collaboration across different stakeholder classes. As there is no single solution for everyone, a multitude of strategies need to be considered to **achieve a more sustainable and resilient** TCLF sector. Yet, all require a higher **level of coordination** within the ecosystem.

8 We prefer to employ the term "users" to facilitate the shift from the consumerism mindset which regards "consumers" as the final actors of the chain that ultimately deplete the value of TCLF products, whereas they can actively contribute to value retention.

2. The Transformation of the TCLF sector

With a series of developments in the EU legislation and in the competitive landscape, there is a common feeling that the TCLF sector stands at a crucial point[9]. **Transformative systemic change is needed to depart from current scenarios that do not show a promising future for the sector in Europe.** An ecosystem that includes quintuple helix stakeholders from Industry, Government, Environment, Academia and Society are needed to transform the TCLF sector. Based in the Netherlands, the New Textile Ecosystems research community (NewTexEco or NTE) is one of the network organisations aiming to steer the TCLF sector and the overarching ecosystem towards a more sustainable present and future. 30 institutions, including businesses, policy experts, academics, environmental, societal institutions and other network organisations have **co-developed practical research agendas, identifying the most important topics to be considered in the transformation of the textile ecosystem.** After the definition of seven research themes[10], and thanks to the interactions with external partners, industry experts, and a combination of interested parties that continue to bring precious insights (e.g. from Circular Textile Days), the development of a new narrative has started to take shape in parallel with the writing of this white paper.

2.1 The economic, technological, social, and environmental perspectives

The Economic, Technological, Social, and Environmental perspectives are deeply interrelated and their topics hold implications for one another. ***Figure 2*** displays the mindmap that helps to visualise dependencies between topics and to **promote holistic approaches to policy-making, business practice, and practice-based research.** At the heart of the four domains, we place "Research, Innovation, and Knowledge sharing" as the primary topic that connects people with technology and the economic sphere with the ecological.

In the following chapters, we will expand upon these topics and connections, with a focus on **digitalization, overproduction, and circular processes**. In this chapter, we start by introducing some of the topics highlighted at the beginning of NewTexEco - in co-design sessions. In these sessions topics were framed within the TCLF trade dependency and the roles that the Netherlands can play to become more sustainable internally and in influencing the EU in the definition of a strategy for the sector.

2.1.1 Trade dependency in EU and the Netherlands

The Netherlands has a long history of trade with nations all over the world. Since 1973, through a series of trade agreements of the World Trade Organization (WTO), Europe began an offshoring trend facilitating the import of textile products especially from far east Asian countries. Driven by the goal to make clothing and textiles accessible to all, these trade partners provided inexpensive labour and raw materials, often leading to cheaper, lower quality, and less durable products. This trade cycle put in motion a paradigm that focuses more on quantity than quality. **These trade agreements still persist today allowing large-scale imports from outside the EU, sometimes with low or no tariffs at all**, as seen in the de minimis business strategies of Temu and Shein.[11]

Data from Eurostat report an outstanding value close to € 83 billions of textile apparel imports in 2023 from non-EU countries[12] (about 50% of the total value of imports), with larger exporters being China (13% of the total), Bangladesh (10%), and Turkey (6%)[13]. The five largest European importers are: Germany (€ 39 bn), France (€ 24 bn), Spain (€ 19 bn), Italy (€ 18 bn), and the Netherlands (€ 17 bn). Despite the value of imports still growing for all top 5 EU importers, the reliance on extra-EU imports seems to be slowly reducing - according to CBI figures.

The most recent Sankey diagram from the European Environmental Agency (EEA) on textile flows (***Figure 3***) showed that the EU is a net importer of textile products with about 28 kg/person. This is slightly larger than the total final consumption (25.9kg/person), suggesting a **dependency on extra-EU economies both to meet the demand for TCLF products (through imports) and to place the stock in excess on other markets (exports)**. In short, the EU exports more than it produces and imports more than it consumes.[14].

9 *Report on an EU Strategy for Sustainable and Circular Textiles- Link*

10 *Article on the seven research themes on the NewTexEco website - Link*

11 *Article from the Guardian - Link*

12 *CBI figures - Link*

13 *The import from Asian countries has reduced compared to a previous Eurostat study on textile - Link*

14 *The presence of imports for re-export (with minimal or no additional edit on the product) makes the picture more complex.*

Mindmap of Economic, Technological, Social, and Environmental topics

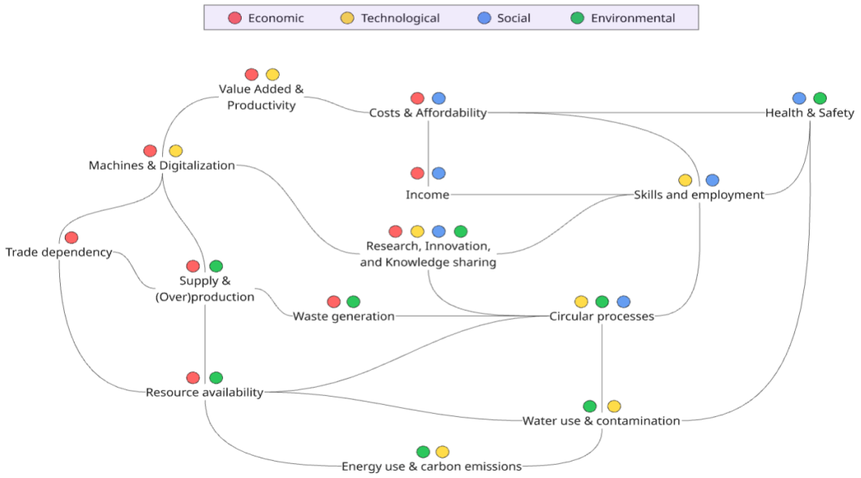


Figure 2: Mindmap representing the connection between the various topics considered in the Economic, Technological, Social, and Environmental domains.

Sankey diagram visualization of EU Material Flow Analysis (MFA)

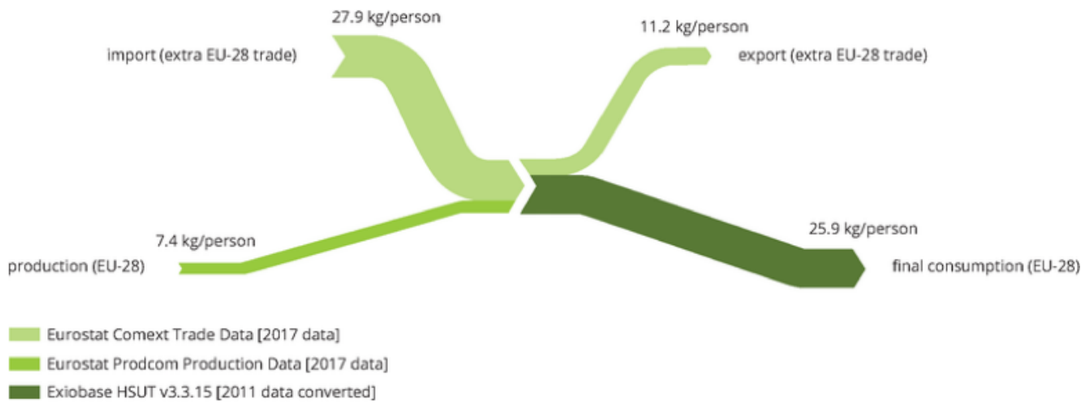


Figure 3: Latest MFA from European Environmental Agency (2019) with 2017 data (link broken a few days before the publication).

Monetary flows of imports and exports in the Dutch TCLF sub-sectors

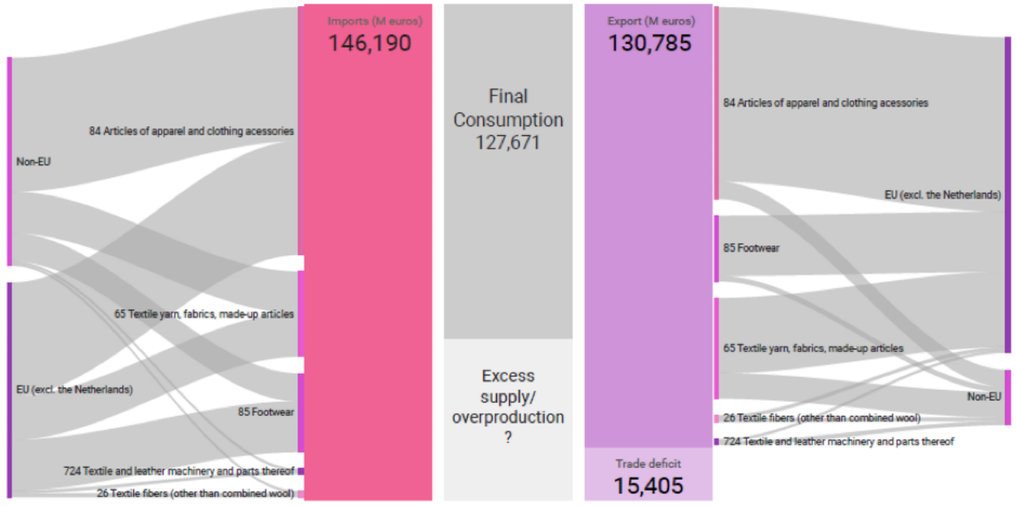


Figure 4: Self-produced Monetary Flow Analysis of Dutch imports and exports. Consumption data are from CBS National accounts but excess supply/overproduction is hard to single out given the uncertainty related to the share of local production and import for re-exports.

Material Flow Analyses (MFAs) are usually hard to replicate on a yearly basis as **data on material in tonnes are not easy to find, especially at the level of granularity that is required** for this task. Much easier instead is to keep track of the economic flows as we can easily find yearly figures broken down by sub-sector. In Figure 4, we can see the economic value of imports and exports for the Dutch textile sub-sectors using the classification from the statistical office (CBS). The story told by the figure is not too different from the European MFA with a large quantity of imports, especially of finished "Articles of apparel and clothing accessories" from extra-EU countries. With historical data from 2015 to 2022 (missing 2021), we can estimate the **cumulative trade deficit of the Netherlands adding up to more than 15B euros loss in less than a decade.**

European countries are not gaining a good position financially by persisting with trade dependency. Additionally, the trend seems to be changing amid geopolitical tension and European leaders and economists seeking to improve authonomy for the TCLF sector. After *The future of European competitiveness* report (Draghi, 2024), it has been widely recognized that the **EU import dependency is a risk for its economic resilience.** The geopolitical transformation and the revision of trade agreements and tariffs (invigorated with the second US presidency of Trump) are prompting European countries to reconsider their relationships (both suppliers of imports and clients for exports) and to **channel towards the near-shoring of textile manufacturing activities.** Alongside expanding production capacity to serve a bigger share of the local population, the biggest challenge for EU producers is to place products affordable enough to compete with Asian imports. This seems very hard today due to the cost structure of textile products made in the EU, which typically serve the luxury segment exports towards countries like the US, China, Japan and South Korea. What remains is **a research gap regarding the feasibility of European production hubs delivering high quality products in larger volumes for 450 million EU residents.**

2.1.2 Affordability, value added, and innovation

In a report from 2014[15] - one of the first and very few on the topic - the economic margins of a T-shirt produced in Bangladesh were disclosed providing rare insights on the reality of the value chain. Another study from the US (Handfield et al., 2020) also argues for the **uneven distribution of margins in favor of the actors at the end of the value chain:** brands and retailers usually have a claim on more than 50% of the price of a T-shirt. Instead, factories in Bangladesh typically earn 4% of the final price, of which as little as 0.6% might be left to the workers (data summarized in Figure 5). Apart from ethical discussions on fairness, it is important to notice that **the labour that adds most of the value, transforming fibers, yarns and textiles into finite products, would be several times more expensive if all these activities occurred in Europe.** Looking at the EU figures from 2019[16](***Figure 6***), we can notice that **the value added per employee (net productivity) of the first tiers of the supply chain** (Man-made fibers, Yarns, Fabrics) **is generally higher than Retail**. If we assume the value added per employee to be a proxy for price, we can get an idea of how expensive a garment made in Europe could be. Therefore, the only possibilities for local producers to make products less expensive without sacrificing quality are:

- **Vertical integration of the production tiers** (from yarn to finished product) to avoid the cumulation of margins that raises the final price;
- **Technological innovation to increase productivity**[17] (e.g through robotic knitting) to create bigger volumes of textile products with a lower numbers of workers/paid hours;
- **Tax reductions for virtuous local producers and for critical activities in the circular economy** (as we explain in Chapter 3.2).

15 Despite being questioned, the Tailored Wages (2014) report remains emblematic of its message and the numbers do match with other studies focusing on T-shirts produced in Bangladesh. (Link)
16 European Commission: Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs and CSIL, Data on the EU textile ecosystem and its competitiveness – Final report, Publications Office of the European Union, 2021 - Link
17 Value added per full-time equivalent (FTE).

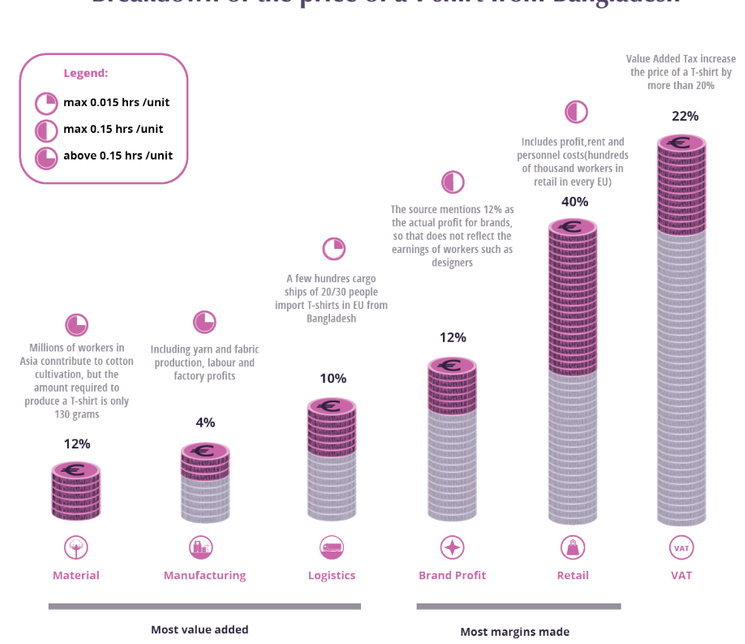


Figure 5: Self-produced infographics on the costs and margins attributed to each step of the supply chain using data from two studies (one focusing on the US and the other on the EU market, both illustrated in APPENDIX A). They both reveal a share lower than 4% of all manufacturing costs and at least 40% going into retail costs and over 10% into profits. The small clock icon instead refers to the time needed to produce one unit, showing that manufacturing is among the most labour intensive activities (APPENDIX B).

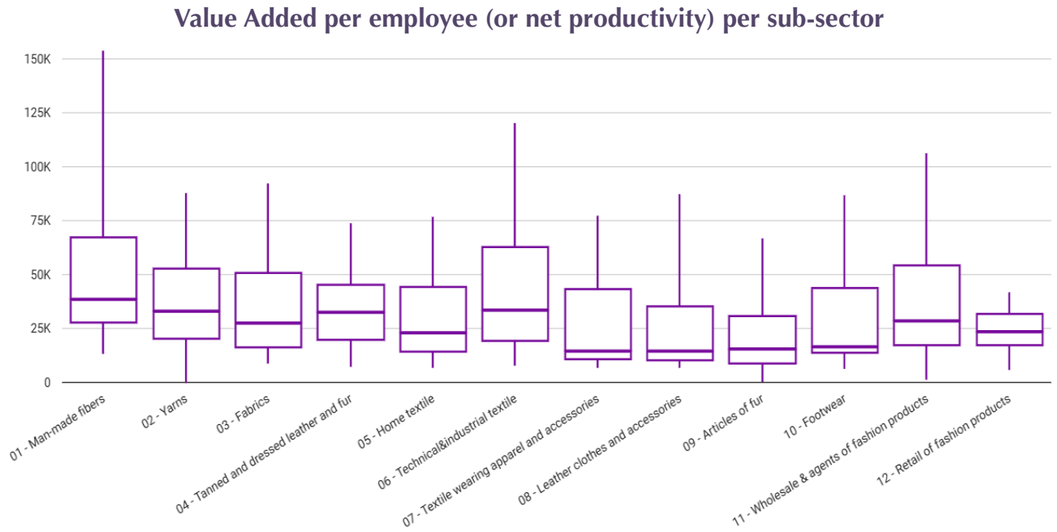


Figure 6: Value added per employee (Net productivity) in 2019 (Eurostat). Each sub-sector (or tier) in the box plot summarises the distribution of value added and employment for each member state (except the Netherlands for which value added statistics are not available for some of the tiers). Value added for circular activities (repair, sorting, recycling) is not easy to estimate also due to the standard classification system (SIC) often bundling textile recovery activities together with other industrial waste recovery.

The boxplot also points out a remarkable variance in productivity for some sub-sectors which is typically influenced by human skills and technological innovation. With both human and technological capital fading towards regions offshore, Europe has lost a competitive advantage that will be hard to offset - as explained by Draghi in The Future of European Competitiveness (2024). **As the textile landscape in the EU is still characterized by a myriad of SMEs[18], it is crucial for them to access innovative technologies and join regional co-production processes to remain competitive.** The localization of different tiers of the value chain (including circular activities like recycling) in regional hubs, vertically integrated by a seamless exchange of data on volumes and textile variety, and the spread of micro-factories is shaping a new and yet not-so-utopian vision of how the industry can transform. However, the transition towards this vision will require the collaboration of many different stakeholders and the support of governmental means to make it financially viable.

18 Table 64, page 157 in the "Data on the EU textile ecosystem and its competitiveness" report.

2.2 The actors in the circular value chain

With public research and development investments attempting to boost technology and the advancing of digitalization, the opportunities for ecosystem coordination improve, increasing the capacity of all actors in regional value chains to handle big volumes of textiles, both on the supply side and the recovery of End-of-Lifes products. While producers have been innovating for centuries in their ways of making textiles, **the new actors in the circular economy - such as sorters and recyclers - have only accrued a few decades of experience in the attempt to retain the value of used textiles.** Taking inspiration from the Value Hill framework[19], we create a visual representation of the Textile Value chain (Fig. 7) showing the circular processes of value creation, retention, and loss.

Economic notion #1: Value definition

In "The Value of Everything" (2018), Mariana Mazzucato narrates the development of the notion of value throughout history, explaining how **its link with the actual amount of labor (hours) put into production activities gradually broke** - as in Marxist theories of value. Neoclassical theories have rejected the distinction between value and money, embracing a subjective perspective on value. Members of this school (such as Marshall, Jevons, Walras) believe that price should be determined by the individual willingness to pay, allowing for big price fluctuation and discrimination strategies that maximise value extraction. In simple words, according to the neoclassical theory, the same bottle of water could be charged 1 euro or 100 based on how desperate the buyer is, or how many alternatives or competitors are present in the same market.

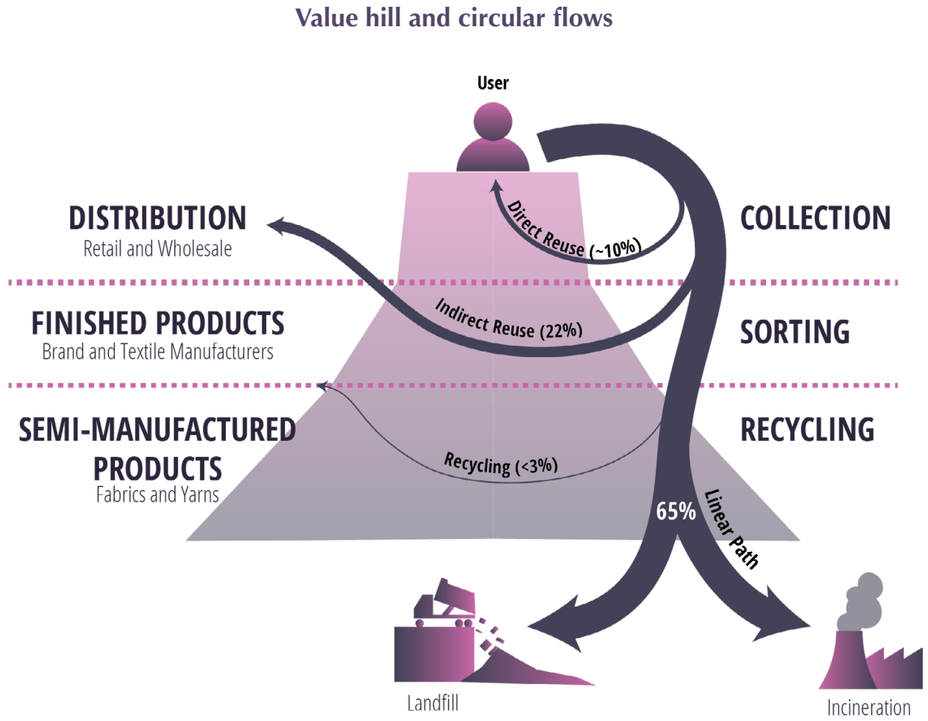


Figure 7: Value hill in textile and circular paths for value retention with estimated values for the Netherlands (Metabolic, MFA, 2024). The first circular flow we show is the direct reuse of garments, including swapping, online and physical resale continentally; The second refers to the rewearable share of garments that is collected by sorters and handled from wholesalers, mostly for exports and switching from pricing per item to price per kg. The third flow refers to the bulk of textiles recycled to make new yarn and fabrics.

With the spread of Material Flow Analyses (MFA), our understanding of the circular flows and their magnitude is improving. In Figure 7, we report rough estimates of the main flows using data from Metabolic's MFA for the Dutch Textile sector (2024). The **Direct Reuse flow is approaching 10% primarily due to the online resale of clothing[20]**. The Indirect Reuse refers to the textiles that are handled by sorting companies and labeled as rewearable. This flow is the hardest to estimate because sorting and distribution occur partly abroad; therefore, 22% is calculated as residual flow. The magnitude of **recycled material is not bigger than 3%**, even if we include filling and downcycling applications. In line with the global estimates from the Circularity Gap Report for Textiles (2024), **the percentage that goes to landfill or incineration is close to 65%**.

With the revised Waste Framework Directive (WFD) including targeted measures for textile, the EU is defining criteria to place a ban on the export of unsorted waste, especially to countries that cannot ensure transparent and sustainable treatment[21]. This intervention might help to reduce the share of textiles ending up in foreign landfills and increase the material that can be reused continentally. **Regional sorting firms alone will not be able to face higher pressure from this mountain of textiles and the need for a cohesive strategy for the collection and sorting of textiles involving all actors in the value chain is paramount.** For the rest of this chapter, we discuss the roles and responsibilities of all the stakeholders

19 From Circle Economy (2016), Master Circular Business with the Value Hill - Link

20 Direct Reuse is calculated as 23 ktons (Online C2C resale) / 322 ktons (Consumption) rounded up to include informal sales and swapping.

21 European Environmental Bureau (2025) - Link

illustrated in Figure 7.

2.2.1 Fibers, Yarn, and Fabrics producers: at the source of value generation

Raw material extraction is often found in remote areas of the world where immense agricultural fields and petroleum extraction sites provide the foundation for cotton and polyester production. China produces about 70% of the world's synthetic fibers with over 60 million metric tons yearly, around 25-30 million metric tons of yarn - including cotton, blends, and other fibers - and 30-40 billion square meters of fabrics[22]. What happens in distant factories, in terms of chemical use[23] and human rights, is hard to track no matter how the legislation intended to prevent it.

Over the last decade, certification companies have supported the recognition of quality standards verifying the presence of a list of substances (i.e. REACH) and providing stamps on textile quality. With the upcoming regulations in ESPR, Digital Product Passports (DPP) and Market Surveillance Regulation (MSR), the enforcement of these standards will increase. **ESPR requires more transparency on textile production processes from the early stages of the supply chain**, allowing for increased collaboration and insight into the environmental and economic efficiency of companies across all tiers. If producers are encouraged to introduce circular materials in their processes, for example, with the lowering of prices for secondary material like recycled yarns and used fabrics, they may embrace long-term collaborations (with contracts) with local or regional recyclers. As pricing and financial pressure have often been obstacles to innovation and circularity, the support of governments and the standardization of verification processes for recycling processes are crucial.

2.2.2 Brands and Manufacturers: from collections design to finished products

The manufacturing of finished products is often determined by the collaboration between brands and garment producers, where brands define technical requirements (Tech Packs) and order quantities, and producers execute and deliver. This relation is complex as it usually involves third parties intervening with specific services like washing, dyeing, finishing, and confectioning. There is a shared pressure for manufacturing tiers offshore to **deliver big volumes of garments with acceptable quality standards in short periods of time**. This causes many companies to produce textiles using forecasting models leading to waste and leftovers. The management of lead times is crucial for these producers - often SMEs - to satisfy foreign buyers' demands, and the chance seems to be higher when they have direct contact[24]. However, it sometimes happens that quality standards are not met either by the contracted or by subcontracted firms, and that orders are withdrawn while they are being prepared[25].

Besides the complexity in managing upstream supply and relationships, brands (and retailers) are also attempting to improve their understanding of the user demand. With increasingly sophisticated prediction models, brands and fast fashion players are reducing batch volumes while proposing frequent seasonal changes or even product customization[26]. And yet, the question remains: to what extent can brands improve their predictions on demand, reducing their unsold inventories? It is hard to believe that a myriad of uncoordinated market players will be able to predict the right quantity and qualities (like design and sizes) to put on the market if governments do not consider a cap on supply (production + imports), as it occurs with other sectors like real estate and some items from agriculture.

Prompted by investors' and shareholders' interests, **big companies typically set ambitious growth targets that cannot be achieved unless people consume more and more**. As the demand for clothing in the EU has stagnated for over a decade[27], new garments and collections will keep accumulating in inventories if all companies predict to grow. Mossinkoff and Stockert

22 *Data from China National Textile and Apparel Council (CNTAC) and National Bureau of Statistics (NBS). - Link*

23 *"More than 1900 chemicals are used in the production of clothing, of which 165 the EU classifies as hazardous to health or the environment..." according to a report from the European Parliament - Link*

24 *Herath, Renuka. (2013). Managing Lead Times in Garment Manufacturing SMEs.*

25 *This phenomenon was particularly common in 2020 during the pandemic - Link to ILO article*

26 *Felipe Caro, Jérémie Gallien, (2009) Inventory Management of a Fast-Fashion Retail Network. Operations Research 58(2):257-273. - Link*

27 *Data from Euromonitor shown in a paper from Maldini (2017) in line with EEA analysis (link)*

Gap between textile supply and user demand

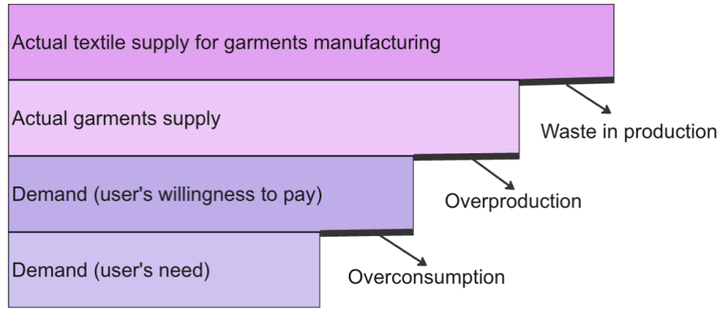


Figure 8: Relationship between demand and supply and their contribution to overconsumption phenomena (own representation).

(2008) argue that the electronic integration in the TCLF sector can help setting more realistic targets and redefine the way seasonal collections alternate, reconciling with natural seasons and material harvests. Hence, to summarise, **there are a few possibilities to be considered simultaneously that can help reduce overproduction**:

- vertical electronic integration to manage stock more efficiently across tiers;
- moving away from big collections orders and already-made inflexible designs, nearshoring the finished products assembly, with shorter lead times in an almost on-demand supply[28].

And yet, we fear that the current system still lacks the means to close the gap between business growth targets and the actual demand. In simpler words, while overproduction is a problem that brands and retailers have an interest in tackling, **overconsumption is convenient to reduce costs from unsold inventories and realise their growth targets.**

2.2.3 Retail and Wholesale: circulating the textile stock

If brands and producers responsibility, economic and environmental, is guessing the right quantity and product quality of new items to create. Retailers and wholesalers have a duty to make sure they circulate textiles efficiently and without contributing to wasteful production. At the end of every sales season, it is normal for stock remainders to go back from small stores to warehouses and wholesalers, then eventually to outlets and exporters if not directly to incineration. According to a study from Maldini (2018), the share of unsold items[29] varies between 5 and 30%, depending on whether we only count what is sent for incineration and landfilling or include in these statistics also the items that will eventually be sold later for a discounted price (i.e., on Black Fridays).

Monitoring unsold items on a regular basis at the regional and national level requires the collaboration of businesses with local authorities in disclosing information about their inventory, but transparency has often been hindered by gate-keeping commercial secrecy. And yet, **a more efficient prediction and distribution of garments and textile products in the market might depend in good part on information sharing, potentially improving the operational and financial performance of several actors in the value chain**[30]. Retailers and brands will soon be required to share more information on their put on the market as part of the EPR legislation, which will prompt them to rethink the role of data within their business strategy. Sharing data with relevant actors in the ecosystem might help to achieve more realistic sales targets and to reduce the pressure on the "waste" sector.

Figure 8 summarises the market dynamics of garments supply and demand, and the cascade effect on the accumulation of textile waste (industrial and post-consumption). The figure also suggests a **collective contribution to wasteful production** that is either

28 *Article from Walter Lutz - Link*

29 *Link to EEA briefing confirming the minimum starting from 5%.*

30 *Chen et al. (2019), Impact of supply chain information sharing on performance of fashion enterprises: An empirical study using SEM - Link*

overlooked or erroneously attributed to the *consumer's hedonistic behavior*. Indeed, we have encountered for a few decades the expression consumer responsibility which was used as a strategy by corporations to obtain political attention and avoid regulation[31]. Perhaps, the emergence of Extended Producer Responsibility (EPR) legislation will help to **balance the focus between consumer behavior**, which surely can be more mindful, and **the producers' consideration for the waste they generate.**

2.2.4 Users: on top of the value hill

Users are on top of the value hill as they pay for the full price of the products. Users "consume" the financial value of their garments as they wear them, and the value they could obtain from resale decreases. The pace at which the value of a garment goes down depends on different factors such as material, style, and user care (APPENDIX C.2). Repair activities are part of user care as they retain the value of a garment and postpone the end of the use phase. Generally, from an environmental perspective, we can say that the impact of a garment that lasts 5 years is twice the impact of one that lasts 10 years, as that should double the speed at which new replacements are in demand. However, **replacement is not the only motive for new purchases because users also tend to expand their wardrobes in terms of style and functional utility.**[32]

The user's responsibility is to acknowledge the impact of their purchases and to extend the lifespan of garments to spread the impact over time, either through caring and repairing, or by circulating them[33]. The DPP provides an opportunity to facilitate these processes, giving the user clearer instructions on washing, eventually embedding feedback systems to explain to other users the perks of the product and their reason for resale. An emerging branch of fashion research is advocating for the importance of user studies like wardrobe management (as in the app COSH!) and surveys to educate users while trying to estimate the potential impact reduction of better care for garments[34].

31 *Article on Consumer Responsibility - Link*
32 *Maldini (2019), From speed to volume: reframing clothing production and consumption for an environmentally sound apparel sector.*
33 *Soyer, Mirella & Dittrich, Koen. (2021). Sustainable Consumer Behavior in Purchasing, Using and Disposing of Clothes.*
34 *Care & Repair - NewTexEco - Link.*

Case studies on Direct Reuse

Vinted: Among the most famous digital platforms in Europe, Vinted has grown into a major player in peer-to-peer clothing resale with more than 100 million users (as of 2023) in 20 countries. According to the French Fashion Institute (IFM), Vinted is now the first retailer by sales volume in France, ranking even higher than Amazon, Decathlon, Shein, and H&M. The app has developed a sophisticated recommendation system that facilitates matching-making of buyers with sellers, and it also manages logistics and "digital wallets" making second-hand online shopping easy, convenient, and secure.

ThredUp: Established in the U.S. market, ThredUp offers both resale and thrift-shopping options and has recently introduced a "Resale-as-a-Service" (RaaS) model. ThredUp's allows other brands to use the infrastructure for their own resale platforms, effectively facilitating match-making and collection for individual consumers. ThredUp's Clean Out Kit feature allows users to send their clothes directly to the platform, which then sorts and lists items for resale or recycling. This reduces the burden on consumers and provides a convenient way to participate in circular fashion.

COSH!: With the spreading of wardrobe management tools, the possibilities for users to interact, resell, and swap clothing are becoming endless. Among the functionalities of the app made in Benelux there is also the listing of local repair shops that facilitate lifetime extension strategies and the revaluation of garments. Besides the options for Peer-to-peer (P2P) interaction, the application also increases user awareness of the environmental impact associated with their choices.

When the quality of the textile degrades, approaching the end-of-life (EoL), the value of the material can only be retained by the circular businesses through the redistribution, repurposing, or remanufacturing of the item. Users, with their disposal choices, take part in the process that channels products in different circular flows, for example, by dropping their used clothing in the appropriate bin within bags that preserve the quality of the textiles. Or choosing new collection services that aim to deliver cleaner waste streams to recyclers (i.e., Byewaste and Droppie in the Netherlands).

2.2.5 Collectors: Facilitating the redistribution of textiles

Like retailers and wholesalers in the value creation phase, collectors act mainly as intermediaries and charge a price for the logistical effort of gathering and moving used products. We can also consider as part of this category peer-to-peer (P2P) platforms like Vinted, thanks to which users are becoming increasingly confident about the possibility to sell their rewearable clothing. **Although this circular flow can contribute to a lower percentage of rewearable clothing received by textile sorters, the direct reselling of garments through digital platforms is often the best option users have to give them another life and spread the environmental impact of garments over time.** Indeed, the Direct Reuse path is the one that ranks highest in the R-scale of circular economy strategies for products already in circulation. However, while it is favourable to users, it is inconvenient to collectors and sorters as high value pieces are no longer found in recycling streams making the circular business model challenging. EPR schemes will need to make up for the economic loss that an increase in Direct Reuse causes.

Critiques of Vinted argue it contributes to light-hearted second-hand shopping and for the long-distance connection between buyers and resellers. We should not forget that the main alternative to peer-to-peer resale is going into a long loop of sorting cycles that often lead to large exports of clothing to Eastern Europe, Africa and Latin America. Moreover, first-hand clothes travel much longer distances in the first place to appear on the market, and that resale not only has a negligible impact, but it also delays the moment in which the garments will have to be disposed of. And given the current capacity of the waste sector, keeping clothes in use for longer is surely a good way to reduce the burden on society.

Another bottleneck in achieving higher percentages of (indirect) reuse and recycling is the collection of cleaner streams. Digital applications that facilitate collection have emerged with picking up used clothing and textiles from households (i.e. Byewaste) or by placing drop-off locations closer to the urban centers (i.e. Droppie). **Getting closer to users, collecting cleaner waste streams, and performing pre-sorting tasks could signal a much-needed evolution of the circular value chain**. This could involve making collection and pre-sorting more decentralized at the urban level (similar to retail), while sorting and disassembly operate regionally with larger volumes (like wholesale of new products). After all, the value and volume of used products are the two main economic factors that drive profitability for these actors in the current system, unless technological platforms enable: 1) preferably, matching rewearable products with new users, or 2) sorting non-resealable products by textile quality for upcycling or downcycling strategies.

2.2.6 Sorting companies: mining the residual value

Another parallel can be found between brands and sorters as they respectively decide what enters the market and what goes back to it for reuse, therefore assessing the value of products and giving a price to it. **These actors must have some knowledge of material quality and user preferences to judge what can be sold and for how much**. The difference, though, is that not all the items handled by sorters are wearable, and their margins heavily depend on the share of directly reusable clothing which is a variable they cannot control. According to a recent study[35], sorters can only break even with their operating costs when more than 45% of the textile products are directly reusable; therefore they need to literally gamble on the quality of the batches they will receive from collectors.

35 *Ellen MacArthur Foundation, Pushing the boundaries of EPR policy for textiles (2024) - Link*

Case studies on "Indirect" Reuse

ReBird: The initiative from Arc'Teryx allows users in the US and Canada to send their gears for repair, refurbishing, and resale through the ReBird platform. The users get back 20% of the original price after the item is sold again for a discounted price.

Decathlon and Byewaste: Following the new EPR schemes, big retailers like Decathlon are now incentivised to implement take-back strategies, arranging the collection of used clothing (from any brand) and contributing to the reverse logistics of the sorting process. Partnering with Byewaste, Decathlon can reduce EPR costs by disclosing the volume of used textiles collected and proving its responsibility within the circular process.

ReCommerce: On the most radical side, ReCommerce has been intercepting (mostly new) items directed to the landfills in the Atacama desert in Chile and giving them away for free. Currently, the organisation has paused its activities in search of a viable financial model for the NGO workers in partnership with the Chilean institutions.

Nevertheless, sorters will always operate with textiles products with little residual value, and they would require special support from governments to operate in a stable manner in all regions of the EU. Beside revised fiscal regimes, public investments in regional sorting centers and in the development of advanced digital applications are needed to increase the capacity of the circular sector and to get closer to the (linear) production output. **Machine Learning and AI are regarded as fundamental innovations to support the sorting sector and to reduce their operating costs, as most of the sorting in the EU is still entirely manual and based on gut feeling** (APPENDIX D).

2.2.7 Recyclers: from waste burden to resource

Recyclers may be last in the hierarchy of circular strategies[36] but their activity is vital for the value chain to reduce material losses (the third flow from the top of the value hill). Eventually, all garments will reach a EoL state, needing to be fundamentally redesigned, and someone has to prevent materials from being wasted, burned, or dispersed in the environment. However, the scale of recycling and the market for secondary materials is still very small, with many countries having a handful of recycling facilities (APPENDIX D). It is estimated that only 1% of the clothing material is recycled into new material and actually used in the production of new garments[37].

Besides capacity gains, the recycling sector is also pursuing innovation that maximise the value recovery both from monomaterial and from material blends (i.e. BioFashionTech) but recycled fibers are still struggling to compete with virgin materials in the market. If we consider the (often) higher price of recycled yarns and the lower quality and performance, it is no surprise that recycled materials are currently not contributing to a demand reduction for virgin materials. Also in this case, the sector could benefit from government support in terms of favourable fiscal regimes that allow recycling firms to innovate and scale up faster, handling high volumes of textiles of different qualities, and transforming them into high-quality yarns.

Case studies on Recycling

Patagonia & Adidas: Since 2020, Patagonia has partnered with Bionic Yarn to produce garments made from recycled plastic waste, including Gore-Tex items and high performance clothing. Similarly, Adidas collaborates with Parley for the Oceans to produce sportswear made from recycled ocean plastic. Parley's collection and recycling processes transform marine debris into yarn, which Adidas uses to produce its eco-friendly clothing lines, such as the Parley sneaker. Both examples, however, refer to the recycling of other sectors' waste, also called "open loop recycling" (i.e. bottles and packaging). Some might argue that "open loop recycling" does not really contribute to the circularity of the textile sector. Thus, the two brands are also looking into textile-to-textile recycling applications such as Infinna™. This Finnish company uses cotton-rich textile waste to create a soft, cotton-like textile to be used in new garments.

36 Recycling is referred to as R9 in the hierarchy from Potting et al. (2017) - Link
37 https://www.thereformation.com/circularity.html

3. Legislation

Debates often occur in the European Parliament and Commission about implementing environmental policies to reduce impacts contributing to climate change and health risks. The TCLF sector, for example, has shown serious implications for water contamination and plastic pollution, especially due to the dispersion of Forever Chemicals (PFAS). As part of the EU strategy 2030 for Circular Textiles[38], the main goal is "to make textile products durable, repairable and recyclable, to a great extent made of recycled fibres, free of hazardous substances, produced in respect of social rights and the environment" in the new safe and sustainable by design (SSbD). In addition, the Draghi Report underscores the need to keep means of achieving this while keeping the sector competitive. In order to ensure the sustainable and technological future of Europe, the two ambitions must come together to ensure European strategic authonomy. This will require **new design frameworks and business models to ensure economic competitiveness while addressing climate imperatives** in accordance with the needs of quintuple helix stakeholders.

In ***Table 1***, we offer an overview of the legislative pillars highlighted in the EC report *Transition pathway for the Textile ecosystem* (2023). There are several inter-relations between the aforementioned proposals, especially in terms of data disclosure; however, there is limited clarity about what will remain mandatory. The continuous development in EU legislation is shaped by negotiations involving many stakeholders. Scope reductions – such as the one proposed in the Omnibus Package for CSRD – recognize the gap between ambition and practical challenges, as well as the compliance burden that SMEs in particular will struggle to bear due to increased costs for reporting. Businesses may achieve exemption or face **uncertainty about how the various performance indicators will be used besides monitoring purposes, and how it will affect their business models, for example through ESPR and DPP compliance.**[39]

Monitoring will bring more clarity about the economic, social, designerly, and environmental hotspots, but it is not sufficient to boost investments and innovation, nor to correct market failures like overproduction and pollution. Therefore, legislators could give clearer guidance about the rewards of compliance or the penalties associated with failure to provide accurate reporting. Detailed material information could help shape the dialogue around benefits and costs in a transparent manner, accelerating consensus building and policy definition. In the next two sub-sections, we discuss more in detail some of the proposals from ***Table 1***, as well as other policy instruments that are often overlooked in the attempt to understand production volumes.

3.1 Global trade: overproduction, transparency, and regulation

The outstanding challenge - largely unaddressed by current policy proposals - is how to tackle overconsumption, bringing volumes to a "sustainable level". At the same time, asking: "How can we achieve better environmental performance without incurring economic stagnation or even degrowth?" in order to maintain our social system. Following World War II, economic growth and international trade proceeded in parallel, with global exports growing exponentially across all industries[40]. The textile sector followed this trend after the Multi-Fiber Arrangement (1974) and the General Agreement on Tariffs and Trade (GATT)[41], with trade volumes growing rapidly in the EU and only leveling off in the past decade, in parallel with imports from extra-EU countries and total clothing consumption[42].

As we have seen in section 2.1.1, the TCLF sector's contribution to economic growth is limited as most of the European countries are net importers,

38 https://environment.ec.europa.eu/strategy/textiles-strategy_en
39 EURATEX response to the European Data Union Strategy Consultation highlights the operational burden of compliance, especially for SMEs, but it remains vague about specific data applications.
40 https://ourworldindata.org/trade-and-globalization
41 World Bank (2019) - Link
42 Data from EEA - Link

Table 1: Overview of EU policy proposals and data implications

Policy name	Description	Schedule	Data implications
Pact for Skills (PfS)	Promoting lifelong learning and raising attractiveness of the TCLF sector. Aligned with ESPR.	Launched in 2020	Openings and skills, supply and demand monitoring
Chemical Strategy for Sustainability (CSS),	Research on best chemicals for finishing and coating, and on the use of biodegradable materials.	Started in 2020 and regularly revised	Updated list of contaminants and chemicals
Textile Labeling Requirements (TLR)	Revision aiming for EU-wide and global alignment, classification of new fibre technologies and caring. It is now embedded in ESPR.	Revision started in 2024	Additional data points and format revision on product characteristics
Corporate Sustainability Reporting Directive (CSRD)	Company reporting on a large variety of quantitative and qualitative indicators, simplified through the Omnibus package.	Initially expected to be implemented between 2024 and 2028	To be clarified
Waste Framework Directive (WFD)	Establishes a waste hierarchy for different treatment options. This is also linked with the ESPR.	In effect from 2025	Qty sorted waste by reporting authority
Extended Producer Responsibility (EPR)	It makes manufacturers legally accountable for the waste and pollution associated with their production volumes.	Expected to be implemented across the EU-27 countries by 2027	Information on new products put on the market (quantity) and quality
Market Surveillance Regulation (MSR)	As part of ESPR, it ensures that all products in the EU market comply with the regulation and that disclosed information is accurate.	Proposed in 2022, and adapting to the schedule of the other policies	Companies will have data on their products portfolio and processes
Ecodesign for Sustainable Product Regulation (ESPR)	As part of the CEAP, it determines a list of design characteristics and criteria that improve circularity.	2025-2030	Characteristics of products affecting durability, repair, recyclability, etc.
Digital Product Passport (DPP)	As part of the ESPR, it will display for every product line a large variety of information accessible to users, businesses, and authorities.	Implemented in 3 phases (2027, 2030, 2034)	Supply chain data, info as established by ESPR criteria

purchasing finished textile products from Asia and exporting intermediate products such as technical fibres and high-quality fabrics[43]. **If the EU were able to reshore (or nearshore) most of the production and bring the TCLF sector into surplus** (with the value of imports lower than the exports), **it would probably also improve transparency and environmental performance.** The textile production will most likely use cleaner energy and better water management systems than Asian countries, still heavily relying on coal. However, the EU will have to face costs to internalize the side effects of production: more industrial waste and pollution will be generated continentally.

As we familiarise ourselves with the trade-offs between economic and environmental performance, primarily related to product quality (which will be thoroughly described in the DPP), we keep wondering if *green growth* is actually possible with a stagnating volume of sales. Even if we would learn to make cleaner, more durable products, **the challenge with decoupling economic growth from environmental impacts[44] lies with the imperative to always grow and to sell as much as possible.** So, how do we tackle overconsumption if there is a perennial surplus of production set upfront by uncoordinated market players? As on-demand production remains an utopian idea, the issue can only be tackled if national authorities have the data to understand what appropriate levels of production, supply, and use are possible and recommended.

Many scenarios from the industrial ecology school attempt to assess interventions and quantify impact reduction, with the two main classes of policy interventions associated with *sufficiency and substitution strategies*[45]. In a report from the Dutch ministry focusing on circular textiles[46], demand reduction appears as one of the goals to pursue through pricing and taxation interventions. Some of the boldest and most progressive instruments still largely unexplored for textiles are: cap and trade systems (i.e. EU Emission Trading System), carbon credits, progressive taxation, and other **schemes that attempt to regulate the quantity** or the volume of production.

Cap and trade systems have also been proposed for textiles on rare occasions[47], but they would have to be tested carefully to avoid undesired effects, especially for SMEs that have limited financial capabilities. However, as we are about to see in the following section, the EPR scheme might also include a progressive fee based on quantity, which might help to mitigate overproduction issues while leaving SMEs competitive.

43 *From the the EEA report "Textiles in Europe and Circular Economy" (2019) - Link*

Economic notion #2: Limits to growth

Competing businesses do not coordinate between each other to establish optimal production volumes, and governments only set limits to growth in a few sectors (i.e. constructions). Even more concerningly, governments actively seek to maximize their economic output (GDP) without acknowledging that **long-term (exponential) growth might not be realistic** (not for every country at the same time, nor for anyone for an indefinite period). The Club of Rome was among the first with their Limits to Growth publication in 1972 to warn the European states about the consequences that will likely stem from the current economic model imposing GDP growth as the only way to repay debt. In 2023, the European Parliament hosted the second edition of the Beyond Growth Conference, showcasing unsustainable elements of the current economic model and opening the public debate between exponents of the Green Growth, Post-growth and Degrowth schools. Despite they all agree on the urgency to review the system for resource distribution (i.e. fiscal regimes), they diverge in the feasibility of a sustainable and just economy without growth.

3.2 Extended Producer Responsibility (EPR)

Following the outcomes of EPR legislation in the electronic waste management[48] and its integration with the Waste Framework Directive (WFD), the TCLF sector is now next in line for the implementation of these new schemes. **The idea behind the policy is that producers will have to be held responsible for the waste their products will generate and pay a fee**

44 *Publication from EEB, Parrique T. et al. (2019), Decoupling debunked - Link*
45 *Holzinger, H. (2020) - Link; Hurmekoski (2024) - Link; Vladimirova, K., Samie, Y., Maldini, I. et al. - Link.*
46 *Ministry of Infrastructure and Water Management (2024), Policy Programme for Circular Textile 2025-2030 - Link*
47 *Article from Textile Focus - Link*
48 *Environmental Protection Agency - Link*

EPR fee structure recommendation

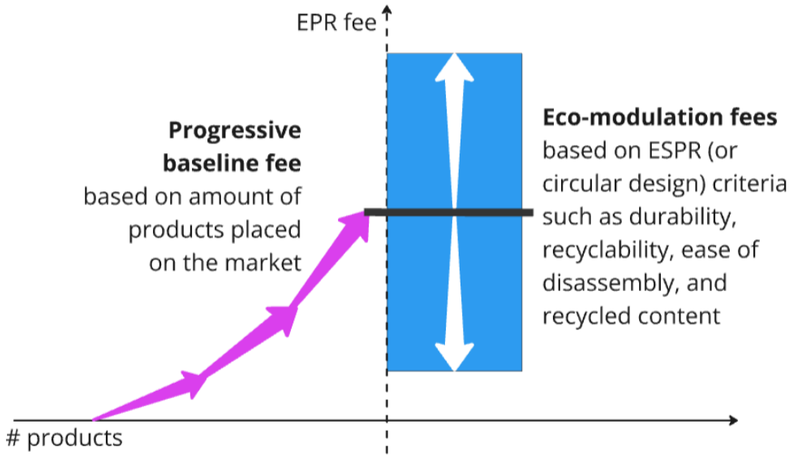


Figure 9: EPR fee structure proposal in France (adapted from Ellen Macarthur foundation, 2024)

for their future disposal at the moment they enter the market. The EPR sets the price in advance and generates funds for the facilitation of waste collection, treatment, and the various circular processes spanning from repair and reuse to sorting and recycling. France is the first member state in the EU to explore the EPR schemes via the Re-Fashion organisation since 2008.

A study from the Ellen Macarthur Foundation[49] provides insights into the experience from Re-Fashion, the appointed Producer Responsibility Organisation (PRO) in charge of implementing EPR fee collection and redistribution. An important aspect mentioned in the report is that **EPR fees for new products will only have a significant impact if this is sufficiently high in relation to the price of the product.** In the figure above (adapted from the report), we can see the presence of two components:

- **a progressive baseline fee**, based on the quantity of products put on the market (in an attempt to tackle the overproduction challenge discussed in the previous section); this element is rarely discussed due to the political sensitivity of non-linear schemes[50].
- and a fee differentiation (or **eco-modulation fee**) based on circular design criteria from the ESPR.

The logic behind the fee structure is very sound from a theoretical economic perspective and it is gaining momentum in research and policy-making. In the Circular Taxation report from Eunomia and EEB[51], the **authors explain that it is important to gradually adjust the differentiated fees over time to avoid undesired effects and market shocks.** For example, they report case studies such as the gradual (and persistent) increase of the incineration and landfill tax in the UK, which boosted the amount of waste sorted for recycling over time at the municipal level. They also point out that earmarking tax levies for specific sectors and purposes is a good practice to avoid financial spillovers. Although EPR schemes are managed by PROs with a certain degree of independence from the government, the concept of collecting levies from textile producers to finance circular activities in the same value chain is a good example of earmarked tax revenues (even if some prefer not to call it tax).

In a recent article from one of the most prominent Textile industry experts in EU[52], the widespread adoption of EPR fees also appears among the most regarded levers to accelerate the transition towards a circular economy. The objective of these fees is to increase the price of products made of virgin materials, with short lifespans and hard-to-recycle, and to lower the price of circular products made of recycled materials, durable, and easy to repair. However, the success of these schemes also depends on the considerations about the geographical scope, as exporting businesses could face EPR compliance barriers in every member state if the EU does not harmonize the implementation. Finally, it will be crucial to understand the interplay with existing tax levies, such as Value Added Taxes, import and export tariffs, income taxes, and other environmental taxes (i.e. carbon tax) to reduce the negative effects of overlapping fees. Jobs in repair and recycling activities, typically operating with residual value, can become more competitive if the net wage would be higher and the businesses would experience lower financial pressure in the hiring of workers[53].

To summarise, **there are several options available to governments for tax differentiation but they need to be well thought out and balanced (over time) to achieve the substitution of products and making circular alternatives more competitive** (including second-hand clothing, items containing recycled material, or reused components like sleeves). In the attempt to achieve a significant impact, all instruments considered so far (like EPR fees, VAT, import tariffs, and income tax) need to be assessed with specific goals in mind, for example, reducing the material and carbon footprint of a region associated with the consumption of textile products. This logic of taxation is based on the old economic theory of externalities, according to which the social cost of pollution, waste management, and environmental degradation has to be paid in proportion to the contribution to the damage.

Taxation has long been considered as an important instrument to deal with market failures[54] such as externalities, but little progress has been made in the last century to embed them in a coherent system of prices, and not just in the TCLF sector. If the social costs of production and consumption had to be internalized in the economy in the years to come, also thanks to the legal development of EPR schemes, would we be able to see a more just and circular economy? It relies on Cost-Benefit Analyses (CBA) the burden of proof that recovering value from used textiles is more convenient than burning them or exporting them. What is certain nowadays is that the **technical feasibility of complex coordination systems of incentives for value chain collaboration is not a barrier anymore.** Data is flowing in large amounts into sparse databases and KPIs on environmental performance are already in use to monitor and facilitate the twin transition. In the next section we will look at some concrete examples of data applications that are promising to improve the way the textile ecosystem operates.

Economic notion #3: Externalities

Back in 1920, in a foggy industrialized England, Arthur Pigou came up with a new ground-breaking theory based on the concept of externalities. By definition, externalities are all those impacts stemming from the production and consumption of a product, affecting also people that are not involved in the transaction. Pollution is the biggest example as it spreads through air, water, and soil and affects people who live and work in the proximity of a production plant. They might bear the costs of dealing with pollution even if they have no stakes in the production activity, nor in the consumption of the product. The Pigouvian tax was then introduced as a way to compensate for the environmental damages and to achieve a new equilibrium in welfare.
This theory was, in many ways, a solution to reconcile the welfare economic models with the physical reality, introducing the idea of (external) social costs based on the geographical proximity. The critics of this theory have managed to slow down the adoption of Pigouvian taxes, arguing that it was almost impossible to calculate them and that markets could provide the mechanisms to offset the externalities (Coase theory, 1960). Today we can find a few example of taxes on externality like carbon tax and plastic tax and, with the development in EPR fees, externalities and social costs will be accounted for also in the TCLF sector.

49 *From Ellen MacArthur Foundation (2024), Pushing the boundaries of EPR policy for textiles - Link*
50 *As mentioned during the ECOSYSTEX conference by some insiders of the French ecosystem.*
51 *Eunomia, European Environmental Bureau (2022) - Link*
52 *Article from Lutz Walter: "Is the Textile Circular Economy out of touch with reality?" - Link*
53 *Studies from Ex'Tax advocate for a just transition towards a circular economy by gradually shifting the tax burden from people to natural resource use. Their papers also include mathematical calculations to demonstrate that the overall fiscal revenues of the Netherlands and the EU can remain constant, if the material and energy taxes are calibrated in parallel with income tax reductions across different sectors. Differentiation would need to take into account the type of economic activity that generated that income, and circular activities (jobs) would have a chance to thrive. - Link*
54 *https://scholarship.law.upenn.edu/cgi/viewcontent.cgi?article=2787&context=faculty_scholarship*

4. Digitalization

As new digital technologies are being adopted in the textile industry, the transition still appears to be happening in silos. In order to protect Intellectual Property (IP) and to preserve their competitive advantage, most businesses are reluctant to share information about their production processes and quantities. In this chapter, we challenge protective behaviors and demonstrate how information sharing can create new opportunities, potentially reducing the costs of duplicative efforts and gaining traction by working in the same direction. Indeed, various digital applications are spreading with the potential of enhancing collaboration among different tiers of the circular value chain, as well as between authorities, users, citizens, and workers. Figure 10 shows some examples of digital applications along different scales: macro, meso, and micro.

4.1 Macro applications: government monitoring and policy calibration

With the new disclosure requirements, it will be possible to account systematically for resource use and trade (in tons and in euros), reducing assumptions, uncertainty, and efforts in modelling results. Despite legislation being notoriously slow, **the information that underpins policy decisions will surely flow faster than ever, removing part of the uncertainty that hinders decision-makers from carrying out their work more efficiently.** For example, with the implementation of EPR and DPP, governments will be able to monitor changes in production and consumption (impacts) almost in real-time, allowing them to embrace a more dynamic approach to policy-making. In this section, we will discuss how data availability is favouring traceability and the mapping of ecosystems, providing a more complete picture across the Economic, Environmental, and Social spheres and their inter-relations (as we initially discussed with Figure 2), potentially paving the way for leaner processes in policy-making and regulation.

4.1.1 Mapping ecosystems

In recent years, the spread of Material Flow Analyses (MFA) has sparked interest in ecological assessments on systemic levels, focusing primarily on material extraction, consumption, and the recycling ratio. Many baseline analyses have been performed at the national, regional, and municipal level to identify hotspots to improve their performance in terms of material efficiency and circularity. Different

The different scales of application of digital and analytical tools

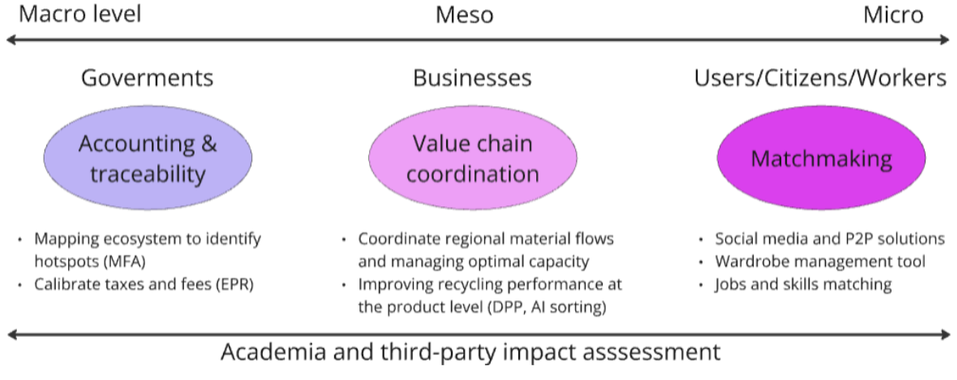


Figure 10: The three domains of digital solutions by scale of application and examples tailored for different stakeholder classes (governments, businesses, users).

organizations, such as Eurostat and Circle Economy, are making **use of MFA data and calculating new sustainability indicators, such as the circularity score, for various regions and countries while providing recommendations on circular strategies** with the biggest expected impact (scenario analysis).

While the MFA - often visualised with Sankey diagrams - **provides an idea of the magnitude of the different material flows of the textile sector, geography and resource distribution is often overlooked.** The HvA has carried out an experimental study as part of the NewTexEco project[55] to map geographical locations of all textiles businesses registered in the Netherlands (KvK). Making use of web scraping methods and text analysis, we can retrieve additional information, generating tags to describe business activities and specializations, creating hybrid classifications, and estimating company size (i.e. number of employees). With the new mandatory information required by the EPR and ESPR (and possibly CSRD), it will be easier to **track or estimate the contribution of each business, region, and tier to the total resource consumption** and other impacts such as carbon and water emissions. Indeed, it is likely that MFA analyses will be updated on a more regular basis and policy-makers will have improved visibility into the effectiveness of their policies.

From the government perspective, **it is crucial to increase the visibility of domestic and import contributions to specific material flows** (i.e. wool), **in the attempt to influence both quantity and quality of textile products** - for example, making use of differentiated trade tariffs. However, in doing so, policy-makers need to consider the firms' capability to adapt, modifying material requirements and upgrading technologies. In our research, as part of the Textile Ecosystem Living Lab (TELL), we make the distinction between SMEs, multinationals, and digital front-runners to facilitate the development of different support strategies from the modernization or scaling-up of textile businesses.

In modern digital marketing applications, **clustering methodologies are often used to tailor different strategies** to improve user engagement. Similarly, **the government can use this approach to distinguish the needs of textile companies and provide**

55 *Textile Ecosystem Living Lab (TELL) on NewTexEco website - Link.*

Textile Ecosystem Living Lab (TELL)

Using a combination of official sources and secondary data collection methods, the TELL can improve the transparency and visibility of the textile ecosystem and the companies that operate within a geographical space. The tool consists of an AI data scraper, a dashboard, and an input form through which users can interact and request their initiative to be listed.

Use case examples:

- Map and monitor contributions of regions to value added, employment, material flows in textile, and environmental impacts (for national and regional governments).
- Identify businesses according to their tier, dimension, specialization, and their readiness level on themes like technological innovation, environmental and social care, and compliance (for academic use, funding bodies, and business coalitions).
- Search for local suppliers and nearby clients through the use of advanced tagging (for businesses to find new partners).
- Reach out to businesses for communications, surveys, and support services using tag filtering for specific clusters - such as SMEs, multi-nationals, and front-runners (for government to interact with and support businesses).
- Facilitate Market Surveillance detecting non-compliant firms, for example, by spotting inconsistent data in textile (as per EPR and DPP) and financial value (tax authority) (for national government to monitor business compliance).
- Facilitate matching of job openings with people with specific skills at the intersections of textile design & manufacturing, computer science, biology and chemistry (for citizens, students, workers to find businesses and vacancies).

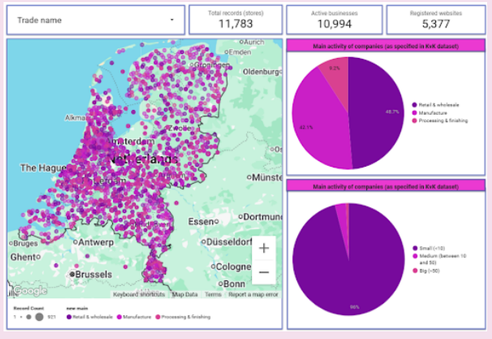


Table 2: Proposed clustering of textile businesses

Cluster	Data capability	Supply chains	Investments
Digital front-runners	Automated collection (i.e. via platforms) and advanced data applications	Reliance on a regional network of suppliers and providers of co-production services	Access to public and private funds during their inception, mainly due to their innovative model
Multinationals	Large data availability from different suppliers but privatised	Several weeks of lead time, with material sourced from multiple countries	Large resources from operating profits
SMEs	Limited information on their supply chain and alternative materials	Reliance on a few suppliers, often local wholesalers	Limited capability, rarely access to public or private funding

Note: Proposed clustering of textile businesses based on data capability, supply chain characteristics and possibilities for investment. The remarks in green refer to great potential, whereas the remarks in orange refer to the limitations.

adequate support. In Table 2, we summarise some of the characteristics of the three clusters we have considered as part of the TELL. The first aspect is the data capability, with digital front-runners getting most of the data through platforms with automated data flows and cutting-edge applications (i.e. real-time customized recommendations). Some examples of the Dutch organisations from this cluster are listed in the report from RVO[56], along with other virtuous initiatives developing web services to facilitate co-creation, co-use, and care of textile products.

Instead, despite the large availability of data from suppliers, **multinational companies can still suffer from "path dependency" due to inflexible data infrastructure, technology, and long-term contracts with suppliers.** SMEs instead have limited amounts of data, typically placing orders from wholesalers, and lacking the resources and skills to improve their technology and IT systems. Another difference lies in the supply chain, with multinationals placing large orders of finished products from several countries. **SMEs have smaller product volumes and styles on the market, reducing their negotiation power and their margins from economies of scale.** Their prices, as a consequence, tend to be higher, making it crucial for smaller players to find a niche market or specialization, producing quality products that justify higher prices. This characteristic puts them in a suitable position to embrace on-demand co-production processes, limiting, as much as possible, unsold items in their inventories.

Lastly, **we consider the access to public subsidies and private investments as the basic means to innovate and scale up technologies**. SMEs can be eligible for small subsidies in cascade funding in collaboration with academic partners, but their possibilities are limited compared to multinationals and front-runners. And yet, facilitating the transition to a circular economy requires also enabling small players to access innovation as they constitute about 98% of the textile ecosystem (Eurostat, 2021). Hence, the government can support the different clusters in the following ways:

- **Digital front-runners** can receive funds to accelerate their growth and scale up the impact, hiring new specialists, and obtaining a bigger visibility, which will cause an interesting development as the EU will soon require all businesses to be digitalized.
- Multinationals can also apply for funds for the acquisition of new IPs and **technological upgrades, especially when they contribute to "cleaner" production processes,** for example, financing the installments of solar panels on factories, or water and waste treatment plants.
- Domestic SMEs with lower EPR fees - due to their smaller volumes of sales and externalities - will be **supported in knowledge acquisition, with access to public IPs, digital technologies, labour training, and hiring subsidies.**

56 RVO et al. (2025), "The Dutch circular textile industry:The time for circularity is now" - Link

4.1.2 Algorithmic calibration of incentives and the fees

For governments to better represent the interests of citizens and maximize their welfare, it is important that externalities are addressed. We can expect legislators to accelerate the circular transition and reduce the trails of destruction that the market failures leave behind through pollution. Think of the clothing mountain that gets burned every year because the market does produce quantities based on unrealistic demand predictions. Besides lobbyism and self-interest, what often prevents and postpones regulation is indecision. **With a clear overview of the ecosystem size and flows, governments can determine trade tariffs and eco-modulation fees, empowering change-makers and eco-conscious businesses** to make a positive impact on the environment and society.

Business incentives to sustainability will follow the implementation of a structured digital accountability system (as imposed by EPR, DPP, and other legislations), which will provide the foundation to calculate eco-modulation fees based on quantitative and qualitative criteria. **As the data exchange is enforced and gradually automated, the calculation of fees can even be suggested by Machine Learning algorithms**[57]. An essential characteristic of these models and algorithms is that they improve with time thanks to feedback loops, allowing fees and levies to adjust based on the goals they support and try to optimise (Circular Taxation, Eunomia, 2023). For example, if the goal of one region is to minimize textile waste incineration and landfilling, the function will have to determine the optimal levies for different businesses and sub-sectors to reduce unsorted waste and maximise value recovery from EoL textiles.

The evolution of **the fiscal system needs to consider the role and the targets of circular activities - such as repair, re-manufacturing, sorting, and recycling - that will need to consistently rescue the residual economic value of used textiles.** These players deserve and require a better regime to operate sustainably, also from the financial and social perspective, breaking even every year and providing a safe working environment to people. Like stock markets continuously generate new prices for traders, externalities taxation can be adjusted on a regular basis using mathematical models.

57 The algorithmic calibration of tax levies is not new in Europe. In the article 'Behind the One-Way Mirror: Reviewing the Legality of EU Tax Algorithmic Governance' from David Hadwick, the opportunities and challenges of AI in tax governance are extensively discussed.

4.2 Meso applications: business cooperation and IP sharing

As the system of incentives comes into effect through levies and subsidies, allocating the right amount of funds to various R&D projects becomes crucial to boost progress. Academic institutions and private businesses often partner up to develop knowledge around specific topics that require collaboration and expertise from different domains. For this reason, **the NewTexEco research community is taking a multi-disciplinary perspective into account from all stakeholders, which helped to identify a wide range of recurring themes in the Dutch TCLF sector**[58]. With the backing of public funds, data collection, and dissemination of new ideas, the seeds for innovation can be spread. And when research efforts result in new patents, they can be made accessible to various SMEs and market players, generating higher value for society and economy, and avoiding privatization practices that could delay diffusion (Eppinger et al., 2021; Mazzucato, 2018).

4.2.1 Cooperation in the circular textile value chain

One of the reasons why business as usual cannot solve the markets' systemic failures, such as overproduction, is that there is no perfect information about the demand or about the quality of clothing and textiles. Data sharing will improve coordination along the supply chain in several ways, for example, when a secure protocol for DPP is established and adopted by all businesses in retail and manufacturing. Authorizing sorters and recyclers to access detailed information about their products, they might be able to increase recycling rates. Hence, the concept of **data spaces is emerging to ensure that the exchange of information occurs in a secure and seamless fashion within**

58 https://newtexeco.nl/newtexeco-presenteert-plannen-op-circular-textile-days/

business cooperatives and project consortia.[59]

At the same time, cooperation groups need to be inclusive with new incumbents. Digital start-ups like Byewaste and Droppie were born with the necessity of providing cleaner waste streams to recyclers. Although their operations might enter into competition with each other and with existing collectors and sorters (like Sympany, which is responsible for collection through municipal containers)[60], they are all contributing to building capacity for value recovery from used textiles (Indirect Reuse flow shown in Figure 7). Filling the operational gap between collection, reusing, and recycling is also a matter of improving the sorting processes through geographic coverage, increased technological capability, and also a well defined role division.

Players involved in collection and sorting can scale-up their operations by **using new AI applications that facilitate textile features recognition from material composition to the aesthetic qualities**. Sorters will need to learn, also through collaboration, to perform functions similar to brand and retailers: defining the quality and appeal of used clothing. A combination of digital tools, such as DPP and AI models trained on image recognition, and human skills spanning from data science to the design domain, may perform sorting tasks increasingly well together. Besides the detection of reusable items and the matching with new users, which might be more localised, technology can also support the sorting for recycling, dealing with an increasing share of clothing from the fast and ultra-fast fashion and a larger variety of fabric structures and materials. However, less durable items can also be easier to recycle if they are mono-material and less complex[61], as long as this information is communicated (i.e. through the DPP).

59 EU-funded projects like SAGE - Link

60 In an article from Circle Economy and AMFI interviewing Boer Group, the profitability of big sorters is explained as well as its dependence on the reusable share.

61 During the ECOSYSTEX conference, the tExtended research consortia has pointed out the need to distinguish between products that are optimized for durability (usually more complex) and those that are optimized for recyclability. - Link to the project website.

DPP model in Phase 2 (2030) from the European Parliamentary Research Service

Figure 14 – Advanced DPP Model for phase 2

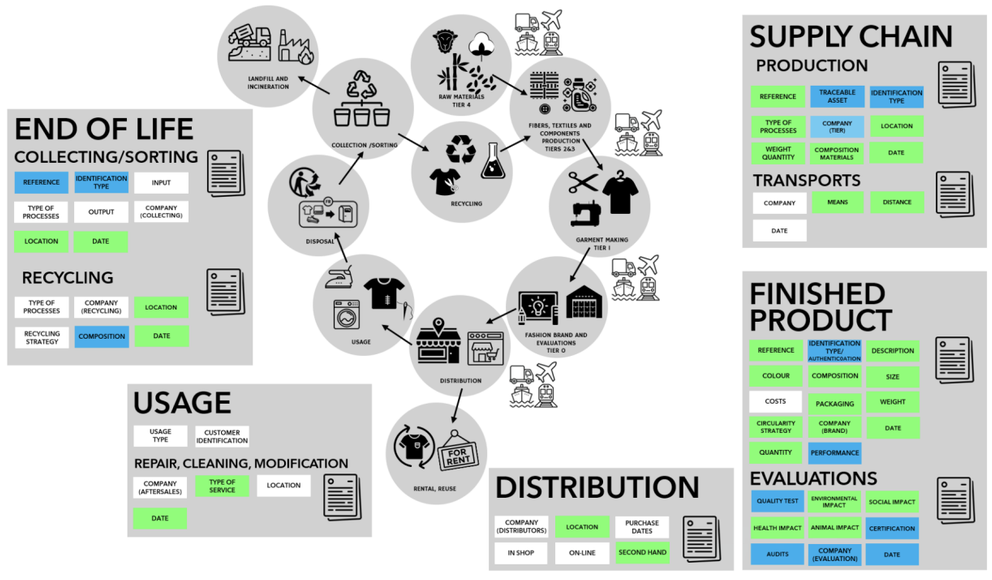


Figure 11: DPP models across the supply chain tiers and life cycle, including the definition of the data building blocks from the EU Parliament report “Digital Product Passport for the Textile Sector” (p. 37). In green, the mandatory information, and, in blue, additional information for lifecycle analysis.

4.2.2 Impacts quantification and LifeCycle Assessment (LCA)

The quality assurance of textile products has become a prominent debate and has brought to the widespread adoption of LifeCycle Analyses and the legislation of DPP requirements. Across different tiers of the supply chain, textile producers are demanding a higher level of transparency and to purchase third-party assessments, certifications such as EU Ecolabel, and product declarations (i.e. EPD), particularly for home textile producers. Despite the evolution of ISO standards and databases like EcoInvent, **the challenges of LCA methodologies to account for longevity and recyclability remain**. The digitalization of material libraries and product labels will have to take further steps also to make LCA tools more usable and accessible for SMEs.

Sustainability front-runners in the Dutch manufacturing sector, like BYBORRE, have been long preparing for DPP compliance but without much certainty of their economic return from durable products, also containing a share of recycled materials. Perhaps, it will become clearer between the first and the second implementation phase (2027-2030) with a large variety of data points displayed for each product, as shown in Figure 11. If the DPP will carry all the information about the social and environmental impact (LCAs) while tracking the geographical movements, the algorithmic calibration discussed in the previous section becomes utterly possible from a technical perspective. **The next challenge will be capturing the territorial impact, as some countries and regions have fewer resources than others or more pollution**, to fine-tune impact weights and the estimation of optimal levies. For example, regions with scarce availability of water, like Australia, can apply bigger weights to textile manufacturing processes that use large volumes of water while they can be less strict with land use. The opposite example is the Netherlands, where fiber cultivation is less convenient, as it would compete

Textile Material Living Lab (TMLL)

Following the development of material samples libraries across universities (primarily for education purposes), the need is also extending to businesses to spread knowledge around the characteristics of textile materials. Creating a shared knowledge base on physical properties and production impacts of mainstream as well as new materials can improve the decision-making processes of brands and designers.

The TMLL is under development as part of the NewTexEco research community to support the visualization of material properties and the recommendation to design students and professional makers to choose and experiment confidently while reducing material waste.

directly with the agrifood sector, but can exploit the economies of density of used clothing to produce secondary (recycled) materials.

However, **what information system will be used to determine the lifespan of textile products is still unclear**, as current LCA methods mostly use cradle-to-gate and neglecting longevity from their considerations. It is possible that users will play a role in the near future, validating longevity estimates and, together with retailers in take-back programs or waste collectors, provide inputs to DPP when the product is approaching End-of-Life. We will discuss in the next section how users can contribute to bottom-up estimates, giving a better glimpse into textile usage behavioral patterns. Because textiles are not only discarded when they are damaged or "consumed", there is a lot more to be considered than physical durability, leading researchers to include emotional durability in their considerations to outline Product Environmental Footprint Category Rules (PEFCRs).[62]

4.3 Micro applications: digital tools for citizens and workers

The participation of users in digital applications has already made them an integral part of the fashion world. Since the mid 2000s, the proliferation of recommender systems has been stunning and at the same time widely overlooked[63]. Billions of digital users have started embracing **content recommendation** (i.e. videos on YouTube and music on Spotify), news feed (ie. on Facebook and Instagram), and other "related products" suggestions without truly realising what sort of machine (or "engine") they were dealing with. The awareness of being users (and items) inside massive databases, each one characterized by many descriptive features, only began to spread in recent years. It is **the advertising industry to first deploy this technological breakthrough on a large scale, and the textile sector is among the biggest beneficiaries of the shift away from traditional (expensive) marketing channels for the adoption of custom ads.**

4.3.1 Match-making users and products

As user data becomes increasingly available through social media and digital platforms, **customised product recommendations and targeting has become the new favorite marketing channel for fashion brands and for interior designers** (Shirkhani et al, 2023). This innovation has precious perks for small designer studios, producers, and retailers as they can more easily find their niche users without investing millions in, for example, TV advertising. However, the competition with big brands has exacerbated also on this platform, rallying for users attention and engagement with the aim to predict the next product to sell them.

Chinese ultra-fashion masters like Shein and Temu have brought this strategy to the next level, learning to predict new fashion trends through online user interaction and advertise products before they are even produced. Integrating their e-commerce platforms with a lean production system of Chinese micro-factories, they have made a notable step towards the definition of on-demand mass production processes. Unfortunately, **the efficiency gains have only brought to the flooding of new ultra-cheap, low-quality products into markets**, as if they were not sufficiently saturated with the regular fast-fashion. The same technology would not look so detrimental if it were to serve the purpose of improving the predictions of new garments supply or reducing the mountain of used clothing by matching them with new users. Imagine if the same recommendation engine were to be used to facilitate the matching of re-wearable garments with digital users consciously defining their preferences. Currently, **user preferences are inferred from their online interactions** and, once aggregated, they are sold to other businesses that seek to know more about fashion trends and target the niche with the highest chance of purchasing that style. When it comes to used clothing, only Vinted (in EU) seems to be capable of inferring user preferences with their large database of online interactions and purchases.

However, their activity is limited to the e-commerce of listed clothing for which users have lost the emotional attachment, and that they believe might pay back some money. This activity (the resale of used clothing uploaded for listing) leaves uncertainty regarding wardrobes dimension and composition, and other information that might provide brands, retailers, governments, and researchers with valuable insights on user behavior, for purposes other than marketing.

4.3.2 Wardrobe management tools

Since Maldini's study (2019), a few research groups have started working with wardrobe surveys and deep dives on favorite items - as well as items to dispose - to understand something more about clothing usage patterns. They discover that between 10 and 30% of items are laying idle for years without being used. These items can be either old or barely ever used. According to the Nationale Kledingkast[64], **about a**

62 Eunomia's report for the European Environmental Bureau (EEB) and EC, 'Understanding the PEFCR for Apparel and Footwear: The Role of PEF in Policy' (2022) - link

63 Gérald Kembellec, Ghislaine Chartron, Imad Saleh (2014), Recommender Systems - link

64 Mirella Soyer initiated a survey in the Netherlands with hundreds of user responses, which is among the biggest wardrobe audits

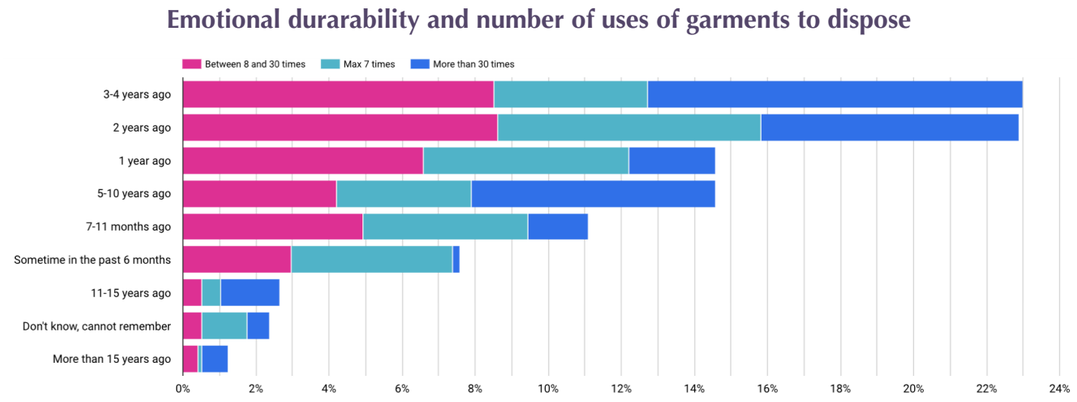


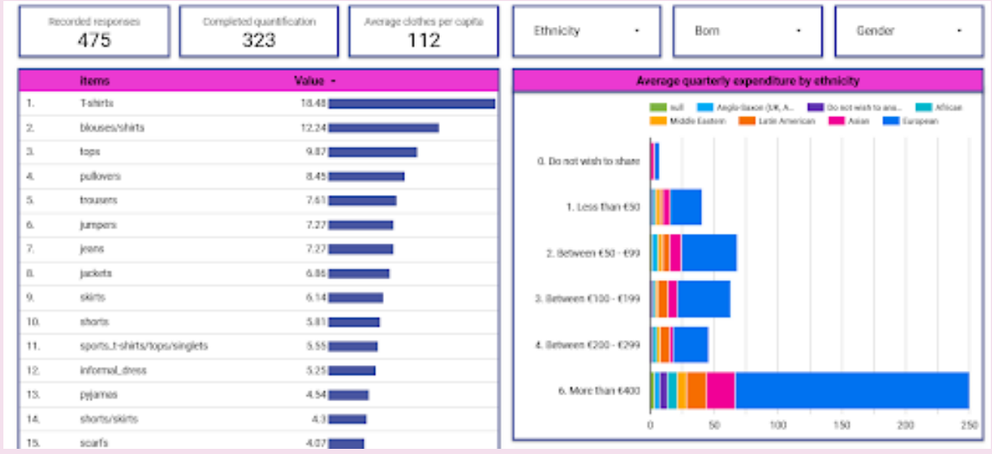
Figure 12: Clothing usage and longevity according to the National Audit from 2024-2025.

Textile User Living Lab (TULL)

Since Maldini's groundbreaking wardrobe study (2019), a growing branch of research is focusing on how people buy, care for, and dispose of their clothes. These insights can help inform textile users, policymakers, and businesses, providing estimates on environmental impacts and the durability of garments.

Use case examples:

- Build a national database of wardrobes, including both quantitative and qualitative features;
- Track progress on sustainable materials, reuse, and recycling targets;
- Develop and test behavioral interventions based on gathered insights;
- Increase user awareness and encourage participants to value and care for their clothes.



third of people's clothing have been worn maximum 7 times, and another third has been worn between 8 and 30 times, leaving us with the suspicion that only a third of them, approximately, have been actually "consumed" and might not be rewearable. Another interesting aspect we can notice from Figure 12 is that some items in the wardrobe might stay even more than 10 or 15 years in somebody's wardrobe despite being worn less than 7 times.

In recent years, **several mobile apps have emerged to help users manage their wardrobe more efficiently,** that is, **by having a better overview of their garments**, their age, color and style combinations, and even connecting with friends to get their recommendations[65]. Some wardrobe apps publicly declare their intent to help users making more environmentally conscious choices - like COSH! (the first 'European' app), Whering, Acloset, Save your Wardrobe) while others mainly focus on providing stats and styling support (Stylebook, developed by Apple, and Indyx). Interestingly, we can even find on some websites lists of KPIs for users to monitor their improvement in terms of sustainability impact. Hereby, a comprehensive list of the indicators that would be available to users and or to other parties who might be interested in accessing them:

- Wardrobe size with breakdown per garment category;
- Yearly variations, including info on new purchases and items disposed;
- Second-hand clothing share, with potential breakdown per garment category;
- Items age, function, and characteristics;

The interest of policy-makers for user surveys and bottom-up statistical evidence has increased, also as a result of scattered information and inconsistency in top-down data collection methods. Hence, **we will see in the next few years a spread of user surveys, wardrobe audits, and - perhaps public - mobile apps for wardrobe management with the aim of tracking clothing usage and consumption.**

4.3.3 Jobs training and skills in textiles

In an age of increasingly connected digital applications, the match-making between workers and businesses has improved the possibility to fulfill specific jobs with rare skills, but also to quickly educate workers to perform highly complex tasks. For example, **training knitting specialists[66] to operate with different machines and design orders to create high value, customizable products**. As part of the NewTexEco project, education programs for new highly specialized jobs become essential for the employment of thousands of graduates from the universities of Applied Science, as well as seniors upgrading their knowledge to better incorporate AI tools in their practice.

From the recruiting perspective, **the textile sector requires very specific knowledge and skills across all tiers of the value chain, from virgin and recycled yarns production to AI for sorting of used clothing.** To conclude the overview of digital applications in textile, we recommend considering **ecosystem tooling, such as the one described in section 4.1.1, as the foundation to develop a networking platform for textile professionals across the Netherlands and Europe**. Establishing an open dataset of all textile businesses is key to this development, as well as giving the possibility to the users to search through keywords that well describe business activities. The Standard Industrial Classification (SIC) taxonomy has some limitations in providing detailed description of textile businesses, especially when it comes to circular activities like sorting and recycling. However, new methods such as web scraping allow for secondary data collection and increased capabilities for the detection and matching of jobs with textile-related skills and locations. **If companies will make a step towards transparency - not only about their products but also about their needs - the digital exchange of information might be beneficial for the whole ecosystem.**

4.4 Summary of digital applications

In the wake of the EU legislation, set to be fully effective by 2030, the textile value chain is undergoing a deep transformation. The data disclosure requirements will not only improve the government's monitoring systems (i.e. MSR) but might also have serious impacts on the economics of the sector (i.e. though EPR fees). Despite the uncertainty regarding their exact implementation, it seems clear that more data at the regional, business, and product level will become available and that those data will influence further decisions. European and the other world leaders are increasingly reliant on the use of data to test and validate policy effectiveness. This obviously leaves some **concerns regarding the ethical aspects of using AI and data models to make decisions that will influence people and society at large, but the urge to keep up regulation and market surveillance with increasingly polluting industries leaves no option than learning to use technology at its best.** Data evaluation models have already been used - somehow unknowingly - in many fields: to evaluate performance of teachers, police, and oftentimes even regular citizens (as explained in Weapons of Math Destruction from Cathy O'Neil, 2016).

The research in the TCLF sector is engaging in data and AI applications to showcase opportunities and to quantify the extent to which improvements are possible. As part of the NewTexEco research community - based in the Netherlands and embedded in continental and global ecosystems - we identify some of the elements that might be necessary for the digital transition to be just and conscious of the environment. **The potential of data to improve processes based on a more transparent and timely information exchange spans from the material innovation and recognition to the recommendation that can influence user and business behaviors.** In Table 2, we provide an overview of the applications discussed and the barriers that are preventing their implementation.

As we might realise, the technological and societal readiness are already considerably high and that European people have been long exposed to most of these technologies. Indeed, we have all been on platforms and apps that **facilitate the match-making between users and content-providers**, and we have all browsed for flights observing algorithmic fee (or price) calibrations. We have familiarized ourselves with the threats (i.e. privacy breach) and enjoyed the benefits of seamless connection and discovery.
We have appreciated and admired the potential of data models and Machine Learning as users, consumers, or private actors, and some of us have started to believe that a better use of technology could improve all our lives. What could go worse and what could go better?

There are a few important barriers (Table 3) to remove before **the most beneficial data applications can create joint value for the TCLF sector and for all the actors in the ecosystem.** One of the risks is to overload servers with data and flooding society with information that they cannot act upon, ultimately creating more economic, social and environmental burdens. But **when data models set as goal the optimisation of (multiple) societal and environmental indicators, then we might see a positive impact for the whole textile ecosystem and society at large.** All means that will be tried to achieve those objectives will have to be carefully evaluated and tested to prevent rebound effects on other indicators that contribute to social welfare. In the meantime, information systems and technology will continue its innovative course, and we hold on to our responsibility to promote a smart use of innovation for higher common goals.

currently available.

65 With the DPP, users might also be able to update their garments on wardrobe apps and integrate feedback systems, reducing some barriers like taking pictures and having to insert features manually.

66 Link to NewTexEco 3D Summer School

Table 3: Summary of the digital applications described in the previous chapter

Level	Application	Principle Users	Barriers
Macro	Ecosystem monitoring	Governments and business associations	Confidentiality demands of businesses
	Algorithmic fee calibration	Regional, national, and ultra-national governments	Political disagreement on differentiated taxation
Meso	AI for sorting and circular value chain optimization	Sorters, Wholesalers, Second-hand stores, Recyclers	Technology costs and IP privatization
	On-demand production in regional microfactories	All actors in textile supply chain	Cost and availability of labour and technology; business model
	LCA tools automation and integration with DPP	Manufacturers, brands and designers, sorters and recyclers	Pressure of LCA firms and assessment specialists to retain exclusive knowledge
Micro	Wardrobe management tools/ apps	Citizens/users, brands and retailers, governments	Reluctance to change behaviour and to buy second-hand clothing
	Matching circular skills in labour market	Workers, businesses (especially SMEs)	Job search platforms are in a competitive market

5. Discussion and Conclusions

The research illustrates some of the ongoing dynamics of the TCLF sector and the interplay between the different actors of the value chain and the overarching ecosystem. All interactions can be meaningful in the attainment of shared value. With globalisation and the offshoring of most of the textile supply, the European ecosystem has bumped into a series of imbalances:

1. From the **economic perspective**, the backbone of European SMEs involved in textile manufacturing and fashion design has been outpaced by multinational retailers importing large quantities of cheap products. Hence, a large part of the value generation happens offshore while large part of the margins are captured by corporate shareholders.
2. From the **social perspective**, the skills required to manufacture textile products are at risk of being lost, with an ageing workforce on the verge of retiring and a new generation that finds wages unattractive and opportunities scarce. Besides the employment standpoint, there are also serious health-related issues affecting society at large stemming from the production and use of textile products.
3. From the **environmental perspective**, the consumer mindset has prompted us to buy "low-grade" products more frequently, generating concerning levels of waste and pollution that the market is not willing (or capable) to deal with.

While the EU ecosystem has offshored a large part of the **value creation process**, the **value recovery** activities have been overlooked and underfunded, making EU a place for distribution and consumption. On top of this, if we consider that circular businesses (from repair to recycling) have been treated as regular businesses in fiscal terms, we can sense that the EU has subscribed to a recipe for failure. One in which people pay to consume products made elsewhere and pay again to dispose somewhere else because the domestic apparatus does not have sufficient capacity and capability to recover value from the used products.

Economic notion #4: Privatization of profits and socialization of losses

Some bold authors like Ayres (2020) have recently contributed to discussions that shed light on the privatization of profits and socialization of losses (or risks). This phenomenon refers to the exploitation of public money, such as publicly funded R&D projects, to create patents that generate private wealth. It also refer to the broader cases of government paying for the failure of banks and big corporates (like in the crisis in 2008), despite profits and rewards are kept within a small circle of shareholders.

Especially when it comes to innovation, the privatization of profits derived from patents is an unfair one. Besides the fact that much of the innovation stems from public money, there is usually a broad range of contributors (like government, academia, and taxpayers) that builds upon previously existing knowledge, making it nearly impossible to attribute a fair share of the innovation to someone. And yet, capital investors and business entrepreneurs have learned ways to make huge amounts of money leaving little even to their employees. As Ayres states:
"[...]I have noted several times that the benefits of technological innovations and economic growth are being captured by a small - and ever smaller - fraction of the population whose actual contribution to the creation of wealth is virtually nil. This situation is closely analogous to that of the urban landowners 200 years ago. The landowners profited from the activities of others driving the growth of cities, and did little or nothing to make those activities more productive."

What we call the "waste sector" operates with products retaining residual value or, in classical economic terms, with undesired goods (or "bads"). **Therefore, these actors need a different fiscal regime to thrive in addition to R&D subsidies and financed machinery upgrades.** As a consequence of inaction, sorters and recyclers in the EU are not having an easy life and even technology leaders like Renewcell[67] have not managed to find a profitable - or financially viable - business model. Despite the strong arguments derived from reputable economic theories on value creation and externalities (or societal spillovers), ultra-national and national governments have not yet found the way to correct the visible paradoxes of the "old" economic system we have lived in.

67 Several articles have tried to analyse the case but none of them mentions the impact that fiscal regimes have played so far in putting recyclers' business model at the same level of manufacturers and other linear activities. However, an interesting article from Forbes (link) explains the challenge that recyclers face operating in the EU rather than having their sites closer to production hubs (i.e. in Asia).

5.1 The role of governments in ensuring a positive collaboration

We have started tracing back the strategy at the EU level as most member states have followed a similar trajectory in terms of trade agreements and economic development since the 1970s. Today, there is a common feeling that change, or a transition, is needed. The **sustainability and competitiveness targets that the EU has committed to achieve will require a revision of strategic partnerships** (Draghi, 2024), such as the definition of activities to nearshore both in the production and the circular phase. And while the new directions are being outlined at the EU level, the member states are attempting to shape a new vision for themselves.

In economics, the role of national and regional governments is to correct market failures and inefficiencies, ensure fair competition, and to maximise social welfare (Randa, 2023). In very practical terms, to achieve those ends, they can regulate markets banning hazardous products or affecting the prices with different tax levies; they can set favourable trade tariffs with extra-communitarian countries based on proximity, or they can put a cap on production and imports specific to garment categories. Ultimately, governments can be active players in economics (Li, Maskin, 2021) as the administrator of the land, water, air, and energy that businesses use for their production processes and that people consume for their living.

To summarize, there are several aspects of government intervention that have been discussed in this paper with considerations to the TCLF sector, and we hope that bold leaders and economists will examine the proposals further:

1. Regulation on quantities might be the only solution to mitigate overproduction and overconsumption patterns reproduced by uncoordinated market players. In particular, **a cap & trade system for textiles should be considered as part of the European Trading Emissions System** (ETS).
2. Taxation is an important lever to reconcile prices with the actual value that products, people, and businesses add. Digital transactions and governance allow for the systemic embedding of (monetary) incentives influencing user behavior and market competition, for example, making used clothing or recycled material cheaper. **The EPR is a first step towards the apt recognition of circular economy activities and the responsibilization of the supply chain**, putting them on different levels of economic competition.
3. Enabling the Market Surveillance Regulation (MSR) bodies to operate efficiently, making use of data disclosure requirements from EPR, DPP, and others to **increase transparency in the markets and reduce health risks for society**.
4. **Review of the norms on the use of IP and accessibility to innovation stemming from publicly-funded R&D projects** (Mazzucato, 2016). Innovation in the TCLF sector is occurring through digitalization, robotization, and AI applications but many SMEs have limited resources and restricted access to cutting-edge technologies. Facilitating the access to regional co-production facilities in textile hubs can boost local economies, create joint value, and perhaps pave the way for on-demand textile manufacturing supply chains.

As we explain in the Econonomic Notions box #4, the innovation that derives from public spending in R&D projects can be subjected to privatization, generating profits and margins that may not be reinvested in the sector that generated them. **Governments, with public funds allocations, can be shareholders of strategic businesses and this could help reinvigorating the TCLF sector in Europe** through the various manufacturing hubs (i.e. Prato, Aachen, and many more). Finally, governments can be promoters of "positive competition" when they tap resources into strategic activities that generate spillover effects for the society, for example, making sure that textile waste becomes the first-choice material for local producers.

5.2 The roles across the value chain in the TCLF sector

It is within a stimulating and observing regulatory environment that businesses can find new ways to collaborate and less reasons to be intransparent. As we mentioned briefly, the vertical integration of the value chain can help reduce information asymmetries with a seamless and automated data exchange, potentially resulting in more efficient and timely production tailored to the needs of the textile users. Digital ecosystems of companies can support the tracking of performance indicators with their challenges in regard to waste minimization. Table 4 summarises the roles of each actor of the value chain as discussed in section 2.2, **keeping in mind that some of them add value, others circulate it, and others recover the residual value**. Prompted to achieve their environmental goals, the economic opportunities for the society as a whole could prevail over the hurdle.

Table 4: Responsibilities and challenges for the actors in the textile value chain

Actor	Roles	Challenges and Opportunities
Semi-finished products	- Regenerative farming (limit soil pollution and excessive exploitation) - Reduce virgin material inputs and increase share of recycled content - Produce durable yarns and fabrics	- Minimize waste in production processes - Minimize unsold inventory
Finished products	- Produce durable textile products	- Minimize water use and pollution, especially from dyeing and finishing - Minimize unsold inventory
Brands/ Wholesalers/ Retailers	- Regulate production volumes to prevent waste (unsold inventory) - Prioritize durable collections over fast fashion products	- Minimize unsold inventory - Improve product performance and material reusability
User	- Buy items only when needed, for example to replace EoL items - Keep good items in circulation as long as possible, taking appropriate care, and reselling or swapping when they remain idle	- Making thoughtful purchasing choices - Deciding what is the best disposal option for their used clothing
Collection	- Facilitate collection from users to avoid unsorted disposal and contamination	- Keeping non-textile waste out of the collection bins and reduce contamination
Sorting	- Separate textile items by reusability (for users or other sectors' businesses) and material composition - Sort items by color for mechanical recycling	- Sorting items with a high chance of being reworn - Finding retailers that attribute a high price to re-wearable items - Finding recyclers that would pay a good price for the rest of the items
Recycling	- Recycle as much as possible of the textile content while limiting environmental impacts - Find different path for the residual materials that cannot be recycled	- Receive garments with clear material composition -Handle contaminated textiles

5.3 The role of textile users and citizens in a digital society

Last but not least, there is potentially a role to play for every citizen to envision and to contribute to a better textile industry and society. Every citizen of the world is also a textile user, from clothing to interiors and many other societal applications, and they can shape the market with their collective choice. **Educating the users to responsible consumption is surely at the foundation of the transition towards a sustainable TCLF sector. Digital information can accelerate the spread of valuable recommendations**, facilitating the matchmaking of users both on peer-to-peer and B2C e-commerce platforms. For example, digital apps like COSH! can develop a responsible mindset for the correct management of clothing, from conscious purchasing to caring, advising on repair and refurbishing strategies, and ultimately facilitating textile circulation and disposal.

As citizens in a digital society, our democratic influence goes beyond purchasing choices and the microeconomic realm. The right to association, participation in NGOs and non-profit organizations, and similar actions are key ways for users to influence politics and legislation. No rules can be taken for granted and the development of a constructive debate is necessary to fine-tune the different instruments and interventions (EPR, ESPR, CSRD, etc.). Perhaps one day there will be a major role for user - or "**consumer" - associations to participate more actively and proactively in the assessment of product longevity and value definition, involving them in Market Surveillance Regulation processes** with citizen science initiatives that improve visibility on textile products quality and compliance, making a safer, resilient, and circular society for all.

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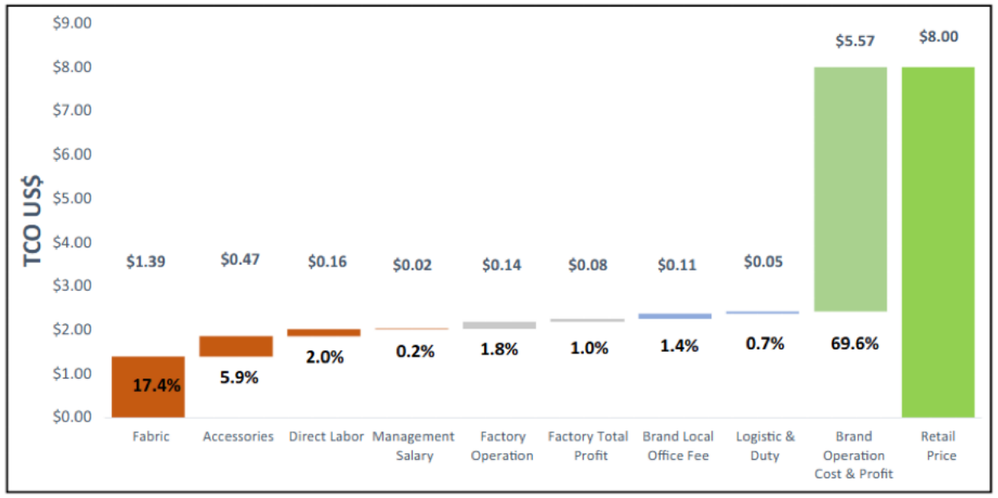
Appendix

APPENDIX A - Average price breakdown of T-shirt sold in US

FIGURE 4
Average T-shirt total cost and retail price [Color figure can be viewed at wileyonlinelibrary.com]



From Handfield, R., Moore, M., Hasan, R. (2020). Addressing social issues in commodity markets: using cost modeling as enabler of public policy in the Bangladesh apparel industry. Supply Chain Management: An International Journal. Link

APPENDIX B - Calculation labour time input on a T-shirt production

The calculation was performed interacting with AI chat Deepseek (link to transcription). The value chain tiers have been aggregated in the following way.

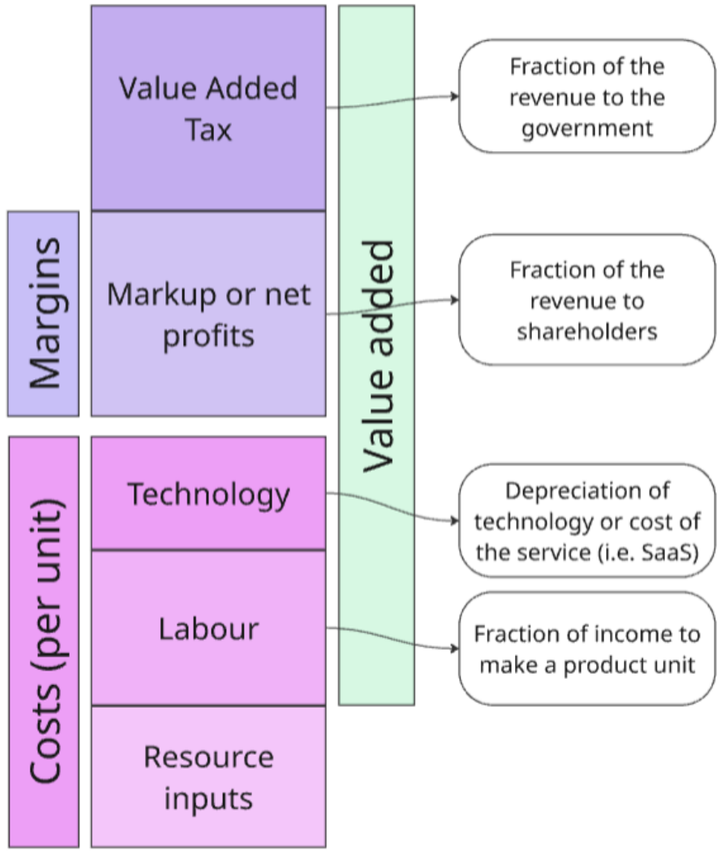
Material, with a **total labour time input** ranging between **0.146 - 0.435** hrs, includes:
- cotton production (0.143 - 0.427 hrs)
- ginning (0.0027 - 0.0081)

Manufacturing, with a total between **0.222 - 0.669 hrs** includes:
- spinning (0.0135 - 0.0405),
- knitting (0.009 - 0.024),
- cutting (0.02 - 0.05),
- sewing/assembling (0.15 - 0.35),
- dyeing/finishing (0.03 - 0.09);

Logistics, with a total between **0.006 - 0.014 hrs**, includes:
- Transport to port (0.0054 - 0.0135),
- International shipping (<0.001),
- Wholesales (0.0005 - 0.003);

Brand and retailers, with a total between 0.01 - 0.053 includes
- Sales associates and cashiers
- Stocking

APPENDIX C: Pricing breakdown (C.1) and factors (C.2) for new and used textiles (own visualisation)



Lifecycle stage	Pricing Factor	Description
Before use	Production costs	Material choice, manufacturing technology, Water and energy consumption
	Brand value	Markup due to the perceived brand value
	Style/design value	Markup due to the perceived aesthetical value
After use	Damages and stains	Depreciation due to incidental damages in the use phase
	Material degradation	Material pilling, colour fading, and other degradation factors due to regular use
	Influence value	Markup due to utilization of influencers or other historical

APPENDIX D - EoL activities for textiles in Europe

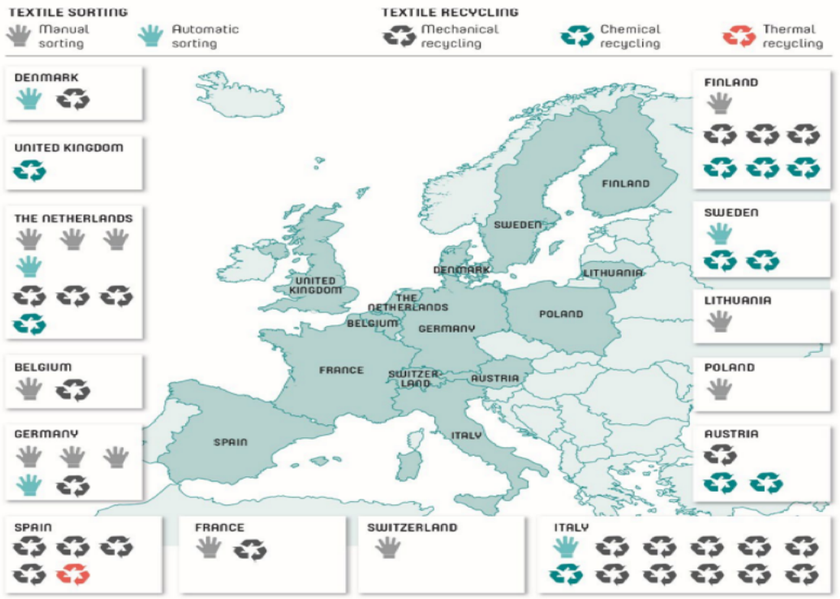
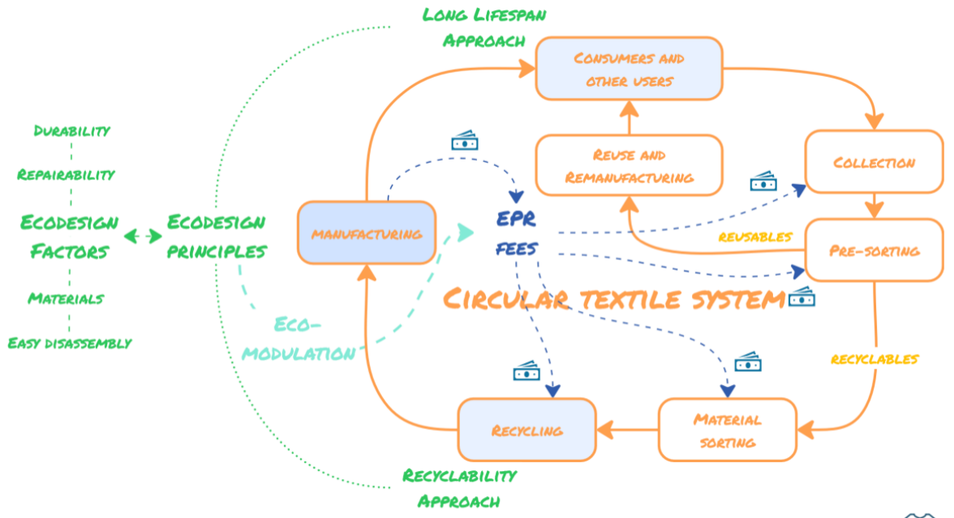


Figure 2. Visualisation of the mapped actors working with sorting and recycling of textiles within Europe (countries with a darker colour has one or more actor), with explanations of the different symbols and colours.

From https://www.diva-portal.org/smash/get/diva2:1733211/FULLTEXT02.pdf

APPENDIX E

Presented at the ECOSYSTEX conference, the framework from tExtended is distinguishing two different design strategies and optimization goals: the Long Lifespan approach (design for durability) and the Recyclability approach (design that facilitates recycling).



tExtended