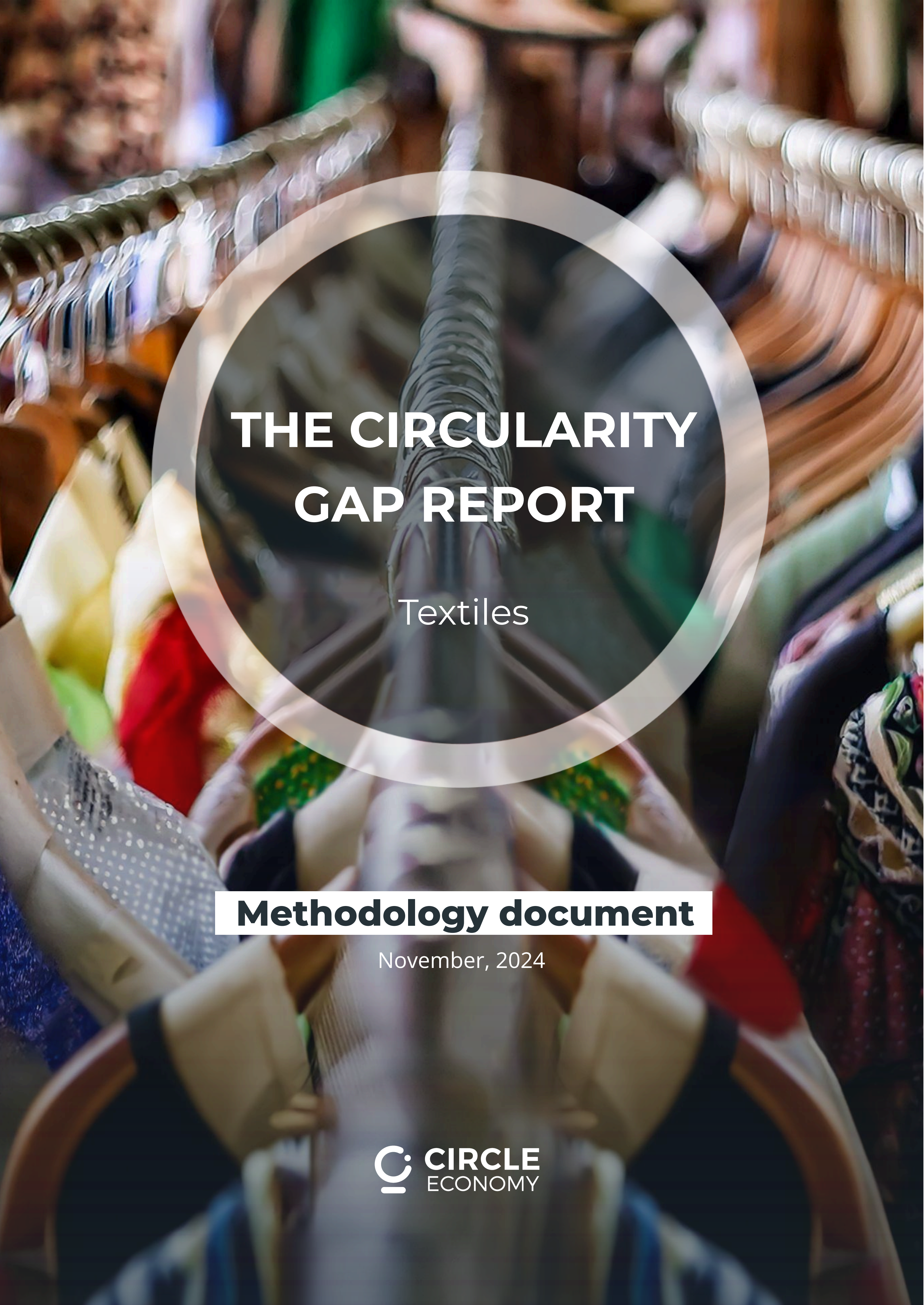

THE CIRCULARITY GAP REPORT

Textiles

Methodology document

November, 2024

CIRCLE
ECONOMY

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1. INTRODUCTION

The concept of circular economy (CE) is gaining increased attention from policymakers, industry and academia. There is a rapidly evolving debate on the concept's definition, limitations, contribution to the wider sustainability agenda, and the need for indicators to assess the effectiveness of circular economy measures at larger scales. To this end, we build upon previous research in an attempt to adapt and apply a framework for a comprehensive and economy-wide biophysical assessment of the circular economy at the global level.[1]

Economies consume material resources, water and energy to operate, a set of processes often referred to as their 'metabolism'. Knowing how materials are extracted, transformed, delivered, consumed and wasted is essential for identifying and addressing opportunities for a more circular economy. While the analysis focuses on materials, their use is largely interwoven with other natural resources such as land and water. At the same time, these processes are embedded within broader ecosystemic relations between nature and people.

The *Circularity Gap Report Textiles* builds upon the foundations laid by the global *Circularity Gap Reports*, and the scientifically validated methodology that sits behind the report. The first global *Circularity Gap Report* was released in 2018 and has been heralded as the first metric on circularity. For the past six years, our *Circularity Gap Report*s have been launched at the World Economic Forum, and have received broad endorsement from leaders across academia, business and policy spheres such as Frans Timmermans, Frans van Houten, CEO of Royal Philips, *Circularity Gap Reports* have received widespread uptake in global media, have driven discussions at the World Economic Forum, and national parliaments, and have been referenced in global studies including IPCC reports.

This analysis takes the socioeconomic metabolism of the global textiles industry—that is, the way raw materials flow through the value chain and are kept in long-term use to meet the population's needs and wants—as the starting point for measuring circularity. We also consider the importance of reducing material consumption. This is because impact prevention through reduced demand is an important first step before exploring other mitigation options—a tenet reflected by environmental management hierarchies wherein reductions of production and consumption, narrowing flows, is always the preferred and most effective strategy.

The analysis of global material flows related to the textiles, clothing, leather, and footwear (TCLF) sector is based on the aggregation and harmonisation of fragment data sets from both peer-reviewed publications and grey literature. This framework builds on the widely applied framework of economy-wide material flow accounting (EW-MFA). On the one hand, it expands it by 'opening up' the economy black box and, on the other, by integrating waste flows, recycling and downcycled materials. The Circularity Indicator measures the scale and circularity of total material consumption and waste flows recycled.

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[1] The *Monitoring Framework for Economy-wide Material Loop Closing*, developed for the EU28 by *Mayer et al. (2018)* and *Haas et al. (2020). See 1)* Mayer, A., Haas, W., Wiedenhofer, D., Krausmann, F., Nuss, P., & Blengini, G. A. (2018). Measuring progress towards a circular economy: A monitoring framework for economy‐wide material loop closing in the EU28. *Journal of Industrial Ecology*, *23*(1), 62–76. doi:10.1111/jiec.12809 and 2) Haas, W., Krausmann, F., Wiedenhofer, D., Lauk, C., & Mayer, A. (2020). Spaceship Earth's odyssey to a circular economy - a century long perspective. *Resources, Conservation and Recycling*, *163*, 105076. doi:10.1016/j.resconrec.2020.105076

2. RESEARCH OBJECTIVES

The *Circularity Gap Report Textiles* largely examines the global textile industry from a physical perspective. The analysis uses 2021 as a baseline year to uncover what, how and from where material resources are extracted, used and disposed of, as well as the key drivers of these processes. It also calculates Textile's Circularity Metric, the share of secondary material consumption, allowing us to explore how the country performs compared to the global average.

Aims of the *Circularity Gap Report Textiles*:

1. Quantify the current state of circularity in the global textile industry.
2. Assess the environmental and health impacts driven by the industry.
3. Identify and model circular economy strategies to mitigate these impacts.
4. Provide actionable recommendations for industry stakeholders.

The main research questions that guide the *Circularity Gap Report Textiles* to achieve these objectives are:

1. What is the level of circularity (Circularity Metric) of the textile industry, as measured by the *Circularity Gap Report's* methodology?

2. What is the extent of the global environmental impacts caused by the textile industry through the planetary boundaries framework?

3. What are the employment characteristics and social profiles of workers in the textile industry, and what key social impacts do they face along the value chain?

4. How effectively can circular economy interventions reduce the environmental impacts attributed to the textile industry on a global scale and what is the resulting Circularity Metric?

5. In what ways can various stakeholders facilitate the implementation of proposed circular interventions within the textile industry?

3. OVERALL RESEARCH APPROACH

The *Circularity Gap Report Textiles* uses a mixed methods research approach. This comprehensive research strategy integrates quantitative and qualitative research methods to better understand the industry's circularity baseline and environmental impacts as well as the potential to drive a just and sustainable circular economy transformation. This methodological approach is particularly valuable in addressing research questions that benefit from a multifaceted understanding, offering a more robust foundation for evidence-based decision-making and policy development.

The quantitative methods are used for a data-driven approach to measure the state of the circular economy in the global textiles industry. The main methods for analysing the socioeconomic metabolism are 1) Economy-Wide Material Flow Accounting (EW-MFA) and 2)

Environmentally-Extended Multi-Regional Input-Output Analysis (EE-MRIOA), which are employed to calculate 1) the material footprint, 2) the environmental impact categories and 3) the Circularity Metric.

On the other hand, qualitative methods, such as expert interviews and workshops with relevant stakeholder groups,[2] are employed to validate, help interpret, fine-tune and enrich the depth and complexity of the quantitative findings as well as complement any existing knowledge gaps. Combining both methods enhances the validity and reliability of the overall analysis.

4. BASELINE ANALYSIS

Measuring circular economy, particularly regarding material flows, is crucial for understanding resource use, waste generation, and overall sustainability. It allows decision-makers such as policymakers and business leaders to assess how effectively materials are used, identify improvement areas, and track progress towards circularity goals. However, analysing an economy from the physical perspective by measuring material flows poses significant challenges. Traditional statistics and metrics often focus on linear production and consumption patterns, making it difficult to capture the complex, interconnected nature of socioeconomic activities. The lack of data availability, consistency, and reliability can also hinder accurate assessment. Overcoming these obstacles requires the development of standardised methodologies, improved data collection mechanisms, and interdisciplinary collaboration to ensure a comprehensive understanding of circular economy performance.

How do we measure circularity?

To measure circularity, we look at how an industry uses material resources. We use the way in which materials flow through an industry and are used over the long term as the starting point. This is what we call a socioeconomic metabolism analysis: the study of the flows of materials and energy through a society's economic system.[3] This approach builds on and is inspired by the work of leading academics in the field.[4] The approach is adapted for each *Circularity Gap Report*; depending on the scope of analysis (a nation, region or industry, for example).

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[2] As part of the project, a Scientific Committee and a Project Coalition were created. Representatives from the industry, the private and public sectors, as well as NGOs, unions and experts attended a series of roundtables to discuss the methodology, results and provide insights.

[3] Just as our bodies undergo complex chemical reactions to keep our cells healthy and functioning, an economy undergoes a similar process—energy and material flows are metabolised to express functions that serve humans. The socioeconomic metabolism analysis focuses on the set of biophysical processes that allow for the production and consumption of goods and services that serve humanity: namely, what and how goods are produced (and for which reason), and by whom they are consumed.

[4] Haas, W., Krausmann, F., Wiedenhofer, D. & Heinz, M. (2015). How circular is the global economy? An assessment of material flows, waste production, and recycling in the European Union and the world in 2005. *Journal of Industrial Ecology, 19*(5), 765–777. doi:10.1111/jiec.12244

4.1 SCOPE

For the purposes of this report, the term 'textiles' refers to the TCLF industries. Thus, the following products are covered by the *Circularity Gap Report Textiles*:

- Apparel, including clothing, handbags, footwear, and other clothing accessories, excluding jewellery and other products not made from textile related materials;
- Knitted and crocheted fabrics and articles thereof (e.g. socks and pullovers);
- Dressing and dyeing of fur;
- All tailoring (ready-to-wear or made-to-measure), in all textile materials (e.g. leather, fabric, knitted and crocheted fabrics), of all items of clothing and accessories from materials not made in the same unit;
- Household/interior textiles, including household linen, blankets, rugs and cordage;
- Luggage, saddlery, harness, footwear, tanned leather, and straps.

The key stages of the textiles value chain that are considered are listed below. Note that a distinction is made between stages that could be covered in the baseline data analysis, and those that could only be covered by desk research. The decision to not cover a subset of stages in the data analysis is due to lack of quantitative data; a mismatch in data availability with regards to the product life cycle (for example, EoL is partially covered in IO databases); and less relevance to physical material consumption (for example, product design sector).

Table one. *Stages of textiles value chain included within quantitative analysis*

Stage	Part of quantitative baseline analysis?
1. Product design a. Research, trends, inspiration gathering b. Sketching, concept development c. Materials and hardware selection, prototype selection/quotes (for material, CMT) d. Sample production, testing, fitting	NO
2. Material extraction and processing a. Crop agriculture b. Raw material to yarn processing	YES
3. Textile production a. Yarn to fabric (woven, knitted) b. Wet processing: dyeing, printing, washing and finishing (fibre, yarn, fabric or garment)	YES
4. Product manufacturing a. Pattern making b. Cut-make-trim c. Product assembly (incl. hardware), sewing	YES
5. Packaging, distribution and retail a. Import & distribution	YES

b. Marketing c. Sales (primary, secondary, rental)	
6. Customer use a. Wearing b. Washing c. Maintenance and repair	NO
7. Post-consumer use a. Collection b. Sorting and resale c. Preparation for recycling d. Recycling	PARTLY

4.2 DATA

Due to the global scope of this analysis, an MRIO database with sufficient regional and sectoral coverage was needed. Of the databases reviewed, Exiobase has good sectoral coverage (with three textiles specific sub sectors in manufacturing, and data for incineration and landfill of textiles waste) while lacking regions that play a key role within the global textiles value chain (e.g. Bangladesh), whereas Eora (in its 26 aggregate sector variant) did not have sufficient sectoral data (breaking down textiles manufacturing activities, and around textiles waste). Therefore, the selected approach for this analysis was to use the high sectoral disaggregation of Exiobase (163 sectors) to augment the Eora26 database, with its high regional resolution of 189 countries. This section summarises the development of this new, highly resolved, MRIO database for analysing environmental footprints in the textiles value chain.

Before moving on to the database construction, a small word on two other highly detailed global MRIOs: Full Eora and GLORIA. Despite being nearly as detailed and comprehensive, we were unable to utilise full Eora and GLORIA. The former due to sectoral aggregation issues and balancing mismatches that are handled in Eora26 through advanced constraint programming. Furthermore, in full EORA, many data-scarce regions are still reported in EORA26 aggregation. And for the latter, while GLORIA is a perfect match on paper, some textile specific sectoral sanity checks revealed data consistency issues (for example, when investigating the inputs into 'Textiles and clothing', we did not identify a significant input of 'Growing fibre crops', but instead encountered unexpected sectors such as 'Growing leguminous crops and oil seeds' for 4.92% of the total input; such a discrepancy is likely due to mapping primary inputs such as 'Seed cotton' to 'Growing leguminous crops and oil seeds' rather than to 'Growing fibre crops', which—while both are valid candidates—made it less suitable for a textile specific lens), causing us to abandon this option. More recent releases may eventually resolve these issues.

Our approach to merging Exiobase and Eora26, can be compared to Cabernard et al. (2021). Cabernard et al. (2021) used Exiobase as the baseline and regionally expanded using Eora. We argue that it is more beneficial to increase sectoral resolution while preserving original country-specific economic information for a vast number of nations than to increase regional resolution while preserving the ‘black box’ ROW region totals that are so prevalent in Exiobase. Note that we return to Exiobase totals for the environmental extensions, as Exiobase reports on a much larger number of stressors, and impact assessment characterisation factors (CF) already exist for Exiobase but not for Eora.

The method of disaggregating sectoral data is relatively simple, albeit applied at scale. For each monetary IOT, a mapping file between sectoral or final demand classifications is used to compute the shares of the detailed sector within the aggregated sector. Where regions overlap between the databases, this results in (near) identical disaggregated sector outputs. But where, for example, Exiobase reports on the Rest of World Asia & Pacific (WA) using an aggregate region, Eora has sectoral economic totals for each individual region. Here, we computed the share of each disaggregated sector in WA and multiplied it with the related aggregate sector total in Eora.

For example, ‘Manufacture of wearing apparel; dressing and dyeing of fur (18)’ is 21% of the aggregated sector total ‘Textiles and Wearing Apparel’ in WA. Therefore, in for example Bangladesh, 21% of its ‘Textiles and Wearing Apparel’ sector as reported by Eora is disaggregated into ‘Manufacture of wearing apparel; dressing and dyeing of fur (18)’.

This is repeated for each sector, final demand, and region combination.

4.3 IMPACT CONTRIBUTION

Using the highly resolved MRIO database and related environmental extensions together with the state-of-the-art IMPACT World+ (IW+) characterisation factors (CF),[5] we performed a Life Cycle Impact Assessment (LCIA).

The impact assessment can be performed at the midpoint and endpoint levels. While midpoint indicators focus on environmental problems as Climate Change or Marine eutrophication, endpoint indicators show the environmental impact at the higher aggregation level of areas of protection being Human Health, Biodiversity and Resource scarcity. Midpoint CF are usually more robust while endpoint CF are more uncertain. We look at both types of impacts, depending on the impact group, to get a more complete view. See Table two for an overview of this grouping.

Table two. *Overview of IW+ impacts considered and their simplified grouping*

Impact	Unit	Impact group
Particulate matter formation (DALY)	DALY	Human Health (DALY)
Climate change, human health, short term (DALY)	DALY	Human Health (DALY)
Human toxicity non-cancer, short term (DALY)	DALY	Human Health (DALY)
Human toxicity cancer, short term (DALY)	DALY	Human Health (DALY)
Photochemical oxidant formation (DALY)	DALY	Human Health (DALY)
Ionising radiation, human health (DALY)	DALY	Human Health (DALY)
Water availability, human health (DALY)	DALY	Human Health (DALY)

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[5] https://zenodo.org/records/8200703

Ozone layer depletion (DALY)	DALY	Human Health (DALY)
Climate change, short term (kg CO2 eq (short))	kg CO2 eq (short)	Climate Change (kg CO2 eq)
Marine eutrophication (kg N N-lim eq)	kg N N-lim eq	Marine eutrophication (kg N N-lim eq)
Particulate matter formation (kg PM2.5 eq)	kg PM2.5 eq	Air Pollution (kg PM2.5 eq)
Freshwater eutrophication (kg PO4 P-lim eq)	kg PO4 P-lim eq	Freshwater eutrophication (kg PO4 P-lim eq)
Terrestrial acidification (kg SO2 eq)	kg SO2 eq	Terrestrial and Freshwater Acidification (kg SO2 eq)
Freshwater acidification (kg SO2 eq)	kg SO2 eq	Terrestrial and Freshwater Acidification (kg SO2 eq)
Water scarcity (m3 world-eq)	m3 world-eq	Water Scarcity (m3 world-eq)
Land occupation, biodiversity (PDF.m2.yr)	PDF.m2.yr	Biodiversity (PDF.m2.yr)
Climate change, ecosystem quality, short term (PDF.m2.yr)	PDF.m2.yr	Biodiversity (PDF.m2.yr)
Terrestrial acidification (PDF.m2.yr)	PDF.m2.yr	Biodiversity (PDF.m2.yr)
Marine eutrophication (PDF.m2.yr)	PDF.m2.yr	Biodiversity (PDF.m2.yr)
Freshwater acidification (PDF.m2.yr)	PDF.m2.yr	Biodiversity (PDF.m2.yr)
Marine acidification, short term (PDF.m2.yr)	PDF.m2.yr	Biodiversity (PDF.m2.yr)
Freshwater ecotoxicity, short term (PDF.m2.yr)	PDF.m2.yr	Biodiversity (PDF.m2.yr)
Freshwater eutrophication (PDF.m2.yr)	PDF.m2.yr	Biodiversity (PDF.m2.yr)
Water availability, terrestrial ecosystem (PDF.m2.yr)	PDF.m2.yr	Biodiversity (PDF.m2.yr)
Water availability, freshwater ecosystem (PDF.m2.yr)	PDF.m2.yr	Biodiversity (PDF.m2.yr)
Ionising radiation, ecosystem quality (PDF.m2.yr)	PDF.m2.yr	Biodiversity (PDF.m2.yr)
Thermally polluted water (PDF.m2.yr)	PDF.m2.yr	Biodiversity (PDF.m2.yr)
Land transformation, biodiversity (PDF.m2.yr)	PDF.m2.yr	Biodiversity (PDF.m2.yr)

As for the material footprint, Domestic Extraction (DE) (production-based material footprint) and Raw Material Consumption (RMC) (consumption-based material footprint) were used in a contribution and hotspot analysis, in order to break down and pinpoint contributions on impacts across the TCLF supply chain.

In order to break down impacts within the TCLF supply chain, we used Input-Output Analysis (IOA) to modify final demand to both capture the subsets of larger sectors that are deemed relevant to the textile industry, while also isolating the different stages within the supply chain.

For each of the stages, including background stages to enable benchmarking between textiles specific stages and the rest of the ‘manufacturing’, ‘retail’, and ‘waste’ industries, the impacts were computed using the modified final demand as seen in Table three.

Note that material extraction is not included as a separate supply chain 'stage'. Internal analysis into tracing impacts across supply chain stages—or intermediate consumption/production layers—revealed that, especially for DE, impact contributions were directly linked to the final demand sectors and intermediate steps in the supply chain could not be isolated. For this reason, impacts caused by the extractive industries related to textiles are already included in the downstream sectors listed in Table three.

For each of the result sets, grouped by material footprints and environmental impacts, we computed the consumption- and production-based impacts, per capita share, and a sectoral breakdown through contribution analysis.

Table three. *Breakdown of supply chain stages and their relevance weighting*

Stage	**Sectors**	**Weight**
Manufacturing	Manufacture of textiles (17)	1.0
	Manufacture of wearing apparel; dressing and dyeing of fur (18)	1.0
	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear (19)	1.0
Retail	Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)	0.058[6]
	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (52)	0.084[7]
Waste	Incineration of waste: Textiles	1.0
	Landfill of waste: Textiles	1.0

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[6] See Annex A for calculation breakdown.

[7] See Annex A for calculation breakdown..

4.4 EMPLOYMENT

To strengthen our analysis on employment in textiles, we compiled a new employment extension based on data gathered from the ILO. We used employment data, broken down by economic activity and sex (EMP_TEMP_SEX_ECO_NB_A), and (in-)formality (EMP_NIFL_SEX_ECO_NB_A, EMP_TEMP_SEX_IFL_EC2_NB_A). By combining these datasets, we prepared a detailed view on employment by economic activity globally. However, not all regions report year on year, and data gaps do exist. We filtered each region for the year closest to the base year of this analysis (2019), and gaps were addressed through sectoral disaggregation based on employment data inherently present in Exiobase. Sectoral data from the ILO datasets was not uniformly present for each region: We had to adopt a stepwise approach using ISIC4, then ISIC3.1, and lastly a high level aggregate.

Furthermore, additional employment data present in Exiobase (skills, hours) was deemed relevant and used directly after rebalancing and disaggregation. Skills data is broadly defined as 'high-, medium-, and low-skilled work', corresponding to that of the International Standard Classification of Occupations (ILO 2012). For further information on the sourcing and definitions of these indicators we refer to the Exiobase 3 documentation.[8] Skills data is not available for the informal sector, as this source data is not available and applying splits similarly to our sectoral disaggregation method would not be reliable in this context**.** We cannot reason about the split between informal and formal within the skill levels. For example, if 33% is high skill, and 50% is informal, we cannot reliably make the assumption that 33% of that 50% is high skill informal.

Lastly, remuneration related to wages data was sourced from Eora's Value Add (VA) IOT. This data has been used to calculate the weekly wages of textile workers per country. The quality of this data has not allowed us to provide sensible national-specific wage figures. A potential explanation for these inaccuracies is related to the fact that the VA data may be extracted from national account reporting and subsequently downscaled to employed workers, but these figures could be rebalanced to satisfy the IOT constraints, and do not necessarily reflect real world wages. Our solution has been to include some analysis of wages for employed people but use them on a relational basis (comparing across regions and across textile phases).

Despite using informal employment data, **our analysis underestimates the contribution of the informal sector in the global textiles value chain,** namely due to the absent data reported from key countries, such as China and US. The prevalence of informal employment significantly complicates the assessment for our absolute figures relating to gender, skills, working hours, wage distribution across the various phases of the textiles value chain. This is mainly because informal workers often operate outside the structured management and regulatory oversight typical of formal employment, making it challenging to accurately assess the figures relating to their skill levels, livelihoods, and working arrangements in this global textile workforce analysis. An illustrative example of this challenge is the dominance of

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[8] Stadler, K., Wood, R., Bulavskaya, T., Södersten, C., Simas, M., Schmidt, S., et al. (2018). EXIOBASE 3: Developing a time series of detailed environmentally extended multi-regional input-output tables. *Journal of Industrial Ecology*, *22*(3), 502–515. doi:10.1111/jiec.12715

medium-skilled workers, where it could be driven by the largely underestimated number of informal textile workers in this analysis, most of which are low-skilled workers.

To conclude, we used all the aforementioned employment indicators in (production based) IOA to compute the contribution (or share) of the different stages in the textile value chain to these employment indicators. This has resulted in a comprehensive breakdown of employment related indicators per gender, sector, phase, and region.

4.5 MATERIAL FLOW ACCOUNTING & THE CIRCULARITY METRIC

The purpose of economy-wide material flow accounts (EW-MFA) is to provide an aggregate overview, in tonnes, of the material inputs and outputs of an economy, including inputs from the environment, outputs to the environment, and the physical amounts of imports and exports. EW-MFA and associated balances constitute the basis for derivation of a variety of material flow-based indicators. The systematic application of EW-MFA principles at sub-national level to individual industry sectors brings to the development of so-called Physical Supply and Use Tables (PSUTs). While EW-MFA generally focus on the mass of material entering the economy from the environment—natural resources and other natural inputs—and the mass of residuals flowing to the environment, PSUTs are focused on the detail of interindustry physical flows, particularly as related to flows within the economy.

While the ideal approach would have consisted in developing either a detailed PSUT for the global textile sector or a sector-wide MFA according to EW-MFA principles, in this analysis we decided to focus exclusively on the quantification of key flows that would enable to estimate the state of circularity of the TCLF industries. The selected flows are:

- **Recycled feedstocks**: They can be sourced either from the same industry (closed-loop recycling) or from other industries (open-loop recycling). In the context of the textile industry, closed loop recycling is also known as ‘Fibre-to-fibre’ (F2F) recycling;
- **Domestic Extraction (DE)**: Consists of raw materials extracted directly from the environment and represents the amount of virgin feedstocks. In this context, ‘domestic’ is intended as related to the TCLF sector;
- **Domestic Material Consumption (DMC)**: Consists of both raw materials (DE) and other manufactured products hereafter referred to as ‘ancillary inputs’ used in the production process;
- **Raw Material Consumption (RMC)**: Transforms the ancillary inputs share of DMC into their raw materials equivalents needed in their production process, thus representing a much larger tonnage. This is also referred to as consumption-based material footprint and was already computed through EE_MRIOA.

Other headline EW-MFA indicators such as Domestic Processed Output (DPO), Balancing Items (BI) and Net Additions to Stocks (NAS) are not quantified. Note that within the context of this analysis, DMC is referring to the overall apparent consumption of the TCLF industries and not only to flows of fibres, clothing and other textile goods. The approach to such estimation would consider the global TCLF industry, thus overlooking trade flows, and will focus directly on physical consumption, building the account using data from literature.

Based on the standard MF classification, the top five material categories relevant to the TCLF industries are selected and customised processes for their calculation are set-up. These include:

- Fibres (MF119): Natural-based fibres such as cotton;
- Other products from animals (MF154): Animal fibres such as skins, furs, leather, silk etc.;
- Products mainly from fossil energy products (MF43): This include synthetic fibres such as polyester;
- Chemical and fertiliser minerals (MF34): Chemicals used in the dyeing and treatment process, but excluding fertiliser minerals;
- Coal and other solid energy carriers (MF41) and Liquid and gaseous energy materials/carriers (MF42): Depending on the energy mix used in the production of TCLF products .

Below, we summarise the approach for the calculation of each headline EW-MFA indicator:

Domestic Extraction (DE): This indicator was approximated with the amount of primary fibre production, thus losses between harvesting and yarn production were not factored in. Figures for primary fibre production were source from the Preferred Fiber & Materials Market Report,[9] including breakdowns by ten types of fibres and three applications (**Table four**). The following assumptions are made to estimate fibre use for each application:

- For ‘Man-made Cellulosic Fibres (MMCF)’ split between applications, the average of five individual MMCF is used as a proxy;
- For ‘Other plants fibres’ split between applications, cotton is used a proxy;
- For ‘Other synthetic fibres’ split between applications, the average of all other synthetic fibres is used as a proxy.

Furthermore, the following assumptions are made:

- Production equals consumption, that is all textiles produced are sold and used in the same year. Additions to or depletions from stocks (e.g. stocking and overstock liquidations) are not taken into account;
- The output of recycled fibres from recycling plants is a proxy for secondary fibre input into the market.

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[9] Textile Exchange. (2022). Preferred Fiber & Materials Market Report. Retrieved from: Textile Exchange website

Table four. *Global fibre primary production by fibre and application*

Fibre / Application	**Primary in Clothing (Mt)**	**Primary in Home Textiles (Mt)**	**Primary in Other (Mt)**	**Recycled in TCLF (Mt)**
Cotton	16.2	6.2	2.5	0.25
Wool	0.7	0.4	0.0	0.07
Other Animal fibres	0.5	0.0	0.0	-
Down & Feather	0.2	0.4	0.0	0.01
Polyester	27.5	16.5	17.1	9.15
Polyamide	1.1	1.7	2.8	0.11
MMCF	4.3	0.9	2.1	0.04
Natural Rubber	0.0	0.0	0.0	-
Other plant fibres	4.4	1.7	0.7	-
Other synthetic	2.9	1.0	1.8	-

Closed-loop recycling (Fibre-to-fibre recycling): This figure represents the amount of secondary fibres sourced within the same TCLF sector. It is calculated by splitting the total reported volume of secondary fibre production (9.6 Mt)[10] by the share coming from the TCLF sector (4.5%). The share is based on a weighted average of data gathered for a sample of most relevant economies, namely EU28,[11] [12] US,[13] India[14] and China[15] [16] [17] and weighted based on the volume of reported post-consumer textile waste in 2018. Table five summarises the main data collected (note that these figures do not yet include pre-consumer waste or processing losses and therefore are not the final shares used to split the outflow into its final destinations).

Table five. *End-of-life treatment shares, by country*

Code	**Label**	**US**	**EU**	**IN**	**CH**	**AVERAGE**
D3	Landfilled or incinerated	85%	63%	22%	85%	78.6%
R1	Reuse/Resale	8%	5%	34%	8.3%	10.2%
D2	Collection and sorting losses	0.6%	28%	4.4%	1.1%	2.8%
R3	Cascaded recycling	6%	5%	17%	3.1%	5.2%
R2.1	**Fibre-to-fibre recycling**	**0.1%**	**0.2%**	**23%**	**2.5%**	**3.2%**
-	Post-consumer waste (kton)	15500	2791	3944	26000	-

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[10] Textile Exchange. (2022). *Preferred Fiber & Materials Market Report*. Retrieved from: Textile Exchange website

[11] Amicarelli, V., & Bux, C. (2022). Quantifying textile streams and recycling prospects in Europe by material flow analysis. *Environmental Impact Assessment Review, 97*, 106878.

[12] Fashion for Good & Circle Economy. (2022). *Sorting for circularity europe: an evaluation and commercial assessment of textile waste across Europe*. Retrieved from: Fashion for Good website

[13] Schumacher, K. A., & Forster, A. L. (2022). Textiles in a circular economy: An assessment of the current landscape, challenges, and opportunities in the United States. *Frontiers in Sustainability, 3*, 1038323.

[14] Fashion for Good & Sattva Consulting. (2022). *Wealth in waste: India's potential to bring textile waste back into the supply chain*. Retrieved from: Fashion for Good website

[15] Bloomberg. (2020). China's Next Problem Is Recycling 26 Million Tons of Discarded Clothes. Retrieved from: Bloomberg website

[16] Ellen MacArthur Foundation & Arup. *The circular economy opportunity for urban & industrial innovation in China*. Retrieved from: Arup website

[17] Spuijbroek, M. (2019). *Textile Waste in Mainland China*. Retrieved from: RVO website

-	Relative weights	32.1%	5.8%	8.2%	53.9%	-

Open-loop recycling: This figure represents the amount of secondary fibres sourced from other industries than TCLF and calculated as the difference between total reported volume of secondary fibre production and fibre-to-fibre recycling.

Pre-consumer waste (or processing losses): This figure is calculated by deriving processing losses coefficients from conversion rates[18] for each supply chain step (Yarn, Fabric and Product) (**Table six**). The coefficients are differentiated by application (Apparel and Home textiles) and fibre (Cotton, Wool, Polyester and MMCF). Processing losses from 'Other' applications and other fibres are not included. No distinction is made between different manufacturing techniques (e.g. knitting versus woven). It is assumed that all processing losses are either landfilled or incinerated.

Table six. *Average processing losses per application and stage*

Application	**Stage**	**Processing losses (D1) (Mton)**	**As share of flow**	**As share of total**
Apparel	Fibre-to-yarn	4.5	8%	34%
	Yarn-to-fabric	5.9	10%	
	Fabric-to-product	9.2	16%	
Home textile	Fibre-to-yarn	1.4	5%	18%
	Yarn-to-fabric	2.4	9%	
	Fabric-to-product	1.4	6%	
Total/average		24.8	-	**22%**

Ancillary inputs: This figure was calculated in an effort to approximate the DMC of the TCLF sector (**Table seven**). It represents the volume of the three most significant materials, namely chemicals and fertilisers minerals (MF34), Coal and other solid energy materials/carriers (MF41), Liquid and gaseous energy materials/carriers (MF42) that are used in the production of primary fibres. All other materials used are excluded. Materials used in the production of secondary fibres are excluded. The approach to the calculation of this figure is the following:

- From primary fibre production, processing losses at each step of the supply chain are calculated (see 'Pre-consumer waste'). This results in figures for total volumes of yarn, fabric and final product produced globally;

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[18] Textile Exchange. (2019). Fibre conversion methodology. Retrieved from: Textile Exchange website

- Using data from LCA,[19] production volumes at each supply chain step are allocated to 6 main economies and 1 ROW region. For the allocation of the 'Dyeing and finishing' step, the same volumes as from 'Fabric manufacturing' are used as the processing losses calculated at the 'Fabric manufacturing' step accounts also for those occurring at 'Dyeing and finishing';

- Based on literature review, a table of material intensity coefficients for each material and supply chain step is assembled. Harmonisation of system boundaries for natural gas and coal coefficients was carried out, resulting in consistent coverage of Yarn processing, Fabric manufacturing and Dyeing and finishing steps. Grid electricity inputs are converted into primary natural gas and coal inputs based on average or sector-specific electricity mixes (depending on the country), average global energy conversion efficiencies of coal- and NG-fired plants and representative Low Calorific Values. On-site electricity and heating generation is assumed to be entirely based on natural gas inputs as diesel and gasoil inputs are minimal. Energy inputs related to the 'product assembly step' are excluded as deemed minimal;
    - Material intensity coefficients are applied to the production volumes at region-stage combination.

Furthermore, the following assumptions were made for each material category:

- Chemical and fertiliser minerals (MF34): Only chemicals are practically included in this category as fertilisers used in fibre production are not part of the TCLF industry. Chemical use varies a lot across applications, thus a simple average between the lowest and highest values for each country is selected;

- Coal and other solid energy materials/carriers (MF41): Coal is exclusively in the production of grid electricity. Intensity coefficients for electricity are usually reported as for 'Fabric manufacturing' and 'Dyeing and finishing' together, sometimes including also the 'Yarn manufacturing'. While it was possible to split electricity consumption for 'Yarn manufacturing', this was not always possible for 'Fabric manufacturing' and 'Dyeing and finishing'. In those cases, the whole coefficient was applied to production volumes at one of the two steps. The selection of the step was based on its significance for the country. Note that this approach leads to overestimation of the energy inputs for countries that are involved exclusively in 'Fabric manufacturing' (India and Pakistan);

- Liquid and gaseous energy materials/carriers (MF42): Only natural gas is accounted for in this category as liquid energy carrier inputs are negligible. The same considerations for coal used for electricity generation apply to natural gas as well (overestimations may occur for EU28, India and Pakistan);

- For estimating material inputs related to energy consumption in ROW region, a simple average of the coefficients for the main economies was applied (for chemicals, this was not necessary as dyeing and finishing activities were deemed negligible).

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[19] Quantis. (2018). *Measuring fashion: environmental impact of the global apparel and footwear industries study. Full report and methodological considerations*. Retrieved from: [Quantis website]

Table seven. *Ancillary inputs summary table (Mton)*

Region/input	**MF34**	**MF41**	**MF42**
Bangladesh	10.8	0	32.8
China	43.0	58.5	41.9
EU28	3.9	0	26.1
India	0.0	5.1	13.2
Pakistan	0.0	1.2	5.1
Turkey	9.4	1.6	18.2
ROW	0.0	10.1	4.9
Total	**67.0**	**76.5**	**142.1**

Reuse: This figure represents the share of End-of-life TCLF that is being collected and reused. The share is based on a weighted average of data gathered from a sample of most relevant economies (EU28, UA, India and China). The weighting was based on the volume of reported post-consumer textile waste in 2018. It is not assumed that reused clothes are disposed of in the short-run and thus this share is not redistributed to each end-of-life destination;

Cascading, Collection and sorting losses and Post consumer waste: These figures represent the share of End-of-life TCLF that is downcycled to other applications outside TCLF, is lost during collection and sorting for open- or closed-loop recycling and is landfilled or incinerated, respectively. All shares are based on a weighted average of data gathered from a sample of most relevant economies (EU28, US, India and China). The weighting was based on the volume of reported post-consumer textile waste in 2018.

Table eight. *Summary table of final End-of-Life destination shares*

R/D code	**R/D flow**	**Share**
R1	To new customers → Reuse	8.0%
R2.1	To textile industry → Fibre-to-fibre recycling (closed-loop)	0.27%
R3	To other industries → Cascading (open-loop recycling)	6.3%
D1	To processing losses → Landfill and incineration (pre-consumer waste)	21.9%
D2	To losses during collection and sorting → Collection and sorting losses	2.2%
D3	To landfill and incineration → Landfill and incineration (post-consumer waste)	61.4%
D4	To the environment → Microfiber leakage	?

The Circularity Metric as calculated in this analysis is part of a broader framework of indicators which are based on EW-MFA principles and are taken from the work of Mayer et al. (2019) and previous research.[20] [21] Within this framework, the Circularity Metric, also referred to as the

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[20] Mayer, A., Haas, W., Wiedenhofer, D., Krausmann, F., Nuss, P., & Blengini. G.A. (2019). Measuring progress towards a circular economy: a monitoring framework for economy-wide material loop closing in the EU28. *Journal of industrial ecology, 23*(1), 62-76

[21] Haas, W., F. Krausmann, D. Wiedenhofer, and M. Heinz. (2015). How circular is the global economy? An assessment of material flows, waste production, and recycling in the European Union and the world in 2005. *Journal of Industrial Ecology, 19*, 765– 777

socioeconomic cycling rate, measures the contribution of secondary materials to the total material consumption—calculated based on both DMC and RMC. Recycled waste from material processing and manufacturing (e.g. recycled steel scrap from autobody manufacturing) is considered an industry internal flow and not accounted for as secondary material. Since the scope of this analysis is global, trade flows of textile waste destined to recycling or second-hand clothes and textile are not relevant as there is no trade at the global level.

Table nine. *Summary table of main MFA and circularity indicators*

MFA Indicators	**Description**	**Circularity Indicators**
Recycled feedstocks	Recycled feedstocks can be sourced either from the same industry (closed-loop recycling) or from other industries (open-loop recycling). In the context of the textile industry, closed loop recycling is also known as 'Fibre-to-fibre' (F2F) recycling	Recycled feedstock = Open-loop recycling + Closed-loop recycling (F2F recycling)
Domestic Extraction (DE) *DE = Virgin feedstocks*	DE consists of raw materials extracted directly from the environment and represents the amount of virgin feedstocks. In this context, 'domestic' is intended as related to the TCLF sector	Closed-loop recycling rate = F2F recycling / DE + recycled feedstock → 0.31Mt / 113.5Mt = **0.27%**
Domestic material consumption (DMC) *DMC = DE + Ancillary inputs*	DMC consists of both raw materials (DE) and other manufactured products (Ancillary inputs) used in the production process. In this context, 'domestic' is intended as related to the TCLF sector	Circularity Metric (DMC-based) = Recycled feedstock / DMC + recycled feedstock → 9.62Mt / 399.1Mt = **2.35%**
Raw material consumption (RMC)	RMC transforms the ancillary input share of DMC into their raw materials equivalents, thus representing a much larger tonnage.	Circularity Metric (RMC-based) = Recycled feedstock / RMC + recycled feedstock → 9.62Mt / 3261Mt = **0.29%**

5. SPOTLIGHT CHAPTER: TEXTILES IN THE US AND CHINA

For a more complete understanding of the current state of the textiles value chain, two case studies in different geographical locations were highlighted. Since the narrative for the *Circularity Gap Report Textiles* and the choice of the two case studies were central to the message and call for action for policymakers and industry stakeholders, we conducted a poll with our teams internally, with H&M Foundation and the Project Coalition. Through this poll, we assessed the group's preferences on whether the analysis should be: equal, comparative or superlative; to maximise the report's impact.

Detailed description of the three suggested narratives to choose from for the spotlight chapter:

- **EQUAL:** Two countries that are active in the most impactful phases of the value chain;
- **COMPARATIVE**: Two countries that are who are doing a similar activity, but in different geographies;
- **SUPERLATIVE:** Two countries that are unequally impacted by the industry.

The results of the poll showed a preference for the ‘equal’ analysis’ narrative. Based on the findings from the baseline analysis, the spotlight chapter focused on the effects of the textiles industry in the two top contributors to the largest share of impact, across all impact categories, China and the US.

- Desk-based analysis was performed of scientific peer-reviewed literature and grey literature.
- A series of semi-structured interviews were conducted with relevant stakeholders and experts to contextualise, verify and validate some of the findings of the literature review.
- Five key-informant interviews were conducted and transcribed. All interviews were conducted via video-conferencing. A qualitative analysis of the interviews was conducted.

Interviewees were representatives from:

1. China National Textile and Apparel Council (CNTAC)
2. China Labour Bulletin (CLB)
3. American Apparel & Footwear Association (AAFA)
4. Shimmy Technologies
5. Resource Recycling System (RRS)

6. SCENARIO MODELLING FRAMEWORK AND DEVELOPMENT

Environmentally extended input-output analysis (EEIOA) can be applied to assess the economic and environmental impacts of implementing circular economy strategies and interventions.[22] IOA, in its various forms, is a static structural model that provides detailed insights into sectoral and economic composition, making it a useful tool for the impact assessment of supply chains. As such, it is a suitable model for the creation of 'what-if' scenarios by applying exogenous changes. One of the advantages of this approach is the transparency of its assumptions, which is crucial for CE impact assessments, as the variety of methodologies can make comparing studies difficult.

As a first step, we developed a CE policy modelling framework based on the work of Aguilar et al. (2018) and Donati et al. (2020) and integrated additional literature on circular strategies frameworks.[23] [24] [25] We begin by asserting that the objective of a CE policy is always the implementation of the circular economy paradigm, which can be achieved through various strategies. In this study, we use the four-strategy classification of Aguilar-Hernandez et al. (2018): Product Lifetime Extension (PLE), Resource Efficiency (RE), Closing Supply Chains (CSC), and Residual Waste Management (RWM). This classification serves as the overarching terminology for modelling the 10Rs strategies outlined by Potting et al. (2017).[26] The classification by Aguilar et al. closely aligns with the Bocken et al. framework, which is primarily used for communication purposes. The main difference is that Aguilar's classification lacks the 'regenerate' element, which addresses the elimination of toxic inputs and the use of more renewable materials. While this regenerate strategy is extremely important and a core element of the circular economy, it is not included in our scenario modelling framework due to the limitations of EE-MRIOA in modelling 'qualitative' aspects of material flows such as toxicity and renewability.

We define strategies as sets of policy interventions and improvement options (or simply interventions). For example, PLE can be achieved, among others, by reusing and remanufacturing or delaying product replacement.[27] In other words, while these two interventions aim at the same objective, the extension of the product's life, the way they are implemented is different. We further distinguish between a general description of interventions and specialised interventions. An intervention (such as reuse and remanufacturing) is specialised when it refers to a specific product or application (such as increased lifetime through reuse and

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[22] Aguilar-Hernandez, G. A., Sigüenza-Sanchez, C. P., Donati, F., Rodrigues, J. F., & Tukker, A. (2018). Assessing circularity interventions: A review of EEIOA-based studies. *Journal of Economic Structures*, *7*(1). doi:10.1186/s40008-018-0113-3

[23] Blomsma, F., Pieroni, M., Kravchenko, M., Pigosso, D. C. A., Hildenbrand, J., Kristinsdottir, A. R., … McAloone, T. C. (2019b). Developing a circular strategies framework for manufacturing companies to support circular economy-oriented innovation. *Journal of Cleaner Production*, *241*, 118271. doi:10.1016/j.jclepro.2019.118271

[24] Morseletto, P. (2020). Targets for a circular economy. *Resources, Conservation and Recycling*, *153*, 104553. doi:10.1016/j.resconrec.2019.104553

[25] Reike, D., Vermeulen, W. J. V., & Witjes, S. (2018). The Circular Economy: New or refurbished as CE 3.0? — exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. *Resources, Conservation and Recycling*, *135*, 246–264. doi:10.1016/j.resconrec.2017.08.027

[26] Potting, J., Hekkert, M. P., Worrell, E., & Hanemaaijer, A. (2017). *Circular economy: measuring innovation in the product chain (No. 2544).* PBL Publishers. Retrieved from: PBL website

[27] Cullen, J. M., Allwood, J. M., & Borgstein, E. H. (2011). Reducing energy demand: What are the practical limits? *Environmental Science & Technology*, *45*(4), 1711–1718. doi:10.1021/es102641n

remanufacturing in final consumers' vehicles). Interventions are modelled through sets of changes that affect the production and consumption systems. We further distinguish between primary and ancillary changes. For instance, if the intervention concerns increasing the lifetime of vehicles, the primary change would be a reduction in sales of vehicles resulting from fewer consumers needing to replace their vehicles. A corresponding ancillary change would be the potential increase in repairing services caused by higher good utilisation. We show this conceptual approach in **Figure one**.

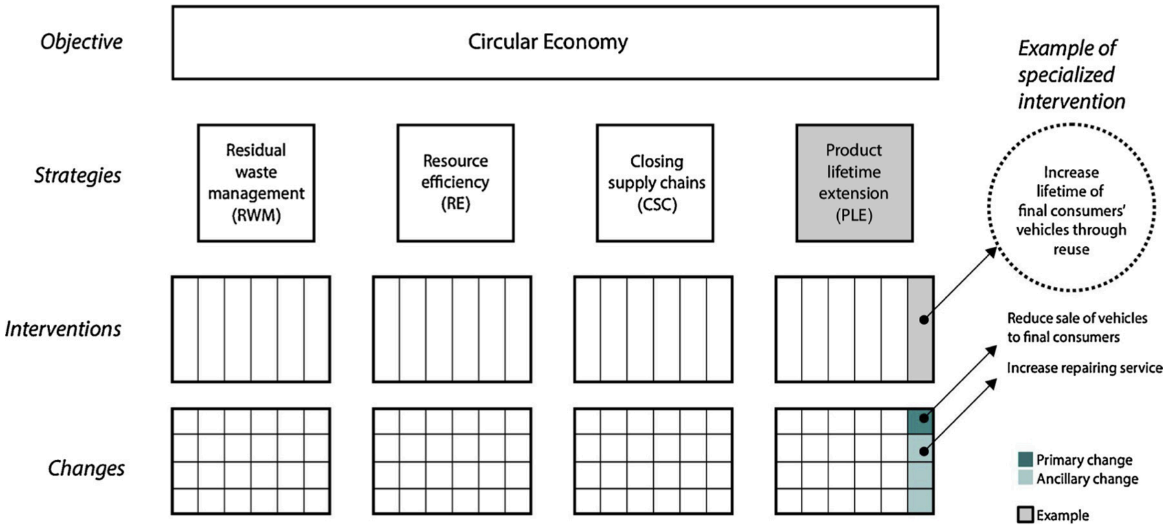

Figure one. *Conceptual approach to scenario modelling*

Hereby, we present systematic methods to build complex CE counterfactual (what-if) scenarios with EEIOTs. The basic Leontief demand-driven model can be framed such that a stimulus vector of final demand leads to a set of impacts occurring in each production sector as:

$$D_{cba} = \widehat{S}\,(I - A)^{-1} Y_{e}$$

Where D^{i}_{cba} is the column vector of impacts occurring in each production sector (the response variable) and Y^{i}_{e} is the column vector of final demand of products delivered by each sector (the control variable). The parameters of the model are the column vector S^{i} of environmental intensities (environmental pressure per unit of economic output) and A is a matrix of technical coefficients (whose entry ij is the volume of inputs from sector i that are required to generate one unit of output of sector j). $\widehat{\ }$ stands for diagonal matrix and I is the identity matrix. For some environmental pressures (such as global warming) there are direct emissions resulting from final consumption activities (such as the combustion of fossil fuels by households leads to the emission of greenhouse gases). When that is the case it is necessary to include emissions from final demand to obtain total emissions, Ge.

$$D_{cba,\,tot} = D^{'}_{cba} e + Ge$$

In the previous expression prime (') denotes transpose. If more information is available, the intensity of environmental pressures from final consumption can in principle be broken down by product category. Note that the system used in application is multiregional. That is, each entry identifies not only economic sector or final demand category in a row or column but also specifies a region (such as EU or Rest of the World).

In order to assess the environmental or socio-economic impact of implementing a CE policy we compare the impact that occurs in the baseline and the impact that occurs in a counterfactual scenario in which the changes corresponding to the CE intervention and strategy have been implemented. More formally, the impact of the CE policy is $\Delta D_{cba} = D^*_{cba} - D_{cba}$, where D_{cba} is the impact in the baseline scenario, and D^*_{cba} is the impact in the counterfactual scenario, defined as:

$$\widehat{S^*}\,(I - A^*)^{-1}\,Y^*_e$$

If there are final consumption pressures, we can further define:

$$\Delta D_{cba,tot} = D^*_{cba,tot} - D_{cba,tot} \text{ where:}$$

$$D^*_{cba,tot} = (D^*)'_{cba} e + Ge^*$$

A counterfactual scenario (an object adjoined with *) is constructed by adjusting particular elements in the objects that define the baseline EEIO system—S, A, Y (and possibly Ge) with this adjustment being as faithful as possible to the concepts underlying the policy intervention, subject to the limitations of the data and model.

The counterfactual scenario is constructed by adjusting only a (possibly) small set of values of some of the matrix objects that define the EEIO system. All other entries remain identical in both scenarios. With the current methods, we do not perform any automatic rebalancing of the counterfactual scenario, as such the system may become unbalanced when changes are applied to the technical coefficient matrix A (that is, total outputs differ from total inputs).

The edit of a particular entry ij of an arbitrary M matrix object from the baseline to the counterfactual scenario, is performed by the **Pycirk**[28] software as:

$$M^*_{ij} = M_{ij}\,(1 - k_a)$$

The change coefficient (k_a) expresses the magnitude by which a value in the IO system is modified. It is obtained as the product of a technical change coefficient (k_t), which describes the intervention's maximum potential effect, and of a market penetration coefficient (k_p), describing the size of the given market affected so that:

$$k_a = k_t k_p$$

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[28] Pycirk. (2021). Pycirk. Modeling the circular economy in environmentally extended input-output tables: Methods, software and case study. Retrieved from: pycirk website

Furthermore, a substitution relation between edits in different entries might exist. For example, a reduction in the volume of a particular material (such as steel) used in a production process might be compensated by an increase of another (such as aluminium). This type of relation is modelled as:

$$M^*_{ij} = M_{ij} + \alpha(M^*_{mn} - M_{mn})$$

Here mn are the coordinates of the original change (reduction in steel) and ij are the coordinates of the substitution (increase in aluminium). α is a substitution weighting factor accounting for differences in price and physical material properties between products, materials or services.

This model considers the impact of actions at the margin if taken tomorrow (so-called 'what-if' scenarios). Modelling the efficacy of the options if they are adopted at different points in time becomes far more complex, as the sequencing creates many different path-dependent trajectories (such as the carbon footprint of polyester production depends strongly on the carbon intensity of the electricity used to produce them). Some of the behavioural changes considered affect the volume of a particular stock, while others affect yearly flows. We considered the impact of a particular behavioural change as the yearly impact in a future year in which the relevant stock has been fully replaced. For example, the impact of improving textile product durability is the comparison between the status quo and a situation where a given fraction of existing textile products and the same fraction of new textile products have improved insulation. In other words, we compare the baseline scenario against a future steady-state situation in which the relevant stock has been replaced following the change. Rebound effects due to re-spending are not taken into account.

Building on this framework, the development of scenarios for the TCLF sector looked at six different scenarios:

1. Shift to more natural, local, and recycled fibres
    1.1. More natural-based fibres
    1.2. More plant-based fibres and increased recycling
2. Increase garment durability
    2.1. Use more durable synthetic garments
3. Nurture lower-impact fibre production
    3.1. Produce natural fibres using eco-friendly methods
4. Embrace slow fashion
    4.1. Align supply with market needs
    4.2. Shift consumer habits to reduce demand
5. Advance circular manufacturing
    5.1. Improve material efficiency
    5.2. Incorporate cleaner production methods
6. Transform regional supply chain dynamics
    6.1. Localise production and consumption

Each scenario is modelled through a number of specialised interventions which are then programmed into the model as a set of specific parameterized changes. The use of data input ranges is used in which the lowest range value represents 'moderate' impact, the middle value represents 'optimistic' impact and the highest value represents 'ambitious' impact. The results of the model are reductions in **Table ten** provides an overview of the scenarios and underlying assumptions.

Table ten. *Scenario descriptions and underlying assumptions*

Scenario	Intervention	Description	Assumptions
Shift to more natural, local, and recycled fibres	More natural-based fibres*	Synthetic fibres are substituted equally by plant-and animal-based fibres	In this scenario, we propose substituting a portion of synthetic textiles with natural fibres—thus regenerating and cycling flows. However, not all clothing can be made from natural fibres. Certain items, such as sportswear and shoes, require synthetic blends to meet specific performance and durability needs. These synthetic blends offer essential qualities like elasticity, moisture-wicking, and enhanced strength, which are crucial for the functionality and longevity of these types of clothing. Consequently, blended materials are necessary for 20% to 60% of products. This scenario assumes a one-to-one replacement of fibres with the same unit cost between product categories representing synthetic and natural fibres. Additionally, the availability and suitability of local fibres, though unspecified, is considered to be unconstrained for this scenario. In the moderate scenario, we assume 40% of newly produced textiles are made with monofibre natural fibres. In the optimistic scenario, this increases to 60%. In the ambitious scenario, 80% of newly produced textiles are produced with monofibre natural fibres.
	More plant-based fibres and increased recycling*	Synthetic fibres are substituted equally by plant-based mono-fibres fibres only as a form of 'design for recycling'	Our modelling assumes a one-to-one substitution rate with the same unit cost between product categories representing synthetic and plant-based fibres. However, not all textiles and clothing can be exclusively produced from plant-based fibres due to technical and economic considerations, necessitating blended materials in 20% to 60% of cases. Furthermore, our approach models an increase in recycled content by assuming a net reduction in virgin fibres consumed. In the moderate scenario, we assume 40% of newly produced textiles are produced with monofibre plant-based fibres. In the optimistic and ambitious scenarios, this increases to 60% and 80%, respectively. This strategy aligns with circular economy principles, aiming to regenerate and cycle flows in the textile production cycle.
Increase garment durability	Use more durable synthetic garments	Natural fibres are substituted with synthetic fibres only. Consumption of textiles and	While synthetic fibres offer durability advantages, not all textiles and garments can exclusively rely on them, with our assumption ranging from 25% to 75% of total composition. Increasing monofibre composition enhances

		clothes is reduced due to increased durability	recyclability, streamlining the recovery process for textile materials. Our model proposes a significant boost in recycled content, aiming for a net 30% reduction in virgin fibre use based on polyester as a benchmark, which currently incorporates 15% recycled or secondary materials. This recycled content encompasses materials sourced from textile fibres as well as other industries, such as plastic bottles. Furthermore, the improved durability and quality of textiles and clothing could potentially lead to a reduction in consumption by 10 to 20%, underscoring the potential for slowing and cycling flows in the textile sector. In the moderate scenario, we assume 25% of newly produced textiles are made with monofibre synthetic fibres, accompanied by a 10% reduction in textile product consumption. The optimistic scenario increases this to 50% monofibre synthetic fibres with a 15% reduction in consumption, while the ambitious scenario reaches 75% monofibre synthetic fibres with a 20% reduction in consumption.
Nurture lower-impact fibre production	Produce natural fibres using eco-friendly methods	More environmental friendly materials are used (mostly low-impact production systems)	To model this scenario, we assume that the strategy is applied exclusively to natural fibres. We also assume that improved agricultural and manufacturing processes can significantly reduce inputs such as water, pesticides, and energy. For cotton, across moderate, optimistic, and ambitious scenarios, potential reductions include a 46% decrease in GHG emissions, -62% in air pollution, -91% in water use, -30% in nitrogen-based fertiliser use, and -30% in phosphorus-based fertiliser use, with a 14% increase in land use. In the moderate scenario, we assume 20% of cotton is produced in a 'low impact way'. This percentage increases to 40% in the optimistic scenario and 60% in the ambitious scenario. Regarding leather and hide, assuming a 50% reduction potential across impact categories excluding land use, where no reduction is anticipated, the scenarios progress as follows: 25% of leather and hide in the moderate scenario is produced in a 'low impact way', 50% in the optimistic scenario, and 75% in the ambitious scenario. This approach aligns with the principles of a circular economy, emphasising the importance of narrowing and regenerating material flows.
Embrace slow fashion	Align supply with market needs	Reducing fashion collections/production (to avoid fiscal destruction of unsold products) and understanding market needs. Design products that are in fact needed/desired	In modelling this scenario, we assume that the global share of unsold clothes, estimated at 30%, represents the baseline from which we aim to decrease the share of unsold clothes. In the moderate scenario, we assume a 25% decrease in unsold clothing, lowering the share of unsold clothes to 22.5%. The optimistic scenario decreases unsold clothing by 37.5%, lowering the share of unsold clothes to 18.75%. The ambitious scenario decreases unsold clothes by 50%, lowering the share to 15%. We further assume a reduction in overall sales, thereby addressing overproduction and aligning production more closely with consumer demand to narrow flows.
	Shift consumer habits to reduce	Reuse, repair and make your own clothes (e.g. clothes libraries, renting, donations, DIY, etc.)	In modelling this scenario, we assume an increase in the use of raw materials by households, reflecting a trend towards more DIY practices amongst consumers. Additionally, we account for a small rebound effect where households purchase textile raw materials to facilitate

	demand		repairs themselves, with an assumption that for every one unit of textiles reduced, 0.2 units of raw textile materials are utilised by households. This factor is integral to accurately modelling the dynamics of consumer behaviour in response to changing consumption patterns. The model also considers three scenarios: an ambitious 5% reduction, an optimistic 3.75% reduction, and a moderate 2.5% reduction in overall consumer textile consumption. These assumptions form the basis for modelling strategies aimed at narrowing flows within the textile sector.
Advance circular manufacturing	Improve material efficiency	Implementation of better technologies (e.g. BATs) for the reduction of post-industrial waste	This intervention's modelling is based on average processing losses of 26% for yarn-to-fabric and fabric-to-product stages in apparel manufacturing, and 14% in textiles, excluding fibre-to-yarn processes. It is estimated that 'avoidable' losses can range between 25 to 75%. Based on these figures, we model three scenarios: a moderate 25% loss reduction, an optimistic 50% loss reduction, and an ambitious 75% loss reduction. To achieve significant reductions in these losses, increased investment in advanced machinery and equipment will be necessary. These assumptions form the basis of our strategy aimed at narrowing flows in the textile industry.
	Incorporate cleaner production methods	Implementation of better technologies (e.g. BATs) for the reduction of environmental impacts	Assumptions in modelling this strategy include varying reduction potentials for emissions, air pollutants, nitrogen and phosphorus levels, and water usage, with targets arbitrarily set between 50 and 100%. Achieving these reductions will require increased investment in advanced machinery and equipment. This strategy aims to make textile production cleaner and more sustainable by narrowing and cycling flows, significantly reducing the industry's environmental impact and paving the way for a more circular future.
Transform regional supply chain dynamics	Localise production and consumption	Shift production from Asia and Pacific to America and EU, localise part of consumption in all regions	In modelling this scenario, we assume that the prices of raw material inputs remain consistent across both production in the Asia Pacific and the US and Europe. The model considers three scenarios: a moderate 10% production decrease in the Asia Pacific, an optimistic 15%, and an ambitious 20%. These reductions are assumed to be compensated (substituted) by increased production in Europe and the US each by 5% (moderate), 7.5% (optimistic) and 10% (ambitious). Finally, the consumption of textiles is decreased globally by 5% (moderate), 7.5% (optimistic) and 10% (ambitious). It is also assumed that there are no infrastructural implications affecting production, ensuring that any differences in output or efficiency are not attributed to variations in infrastructure between regions.

* Not included in the combined scenario

ANNEX A: CALCULATION OF TEXTILES CONTRIBUTION TO VALUE CHAIN STAGES

The following provides a breakdown of the share of textiles contribution assumed for the following value chain stages (see Table three).

Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)

The Observatory of Economic Complexity (OEC) database is used to determine the share of the textile industry within this value chain stage. Based on 2021 data about global wholesale and commission trade, the following sectors are summed:

Trade in Textiles represents 4.19% of total world trade.[29]
Textile footwear 0.2%[30]
Leather footwear 0.24% [31]
Leather apparel 0.034%[32]
Trade in Fur Clothing represents 0.029% of total world trade.[33]
Trade in Textile & Fabrics represents 0.59% of total world trade.[34]
Animal hide 0.5%[35]

Total share = 5.78%

Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (52)

Based on a range of data collection about global global retail trade, the following steps are taken to determine the contribution of the textiles industry within this value chain stage:

The global retail market generated sales of over US$27 trillion in 2021.[36]

The global automotive retail market size is estimated to be between US$3,600 and US$4,900 billion in between 2020 and 2023.[37] We assumed US$4,000 as an estimate.

The total value of the sector is thus estimated to be = US$27,000 - US$4,000 = US$23,000 billion.

The size of the global apparel and footwear market in 2022 was US$1.9 trillion.[38]

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[30] Observatory of Economic Complexity (OEC). (2021). Textile Footwear. Retrieved from: OEC website

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The global fur retail trade in 2020 is estimated to be in the order of US$25.1 billion.[39]

The total value of the textiles retail industry is thus estimated to be = US$1,900 billion + US$25.1 billion = US$1,925.1 billion

Total share = US$1925.1 billion /US$23000 billion = 8.37%

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