European Commission

JRC SCIENTIFIC AND POLICY REPORTS

Environmental Improvement Potential of textiles (IMPRO Textiles)

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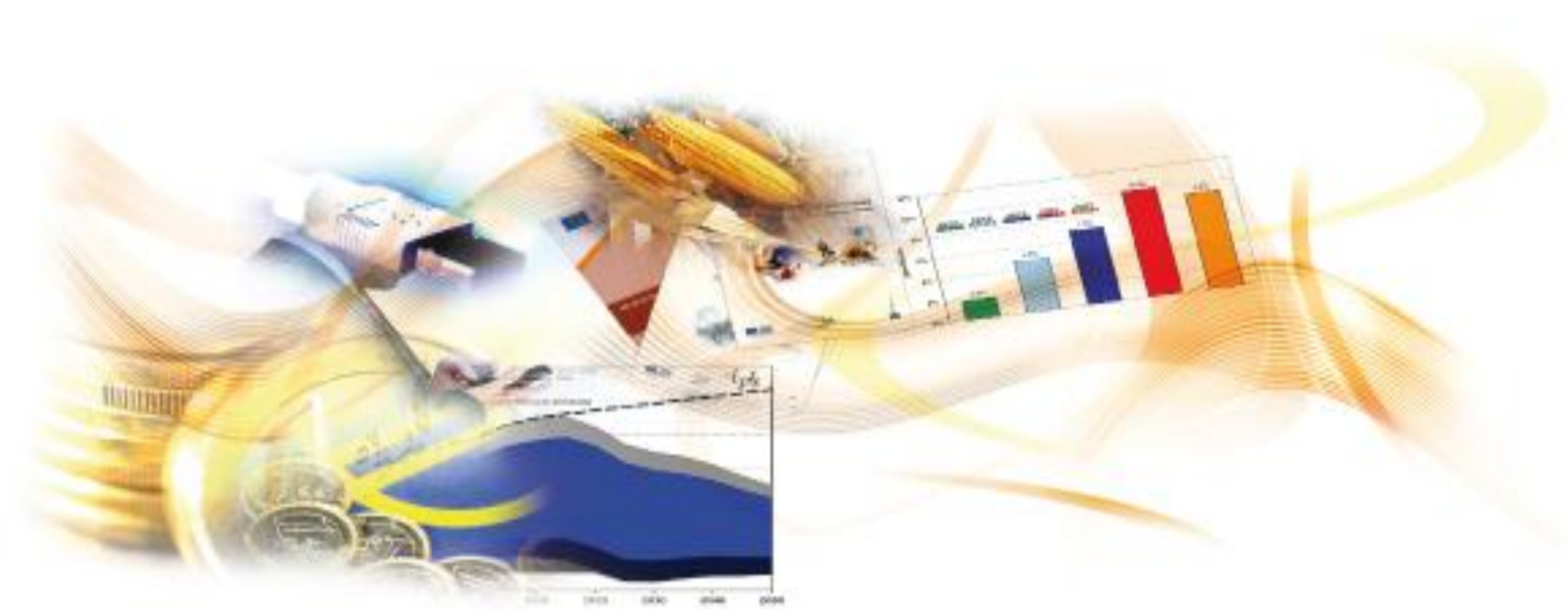
January 2014



Joint Research Centre

Report EUR 26316 EN

European Commission
Joint Research Centre
Institute for Prospective Technological Studies (IPTS)

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JRC85895

EUR 26316 EN

ISBN 978-92-79-34554-8 (pdf)

ISSN 1831-9424 (online)

doi:10.2791/52624

Luxembourg: Publications Office of the European Union, 2014

Printed in Spain

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Results presented here are based on circumstances and assumptions that were considered during the study. If these facts, circumstances and assumptions come to change, results may differ. It is strongly recommended to consider results from a global perspective keeping in mind assumptions taken rather than specific conclusions out of context.

SUMMARY

INTRODUCTION

Regardless of the life cycle stage, all products and services inevitably produce an impact on the environment. By identifying critical issues present in the life cycle of products and taking constructive response actions in practice, the European Integrated Product Policy (IPP) aims to reduce the environmental impacts of products and to improve their performances with a "life cycle thinking". The first action taken under IPP was to identify the market products contribute most to the environmental impacts in Europe.

Completed in May 2006 by the European Commission’s Joint Research Centre (JRC), the *Environmental Impact of Products* (EIPRO) study was conducted from a life cycle perspective. The EIPRO study indentified food and drink, transport and private housing as the highest areas of impact. Together they account for 70–80 % of the environmental impact of consumption. Of the remaining areas, clothing dominated across all impact categories with a contribution of 2–10 %.

While initially analysing the current life cycle impacts of products, studies on the *Environmental Improvement of Products* (IMPRO) have been developed in order to identify technically and socioeconomically feasible means of improving the environmental performance of products.

As identified by the EIPRO study as a priority group which makes a significant contribution to environmental impacts in Europe, textile products are the focus of this study.

OBJECTIVES

The main objectives of this study are to:

- identify the market share and consumption of textile products in the EU-27;
- estimate and compare the potential environmental impacts of textile products consumed in the EU-27, taking into account the entire value chain (life cycle) of these products;
- identify the main environmental improvement options and estimate their potential;
- assess the socioeconomic impacts of the identified options.

THE TEXTILES MARKET IN THE EU-27

A major challenge in this project was to appropriately tune the level of detail of the textile sector in order to identify individual products for which to gather realistic data on their production and use patterns. In the fulfilment of this task, it was very important to cope with the uncertainty of environmental data and the lack of detailed market information.

Apparent consumption figures in Europe were determined for all the textile products. The products were categorised by broad types and further broken down by their most important characteristics (e.g. fibre type, product type). The initial phase of the study thus consisted in gathering exhaustive market data of textile products in Europe. The EUROPROM database was used as the main data source, focusing on clothing and household sectors. EUROPROM combines information on the production (PRODCOM database) and information on the import and export of manufactured products in the EU (COMEXT database). Apparent consumption in the EU-27 was calculated as production plus imports minus exports.

In total, 101 clothing product categories and 27 household product categories were identified. The available market data was extracted for each one. For simplification, major end product categories were identified for both sectors from the full list of products presented in the database. In total, clothing textiles were broken down into 63 different end product categories. As each of the household textile products listed were quite distinct, 27 end product categories were maintained. A breakdown by major materials involved was also ascribed to each end product type (e.g. trousers, shorts, shirts, blouses). The baseline scenario of the model covered:

- 9 fibre types, i.e. cotton, wool, viscose, flax, silk, polyester, polyamide, acrylic and polypropylene;
- polyurethane/polypropylene, feathers, and polyvinyl chloride (PVC).

Two additional fibre types were addressed as improvement options: hemp and polycotton (i.e. polyester/cotton mix). Table 1 recapitulates which fibre types and materials were addressed in the model.

Table 1: Fibre types and materials used in the baseline scenario of the study and in the evaluation of improvement options

	Fibre types	Materials
Baseline scenario	Cotton Wool Viscose Flax Silk Polyester Polyamide Acrylic Polypropylene	Polyurethane/Polypropylene Feathers PVC
Improvement options	Hemp Polycotton (Polyester/Cotton)	-

In terms of breakdown per item (by mass), the analysis of the textile market revealed that tops, bottoms and underwear are the most significant items covering all together more than 78 % of the clothing market. For household textiles, floor coverings clearly dominate the market (38 %). The analysis also highlighted that the volume of clothing, on a weight basis, is almost twice that of household textiles. Average apparent annual consumption was estimated at 9 547 000 tonnes of textile products (19.1 kg / citizen and year), of which 6 754 000 are clothes and 2 793 000 are household textiles.

In terms of clothing textiles production weight, the market is dominated by cotton, which accounts for more than 43 % of all fibres, followed by polyester (16 %). Acrylic, wool and viscose represent approximately 10 % of the market each. The ratio between natural and synthetic fibre is 54:46.

For household textiles, cotton and polyester are the most common fibres accounting for approximately 28 % each, followed by polyamide (23 %). In contrast to clothes, acrylic and polypropylene feature significantly in this area, accounting for nearly 30 % as they are important fibres found in carpets. The ratio between natural and synthetic fibre is 30:70 (see Figure 1).

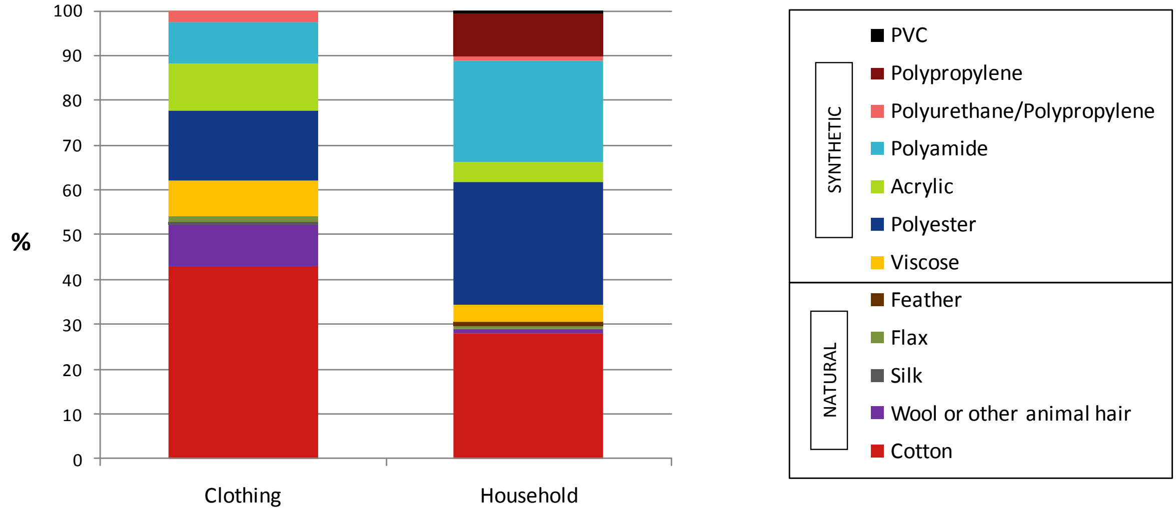


Figure 1: Percentage breakdown of consumption by fibre type for clothing and household textiles

ENVIRONMENTAL IMPACTS

The environmental performance of textile products in the EU-27 was then assessed according to the Life Cycle Assessment (LCA) methodology and following a bottom-up approach. A LCA model was developed in order to evaluate impacts of both first- and second-hand textiles ([1]). Potential impacts associated with the overall life cycle of textiles consumed in EU-27 in 2007 (baseline scenario) were taken into account. Figure 2 shows a schematic representation of the life cycle stages considered in the LCA model.

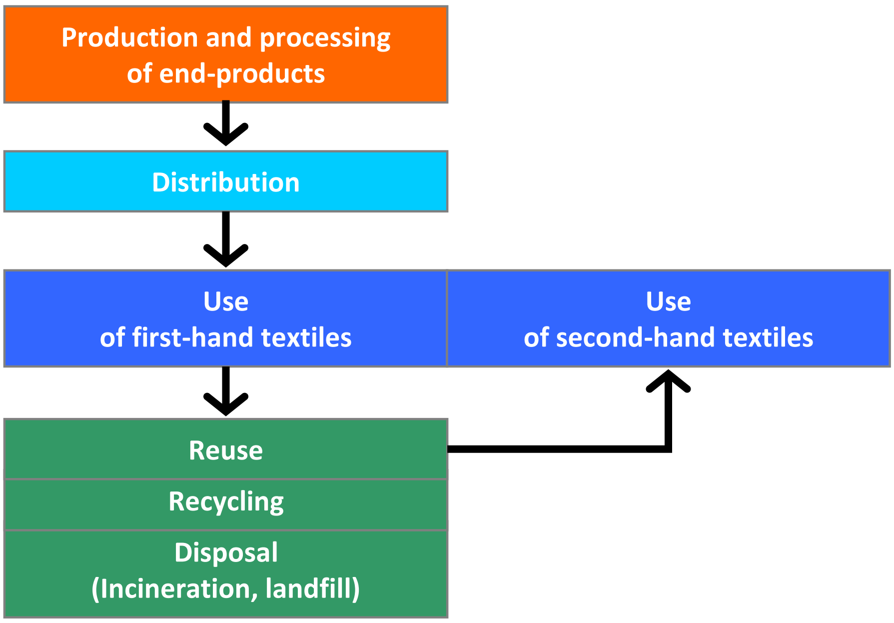


Figure 2: Stages considered in the LCA model of textile production and consumption

([1]) Second-hand textiles refer to products that are reused after they reach the end-of life phase.

The life cycle impacts of the textiles value chain were thus analysed within the four phases described below:

- **Production and processing**. This phase includes the production or extraction of raw materials (e.g. cultivation of fibre-producing crops), leading to the processing of the fibre, followed by the confection of yarn and fabric, and finally the finishing, cutting and sewing steps**.**
- **Distribution**. This phase takes into consideration the distribution of textile end-products, based on a distribution scenario developed for textiles in the EU-27.
- **Use**. This phase takes into account consumer behaviour and the use patterns of textile end products. This step incorporates the impacts of washing, tumble drying and ironing. These impacts occur during the entire lifetime of textiles following production, measured in number of washes.
- **End-of-life**. This phase includes reuse, recycling, incineration and landfilling of textiles. However, despite it can be considered an end-of-life business, the reuse of old items was taken into account for the calculation of the real consumption of textiles, so that a discount was implicitly assigned to the impacts from the production stage.

Environmental data on each of these phases were gathered from the literature. Life cycle input and output data were obtained from the Ecoinvent 2.0 database (Ecoinvent Centre, 2007) with the exception of the end-of-life treatment processes, which were modelled using the WISARD 4.2 tool (Price Waterhouse Coopers, 2007). The life cycle impact assessment was based on the ReCiPe method – hierarchist perspective (Goedkoop et al., 2008), which allowed for the quantification of potential environmental impacts both at midpoint and endpoint level. In total, 18 midpoint indicators (e.g. climate change, ozone depletion, human toxicity) and 3 endpoints indicators (i.e. damages to human health, ecosystems and resource availability) were included in the textile LCA model.

Results show that significant contributions to the environmental impacts are due to the production and to the use phases (see Figure 3). Product distribution and recycling/disposal activities at the end-of-life phase are both of minor importance only. For some midpoint categories, the end-of-life phase even results in credits which contribute to a net reduction of the impacts.

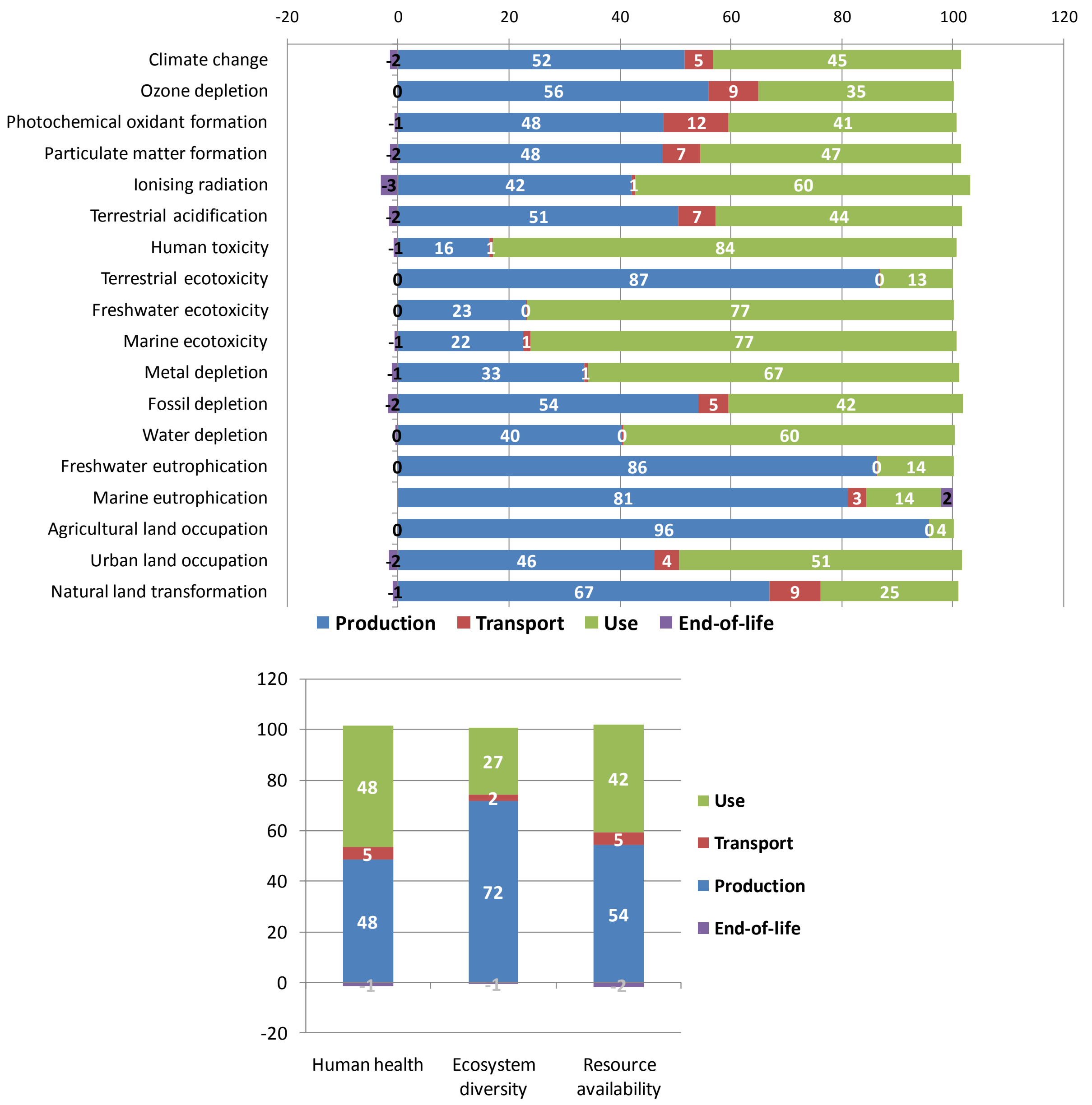


Figure 3: Impacts of textile consumption in the EU-27 according to the ReCiPe's midpoint (a) and endpoint (b) indicators. The percentage contribution of the different life cycle stages is reported

The production and processing phase is predominant for indicators such as eutrophication, agricultural land occupation and natural land transformation which are mostly associated with the use of natural fibres, which requires land and fertilisers during the cultivation step. Cotton is in particular the main contributor among all the fibres due to its large share in the textiles market and to the nature of its production.

The use phase includes washing, tumble drying and ironing. The detergent used for the washing process and the energy used during the washing process itself have been found to be significantly responsible for a high share of the impacts. The contribution of this stage is higher than 40 % in most of the midpoint categories and it appears particularly significant for the toxicity indicators related to human beings and water ecosystems. The textile end-products that contribute most significantly to overall impacts during the use phase are those which require frequent washing and/or that are consumed in important quantities (e.g. tops, bottoms, underwear, etc.). As a potential consequence of the significant contribution to freshwater and marine toxicity, the use phase scores the highest contribution also to the damage category 'ecosystem diversity'.

Energy and water are demanded all along the value chain of each textile products, which explains a relative balance between production and use phases in categories related to water depletion and energy consumption (e.g. fossil fuel depletion, climate change, ozone depletion, photochemical oxidant formation, particulate matter formation). The damage to human health and to resources is also allocated almost equally between production and use phases because of their dependence on the mentioned midpoint indicators.

Interestingly, with respect to water depletion, the use phase is even more important than the production and processing phase due to high water use for washing.

With respect to the distribution phase, air freight contributes to about 90 % of the impacts despite its relatively small share (8 % of the transported textiles). In comparison with the other three life cycle phases, the end-of-life phase instead shows some unique features. For some indicators, the apparent contributions due to the end-of-life phase are quite small, also because impacts are offset by credits due, for example, to energy and material recovery. Nevertheless, the environmental benefits associated with the reuse of textile products are not directly visible in figure 3 because they were implicitly included in the calculation of the impacts of the production stage.

➢ Assumptions and limitations

The baseline scenario has been modelled to reflect current state-of-the-art technologies. However, the textile industry is one of the longest and most complicated industrial chains in the manufacturing industry, bringing into play actors from industry (i.e. agricultural, chemical fibres, textile, apparel, non-conventional), retail services and waste management. Thus, some limitations have been encountered because of the unavailability of area-specific data. In order to cope with this issue, the assumptions detailed below were necessary.

- Importation for EU consumption could not be distinguished from importation for transit. Distribution impacts were therefore allocated to all end products consumed in the EU.
- Reused textiles in Europe were included in the model. A lifetime extension of 50 % was considered, assuming they avoid the production of new items with a 1:1 ratio. Only the impacts of exportation were considered for items that are reused abroad.
- Blended fibres are integral part of the model as the breakdown per fibre of each item was considered. However, blended end products could not be distinguished from non-blended items and it was therefore not possible to take into account some of their specific characteristics (processes, care habits, disposal routes, etc.). A simplified case study was carried out in order to understand the significance of considering these aspects in the assessment of the environmental performance of a specific end product (i.e. a T-shirt).
- In the textile LCA model, textiles were considered to be recycled into rags. It is then assumed that rags from textiles can replace paper towels and, therefore, that the impacts associated with paper towel production are avoided. Only energy benefits were included in the model. This is moreover only one of the many possible recycling routes for textiles.
- Concerning the production of fibres, some processes were extrapolated to different fibres where no fibre-specific data were available.
- Processes are tightly linked to product quality, implicitly meaning that for a given fibre type, end products will not necessarily follow the same processes. However, as this information could not be obtained and included in the model, it is assumed that all fabrics undergo a complete chain of processes which is likely to overestimate the impacts.
- Most of the life cycle phases take place in different locations around Europe and the world. This implies technological and user behaviour variability and complex transportation schemes of fibres, yarns, intermediary or end products that could not be always taken into account. For what that concern the production stage, it was generally assumed that European practices are representative, for most processes, of the average global production.

IMPROVEMENT OPTIONS

A list of feasible improvement options was established to identify the improvement potential of the textile life cycle in the EU-27. First, through literature research and consultation of experts, a long list of 52 improvement options was determined. This list was shortened by applying the following criteria:

- relevance in the context of Integrated Product Policy (IPP)
- potential to improve processes that generate significant impacts
- coverage by existing legislation
- reliability and availability of data to quantify the environmental impact.

Based on these criteria, the following short list of 13 improvement options was determined:

- **production and processing phase:**
  1. reducing agrochemical use
  2. developing easy-to-grow crop cultivations by replacing cotton with hemp or flax
  3. reducing consumption of sizing chemicals
  4. replacing chemicals with enzymes
  5. using alternative knitting techniques (e.g. fully-fashioned knitting or integral knitting)
  6. using dye controllers and low liquor ratio dyeing machines
  7. water recycling.
- **distribution phase:**
  8. reducing air freight
- **use phase:**
  9. reducing washing temperature
  10. reducing tumble drying
  11. optimising the load of appliances
  12. improvement of washing/drying appliances efficiency
- **end-of-life phase:**
  13. promotion of reuse and recycling

Scenarios were thus modelled in order to estimate the potential environmental benefits of these options. A simplified analysis of the potential benefits associated with fibre blending was also addressed through a case study referred to a specific end product (i.e. a T-shirt)

ENVIRONMENTAL BENEFITS

Table 2 presents the benefits of each of the 13 improvement options expressed in relation to the three endpoint indicators included in the assessment method selected for this study (i.e. ReCiPe).

Table 2: Potential reduction of the environmental impacts due to the improvement options considered in this study. Results are expressed with reference to the ReCiPe's endpoint indicators and in comparison with the baseline scenario

Stage	Option	Impact reduction (%)		
		Human Health	Ecosystem diversity	Resource availability
Production	Reducing agrochemical use	0.7	3.7	0.4
	Replacing cotton with hemp or flax	0.3	5.8	0.7
	Reducing consumption of sizing chemicals	0.2	0.3	0.2
	Replacing chemicals with enzymes	0.0	0.1	0.0
	Using alternative knitting techniques	1.2	2.0	4.0
	Using dye controllers and low liquor ratio dyeing machines	0.1	0.8	0.1
	Water recycling	0.6	11.3	0.6
Distribution	Reducing air freight	3.9	1.9	4.5
Use	Reducing washing temperature	4.7	2.1	4.3
	Optimising the load of appliances	3.9	2.4	3.3
	Reducing tumble drying	1.6	0.7	1.5
	Improvement of washing/drying appliances efficiency	3.8	1.7	3.6
End-of-life	Promotion of reuse and recycling	8.1	5.7	7.7

NB: Different sub-scenarios were examined for some improvement options. The results of the most optimistic sub-scenarios are shown here

Concerning the midpoint indicators, the most promising options for the reduction of the contribution of each indicator is presented intable 3.

It is worthy noting that most of the best improvement options are consumer oriented, which emphasises the key role in the model of the parameters related to the social sphere and the importance of users behaviour on the overall environmental performance of textiles.

Table 3: Best improvement options to decrease the environmental impacts of the textile life cycle. Results are expressed with reference to the ReCiPe's midpoint indicators and in comparison with the baseline scenario

Midpoint Indicator	Most promising option to decrease the contribution to the indicator	% reduction reached
Climate change	Increase of the collection of used clothing for reuse and recycling	8
Particulate matter formation		8
Ionising radiation		12
Terrestrial acidification		8
Fossil depletion		8
Urban land occupation		7
Freshwater ecotoxicity	Increase of the load capacity of washing and drying appliances	10
Marine ecotoxicity		9
Metal depletion		7
Human toxicity		10
Freshwater eutrophication	Substitution of cotton by hemp	31
Marine eutrophication		18
Agricultural land occupation		24
Water depletion	Recycling of effluent water by ion exchange technology	25
Natural land transformation		12
Ozone depletion	Use of fully fashioned knitting	9
Photochemical oxidant formation	Avoidance of air transportation	8
Terrestrial ecotoxicity	Replacement of traditional cotton by GM cotton	45

In addition to considering single options individually, an estimation of the maximum benefits that could be gained by combining all the compatible improvement options was assessed.

The maximum environmental benefits resulting from the combinations of the improvement options are shown in figure 4. The overall impact of the textile life cycle could be decreased by 17 % to 51 % depending on the midpoint category considered. The highest reduction was registered for terrestrial ecotoxicity (51 %), followed by water depletion and marine eutrophication (35 % and 34 %), land transformation (30 %) and climate change and fossil depletion (22 % and 21 %, respectively. A reduction potential between 21 % and 27 % was instead registered for the endpoint indicators.

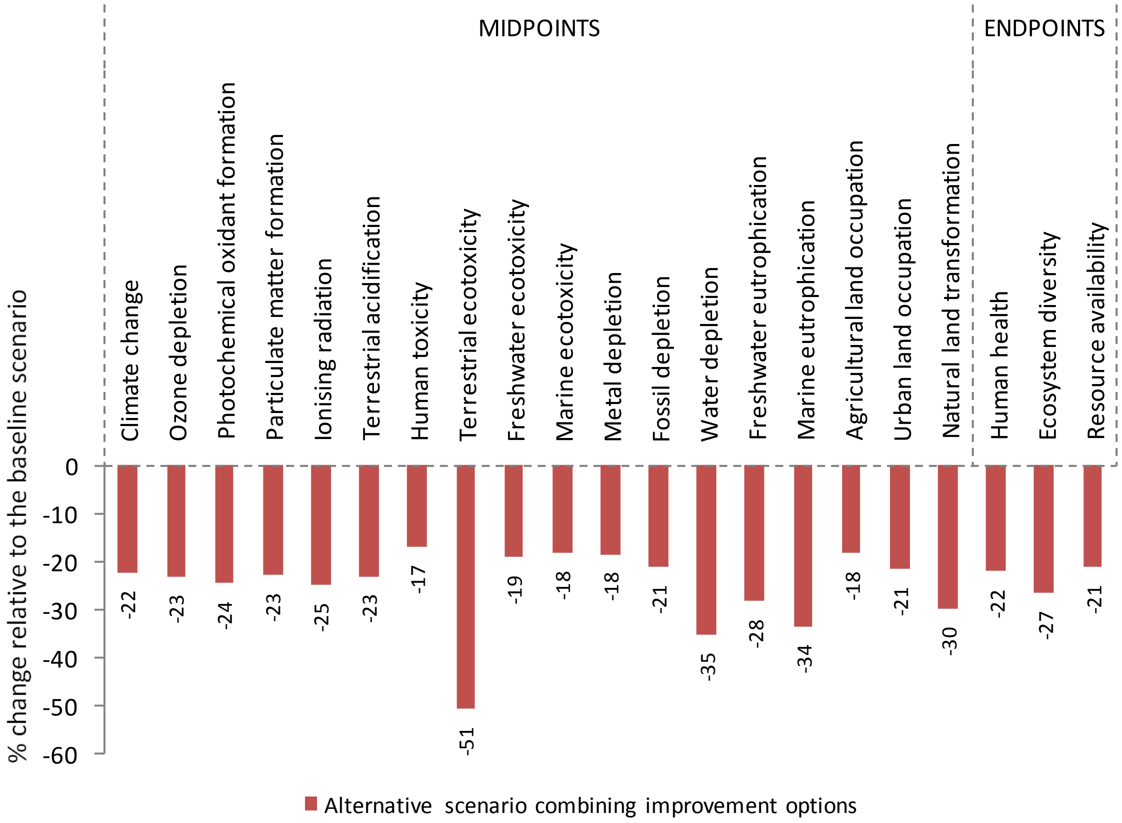


Figure 4: Maximum environmental benefits resulting from the combination of the improvement options

CONCLUSIONS

The environmental impacts of textile consumption and use in the EU-27 are both supply- and demand -driven.
Supply factors include:

- agricultural practices
- production processes of the textile industry
- product design and functionalities of washing/drying/ironing appliances
- existence of sorting and recycling schemes.

Demand factors (which are mostly driven by social parameters) include:

- choice of products/fibres
- care practices (washing, drying, ironing)
- lifetime of product in a context of fast fashion
- disposal practices.

The production and the use phase of textiles contribute most to the environmental impacts compared to the other life cycle phases. Efforts to reduce the total impact of the EU-27 textiles market should thus be related to these stages.

The analysis of the possible improvement options suggest that a significant reduction of impacts can potentially be achieved by targeting consumers. In particular, some of these options would require small behavioural changes. Examples for such changes are: reducing washing temperature, washing at full load, avoiding tumble-drying whenever possible, purchasing eco-friendly fibres, and donating clothes being not used anymore. To achieve such changes it is necessary for consumers to be aware of these issues, and it is imperative that infrastructural requirements can be met. Raising awareness and dissemination therefore become important drivers of change. Promotion of ecolabels, and examples of best practice cases, could therefore be used as tools for the overall improvement of environmental performance.

Concerning with improvement options related to supply factors, it is more challenging to the accurate assessment and comparison of the improvement potential of single actions is more challenging due to a lack of experience with emerging techniques. Nevertheless, the analysis suggests that significant improvements could be achieved by appropriately encouraging practices which can produce less environment impacts, such as the recycling of effluent water.

Environmental policy intervention should aim at either the supply or demand factors considering the overlap between the two areas. At the European level, the initiatives launched so far have mostly focused on the production phase. One can for instance mention the directives and voluntary schemes promoting cleaner production such as the REACH legislation or the EMAS voluntary instrument that have a strong influence on the industry. Other notable actions include product-targeted measures such as the Ecodesign Directive which is a key EU strategy. However, when it comes to the textile industry, the field of action of European policies and legislation is limited by the fact that most of the production takes place outside of the EU borders. One way to tackle this limitation is thus to further develop the use of market and policy instruments which are more consumer-oriented, such as the European Ecolabel scheme.

INTRODUCTION

Regardless of the life cycle phase, all products and services inevitably generate an effect on the environment. By identifying critical life cycle aspects and taking constructive action, the European Integrated Product Policy (IPP) aims to improve the environmental performance of products with life cycle thinking as a central methodology. To accomplish this, the IPP must stimulate all the actors of the value chain by influencing the design, manufacture, distribution, and consumption patterns.

The first action taken under IPP was to indentify which market products contribute the most to environmental impacts in Europe. Completed in May 2006 by the European Commission's Joint Research Centre (JRC), the *Environmental Impact of Products* (EIPRO, Tukker *et al*., 2006) was a study conducted from a wide life cycle perspective. The resulting list of products was aggregated into major groups, and priority has been given to those products consumed in Europe being considered to produce higher environmental impacts.

EIPRO indentified food and drink, transport and private housing as the highest impacting areas. Together they account for 70–80 % of the environmental impact of consumption. Of the remaining areas, clothing dominated across all impact categories, with a contribution of 2–10 % (Tukker *et al*., 2006). An alternative study (Labouze, 2006) reached similar conclusions and found textiles to be contributing between 1 and 16 % to the environmental impacts of consumption in Europe. Although not part of the top three areas, textiles still contribute to a significant proportion of the environmental impacts in the EU-27.

While initially analysing the current life cycle impacts of products, the *Environmental Improvement of Products* (IMPRO) also focuses on identifying technically and socioeconomically feasible means of improving their environmental performance. IMPRO analyses of passenger cars (Nemry *et al*., 2008a), residential buildings (Nemry *et al*., 2008b), and meat and dairy products (Weidema *et al*., 2008) have already been completed.

As a priority group which makes a significant contribution to the environmental impacts in Europe, textile products are the focus of this study.

In addition to providing an insight into the environmental impacts of textile consumption in Europe, this project could be useful for the Ecolabel scheme for textiles by providing a quantitative assessment of the improvement options of textile consumption. Indeed, this study does not only provide a baseline scenario for the current impacts of the textiles market, but can also help to design further ecolabel criteria by which the environmental performance of textiles can be judged.

The objectives of this study are to:

- identify the market share and consumption of textile products in EU-27;
- estimate and compare the environmental impacts of textile products consumed in EU-27, taking into account the overall value chain (life cycle) of these products;
- identify and estimate the magnitude of the main environmental improvement options;
- assess the potential socioeconomic impacts of the identified options.

1 TEXTILE CONSUMPTION AND DISTRIBUTION IN EU-27

1.1 Introduction

Textile products have one of the longest and most complicated value chains within the manufacturing industry. The textile industry involves actors from the agricultural, chemical fibres, textile, and apparel industries, from the retail and services sectors, and from the waste management field. The industry is fragmented and heterogeneous dominated by small and medium enterprises (SMEs) which account for more than 80 % of the market. According to the *Reference Document on Best Available Techniques (BAT) for the Textiles Industry* (BREF, 2003), in the year 2000, the contribution of this sector to EU manufacturing added value and to industrial employment was 3.8 % and 6.9 %, respectively. According to the article *Trends in EU Textile and Clothing Imports* published in August 2009 ([1]), European Union textile and clothing imports rose in value, reaching EUR 80.46 billion in 2008. However, clothing imports alone were up by 2.4 % in value while textile imports declined by 5.7 % and, most important for this study, the trends were similar in volume. Market figures on textiles and clothing are reported in Table 4 for the years 2006 and 2007.

Table 4: Market figures for imported and exported textile and clothing

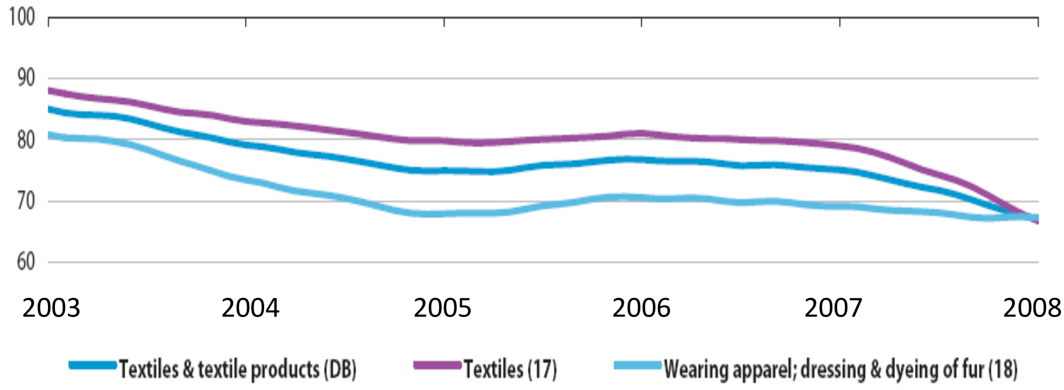
In thousand EUR	Import		Export	
	2006	2007	2006	2007
Textiles	19 035 988	19 896 428	16 940 322	17 120 527
Clothing	59 249 913	61 419 964	16 728 524	18 187 657
Source: EURATEX, 2008a, 2008b				

On Table 4 it is possible to observe the repartition between imports and export in the European Union. In geographical terms, Euratex explains that more than half of the total extra-EU textiles and clothing imports in 2007 came from the top three suppliers: China (39 % of all imports in terms of value), Turkey (14 %) and India (7.7 %) (statistics extracted from the European Commission website ([2])). As far as imports are concerned, it is clear that in the EU-27, the largest producers in the textile and clothing industry are the five most populated countries, that is to say Italy, France, Germany, and Spain and the UK. These five countries account for about three quarters of the EU-27 production of textiles and clothing. It is worth mentioning that Italy is by far the most important exporter in extra-EU textile trade with 33.7 % of the total EU textile exports.

Although domestic production prices of textiles have increased by 7.2 % between 2000 and 2008, European textile and leather production has declined by 26 % since the year 2000 according to Eurostat (2009) (see figure 5). During 1990–2003, industry employment decreased from 3 million to 2 million employees. As output prices increase, the demand for imported products is likely to increase, as the costs of production and labour are often lower in foreign areas. Despite this, the sector represents over 110 000 enterprises, or about 10 % of European industrial companies (UIT, 2009),

([1]) http://www.bharatbook.com/detail.asp?id=8207&rt=Trends-in-EU-Textile-and-Clothing-Imports.html
([2]) http://ec.europa.eu/enterprise/sectors/textiles/external-dimension/trade-issues/index_en.htm

allowing Europe to remain the world's largest exporter of textiles and the second largest exporter of clothing.



Source: Eurostat, 2009
NB: year 2000 = 100

Figure 5: Index of production, trend cycle for the EU-27

Each step of the textiles life cycle is dependent on several factors which lend themselves to the complexity of the industry. Patterns of production and consumption can vary greatly, with several intermediary flows, both at the manufacturing and distribution levels. In the face of ever-changing consumer demands, the textiles industry is constantly under pressure to evolve, creating textiles with varying designs and functions. More so than many other product types, the characteristics of a textile product can be influenced by not only their practical purpose, but also the tastes of those who purchase them. It is because of both of these factors that such a wide variety of different textile products is available. Furthermore, these factors can have an influence on the colour, size, weight, fibre type and texture of a specific product type. Because of this diversity of characteristics, it is misleading to analyse the impacts of one product and to attribute the results to several other types of products. It is not reasonable to assume, for example, that the life cycle impacts of a polyester shirt would be the same as those of a linen bed sheet.

The processes for textile manufacturing can be more or less intensive, depending on the added value of the final product. But even the less intensive activity requires large amounts of water, chemicals and energy. Although there are a variety of studies (ERM ,2002a; Maiorino *et al*., 2003; Laursen *et al*., 2007) which focus on specific individual products, the intention here is to determine the impacts of all end product-types in the EU-27. In order to do this, it was necessary to determine the market share of all textile products in Europe, categorise products by broad types, and further break down each type by their most important characteristics in terms of life cycle effect, a major criterion being the cloth's fibre type.

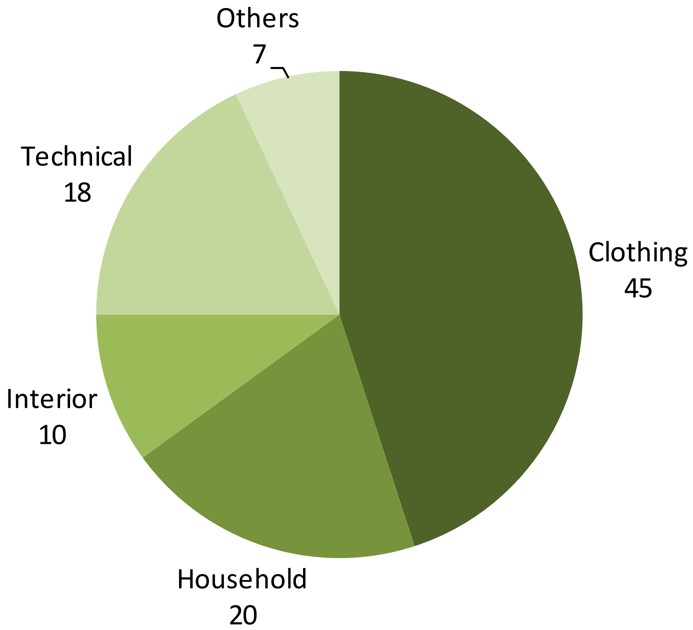
The textile and clothing industry comprises 'natural' fibres (including cotton, wool, silk, flax, jute) and synthetic fibres (including fibres coming from the transformation of polymers and inorganic materials). Regarding the order of magnitude of the repartition between natural fibres and synthetic fibres, EURATEX stipulates that in 2007, EUR 1.7 billion of natural fibres were imported against EUR 0.9 billion of synthetic fibres. In addition, EUR 0.6 billion were collected by the export of natural fibres against EUR 0.8 billion for synthetic fibres. It can be assumed that Europe is an importer of natural fibres whereas imports and export of synthetic fibres are globally the same. This trend is not new; one can observe this in *Statistics in focus* by EUROSTAT ([1]): the European Union exported textile products worth EUR 38 billion in 2005. At the same time, imports amounted to roughly double that value (EUR 77 billion). The trade deficit of the European Union thus amounted to EUR 39.5

([1]) Eurostat, *EU-25 trade in textiles 2005*, Issue 63/2007, http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-07-063/EN/KS-SF-07-063-EN.PDF billion. The CIRFS (The International Rayon and Synthetic Fibres Committee) ([1]) gives us more information on polyester fibres: worldwide, over 30 million tonnes of polyester fibre are produced and consumed, furthermore the world market for polyester fibre is growing at around 5 % per year. In the European Union, the imports of yarn are large and rising (its share has increased from 45 % to 53 % in 2007).

As far as inside trade is concerned, the textiles industry provides 9.5 % of jobs in European Union, but only 5 % of value added. This shows that the productivity per person is very low in this sector. Once again, Italy contributes to one third of the total amount of value added which was of EUR 25.2 billion in 2001. Apart from Italy, six other Member States have trade surpluses, even if none of these six are major actors in the textile business. Large deficits prevail, especially those of Germany and the United Kingdom, accounting for 28 % and 30 % of the total EU trade deficit respectively.

1.2 Scope and methodology

Although clothing is considered an important group of textile products, household, interior and technical textiles are also other significant functions. The breakdown of the European textile market (see figure 6), shows that clothing products make up the most prominent share, followed by household and technical textiles in terms of mass. Due the vast diversity and highly specific nature of some of these products, technical textiles have been omitted from the scope of the study. One of the reasons for this is that technical textile products are very heterogeneous. It would be difficult to aggregate some individual products into categories given the different types of industrial settings they may be used in. Not enough exhaustive market and production data are available for these different products to analyse them in the context of the EU-27 market. Moreover, because the settings they are used in can differ so much, it would be difficult to determine use phase patterns, and thus impossible to quantify the overall impacts of this phase. As they can also be combined with other product types, it would be difficult to determine which share of the market data relates only to the textile parts of these products. The study therefore focuses on the 'Clothing' and 'Household' textiles share. Note that the 'Household' textiles group includes both household and interior textiles. The classification and market research results will be presented below for each of these two major groups.



Source: European Commission, 2003

Figure 6: Breakdown of the European textile market

([1]) CIRFS, *Key statistics*, http://www.cirfs.org/KeyStatistics.aspx

First, market data was gathered to determine the apparent consumption of textile products in Europe. The Europroms (Europroms 2010) database was used as the main data source, focusing on clothing and household sectors. Data from 2007 were used for the purpose of this project. Apparent consumption in the EU-27 was calculated as production plus net imports:

Apparent consumption = Production + Import - Export

In accordance with the Europroms classification, each end product-type (e.g. shirts, blouses, sweaters) has been further broken down into two main fabric types: 1) knitted and crocheted or 2) woven. Data on the market breakdown of products by fibre type were collected. The analysis was based on main fibre types showing high market shares. Although natural fibres of vegetable origin are represented by cotton and flax, many others exist such as hemp, jute, ramie, and bamboo. Of these additional fibres listed, only hemp has been included in later steps of the analysis as an improvement option but this fibre is not considered in the baseline scenario. Other fibres have also been included in the context of their improvement potential, such as polycotton ([1]) blends (see Section 4.7.1). The full list of fibres and materials considered in the model is listed below:

- cotton
- polyester
- wool
- flax
- viscose
- silk
- polyamide
- acrylic
- hemp
- polyurethane
- polypropylene
- PVC
- feathers.

Product-specific breakdown percentages were determined for each of the end product categories. Where data were not available, average figures were used. The full breakdown for each end product type is included in Annex 1.

Since the Europroms database gives production figures of some end products in amounts of units or pairs, it was necessary for those products to estimate the corresponding weight. A literature review was thus carried out and completed by Ensait in order to determine a range of weight for each type of products and to estimate the maximum and minimum impacts associated (see Annex 1). In total, 101 clothing product categories and 27 household product categories are included in the Europroms database, the full list of which can be seen in Annex 1. The available market data was extracted for each category. Each of these products falls under broader product categories (10 for clothing and 8 for household textiles), as listed in table 5. As some end product types for clothing textiles were found to be very similar, it was necessary to aggregate them into representative end product categories. For example, it was assumed that there is little difference between ‘women's or girls' blouses, shirts and shirt-blouses’, and ‘men's or boys' shirts and under-shirts’. Therefore the market data for these products were combined into a new end product category. In total, clothing textiles were grouped into 63 different end product categories. As each of the household textile products listed were quite distinct from one another, 27 end products were identified (i.e. each its own category). The full classification for clothing and household textiles is available in Annex 1.

([1]) Polycotton is a term used for cotton and polyester fibre blends

Table 5: List of broad textile product categories

Clothing	Household
Tops Underwear, nightwear and hosiery Bottoms Jackets Dresses Suits and ensembles Gloves Sportswear Swimwear Scarves, shawls, ties, etc.	Floor coverings Bed linens Curtains, blinds, etc Articles of bedding Kitchen and toilet linens Blankets and travelling rugs Floor cloths, dishcloths, dusters, etc. Table linens

Some products are not considered within the scope of this study. Shoes and bags have been for example excluded because market data for this category comprise products made from leather and rubber (especially in the case of shoes). Also other leather products are not included as they do not fall within the scope of this study.

A major challenge in this project was the lack of detailed market information. This made difficult to tune the level of disaggregation of the textile model and to allow a precise identification of individual products, necessary in order to build the model with realistic data on production and use patterns and, more importantly, to cope with the inherent uncertainty of environmental data and the potential lack of detailed market information. A simplified model of the actual textiles market was thus considered following a bottom-up approach. The following sections provide an outline of the steps taken to determine the EU-27 textiles market consumption data, as well as an indication of which products and fibre types may play a more significant role.

1.3 Consumption breakdown results

The calculations in this study give an average apparent consumption of 9 547 thousand tonnes of textile products in the EU-27 of which 6 754 are clothing textiles and 2 793 are household textiles. Total consumption corresponds to an average of 19.1 kg per citizen and year. This is slightly higher than values found in the literature for the year 2003, corresponding to 14.5–17.2 kg per citizen and year (Arias, 2003). The total amounts of consumption for clothing and household textile in relation to different product types are presented in figure 7. The figure clearly indicates that, overall, clothing products are consumed at much higher quantities than household textile products.

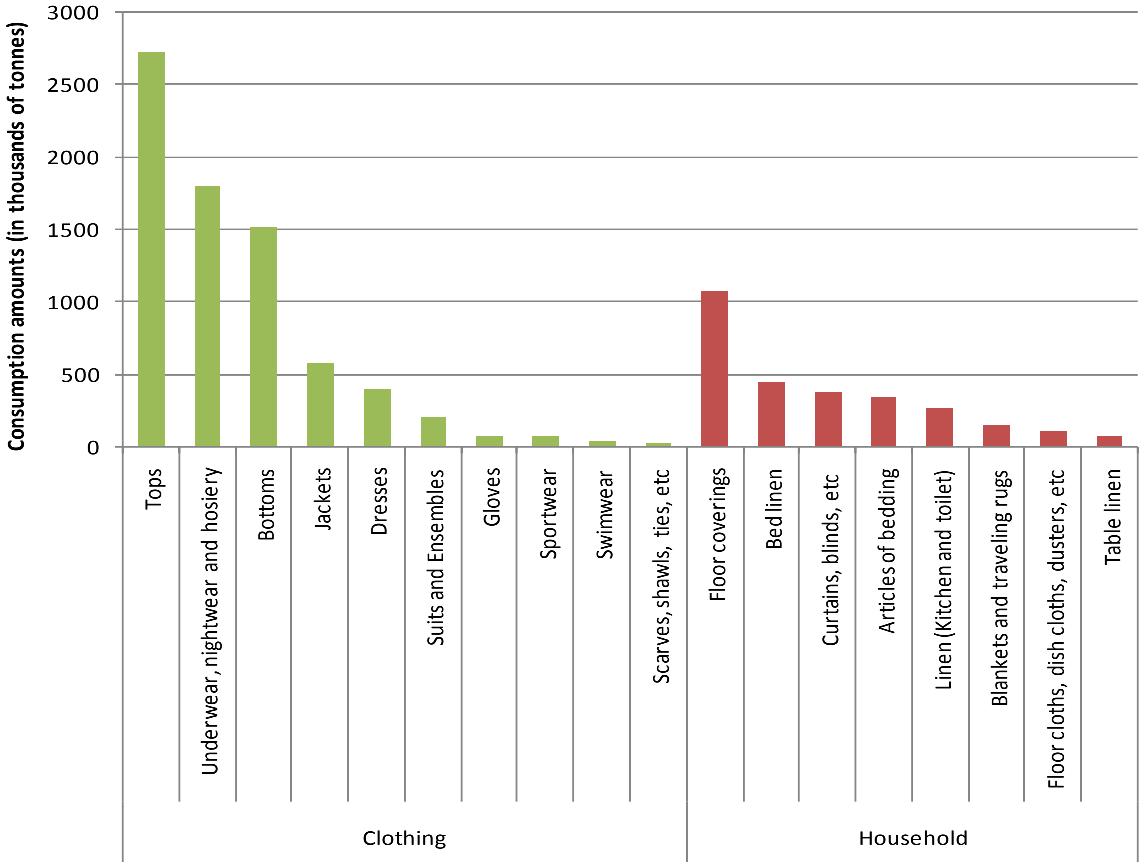


Figure 7: Consumption of different categories of clothing and household textile products in the EU-27 (2007)

The percentage breakdown of consumption for clothing products is shown in Ttable 6. The broad category of "Tops" was found to be consumed in the greatest amounts, comprising 36.7 % of clothing product consumption. Within this category, T-shirts and vests had the highest consumption amounts (at 803 857 tonnes) followed by jerseys, jumpers and pullovers of synthetic fibres (at 712 756 tonnes). Other broad categories found to be consumed in high amounts include: "Underwear, nightwear and hosiery" and "Bottoms" (e.g. trousers, shorts, etc.), at 24.2 % and 20.4 % of the total consumption, respectively.

Table 6: Percentage breakdown of consumption for clothing textile products

Product category	Share of consumption (%)
Tops	36.7
Underwear, nightwear and hosiery	24.2
Bottoms	20.4
Jackets	7.7
Dresses	5.3
Suits and ensembles	2.8
Gloves	1.0
Sportswear	0.9
Swimwear	0.6
Scarves, shawls, ties, etc.	0.4

The breakdown of the consumption of household textile products is presented in table 7. Floor coverings make up the highest share of household textile products consumed, mainly due to the high consumption of tufted carpets (771 057 tonnes).

Table 7: Percentage breakdown of consumption for household textile products

Product category	Share of consumption (%)
Floor coverings	38.0
Bed linens	15.6
Curtains, blinds, etc.	13.4
Articles of bedding	12.3
Kitchen and toilet linens	9.4
Blankets and travelling rugs	5.2
Floor cloths, dishcloths, dusters, etc.	3.8
Table linens	2.4

Figure 8 shows the amount of consumption by materials for both clothing and household textiles. The figure shows that for both clothing and household products, cotton is the most purchased fibre in terms of quantities and polyester is the second most purchased. Following these, the third most common fibre types are acrylic for clothing products (present in comparatively small amounts in household products) and polyamide for household textiles.

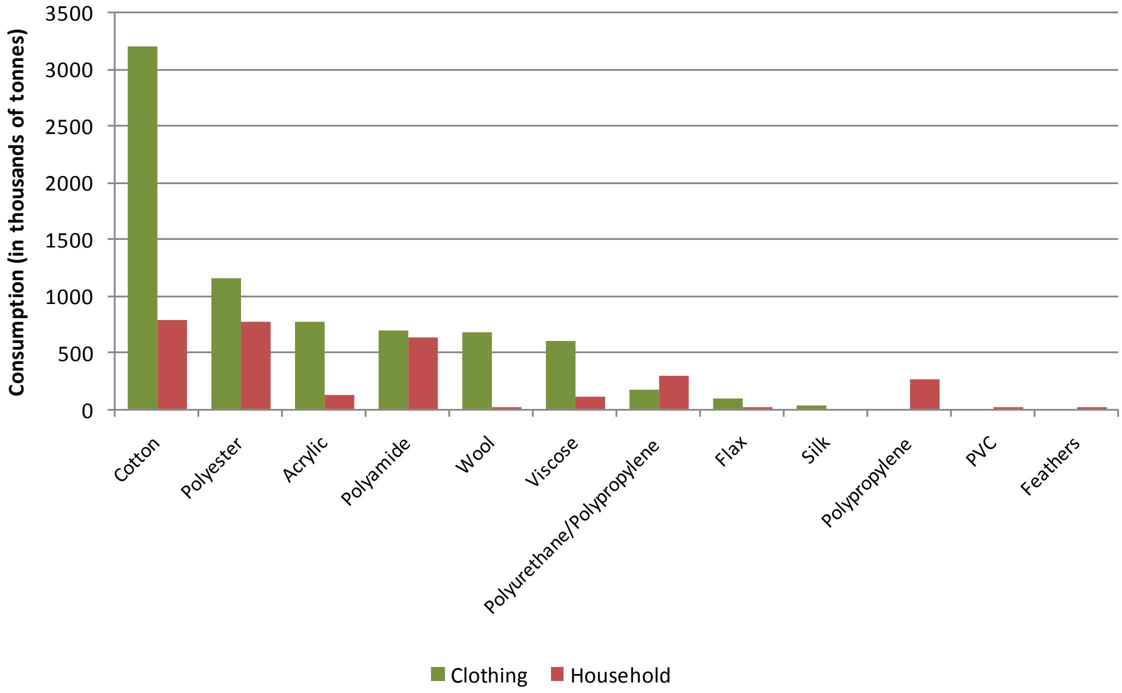


Figure 8: Consumption by materials for clothing and household textiles

Compared to clothing products, the share of synthetic fibres (e.g. polyamide and polypropylene) for household textiles is higher (see figure 9). However, it is also worth noting that the total weight of production for clothing textiles appears to be more than twice that of household textiles, at 6.8 million tonnes compared to 2.8 million tonnes.

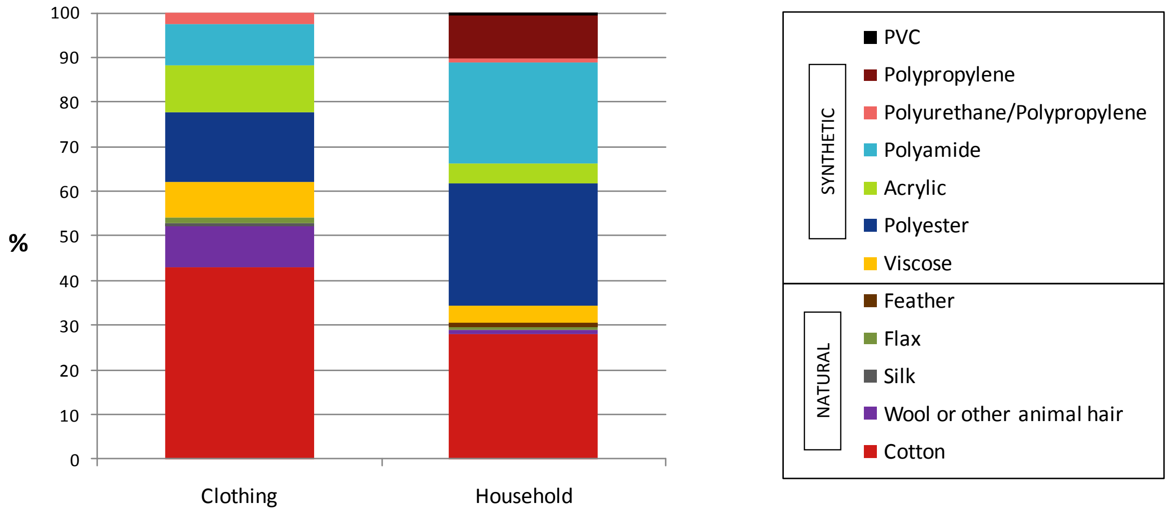


Figure 9: Percentage breakdown of consumption by material for clothing and household textiles

1.4 Data uncertainties, gaps and limitations

The market analysis of this study is based on the Europroms database which combines data on the production of manufactured products (Prodcom database) and data on external trade (Comext database). As production and trade data come from different sources (surveys for production, and custom clearance for trade), data representativeness may differ as the coverage of production statistics is not necessarily in line with that of trade statistics. Matching this information can therefore cause some representativeness problems that are difficult to solve.

The level of accuracy of the Europroms database is also uncertain. When production, import and export amounts for individual EU-27 Member States are added together, for most categories the totals do not appear to match those already aggregated for the EU-27. Experts at Euratex confirmed that confidential or missing data are common in textile statistics. The main problem is that it is difficult to determine whether data included in the Europroms (or Euratex) database were derived from the production of all textiles manufacturers.

Finally, some product categories presented in Europroms are very generic, meaning that detailed information on fibres or processes used for manufacturing end products can be difficult to assess and that the composition of production can in some cases differ from that of trade. Experts from Ensait were consulted to establish a few different typologies representing the most common technologies in use.

The above factors may have some influence on the final figures although it is assumed that the figures are as close as possible to the present condition of the textiles market.

1.5 Key points of the market analysis

The analysis of the textile market revealed that, in terms of mass, the three product categories "Tops", "Bottoms" and "Underwear" are the most important items amounting to more than 78 % of the clothing market consumption. For household textiles, floor coverings clearly dominate the market (38 % of mass share of consumption). In terms of mass, the volume of clothing is almost twice as that of household textiles. The calculation in this study give an average apparent consumption of 9 547 000 of tonnes of textile products in the EU-27 of which 6 754 000 are clothing textiles and 2 793 000 are household textiles. Total consumption corresponds to an average of 19.1 kg per citizen and year. This is slightly higher than the values given in Arias (2003), where the total consumption was estimated between 14.5 and 17.2 kg per citizen per year.

When observing different fibre types, the following conclusions can be drawn: for clothing textiles, the consumption is dominated by cotton which accounts for more than 43 % of all fibres, in terms of mass, followed by polyester (16 %). The ratio between natural and synthetic fibre is 54/46.

For household textiles, cotton and polyester are the most common fibres accounting for approximately 28 % each, in terms of mass of consumption, followed by polyamide (23 %). Compared with clothes, polyurethane and polypropylene consumption in terms of mass is much higher and it accounts for nearly 10 %. The ratio between natural and synthetic fibre is 30:70.

2 THE TEXTILE LCA MODEL: SCOPE AND METHODOLOGY

In order to quantify the improvement potential of the textiles industry, it was necessary to calculate the environmental impact of the sector. This step involved the quantification of the input of resources and of the environmental outputs occurring in each of the life cycle stages of the textile products (i.e. production, distribution, use and end-of-life). The environmental impacts were then assessed based on a number of environmental indicators. The result of this assessment provided the baseline scenario for the textiles industry, considering both clothing and household textiles. The methods used to build the baseline scenario are presented in the sections to follow.

2.1 Presentation of the textile LCA model

2.1.1.1 Overview

The textile LCA model takes into account both first- and second-hand textiles. Second-hand textiles refer to products that are reused after they reach the end-of life phase. All environmental impacts associated with the complete life cycle of textile consumed in one year (2008 in the baseline scenario) are taken into account.

The system boundaries considered in the textile LCA model are shown in figure 10.

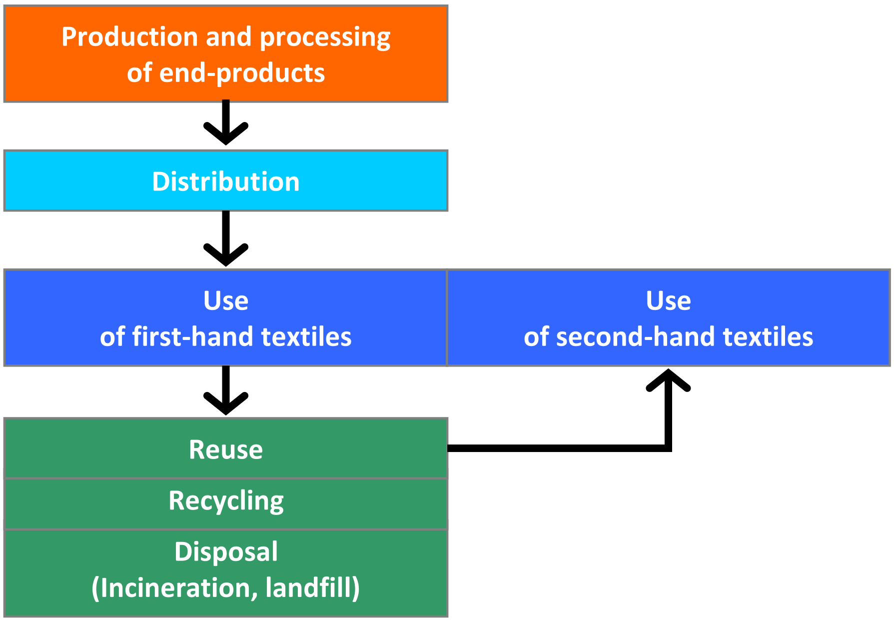


Figure 10: System boundaries of the textile LCA model

The life cycle of textile products can essentially be split into four main stages:

> **Production and processing** – This phase begins with the production or extraction of raw materials (e.g. cultivation of fibre-producing crops), leading to the processing of the fibre, followed by the confection of yarn and fabric, and finally the finishing, cutting and sewing steps needed to make a complete end product. Given the very different types of materials used to package products, and the varying practices carried out by individual companies along the supply chain, the life cycle of packaging has not been included in the model. This stage is described in more detail in Section 2.2.1

Distribution – This phase takes into consideration the importation and distribution of textile end products, based on the construction of a distribution scenario for textiles in the EU-27. Only the transportation of final end products has been included in the model, while the import/export of intermediate components has not been considered (e.g. a fibre produced in one country which is then exported to another for further processing). This phase is described in detail in Section 2.2.2

Use – This phase takes into account consumer behaviour and the use patterns of textile end products. This step incorporates the impacts of washing, tumble drying and ironing. Assumptions and models related to this stage are presented in Section 2.2.3

End-of-life – The end-of-life phase includes the reuse, recycling and final disposal (i.e. incineration or landfilling) of textile products. This phase is presented in Section 2.2.4. The reuse of old items was taken into account for the calculation of the real consumption of textiles (a 50% lifetime extension is given to collected textiles which are reused), so that a discount was implicitly assigned to the impacts from the production stage.

2.1.1.2 Integration of reused items in the textile LCA model

The following section explains how the apparent consumption, corresponding to the consumption of first-hand textiles and calculated through the Europroms database, was incorporated into the textile LCA model and how reused textiles were also taken into account to estimate the real textile consumption, as some of the demand in the EU is covered by second-hand textiles.
Real consumption of textiles in a year *n* (D_n) can be calculated as the sum of consumption of new textiles in the same year (d_n) and consumption of second-hand textiles ($d_{n-1} \times r_{n-1}$) from the year before.

If d_n is the apparent consumption of new textiles calculated through the Europroms database for a given year n and r_{n-1} is the textile reuse rate in the EU in the previous year, the real consumption D_n in the year n is given by $d_n + (d_{n-1} \times r_{n-1})$.

A first assumption considered in the model is that the demand of textiles in year n is equal to the apparent offer in the same year. Moreover, it was also considered that consumption data and textile reuse rate do not change significantly from one year to another (Textile Recycling Association, 2005),
After simplification of the market model based on this assumption, it follows that the real consumption D_n is given by $d_n/(1-r_{n-1})$.

table 8 provides the underlying calculations for first- and second-hand flows that have been used in the model.

Table 8: Calculation of the environmental impacts of first- and second-hand products in the textile LCA model

Life cycle phase	First-hand textiles	Second-handtextiles	Total (first-hand + second-hand)
Production and processing	$D_n \times (1\text{-}r_n) \times P$		$D_n \times (1\text{-}r_n) \times P$
Distribution	$D_n \times (1\text{-}r_n) \times T$		$D_n \times (1\text{-}r_n) \times T$
Use	$D_n \times (1\text{-}r_n) \times U_1$	$D_n \times r_n \times U_2$	$D_n \times (1\text{-}r_n) \times U1 + r_n \times D_n \times U2$
End-of-life	$D_n \times (1\text{-}r_n) \times W$	$D_n \times r_n \times W$	$D_n \times W$
Parameters related to the material flow D_n: real consumption at year *n* (Mt) r_n: reuse rate at year *n*		**Impacts per unit of mass** (e.g. kg CO_2/kg) *P*: impact of production *T*: impact of distribution *U1*: impact of using first-hand textile *U2*: impact of using second-hand textiles *W*: impact of end-of-life	

2.1.1.3 Data sources

Raw data for material and energy requests, process losses and emissions were derived from the literature specialised in the field of textiles and LCA or from technical studies carried out by BIO Intelligence Service. The list of publications consulted is presented in the references section (see Section 0). Metadata were then coupled with the environmental information contained in the Ecoinvent 2.0 database (Ecoinvent Centre, 2007). Ecoinvent is one of the most exhaustive Life Cycle Inventory databases and it allowed the high number of materials, chemicals and processes that enter the textile life cycle to be considered in a consistent and reliable way. Further sources of input/output data included Wisard 4.2 (PricewaterhouseCoopers, 2007), for end-of-life stage, and PlasticsEurope, for what concerns plastic compounds. Where data were not readily found in the database, other sources outlined in the report were used (in particular for the production of individual fibre types). Where no suitable data was available, research institutes and universities were contacted. Section 2.2 outlines how the model has been organised, including its limitations and the major assumptions made throughout its construction.

2.2 Model description

2.2.1 Production and processing phase

The manufacturing phase of textile products can essentially be separated into two main consecutive steps. A finished sheet of fabric must first be made (fabric production) which is used to make the final end product in the second main step (product confection), as outlined in Figure 11). Fabric production is presented in detail in Section 2.2.1.1. This step differs between the fibre types. In Section 2.2.1.2, the product confection is shown.

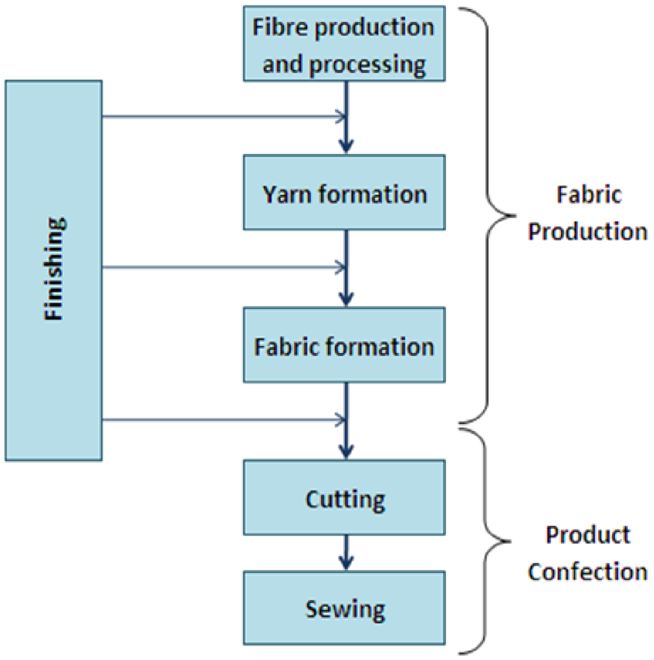


Figure 11: Schematic overview of textile product manufacture

Losses have been taken into account along the textile manufacturing chain. Furthermore, their own end-of-life phase has been modelled within the textile production phase. It has been assumed that 50 % of the lost fabric material is reused within the chain, the rest of the losses (50 %) are disposed of and their end-of-life treatment mix is the same as that of textiles which are presented below in Section 2.2.4 namely:

- 29.6 % to incineration with energy recovery
- 0.8 % to incineration without energy recovery
- 69.6 % to landfill.

For the fabric production, processing and confection phases, clothes and household textiles made from fibres were modelled in a similar way since the life cycle steps are assumed to be the same. However, carpets had to be treated differently, as it will be shown in the following.

2.2.1.1 Fabric production

Several processes must be undertaken in order to create a finished sheet of fabric. Four stages can be detected:

- fibre production and processing
- yarn formation
- fabric formation
- finishing.

A life cycle inventory (LCI) was built for each of the main fibre types detected during the market analysis (see Section 1) including: cotton, wool, polyester, polyamide, acrylic, silk, viscose, flax, and polypropylene. The following sections will outline the inventory data considered for each fibre.

➢ **Cotton**

Cotton is one of the most common fibres present in the textiles industry. This is especially true for clothing products, where cotton fibres take up the largest share. Figure 12 presents the four main steps in the production of cotton fabric: cotton fibre production, yarn formation, fabric formation and finishing. Although it is not presented in this figure, the cultivation of cotton was also included in the model. The LCI for the production of cotton fibres included fertiliser and pesticide use, transportation, as well as the separation of cotton fibres for the further steps. Information about cotton production (e.g. the amount of fertilisers and pesticides required) were derived from a series of literature sources as well as from sector experts. Environmental inputs and outputs were then quantified from the Ecoinvent database (Nemecek *et al*., 2007).

The LCI of the cotton cultivation was disaggregated into seven processes: use of cultivating machinery; seed growing; production and provision of pesticides and fertilisers; irrigation; and tractor-use emissions. This disaggregation allowed for an easier modification of the model parameters, performed during the analysis of the improvement options (e.g. modelling of organic or genetically modified (GM) cotton).

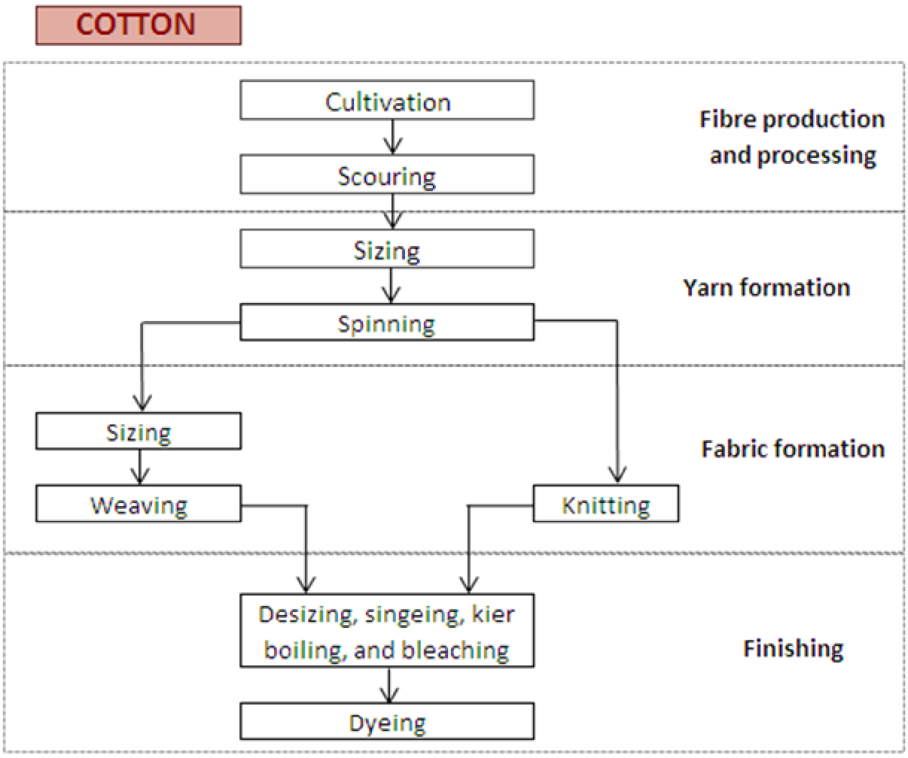


Figure 12: Main life cycle steps in cotton fabric production

Concerning yarn formation, fabric formation and finishing, cotton-specific LCI data could be found. However, certain steps, especially those concerning the finishing of fibres (e.g. desizing, singeing, and kier boiling), have been based on general figures for fabric production. References for the data used are shown in table 9.

Table 9: Data sources used to model the production and processing of cotton fabric

Processing step	Source
Cultivation	BIO (2008), Kalliala *et al.* (1999)
Scouring	TheSmartTime (2008)
Bleaching	European Commission (2003), BTTG (1999b)
Lubrication/Sizing	European Commission (2003)

Processing step	Source
Spinning	BIO (2005), Laursen *et al.* (2007)
Desizing	BTTG (1999b), TheSmartTime (2008)
Weaving	BTTG (1999a)
Knitting	BTTG (1999a), BIO (2005)
Singeing	BTTG (1999b)
Kier boiling	BTTG (1999b)
Dyeing	BIO (2005), European Commission (2003)

Cotton is by far the most studied fibre type and the literature provide for accurate and exhaustive LCIs. Nevertheless, the overall results of the analysis may be affected to some extent by the lack of information available for other vegetable fibres, since input/output data are in this case scarcer and more uncertain.

➢ **Wool**

The production of fibres has been based on figures from previous studies. The main steps in wool fabric production are shown in figure 13. Wool cultivation relies on the use of farm equipment, production, provision and application of agrochemicals (e.g. sheep dip), animal feed production and water. The majority of the data have been derived from a recent study based on the production of Merino sheep’s wool (Barber *et al.*, *2006*) and a recent study on the impacts of cotton, wool and acrylic fabric production (BIO, *2005*). Although the former focuses on a specific type of wool, it has been assumed here that the production steps are similar. After wool production, the washing and preparing of the wool for yarn formation appeared to be an important step, in which large quantities of water and energy are used. It is also worth noting that there is a large loss of material during this phase, on average estimated being around 45 % by weight. This loss can be broken down as follows (Barber *et al*., *2006*):

- 34 %, dirt
- 31 %, grease
- 24 %, water
- 11%, suint.

The majority of grease and suint are made up of a by-product of wool known as lanolin, which is often used in other applications. Dirt is also sold as a by-product of wool, for fertiliser production. As adequate equivalents of these materials could not be found in the Ecoinvent database, it has been assumed that this material is disposed of. Wool carbonisation is an optional step used to remove vegetable matter from the wool. It is mainly used to prepare wools that have high vegetable matter content and are not destined for worsted processing (OECD, 2004). High vegetable matter content was here assumed for the wool and carbonisation has thus been included. Another notable difference between wool and other fibres is the presence of an anti-felt treatment step. Similarly to cotton, the majority of the data gathered for wool fabric production relied on little extrapolation of information from different processes, with the exception of the weaving and knitting processes.

Table 10: Data sources used to model the production and processing of wool fabric

Processing step	Source
Cultivation	Barber *et al.* (2006)
Scouring	Barber *et al.* (2006), BIO (2005), Dahllöf (2004)
Top making	Barber *et al.* (2006)
Carbonisation	BIO (2005), European Commission (2003)
Bleaching	Lacasse (2004), BIO (2005)
Lubrication/Sizing	European Commission (2003)
Spinning	BIO (2005), BTTG (1999b)
Desizing	Lacasse (2004)
Weaving	BTTG (1999b)
Knitting	BTTG (1999b)
Anti-felting treatment	BIO (2005)
Printing pretreatment	European Commission (2003)
Softening	BIO (2005)
Dyeing	BIO (2005)

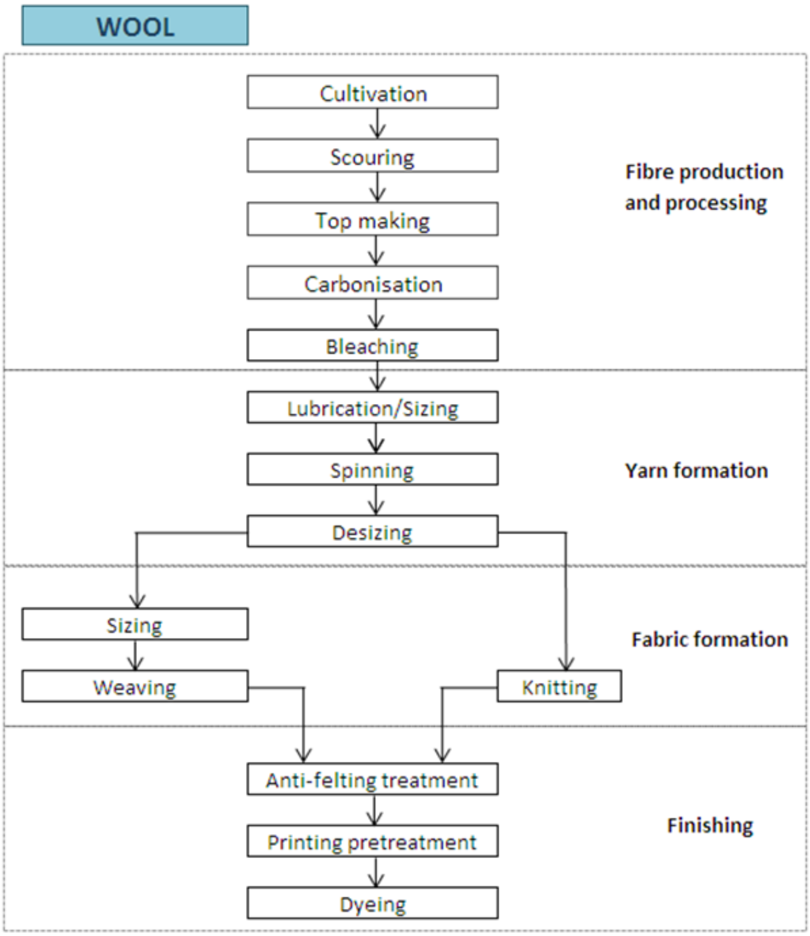


Figure 13: Main life cycle steps in wool fabric production

➢ Polyester

Polyester is another fibre of significant importance in the textiles industry. For the production of fibres, the LCI for polyester fibre has been based on that of amorphous polyester, obtained from the Association of Plastics Manufacturers in Europe ([1]). This database provides the most up to date figures for the environmental impacts of the production of plastics. The subsequent steps are assumed to be the same as for cotton fabric production. Sizing has been considered also for synthetic fibres although it is more commonly used in natural fibres processing. However, the sizing chemicals used for either type of fibre can differ. The sizing of warp and weft polyester fibres for weaving has been based on the use of ethylene glycol. Figure 14 shows the main steps in polyester fabric production. The list of references for polyester production and processing can be found in table 11.

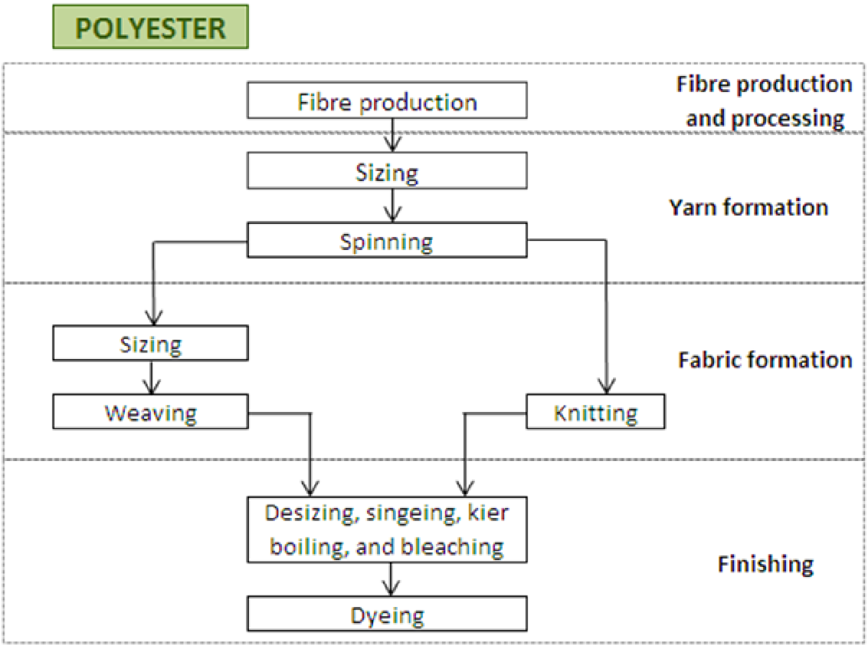


Figure 14: Main life cycle steps in polyester fabric production

Table 11: Data sources used to model the production and processing of polyester fabric

Processing step	Source
Fibre production	European Commission (2007a)
Lubrication/Sizing	European Commission (2003)
Spinning	BTTG (1999a), European Commission (2003)
Desizing	BTTG (1999b), Labouze (2008)
Weaving	Blackburn (2004), BTTG (1999a) , European Commission (2003)
Knitting	BTTG (1999b), European Commission (2003), BIO (2005)
Singeing	BTTG (1999b)
Kier boiling	BTTG (1999b)
Bleaching	BTTG (1999b)
Dyeing	Lacasse (2004), European Commission (2003)

([1]) PlasticsEurope database: http://www.plasticseurope.org

➢ Polyamide 6 and 6,6

The main steps in polyamide fabric production are similar to those of cotton and polyester and they are presented in figure 15. As with polyester, the majority of data used were unique to this type of fibre (with the exception of sizing and fabric formation steps). A list of references consulted for raw data is listed in table 12. Inventory data related to the production of this fibre refers to both polyamide 6 and 6,6. The raw material production data for either fibre have been obtained from the PlasticsEurope database, like in the case of polyester. For the other steps, the same LCI data have been used for both fibres. For steps in which data specific to polyamide could not be found (i.e. sizing and fabric formation), data have been extrapolated from the polyester fabric production inventory.

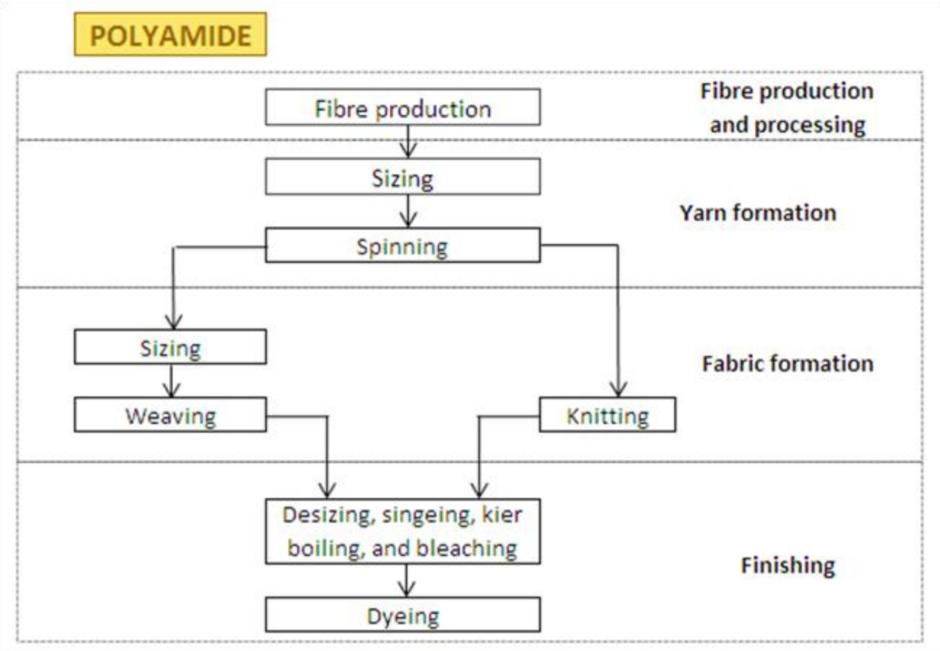


Figure 15: Main life cycle steps in polyamide fabric production

Table 12: Data sources used to model the production and processing of polyamide fabric

Processing step	Source
Fibre production	BIO (2008), European Commission (2007a)
Lubrication/Sizing	European Commission (2003)
Spinning	Laursen *et al.* (2007), European Commission (2007a)
Desizing	BTTG (1999b) , Labouze (2008)
Weaving	Blackburn (2004), BTTG (1999a), European Commission (2003)
Knitting	BTTG (1999b), European Commission (2003), BIO (2005)
Singeing	BTTG (1999b)
Kier boiling	BTTG (1999b)
Bleaching	Lacasse (2004)
Dyeing	European Commission (2003)

➢ Acrylic

Despite its significant presence in the textiles market (as evidenced by figure 9), there is a scarcity of data related to this fibre type (Laursen *et al*., 2007). LCI data specific to acrylic have been found only for the fibre production and dyeing phases. For the other life cycle steps, LCI data were mainly extrapolated from polyester fabric production. The raw data sources for each processing step are listed in table 13. LCI data related to the production of polymethyl methacrylate (PMMA) (BIO, 2005) were considered for the production of acrylic fibres. Consultation with experts confirmed that the extrapolation does not result in poor reliability of the results. Figure 14 depicts the main steps in acrylic fabric production.

Table 13: Data sources used to model the production and processing of acrylic fabric

Processing step	Source
Fibre production	BIO (2005)
Lubrication/Sizing	European Commission (2003)
Spinning	European Commission (2003), BIO (2005)
Desizing	BTTG (1999b), Labouze (2008)
Weaving	Blackburn (2004), BTTG (1999a), European Commission (2003)
Knitting	BTTG (1999b), European Commission (2003), BIO (2005)
Singeing	BTTG (1999b)
Kier boiling	BTTG (1999b)
Bleaching	BTTG (1999b)
Dyeing	BIO (2005)

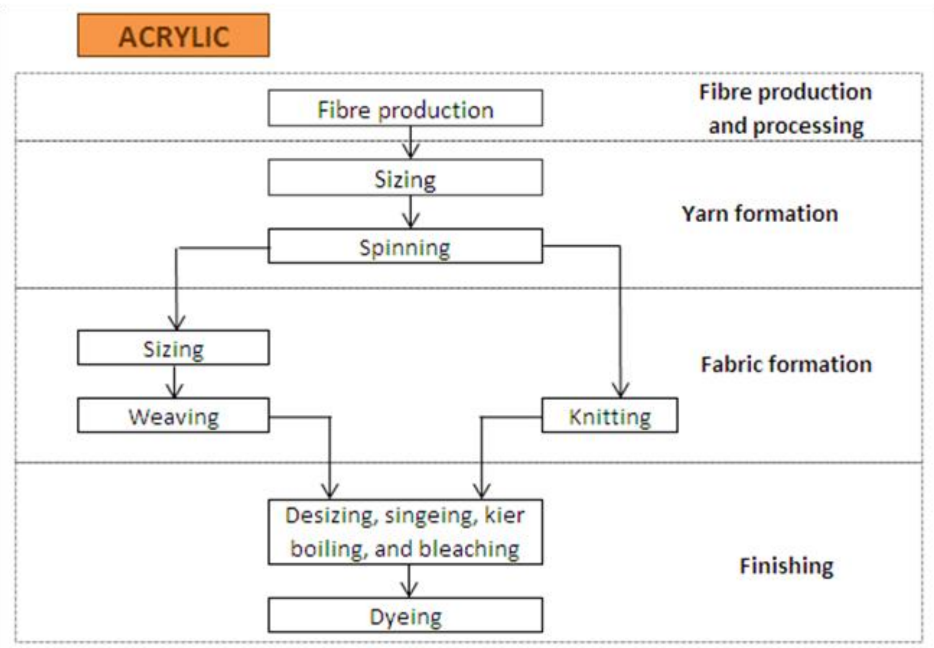


Figure 16: Main life cycle steps in acrylic fabric production

➢ Silk

Although it only accounts for a small share of the textiles market (see Figure 9), silk fabric is used extensively in certain types of products, such as scarves, ties and underwear. Data on silk fabric production could be found mainly for the later steps of fabric production (i.e. scouring, dyeing and printing). No data on silk fibre production could be found. Thus, this step was omitted from the LCI. Consultation with experts revealed that the inputs related to the spinning of silk yarn are also quite particular to this fibre type. This step, therefore, was also excluded from the inventory. Both the dyeing and printing of fabric has been considered here, at an assumed 50:50 ratio. A list of references for silk fabric production is presented in table 14; the main production steps for this fibre are instead presented in Figure 17.

Table 14: Data sources used to model the production and processing of silk fabric

Processing step	Source
Scouring	Sára *et al.* (2) (2003)
Lubrication/Sizing	European Commission (2003)
Desizing	BTTG (1999b), Labouze (2008)
Weaving	Blackburn (2004), BTTG (1999a), European Commission (2003)
Softening	Sára *et al.* (2) (2003)
Colours preparation	Sára *et al.* (2) (2003)
Bleaching	BTTG (1999b)
Washing/Soaping	Sára *et al.* (2004), Sára *et al.* (2) (2003)
Dyeing	Sára *et al.* (2003), Sára *et al.* (2) (2003)
Printing	Sára *et al.* (2004)

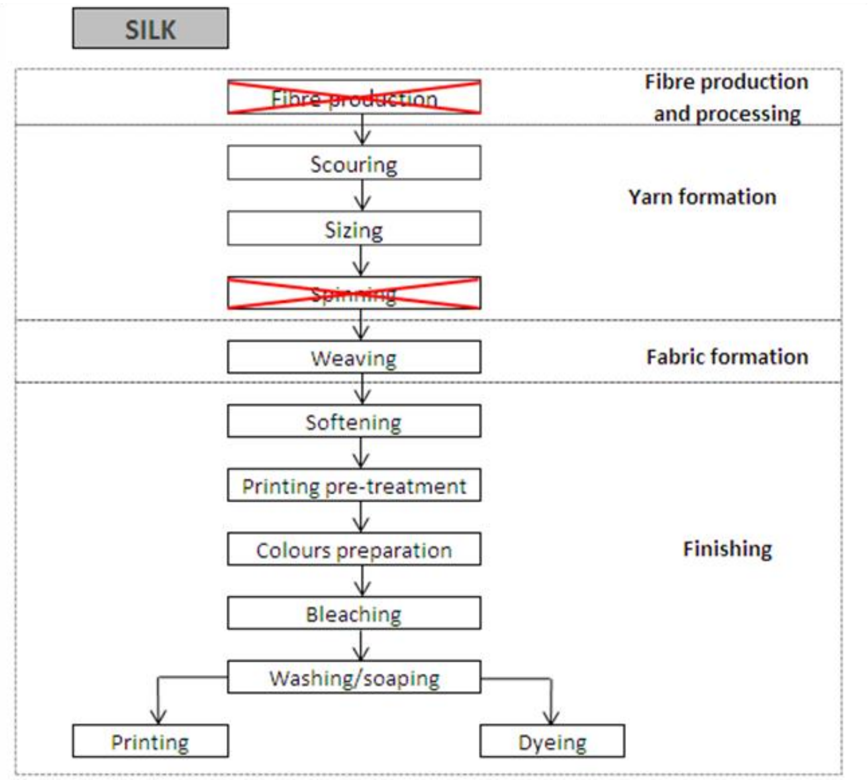


Figure 17: Main life cycle steps in silk fabric production

➢ Viscose

As with silk, much of the data available for viscose fabric production focus on finishing steps, although scouring and fibre production steps are also included in some detail. Furthermore, both the printing and dyeing of viscose fabric were considered to be applied with a 50:50 ratio. For the remaining steps, data were extrapolated from polyester fabric production. Figure 18 shows the main production and processing steps considered in the inventory of viscose fabric production. A full list of raw data references is presented in Table 15.

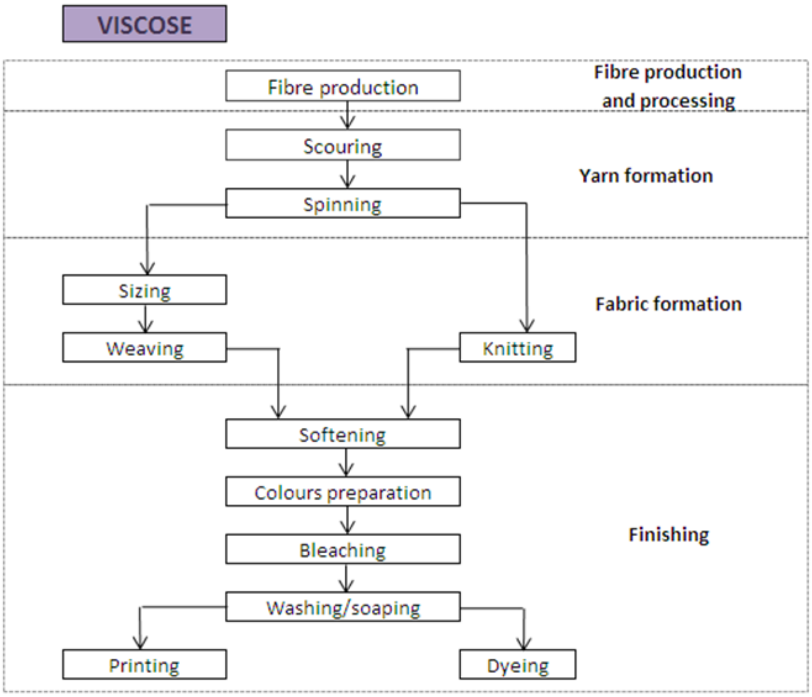


Figure 18: Main life cycle steps in viscose fabric production

Table 15: Data sources used to model the production and processing of viscose fabric

Processing step	Source
Fibre production	PlasticsEurope database
Scouring	Sára *et al.* (1) (2003)
Lubrication/Sizing	European Commission (2003)
Spinning	European Commission (2003), BIO (2005)
Desizing	BTTG (1999b), Labouze (2008)
Weaving	Blackburn (2004), BTTG (1999a), European Commission (2003)
Knitting	BTTG (1999b), European Commission (2003), BIO (2005)
Softening	Sára *et al.* (1) (2003)
Colours preparation	Sára *et al.* (1) (2003), Maiorino *et al.* (2003)
Bleaching	Maiorino *et al.* (2003)
Washing/Soaping	Sára *et al.* (1) (2003), Maiorino *et al.* (2003)
Dyeing	Sára *et al.* (1) (2003)
Printing	Maiorino *et al.* (2003)

➢ **Flax**

The majority of the data for flax fabric production have been derived from BIO (2007a). A full list of references is presented in table 16. Inputs for the production of flax crop and fibres were also obtained from this study, which included energy and irrigation, as well as agrochemical use (i.e. pesticides and fertilisers). The dyeing of flax has not been included in the model as data on this step were unavailable. The main steps considered for flax fabric production are shown below in figure 19.

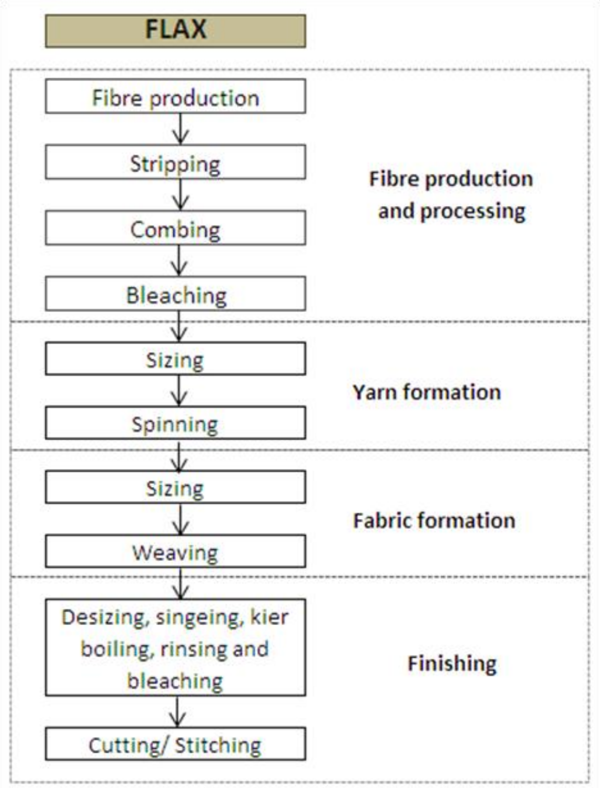


Figure 19: Main life cycle steps in flax fabric production

Table 16: Data sources used to model the production and processing of flax fabric

Processing step	Source
Fibre production	BIO (2007a)
Stripping	BIO (2007a)
Combing	BIO (2007a)
Bleaching	European Commission (2003)
Lubrication/Sizing	BIO (2007a)
Spinning	BIO (2007a), BTTG (1999a)
Desizing	BIO (2007a)
Weaving	BIO (2007a), BTTG (1999a)
Singeing	Kazakevičiūtė *et al.* (2004)
Kier boiling	European Commission (2003)
Rinsing	BIO (2007a)

➢ Polypropylene

As there is a scarcity of data related to this fibre type, data were only indentified for the production of polypropylene raw materials. As a consequence, only raw material production (polypropylene granulates) is considered in the fibre production and processing stage. Apart from raw material production, LCI data were mainly extrapolated from polyester fabric production. The references consulted for the raw data gathering are listed in Table 17; the main steps of polypropylene production are instead presented in Figure 20 Reference source not found..

Table 17: Data sources used to model the production and processing of polypropylene fabric

Processing step	Source
Fibre production	PlasticsEurope database
Lubrication/Sizing	European Commission (2003)
Spinning	BTTG (1999a), European Commission (2003)
Desizing	BTTG (1999b), Labouze (2008)
Weaving	Blackburn (2004), BTTG (1999a), European Commission (2003)
Knitting	BTTG (1999b), European Commission (2003), BIO (2005)
Singeing	BTTG (1999b)
Kier boiling	BTTG (1999b)
Bleaching	BTTG (1999b)
Dyeing	Lacasse (2004), European Commission (2003)

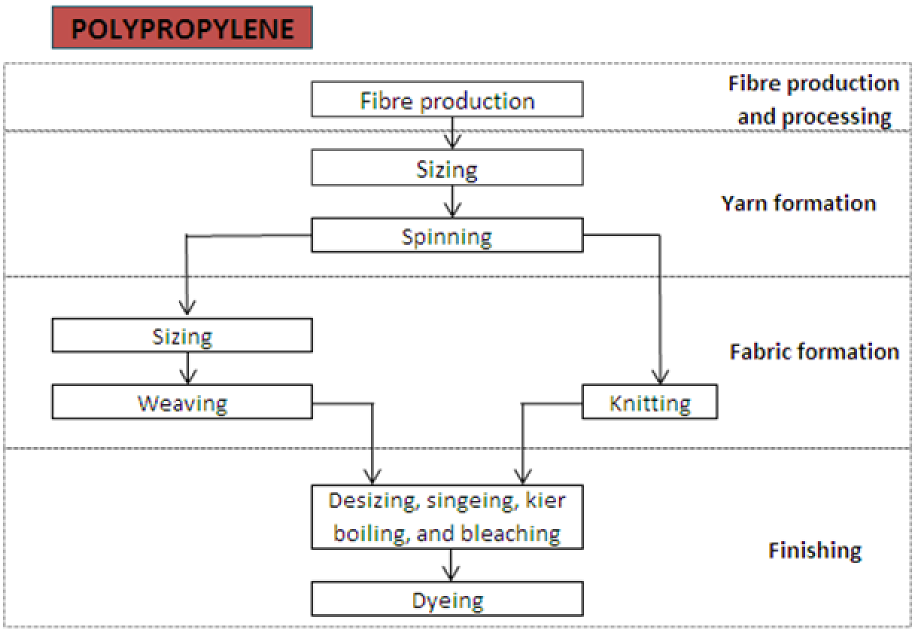


Figure 20: Main life cycle steps in polypropylene production

➢ Additional materials

During the finishing and product confection steps, certain materials may be added or attached to the fabric to prepare the final product. These materials are not considered textiles, although they can form an essential part of the product. These include: polyurethane, polyvinyl chloride (PVC) and feathers. The details on their inclusion or exclusion from the model are briefly outlined hereafter.

▪ Polyurethane/polypropylene

Polyurethane/polypropylene (PUR/PP) is one of the main backing materials used in the production of carpets. A few clothes also include PUR/PP in their compositions, such as swimwear or sportswear. LCI data referred to the production of polyurethane foam and of polypropylene granulates and they were derived from the Ecoinvent 2.0 database.

▪ PVC

Certain products have also undergone lamination which provides a waterproof coating. PVC has been considered in the model as the main coating material for the following products:

- anoraks, ski jackets, etc.
- raincoats
- overcoats, car coats, and capes
- ski suits.

Waterproofing has therefore been applied for all of these end product categories, for each type of synthetic fibre.

▪ Feathers

Feathers are mainly packed into household bedding items such as pillows, eiderdown comforters, cushions, etc. This material has been excluded from the model as relevant LCI data could not be found. However, it is worth noting that this material makes up less than 1 % of the total consumption and its exclusion is therefore not thought to significantly influence the results of the analysis.

2.2.1.2 Product confection – all products except carpets

Once the finished panel of fabric is made, it must then be cut and sewn into the final product. Due to their intricate shapes and varying sizes, the cutting of apparel into the necessary shapes can result in large amounts of fabric loss. This fabric must then be disposed of or reused for other applications. Table 18 presents average figures of the material losses associated with the cutting process of the different products. Certain weaving and knitting technologies allow for preshaped parts or complete garments to be produced instead of large panels (e.g. fully fashioned). This, however has not been included in the inventory as it is difficult to quantify what share of products on the market are produced using these technologies.

In addition to taking losses into account, the energy consumption of the confection process was also considered in the LCI (Schäfer *et al*., 2003; Collins *et al*., 2002).

Table 18: Fabric losses from cutting process according to Ensait

Textile products	Losses (%)
Clothing products	
T-shirts, vests, singlets, etc.	13
Shirts or blouses	13
Jerseys, jumpers, pullovers, etc.	10
Briefs, panties, underpants, etc.	16
Hosiery	0
Slips, petticoats and girdles	18
Nightwear	13
Negligees, bathrobes, dressing gowns, etc.	15
Other underwear, nightwear and hosiery	18
Anoraks, ski-jackets, etc.	12
Jackets and blazers	16
Raincoats	14
Overcoats, car coats, capes	14
Trousers, breeches, overalls, etc.	14
Shorts	15
Skirts	14
Dresses	18
Swimwear	18
Tracksuits	15
Ski suits	14
Suits and ensembles	14
Gloves	18
Scarves, shawls, etc.	4
Ties, bow ties and cravats	5
Household products	
Table linens	9
Kitchen and toilet linens	5
Floor cloths, dishcloths, dusters, etc.	4.5
Bedding	4
Bed linens	3
Blankets and travelling rugs	3
Curtains, blinds, etc.	3

2.2.1.3 Product confection – Carpets

Carpets should be considered apart from the classification described in table 18. First, carpets are not only made of fibres, since they have a plastic backing, assumed in the model to be made of polypropylene and polyurethane (Potting and Blok, 1995). This PUR/PP mix is not a fibre but a backing material. In addition, the conversion of yarn to carpet can be done through a specific process called tufting. It was therefore necessary to search for data on this process. Concerning with the first steps, i.e. from fibre production to dyeing, the modelling was based on the different fibres that compose the carpets. References for the data used are shown in table 19. Tufting is the final phase of this production chain and the carpet was therefore considered a finished product once tufted.

Table 19: Data sources used to model the production and processing of carpets

Processing step	Source
Fibre production and processing	Data sources for the corresponding fibres
Yarn formation	Data sources for the corresponding fibres
Dyeing	Data sources for the corresponding fibres
Tufting (confection)	Potting and Blok (1995)

2.2.2 Distribution phase

The distribution of textile components can occur throughout the whole production cycle. For example, fibres may be exported to one country for processing, to another for finishing, and the resulting fabric may be exported to yet another country for manufacturing of the final end product. As transportation processes occur several times throughout the production process, it would be challenging to build a model which accurately represents the distribution of textile products during their production cycle. Furthermore, it would be necessary to use import and export figures for textiles at very specific stages during the production stage. However, this data was found to be unavailable or unreliable. For simplification, thus, only transportation of the finished end product has been taken into account in the model.

To build the transport model, it was necessary to determine the origin of product imports. To simplify the model further, instead of focusing on several individual areas, countries of origin were aggregated into groups.

Table 20 presents the main areas considered in the model, along with a list of the countries they represent. Ideally, distribution impacts should only be considered for those end products that are imported and actually consumed in the EU-27. However, EUROPROMS data does not allow for distinguishing between products that have been imported from outside Europe, and those that have just transited within the EU-27 and then been re-exported. In this context, the distribution impacts have been allocated to all end products (considering the apparent consumption). This potentially results in overestimating the distribution impacts as we could not distinguish between products that are in transit, imported for consumption in the EU-27, or produced in the EU-27 for domestic consumption. The share of each import area over total imports is shown in table 21.

Table 20: Sources of end product imports

Processing step	Source
Mediterranean	Turkey, Morocco, Tunisia, Israel, Egypt
North America	US, Canada, Mexico
South America	Argentina, Brazil, Paraguay, Uruguay
China	China
South Asia	India, Pakistan, Bangladesh, Maldives, Sri Lanka
South East Asia	Vietnam, Thailand, Indonesia, Malaysia
Emerging Asian countries	South Korea, Singapore, Hong Kong, Taiwan

Table 21: Share of import areas according to product types

Product type (%)	Zone						
	Mediterranean	North America	South America	China	South Asia	South East Asia	Emerging Asian countries
Woven garments	29	3	0	44	15	7	2
Knitted garments	28	4	0	31	21	8	5
Carpets	20	10	3	14	45	1	0
Source: EURATEX, 2008							

The majority of textile products (approximately 92 %) are imported by maritime transportation (Rodrigue *et al*., 2006). The transport distances for this method of transport were based on sea freight from major ports in the above countries to Rotterdam. This port was chosen as it is the largest in Europe, and it is centrally located. The distances used in the model are presented in table 22.

Table 22: Average distance for major textile import sources in km

Transportation mode	Average distance by zone (km)						
	Mediterranean	North America	South America	China	South Asia	South East Asia	Emerging Asian countries
Sea	4 894	10 398	11 598	19 601	12 354	15 999	17 885
Air	2 418	6 786	10 384	9 262	7 482	10 154	9 774

Of the textile imports, 8% are transported by air freight (Thuermer, 2009). For this transport mode, the same distances as for maritime transportation were used. Paris, with both very significant cargo traffic and with a central location in Europe, was the destination chosen to calculate air distances. The distances by sea were calculated using the following tool: http://e-ships.net/dist.htm.

Distances were then averaged in order to get realistic values per product type and per transportation mode. These values are shown in table 23, as they were used in the model.

In addition to overseas transport, products can be distributed by inland transportation. Truck is the vehicle of choice in this case. However, distances can vary enormously. A hypothetical average figure of 600 km was determined for all product types.

LCI data for each of these transportation modes have been derived from the Ecoinvent 2.0 database. Inland waterways have not been considered in the model.

Table 23: Distances taken into account according to product type and transportation mode in km

Product type	Average distance, (km)		
	road	sea	air
Woven garments	600	13 601	6 969
Knitted garments	600	12 722	6 738
Household textiles	600	10 758	6 199

2.2.3 Use phase

To model the use phase, it was necessary to include data on European clothes washing, drying and ironing patterns (see references for list of publications). Several factors must be taken into account when considering the textiles use phase. Both the characteristics of each appliance, the detergents used and the user behaviour all have an important influence on the environmental impacts related to this phase. Ultimately it is the individual consumer who has the greatest influence in determining the environmental impact of this phase because factors such as washing frequency, wash temperature and drying methods are ultimately decided by the individual consumer. Moreover, these patterns can differ from country to country. In Figure 21, a comparison of tumble drying habits in Poland and the UK is shown. Apparently, tumble drying is used more frequently in the UK than in Poland.

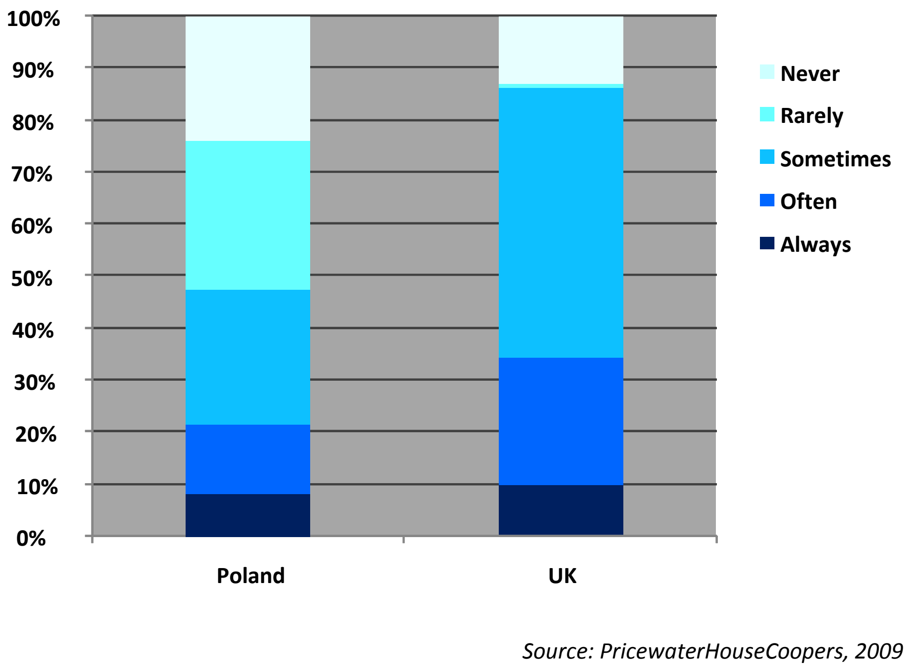


Figure 21: Tumble drying habits of residents in Poland and the UK

As habits can differ greatly from one country to another, the model has been based on the average scenario in the EU-27. The data below have been derived from a series of European studies which have focused mainly on user washing habits across the EU-27. The washing, drying and ironing parameters included in the model are described in the following subsections.

Note that for all the washable end products, the same basic assumptions on user behaviour (e.g. washing temperature, iron power) have been taken for both clothing and household textiles and are reported below in the following subsections. In addition, we made user behaviour assumptions specific to each end product (e.g. number of washes, ironing time) and these are reported in Annex 1.

Due to unavailability of data, the use phase of carpets and floor coverings (vacuuming, stain removal, etc.) was not considered in the study.

2.2.3.1 Washing

- **Washing machine use**

The energy and water consumption of washing machines was derived from the European Commission Ecodesign preparatory study (Presutto *et al*., 2007). The majority of clothes washing machines fall within energy class A. The average capacity is 5.36 kg (Presutto *et al.*, 2007). The model is based on standard testing values that have been corrected to take into account real life practices. The main characteristics of standard and real life washing machines are presented in table 24.

Table 24: Standard and real life characteristics

	Standard case	Real life case
Washing temperature (°C)	60	45.8
Load (kg/cycle)	5.36	3.43
Energy consumption of program selection (kWh/cycle)	0.998	0.72
Water consumption of program selection (l/cycle)	50.7	46.3

Source: Presutto et al. (2007)

Although in the standard case, a washing machine can wash a full load of approximately 5.36 kg/cycle, in reality, loads are often smaller (3.43 kg/cycle, which is approximately 64 % of the standard case). Clothes washing temperatures also vary depending on the type of fabric washed. In Presutto *et al.* (2007), it was determined that the average wash temperature is 45.8 °C in the real life case, compared to standard testing.

With the reduction in washing temperature, energy consumption is also reduced. In the textile LCA model, energy consumption was corrected using a scaling factor of 0.038 $kWh \cdot kg^{-1} \cdot K^{-1}$ in order to take into account the impact on energy consumption of reducing washing temperature (Presutto *et al.*, 2007). With a decrease in capacity, energy and water consumption of washing machines are lower than those obtained in standard conditions at full load. These effects have been taken into account using a dependency factor of 0.0567 kWh/kg for energy and 2.817 l/kg for water. Detailed calculations and sources are available in Presutto *et al.* (2007).

Washing frequency is an important parameter too. Table 25 shows the washing, drying and ironing consumption patterns that have been considered in the study, for the 10 most important cloth categories in terms of volume. The exhaustive data and sources can be found in Annex 1.

LCI data on electricity and water consumption have been gathered from the Ecoinvent database. The European electricity grid mix ([1]) and the domestic consumption of tap water ([2]) have been considered, respectively.

It should be noted that based on the findings of Presutto *et al.* (2007), the penetration rate of washing machines in the EU is said to be close to 100 %. It is therefore assumed that washing is always carried out in a washing machine. As a consequence, hand washing and dry cleaning have been excluded from the model. Production, repair and end-of-life of the appliance were also not taken into account in the textile LCA model.

([1]) Electricity, low voltage, production RER, at grid/RER S.
([2]) Tap water, at user/RER S.

Table 25: Washing, drying and ironing parameters for the 10 most important categories in volume

Textile product	Number of washes	Ratio machine wash/handwash (%)	Ratio dry/wash (%)	Ratio iron/wash (%)	Lifetime (years)
Hosiery (knitted or crocheted)	104	100	0	0	2
T-shirts, vests, singlets, etc.	50	100	25	100	1
Briefs, panties, underpants, etc. (knitted or crocheted)	104	100	25	0	2
Gloves (knitted or crocheted)	4	100	0	0	2
Shirts or blouses (excluding knitted or crocheted)	25	100	25	100	1
Jerseys, jumpers, pullovers, etc.	50	100	25	100	3
Shirts or blouses (knitted or crocheted)	25	100	25	100	1
Jerseys, jumpers, pullovers, etc. (cotton)	50	100	25	100	3
Curtains and interior blinds, curtain or bed valances, of woven materials (m^2)	20	100	45	100	10
Brassieres	40	100	0	0	2

➢ **Detergent use**

An average consumption of 139.76 g of detergent per wash cycle has been assumed according to Presutto *et al*. (2007). Considering an average load of 3.4 kg, this gives a detergent consumption of 41.1 grams per kilogram of clothes washed. The LCI for the production of detergent is based on a Procter and Gamble study from 2000 (Saouter and Van Hoof, 2000).

Modelling detergent products is challenging, as detergents can be used under several distinct forms, e.g. powder, liquid, tablets. Their production processes are evolving rapidly. Modern detergents are usually based on concentrated formulas and they are also efficient at low temperatures. An average inventory was modelled by Saouter and van Hof (2000) and has been used here. However, the proportions or even the nature of components are likely to vary significantly in the upcoming years. Formulation and associated life cycle inventories taken into account are listed in table 26.

Due to the lack of availability of some data in Ecoinvent 2.0 (4 substances are indeed missing), it has been necessary to scale other proportions up. Some inventories have been substituted by similar products' inventories, such as acetic acid for citric acid and sodium percarbonate for sodium carbonate. The impacts of packaging materials have been moreover considered (see table 27).

In addition to the production of the individual components and the packaging material, the production and the end-of-life phases of the detergent (emissions to water) have been included. The direct emissions considered are shown in Table 28. As no direct emissions to air were available, these potential flows have been disregarded and water emissions are therefore considered the only potential impacts associated with the detergents.

Table 26: Typical composition of a powder detergent and LCI data used for modelling

Ingredient	Initial formulation ([1]) in %	Life cycle inventory considered ([2])	Final formulation in %
AE11-PO	2	Ethoxylated alcohols (AE11), palm oil at plant/RER U	2.1
AE7-pc	4	Ethoxylated alcohols (AE7), palm kernel oil at plant/RER U	4.3
LAS-pc	7.8	Alkylbenzene sulphonate, linear, petrochemical at plant/RER U	8.3
Citric acid	5.2	Acetic acid, 98 % in H2O at plant/RER U	5.5
NA-Silicate powder	3	Layered sodium silicate, SKS-6, powder at plant/RER U	3.2
Zeolite	20.1	Zeolite, powder at plant/RER U	21.5
Sodium carbonate	17	Sodium percarbonate, powder at plant/RER U	18.1
Perborate monohydrate	8.7	Sodium perborate, monohydrate, powder at plant/RER U	9.3
Perborate tetrahydrate	11.5	Sodium perborate, tetrahydrate, powder at plant/RER U	12.2
Antifoam S1,2-3522	0.5	Unavailable	0
FWA DAS-1	0.2	Unavailable	0
Polyacrylate	4	Unavailable	0
Protease	1.4	Unavailable	0
Sodium sulphate	0.4	Sodium sulphate, powder, production mix at plant/RER U	0.4
Water	14.2	Water, completely softened, at plant	15.1

(1) Source: Saouter and van Hof
(2) Source: Ecoinvent v2.0

Table 27: Packaging used for 1 kg of powder detergent and LCI datasets used

Ingredient	Life cycle inventory considered ([1])	Quantity in g ([2])
Paper	Paper, wood-containing, LWC at regional storage/RER S	217
Corrugated board	Packaging, corrugated board, mixed fibre, single wall at plant/RER S	1082
HDPE	HDPE resin E	81

(1) Source: Ecoinvent v2.0
(2) Source: Saouter and van Hof (2000)

Table 28: Direct emissions to water from 100 kg of detergents according to

Flow	Unit	Production	Fabrication	End-of-Life	Packaging
BOD	g	117	4.9	8580	1.59
COD	g	175	10.1	20700	9.01
Total P	g	45.9	-	0.06	0.00
Total N	g	19.1	-	0.12	0.15
Solids	g	56.6	-	-	-
Oil, grease	g	10.2	-	0.91	0.70
Phenol	g	0.17	-	-	-
Ammonia	g	1.09	-	0.07	0.40
Metals	kg	0.1	-	14.2	-

Source: Saouter and van Hoof (2000)

The emissions assumed in Table 28 are, however, only valid for Belgium, where 37 % of the households are not connected to a waste water treatment facility (Saouter and Van Hoof, 2000). In Europe, on average, more households are connected to waste water treatment (table 29). Thus, adjustments have to be made for the end-of-life phase. Concerning the large amount of metals (14.2 kg), it should be noted that it refers to the amount of sodium ion that is released into the water.

Table 29: Fraction of households connected to a waste water treatment facility in %

Country	No connection	Primary treatment	Secondary treatment	Tertiary treatment	Inhabitants (in millions)
Belgium	37	30	30	3	10.46
Denmark	0	20	71	9	5.44
UK	26	23	43	8	60.77
France	0	35	62	3	63.5
Germany	14	9	57	20	82.6
Italy	40	15	45	0	58.88
Netherlands	10	9	79	2	16.42
Spain	53	5	40	2	44.28
Sweden	5	1	10	84	9.12

Source: Saouter and van Hoof (2000)

When the shares were weighted according to the population, the average share of households that were not connected to waste water treatment systems was 23 %. This share was used as an average for the EU-27.

An average abatement rate of 80 % when waste water is treated was considered *(BIO 2007a)*. Thus, 38 % of total emissions are not removed in Europe, while the same parameter reaches 50 % for Belgium. The scaling factor is then 38/50 = 77 %. These adjusted values are used for modelling the life cycle inventory of detergent in the present model.

The adjusted figures for end-of-life emissions are shown in table 30.

Table 30: Direct emissions to water per 100 kg of detergents considered in the textile LCA model

Flow	Unit	End-of-Life
BOD	g	6623
COD	g	15980
Total P	g	0.046
Total N	g	0.093
Solids	g	-
Oil, grease	g	0.70
Phenol	g	-
Ammonia	g	0.054
Metals	kg	11

2.2.3.2 Drying

The drying of clothes was modelled based mainly on the European Commission Ecodesign preparatory study for clothes dryers (PricewaterhouseCoopers, 2009). The calculations have been based on the use of machines which fall under energy class C. This category has been chosen as it appears to be the most common type of machine used in European households. Moreover, figures for the ‘Air vented tumble dryer’ have been used in the calculations as it is the most widespread appliance. The energy use was thus assumed to be 2.01 kWh/cycle (full load of 6 kg) according to PricewaterhouseCoopers (2009). Key figures for the drying phase can be found in Annex 1.

We also assume that the average load of the dryer is 3.4 kg (compared to the maximum load of 6 kg capacity). This is the same as the load assumed for washing machines (see Section 2.2.3.1).

PricewaterhouseCoopers (2009), gives a function to calculate the energy used depending on the load. According to this function, the energy use in this study was estimated at 2 kWh/cycle.

As the lifetime of textile products has been based on the number of washes, the frequency of tumble drying was calculated in accordance with the number of washes. In PricewaterhouseCoopers (2009), it was determined that washing machines are used at an average frequency of 220 cycles/year in EU-27 households. It is assumed that the frequency of tumble drying differs on average across the EU-27. Figures obtained from PricewaterhouseCoopers (2009) determine tumble drying cycles at 2.36 per week in summer, and 3.62 per week in winter. This equates to approximately 156 tumble dryer cycles per household and year. It is therefore assumed that for every 100 washes, tumble drying occurs 71 times in households where both appliances are present. However, the ownership of tumble dryers must also be taken into account and the rate of tumble dryer ownership can vary greatly from one country to another. This discrepancy is mainly attributed to climatic differences, although economic factors can also affect the rate of ownership. The tumble dryer ownership rate in different Member States is presented in table 31.

Table 31: Rate of tumble dryer ownership in different EU-27 Member States

Country	Climatic zone	Dryer ownership (%)	Data Year
Finland	Cold	59	2004
Sweden		52	2004
France	Moderate	35	2008
Germany		39	2005
Poland		5	2008
Denmark		44	2004
Ireland		46	2005
United Kingdom		42.4	2008
The Netherlands		68	2005
Malta	Warm	12.2	2001
Portugal		13	2006
Slovenia		18	2003
Italy		9	2006

Source: EEDAL 2009

Based on the figures given in table 31, it has been assumed that the average rate of ownership is 35 % in the EU-27. The average frequency of tumble drying compared to the frequency of clothes washing was therefore determined to be 25 % (i.e. 35 % × 71 %).

Consistent with the methodological choices used for modelling washing machines, the European electricity grid mix ([1]) has been considered while the potential impacts of dryer production, repair and end-of-life have been disregarded.

2.2.3.3 Ironing

For the ironing of clothes, energy consumption has been calculated assuming an iron with an average power of 1600 W. The duration of each ironing session for any item of clothing, which was determined through the literature review and consultation with Ensait, is given in Annex 1; these estimates were directly used to assess the energy consumption assuming that ironing requires 1.6 kWh per hour.

Consistent with the methodological choices used for modelling washing machines, the European electricity grid mix ([1]) has been considered and the potential impacts of iron production, repair and end-of-life have been disregarded.

([1]) Electricity, low voltage, production RER, at grid/RER S

2.2.4 End-of-life

2.2.4.1 Overview over end-of-life routes

In the textile LCA model, impacts are related to the complete life cycle of textiles consumed in one year in the EU-27. It was assumed that the stock of textiles is constant, i.e. the amount of textiles disposed of equals the amount of end products produced.

At the end of their lifetime, textiles can be reused or recycled or they are disposed of by landfilling or incineration (with and without energy recovery). Ideally, complete, specific and homogeneous datasets are required for all Member States in order to model the end-of-life stage with accuracy. However, few specific data on the end-of-life route of textiles have been found in the literature. For household textiles, it has been assumed that no recycling or reuse takes place since the collection of household textiles is not very common, unlike for clothing. It has therefore been assumed that household textiles follow the ultimate disposal route (landfill or incineration). The end-of-life routes of clothing waste were modelled according to data from the Ouvertes project (Textile Recycling Association, 2005), an initiative of textile reuse and recycling players on the status of the industry in Europe.

Across Europe, it is estimated that between 15 % and 20 % of the disposed textiles tonnage is collected (Textile Recycling Association, 2005), the rest are landfilled or incinerated. A 20 % collection rate was considered in this study. First, the collected textiles are sorted and approximately 10–15 % is discarded for landfilling or incineration. Of the collected textiles, 50 % are recycled into rags or are shredded, the top 3–10 % in quality is reused in Europe, while between 30–40 % are exported for reuse in developing countries (Textile Recycling Association, 2005).

In order to model the share of landfilling and incineration (with or without energy recovery), data from OECD (2008) on the disposal routes of municipal solid waste (MSW) were used. Six treatment routes are given in OECD statistics for MSW (landfilling, composting, incineration with or without energy recovery, recycling, other) for 20 countries of the EU-27 ([1]) (see table 32). Composting was not considered relevant for textile disposal and recycling and reuse have already been considered. , The shares of incineration and landfilling where thus rescaled up to 100%, as shown in Table 32.

Table 32: End-of-life routes of municipal solid waste

End of life route	EU-27 totals in %
Recycling	17
Composting	18
Incineration with energy recovery	19
Incineration without energy recovery	0
Landfill	44
Other	2

Source: OECD, data from 2005

([1]) Only Bulgaria, Cyprus, Estonia, Latvia, Lituania, Malta, Romania and Slovenia are missing.

Table 33: Rescaled shares of the end-of-life routes of interest for the disposal of textile waste

End of life route	EU-27 totals in %
Incineration with energy recovery	29.6
Incineration without energy recovery	0.8
Landfill	69.6

Figure 22 summarises the disposal routes and their corresponding shares, which were considered in the baseline model.

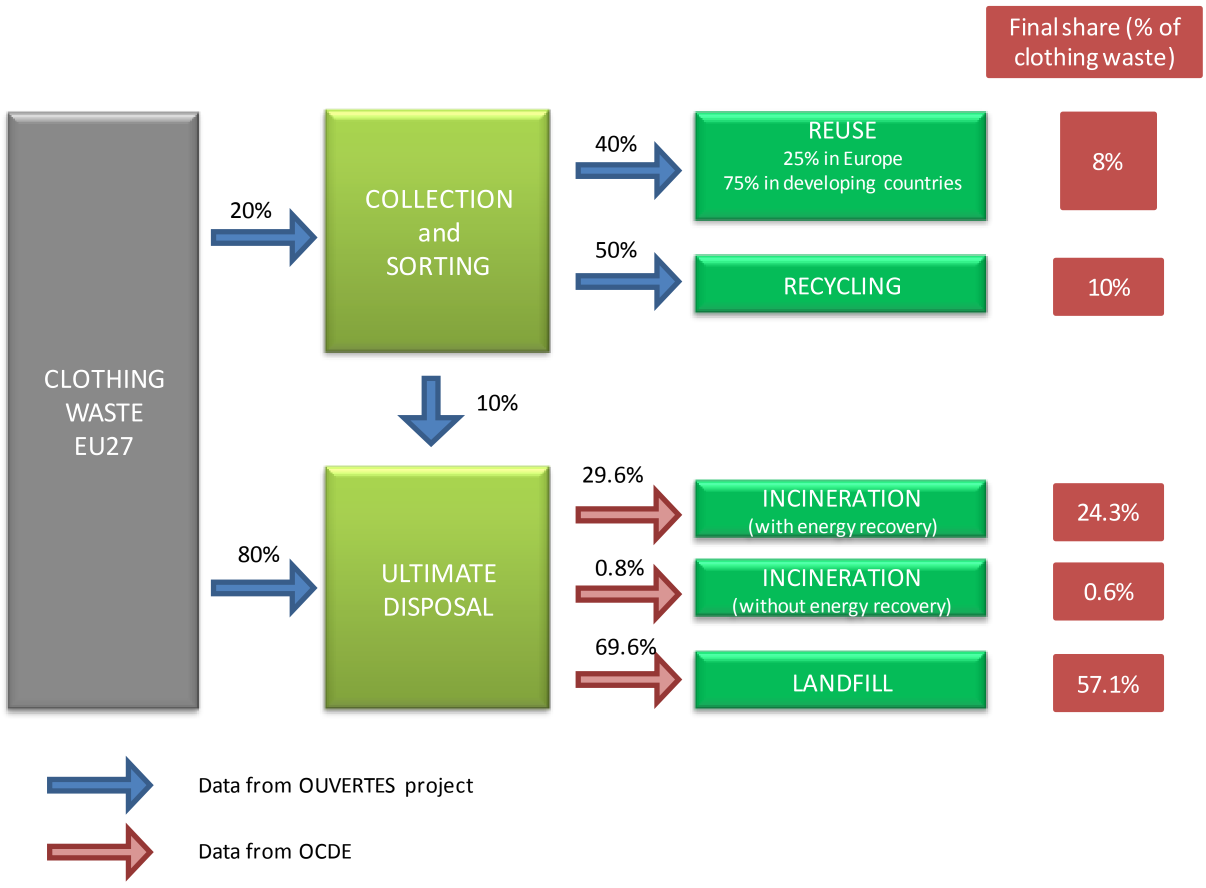


Figure 22: End-of-life routes of textile waste in EU27

2.2.4.2 Detailed description of the end-of-life model

➢ **Landfilling and incineration**

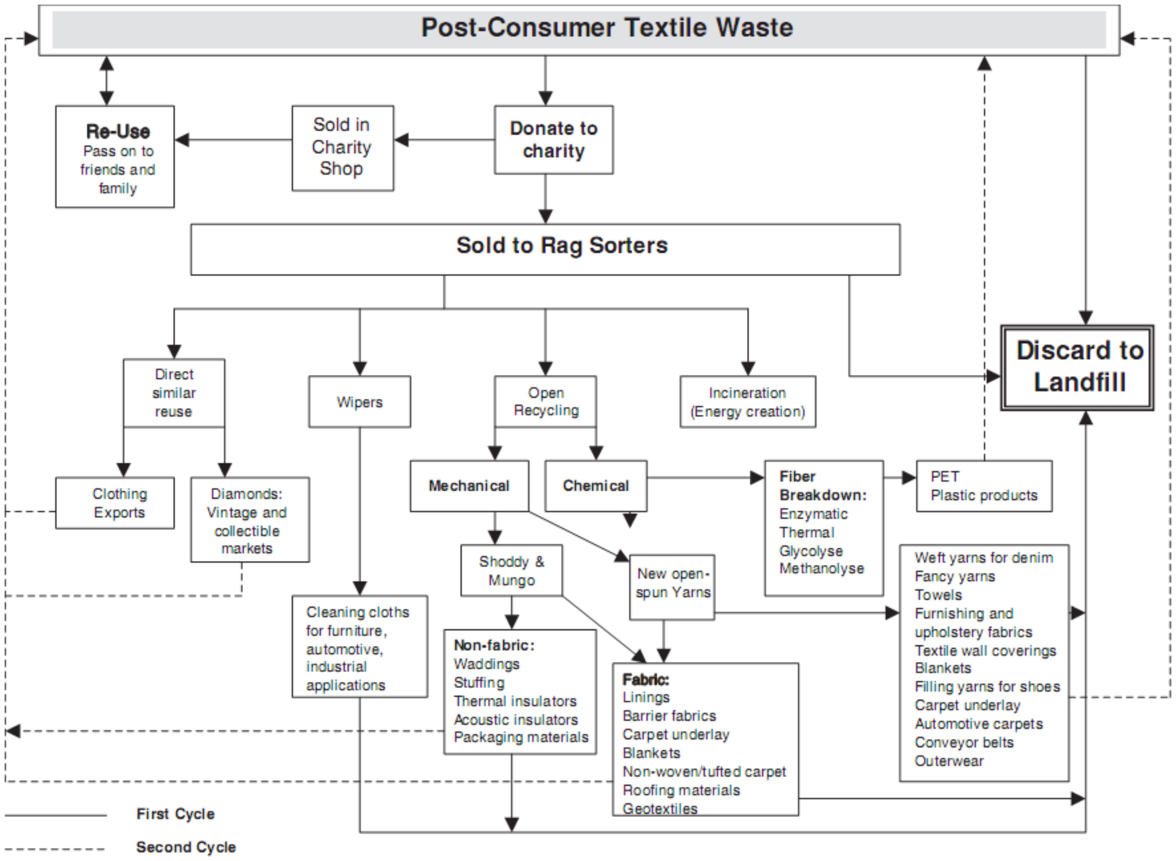
Concerning incineration, a generic LCI of textile incineration from the Ecoinvent 2.0 database was used. This inventory is representative of the average situation in the EU. The impacts of the incineration of natural and synthetic fibres were distinguished by setting the carbon dioxide emission factor for natural fibre at 0, as CO_2 from the incineration of natural fibres is compensated by the CO_2 absorbed during the plant growth.

Energy recovery provides environmental benefits as the heat and/or electricity that is recovered prevents the production of energy from alternative sources. According to Ecoinvent, 1.36 MJ of heat and 2.86 MJ of electricity are recovered on average for 1 kg of textile incinerated ([1]). It has been considered that electricity substitutes the average EU electricity mix ([2]), and that heat substitutes heat provided from natural gas ([3]).

Concerning landfilling, WISARD 4.2 was used to produce LCIs of landfilling because it allows for distinguishing between synthetic fibres and natural fibres. The modelling of synthetic and natural fibres was based on data referred to nylon and cotton, respectively.

➢ Recycling and Reuse

Once a textile product is sent to recycling it can face many potential fates depending on its quality and condition. Once sorted, each product can either be recycled or reused. The end-of-life routes can be particularly complex as presented in Figure 23.



Source: Hawley J M, 2006

Figure 23: General Life Cycle Scheme for Postconsumer Textile Waste

Recycling – Fabric must be converted into fibres in order to be reused. Fibre breakdown can be carried out by cutting, shredding, carding and other mechanical processes. The separated fibres can be converted into an array of different products, including stuffing for upholstery products, insulation and roofing felt, carpet components and lower quality blankets. The majority of garment products used for this process are unwearable, although some products can be created with pieces of used garments (such as designer clothing). It is not possible to recover fibres from most fibre blends however. Some textile fibres can also be broken down to be incorporated into high quality paper. Textile products that have become completely un-usable can be cut to produce industrial polishing and wiping rags.

([1]) Disposal, textiles, soiled, 25 % water, to municipal incineration/CH S.
([2]) Electricity, low voltage, production RER, at grid/RER S.
([3]) Heat, natural gas, at boiler condensing modulating <100kW/RER S.

Usually, cotton is sought out for this purpose due to its absorbent qualities. Some synthetic fibres with good wicking properties (such as sports attire) are also sought after.

Environmental benefits may arise from recycling because the environmental burdens associated with the manufacture of new products can be avoided. Benefits can also be due to avoided disposal of wastes provided that these impacts are higher than those of the recycling processes themselves. Although textile recycling is one of the oldest types of recycling, the average rate of textile recycling is still somewhat low. This rate can also differ greatly from one country to another depending on factors such as infrastructure and education.

As no detailed data on recycled textile waste were found, the baseline model considers that all recycled clothing waste (i.e. 10 % of all clothing waste) is recycled into cleaning rags. We assume that they substitute paper cleaning rags as in the life cycle assessment for reuse/recycling of donated waste textiles conducted by Woolridge *et al.* (2006). Assuming that 1 tonne of rags made out of clothing is equivalent to 1 tonne of paper rags, there is an energy credit of 18 303 kWh electricity per tonne (Woolridge *et al*., 2006). The average EU electricity mix has been considered ([1]).

Reuse – Most of the reusable clothing waste is exported to be sold as second-hand clothing. Apart from the impacts of transportation, this requires little to no modification of the products, especially if they are already clean. At times, a rummage through items in the textiles banks produces what is known by some as 'diamonds'. These are garments which are of high value even in their used state (although usually in good condition). These include vintage and collectors' items, as well as certain branded or designer items. Although this is often the smallest category, it is usually the most lucrative for end-of-life managers. With the advent of fast and cheap fashion, however, it is believed that this category will decrease within coming years.

The advantage of reusing clothing is to prolong its useful life, thus reducing the need to produce new natural or synthetic fibres. In the baseline model, 8 % of discarded clothes were considered to be reused and 25 % of the reused textiles were considered to be reused in the EU, the rest being exported to developing countries to be sold on second-hand markets. Reused clothes in the model are given a 50 % longer lifetime compared to non-reused clothes. Regarding transportation issues, clothes reused in the EU are assumed to travel 600 km by truck while clothes exported outside the EU are assumed to travel 600 km by truck and 10 000 km by ship. No washing has been included.

Reusing clothing offers environmental benefits as second-hand clothing prevents the need for producing new items. These benefits are dependent on the substitution ratio between new clothes and second-hand clothes. This ratio is likely to be higher and closer to 1 in developing countries than in the EU as in a context of fast fashion and greater purchasing power, consumers are keener on buying new clothes. For simplification, and in the absence of reliable data, this ratio has been set to 1 for all reused textiles in Europe.

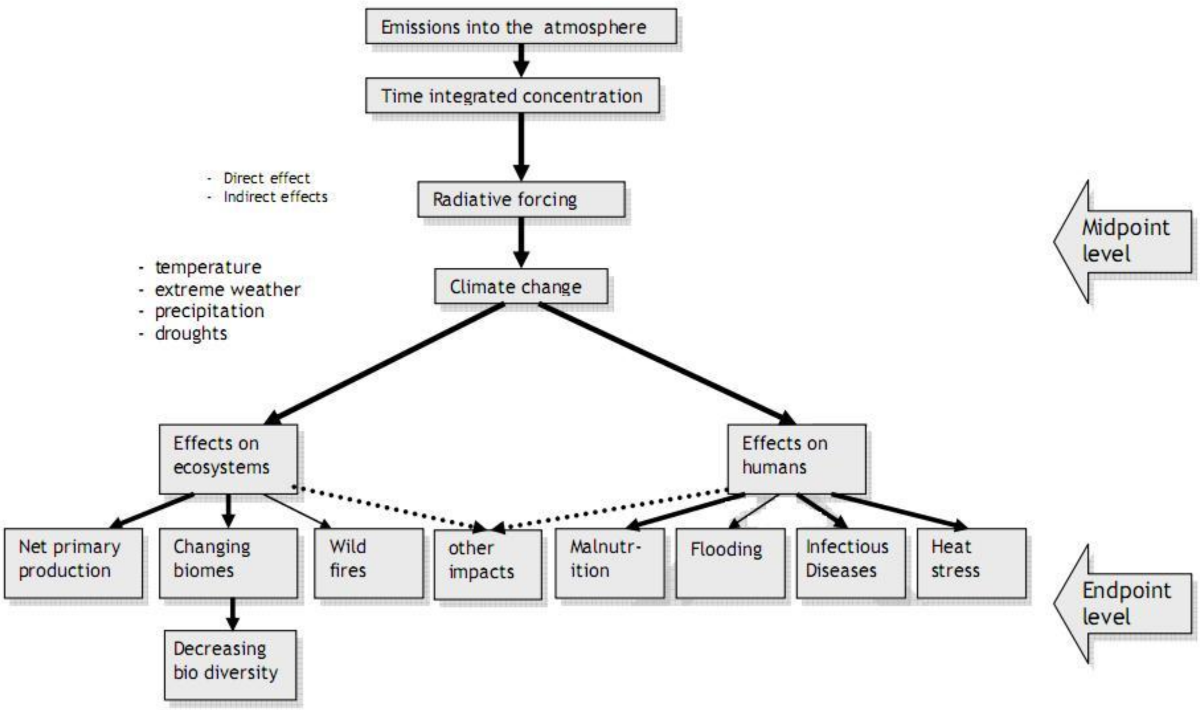
As the use of textiles in non-European countries falls out of the scope of the study, reused clothes in other parts of the world were not taken into account in the model and were only given impacts related to exportation.
A description of how reuse was included in the model is given in Section 2.1

2.3 Life Cycle Impact Assessment

The life cycle impact assessment (LCIA) phase aims at evaluating and understanding the magnitude and significance of the potential environmental impacts of a product system. The purpose of the impact assessment phase is to convert the LCI results into potential impacts on Areas of Protection (AoPs) or damage categories. The UNEP/Setac framework for LCIA operates with three AoPs: human beings, ecosystems, and resources.

([1]) Electricity, low voltage, production RER, at grid/RER S.

Environmental impacts result from a complex chain of environmental mechanisms. For instance, the release of greenhouse gases will contribute to radiative forcing ultimately affecting ecosystems and human health. According to ISO 14044, the indicator of an impact category can be chosen anywhere along the pathway linking inventory data to impacts on the AoPs (see Figure 24). Characterisation at midpoint level models and expresses impacts through indicators located somewhere along the environmental mechanism. Characterisation at endpoint level models and expresses impacts on the entities described by the AoPs, i.e. on human health, on the natural environment and on natural resources, so that subsequent modelling becomes necessary.



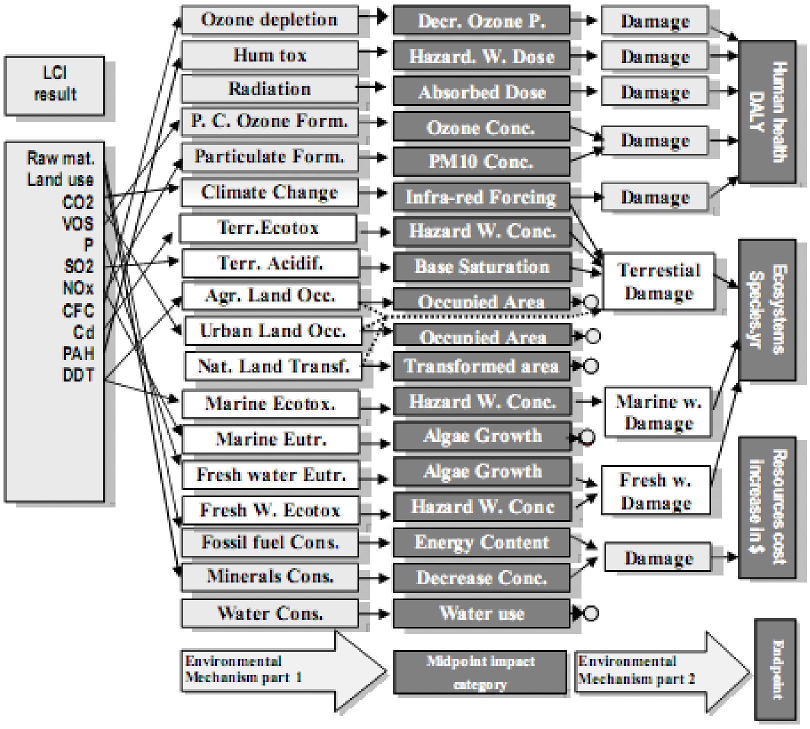
Source: ILCD Handbook, 2009

Figure 24: Midpoints and endpoints levels relative to emissions of greenhouse gases

The main criterion for choosing an impact characterisation model is to evaluate whether the environmental mechanism is sufficiently and effectively modelled and the inventory substances consistently included in the model. The latter aspect is particularly relevant for toxicity and aquatic ecotoxicity, due to the large amount of chemicals released to water in the textile finishing industry. Providing characterisation factors at midpoint and endpoint levels, ReCiPe – hierarchist perspective – was chosen as the LCIA methodology for this project (Goedkoop *et al*., 2008).

ReCiPe, which is a recommended LCIA method in the ILCD handbook with reference to endpoint indicators, proposes a harmonised set of characterisation factors, hence limiting interpretation incoherence that would have been obtained by using multiple methodologies.

Endpoints usually ease the understanding of LCA results as they are less numerous than midpoints indicators and they are more concrete (see Figure 25). However, it should be kept in mind that endpoints indicators are less robust than midpoint indicators because the environmental impacts are modelled further in the environmental chain.



Source: Goedkoop et al., 2008

Figure 25: The ReCiPe framework

In total, 18 midpoint indicators and 3 endpoint indicators have been included in the textile LCA model as presented in table 34 with their respective units.

Table 34: Midpoint and endpoint indicators considered in ReCiPe

Midpoint indicators	Unit
Climate change	kg CO_2 eq
Ozone depletion	kg CFC-11 eq
Photochemical oxidant formation	kg NMVOC.
Particulate matter formation	kg PM_{10} eq
Ionising radiation	kg ^{235}U eq
Terrestrial acidification	kg SO_2 eq
Human toxicity	kg 1.4-DB eq
Terrestrial ecotoxicity	kg 1.4-DB eq
Freshwater ecotoxicity	kg 1.4-DB eq
Marine ecotoxicity	kg 1.4-DB eq
Metal depletion	kg Fe eq
Fossil depletion	kg oil eq
Water depletion	m^3
Freshwater eutrophication	kg P eq
Marine eutrophication	kg N eq
Agricultural land occupation	m^2 * a
Urban land occupation	m^2 * a
Natural land transformation	m^2
Endpoint indicators	**Unit**
Human health	Disability Adjusted Life Year (DALY)
Ecosystem diversity	Species*yr
Resource availability	USD

2.4 Limitations of the model

➢ **Lack of differentiation for blends of fibre types**

Although the breakdown provides differentiated amounts for each fibre type, fibre blends cannot be distinguished. The breakdown of market share for different fibre blends is difficult to determine. However, often during production steps, the different constituent fibre types are produced separately and then woven together. Therefore, by weighting the percentage of fibre types for each item, the model takes into account fibre blends to a certain extent, but their production and impacts cannot be isolated from pure products.

Furthermore, dyeing steps may have to incorporate techniques used for the different fibre types that are blended in successive steps. This may imply that results for production are not significantly affected by considering fibre types separately. However, later steps may be compromised. In the use phase, for example, the lifetime of blended items (measured in the model as a number of washes) could be different. The baseline model does not take this issue into consideration since the data used do not allow for identifying the various possible blends for each product.

A simplified analysis was carried out in Section 4.7.1 in order to understand if a better environmental performance could result from the inclusion in the LCA model of more detailed parameters related to fibres blending.

➢ **Technological representativeness, and production data uncertainty and specificity**

Due to the complexity of the textile production, it is challenging to gather all the data necessary in order to build an accurate LCI baseline scenario. Table 35 presents a qualitative indication of the specificity of the data gathered to perform the environmental analysis. PUR/PP and feathers are not fibres and they do not appear in the table because they follow different process chains. Only the 9 fibre types used in the baseline scenario (see table 1) are included in table 35.

Table 35 shows that some of the fibre types are affected by lack of data. It should be kept in mind that the inputs for processing steps have been based on the findings of a few available studies. These studies can only provide a sample of production practices, as these can vary greatly from one country to another and indeed from one mill to another. The data above were mainly derived from European studies; however a significant market share of textile products is produced outside the EU-27. The sources of these differences and their influences can vary. For example, producers in the EU-27 may have stricter legislation governing their manufacturing practices in comparison with other countries. Labour and running costs may also be higher, and therefore, there is an incentive to cut down on raw material consumption and also optimise the running of manufacturing technologies which may replace manual labour. The quality and types of items produced can also have global variations. Italy, for example, is currently the leading manufacturer of luxury textile goods. The types of techniques used to manufacture these products can differ somewhat from those of conventional or lower quality products ([1]). In particular, data for viscose and silk were based on production practices in Italy and it is therefore uncertain whether the data are truly representative of the global market.

However, the differences in production technologies could not be taken into account due to the scarcity of geographically-specific data as well as the lack of detailed information on product flows considering the high level of fragmentation of the textile industry. Therefore global or EU life cycle inventories are implicitly considered to be representative of average practices.

➢ **Variations in consumer behaviour**

Several factors can contribute to discrepancies between different countries. Factors such as climate can influence clothes washing habits. In countries with a warmer and drier climate, consumers may opt more for air drying than machine drying, however the washing of clothes may be more frequent. The price of energy and water may also have an effect on consumer behaviour with regard to the

([1]) Textile Exchange, *Industry overview*, http://www.teonline.com/industry-overview.html maintenance of textile products. Where prices are high and the average household income is low, more consumers may opt for more traditional care methods such as hand washing. Living conditions can also affect use phase habits, and these can also differ within each country. Individuals who are accommodated in households with less space (especially lesser outdoor space) may tumble dry items due to lack of space to line dry them. In countries where a large proportion of the population lives in cities, the frequency of tumble drying may also be higher than in countries where a larger rural or suburban population exists. Ownership of electric appliances like washing machines, or dryers also depends on household income (Berry, 2002).

In our model, we used a fixed set of assumptions to represent many individuals. The habits related to textile use and cleaning are unlikely to be accurately represented by such a narrow set of assumptions. Consumer behaviour data are important for producing accurate LCAs because the assessment of environmental impacts and prioritisation relies on these assumptions on behaviour. Due to the above factors, variability from one consumer to another can be a significant source of uncertainty. As the data cannot account for such variations, the model was based on an average scenario for EU-27 households.

Table 35: Qualitative assessment of data specificity according to fibre type and production step

Production or processing step		Fibre type								
		Wool	Cotton	Polyester	Polyamide	Acrylic	Silk	Viscose	Flax	Polypropylene
Yarn production	Raw materials production	+++	+++	++	++	+	–	+++	+++	++
	Stripping								+++	
	Combing								+++	
	Scouring	+++	++				+++	+++		
	Top making	+++								
	Carbonisation	+++								
	Bleaching	++	++				+++	++	+++	++
	Drying	+	–	–	–	–	–	–		++
	Lubrication/Sizing	++	++	++	+++	++	++	++	++	++
	Spinning	+++	+++	+++	+++	++	–	+++	+++	++
	Desizing	++	+++	++	++	++	–	–	+++	++
Fabric formation	Weaving	++	++	++	++	++	++	++	++	++
	Knitting	++	++	++	++	++	++	++		++
	Singeing		++	++	++	++			+++	++
	Kier boiling		++	++	++	++			+++	++
Finishing	Anti-felting treatment	+++								
	Printing pretreatment	+++	–	–	–	–	+++	+++	–	–
	Softening	++	–	–	–	–	–	+++	–	–
	Colours preparation	–	–	–	–	–	+++	+++	–	–
	Washing/soaping	–	–	–	–	–	+++	+++	–	–
	Rinsing	–	–	–	–	–	–	–	–	–
	Dyeing	+++	+++	+++	++	+++	–	+++	+++	+
	Printing	–	–	–	–	–	+++	–	–	–
	Stitching	++	++	++	++	++	++	++	++	++

+++ = Very specific to this fibre type.
++ = Somewhat specific, though extrapolated from similar fibres.
+ = Low specificity as data were based on assumptions, or data were partially missing.
– = Process may be common to this fibre type but data unavailable or very unreliable.
(grey) = Not applicable to this fibre type.

➢ **End-of-life uncertainties**

Due to a lack of information on end-of-life of textiles, some assumptions had to be made. To begin with, a key assumption concerns the substitution ratio between new clothes and second-hand clothes. This is an essential assumption since it determines the avoidance of the production of new clothes which is directly linked to the environmental benefits of reusing clothes. In the absence of reliable data, it was assumed in the model that every second-hand item reused in Europe replaces the production of a new item but this assumption is believed to be optimistic. However no study has been able to come up with a reliable method in order to evaluate the substitution ratio between new and second-hand clothes. In the streamlined LCA conducted by ERM based on the Salvation's Army recycling and reuse activities (ERM, 2002a) it is reported that 'it would be extremely difficult to define the scope and a methodology for a study that could answer this question'. This issue is where the most controversy lies with regard to the evaluation of the environmental credits of clothing reuse.

Another issue linked to clothing reuse is the uncertainty associated with the estimation of the lifetime of second-hand clothes compared to new clothes. In the model, reused clothes are given a 50 % longer lifetime compared to non-reused clothes but no study has been found to support this assumption. More information would be needed to be able to assess the possible difference in the lifetime of new clothes and second-hand clothes.

In addition, the impacts due to the collection and sorting of the used clothes were not included within the model. However, the sorting is usually manual and thus the associated impacts can be assumed to be very low. The impacts of the packaging of the clothes for transportation to their second-use destinations were also left out also because the benefits from preventing new clothes production largely prevail over these impacts: in a 2007 study on a linen shirt (BIO, 2007a), for example, packaging was found to represent less than 0.5 % of overall impacts of the shirt life cycle.

In order to be able to model the benefits of clothes being recycled it was also necessary to determine the material that is substituted by recycled products. The model is based on the approach proposed by Woolridge *et al*. (2006) which considers that the recycled used clothes are converted to cleaning rags and substitute paper cleaning rags on a 1 to 1 equivalence ratio. However, this assumption is rather simplistic and appears questionable. There is thus some uncertainty regarding the evaluation of the environmental credits brought by clothes recycling but unfortunately no specific information on this issue could be found.

2.5 Summary

➢ **The textile LCA model at a glance and its main underlying assumptions and limitations**

The key characteristics of the textile LCA model are given below.

- The model is a bottom-up life cycle analysis of the consumption of household textiles and clothes in the EU-27. The model takes into account all impacts of the production, distribution, use and end-of-life of textiles that are produced in a given year to satisfy the European apparent consumption.
- Market data for 2007 was retrieved from the Europroms database. There were 101 end products linked to specific information regarding their composition (fibre type breakdown), their weight, their production processes (knitted, woven, laminated), their lifetime and the care practices they were associated with (e.g. ironing or not).
- The baseline scenario of the model covers the following fibre types: cotton, wool, viscose, flax, silk, polyester, polyamide, acrylic, and polypropylene. In addition to these fibre types, additional data were gathered to assess the improvement potential due to organic and GM cotton and hemp. Polyurethane, PVC and feathers were also included.
- Technical and environmental information were gathered from an exhaustive literature review. The life cycle inventory was then built based on the data contained in Ecoinvent 2.0, in Wisard 4.2 and in PlasticsEurope.

- The life cycle impacts were assessed according to the ReCiPe method – hierarchist perspective. This methodology allows for the quantification of potential impacts at both midpoint and endpoint level.

Due to a lack of data, the assumptions given below were necessary:

- Importation for EU consumption could not be distinguished from importation for transit. Importation impacts were therefore allocated to all end products consumed in the EU.
- Reused textiles in Europe were included in the model and a lifetime extension of 50 % was given to the reused item. Reused clothes are also assumed to prevent the production of new items with a 1:1 ratio. In addition, only the impacts of exportation were considered for items that are reused abroad.
- Blended fibres were included in the model as the breakdown per fibre of each item was considered. However, it was not possible to take into account for some specific features that blended fibres holds compared to 'pure' fibres. A simplified case study was carried out in order to understand the significance of considering these aspects in the assessment of the environmental performance of a specific end product (i.e. a T-shirt).
- Recycling was modelled as recycling into wiping rags considering that textile wiping rags can replace paper towels. Only energy benefits were included in the model.
- Concerning the production of fibres, some processes were extrapolated from other fibre types as no fibre-specific data were available.
- Processes are tightly linked to product quality, implying that for a given fibre type, end products will not necessarily follow the same processes. However, as this information could not be obtained, it was assumed that all fabrics undergo a complete process chain which might lead to an overestimation of environmental impacts.
- No specific data were found to differentiate production practices based on the geographical location. Thus, it was assumed that European (or, more generally, western) practices are representative for the all textiles industry.

➢ **Summary of baseline parameters**

Table 36 sums up the main parameters that were selected to model the baseline scenario for the distribution, use and end-of-life stages. Regarding the production stage, the parameters and assumptions are specific to each fibre type and thus it was not possible to provide a simple overview. More detailed information can be found in Section 2.2.1.

Table 36: Summary of the main baseline parameters of the textile LCA model

<table>
<tr><th>Life cycle phase</th><th colspan="6">Main parameters in the baseline scenario</th></tr>
<tr><td rowspan="4">Distribution</td><td>All products</td><td colspan="5">600 km by truck</td></tr>
<tr><td>Woven clothes</td><td rowspan="3">Sea (km)</td><td>13 601</td><td rowspan="3">Air (km)</td><td>6 969</td><td rowspan="3">• 92 % ship freight
• 8 % air freight</td></tr>
<tr><td>Knitted clothes</td><td>12 722</td><td>6 738</td></tr>
<tr><td>Household textiles</td><td>10 758</td><td>6 199</td></tr>
<tr><td rowspan="8">Use</td><td rowspan="5">Washing</td><td colspan="4">Load</td><td>4.3 kg/cycle</td></tr>
<tr><td colspan="4">Average temperature</td><td>45.8 °C</td></tr>
<tr><td colspan="4">Energy consumption</td><td>0.72 kWh/cycle</td></tr>
<tr><td colspan="4">Water consumption</td><td>46.3 L/cycle</td></tr>
<tr><td colspan="4">Detergent use</td><td>139.76 g/cycle</td></tr>
<tr><td rowspan="2">Drying</td><td colspan="4">Load</td><td>4.3 kg/cycle</td></tr>
<tr><td colspan="4">Energy consumption</td><td>2.01 kWh/cycle</td></tr>
<tr><td>Ironing</td><td colspan="4">Energy consumption</td><td>0.027 kWh/min</td></tr>
<tr><td rowspan="2">End-of-life</td><td>Clothing waste</td><td colspan="5">• 8 % reuse as second-hand clothes:
25 % EU
Associated transport: 600 km by truck
75 % world
Associated transport: 600 km by truck + 10 000 km by ship
10 % recycling as wipers
• 24.3 % incineration with energy recovery
• 0.6 % incineration without energy recovery
• 57.1 % landfill</td></tr>
<tr><td>Household textile waste</td><td colspan="5">• 29.6 % incineration with energy recovery
• 0.8 % incineration without energy recovery
• 69.6 % landfill</td></tr>
</table>

3 RESULTS OF THE BASELINE SCENARIO

3.1 Overview

This section presents the results for the baseline scenario. As presented in the previous section, the LCA model encompasses the impacts related to the full life cycle of clothes and household textiles to satisfy the final consumption in the EU-27 in 2008. Reused items from the previous year were also included assuming that reuse rate and textile apparent consumption would be constant over the following two years. As already mentioned in Section 2.2, in the baseline scenario, the average weights of each end product are considered. Results for minimum and maximum weights are presented in Annex 3. Though there is uncertainty in the absolute impacts of textile consumption, this does not affect the improvement option assessment. Table 37 presents the environmental impacts of textile consumption in the EU-27 in 2008 according to the midpoint and endpoint indicators of ReCiPe.

Table 37: Environmental impacts of textile consumption in the EU-27 according to the midpoint and endpoint indicators of ReCiPe

Indicator	Unit	Production	Distribution	Use	End-of-life	Total
Climate change	Mt CO_2 eq	213	20.7	185	-6.38	**412.52**
Ozone depletion	t CFC-11 eq	16.5	2.60	10.4	-0.0348	**29.42**
Photochemical oxidant formation	Mt NMVOC	0.521	0.127	0.447	-0.001	**1.09**
Particulate matter formation	kt PM_{10} eq	263	37.4	260	-8.36	**552.29**
Ionising radiation	Mt ^{235}U eq	79.9	1.20	114	-6.04	**189.32**
Terrestrial acidification	kt SO_2 eq	851	112	747	-27.2	**1682**
Human toxicity	Mt 1.4-DB eq	12.5	0.443	63.5	-0.568	**75.81**
Terrestrial ecotoxicity	kt 1.4-DB eq	943	1.91	144	-0.983	**1090**
Freshwater ecotoxicity	Mt 1.4-DB eq	1.68	0.0124	5.64	-0.00713	**7.58**
Marine ecotoxicity	Mt 1.4-DB eq	0.376	0.0232	1.28	-0.0118	**1.67**
Metal depletion	Mt Fe eq	10.9	0.213	21.9	-0.374	**32.67**
Fossil depletion	Mt oil eq	73.0	7.21	57.0	-2.48	**134.76**
Water depletion	Billion m^3	5.77	0.0376	8.57	-0.0600	**14.32**
Freshwater eutrophication	kt P eq	49.5	0.109	7.94	-0.104	**57.45**
Marine eutrophication	kt N eq	342	13.9	57.2	8.65	**421.82**
Agricultural land occupation	$km^2 \cdot yr$	81200	34.7	3720	-142	**84821**
Urban land occupation	$km^2 \cdot yr$	939	89.7	1030	-33.2	**2030**
Natural land transformation	km^2	75.8	10.3	28.1	-1.07	**113.23**
Human health	1000 DALY	377	39.1	373	-11.6	**777.39**
Ecosystem diversity	1000 species · yr	5.74	18.2	2.12	-0.0544	**7.98**
Resource availability	Billion USD	1180	116	918	-39.9	**2170**

Figure 26 present the share of each life cycle phase over total impacts according to each of the midpoint and endpoint indicators.

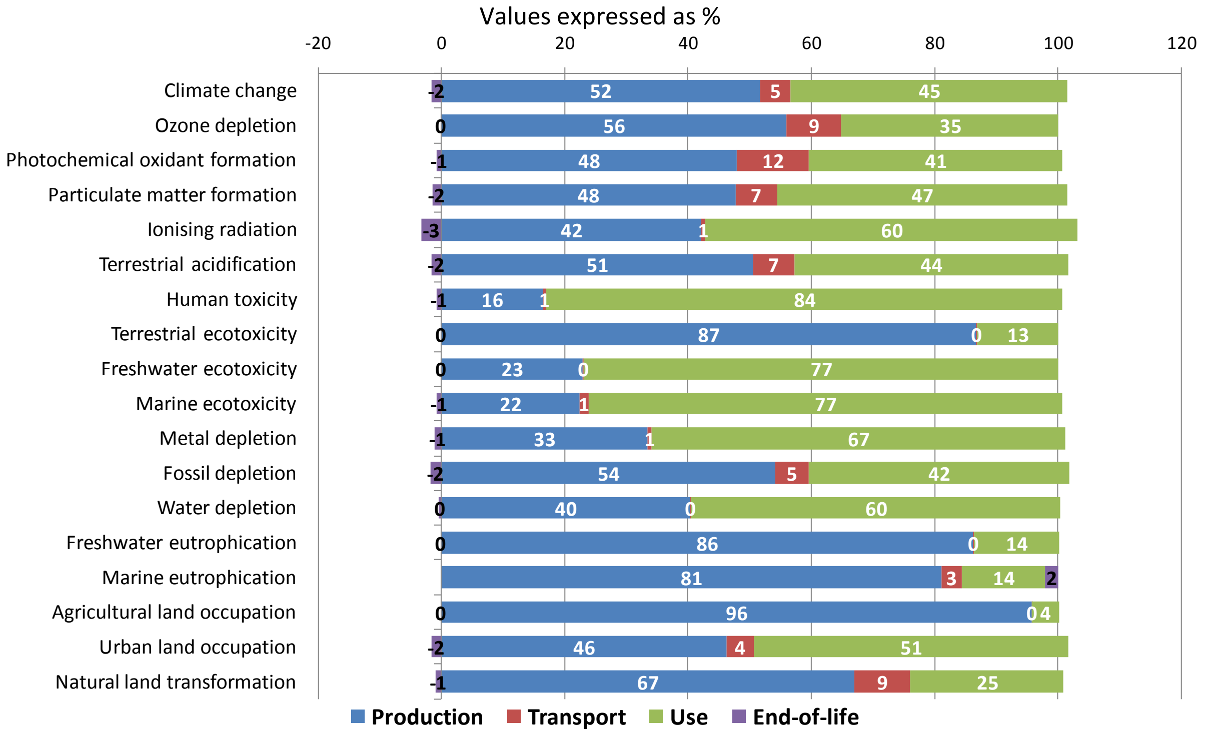


Figure 26: Environmental impacts of textile consumption in the EU-27 according to the midpoint indicators of ReCiPe

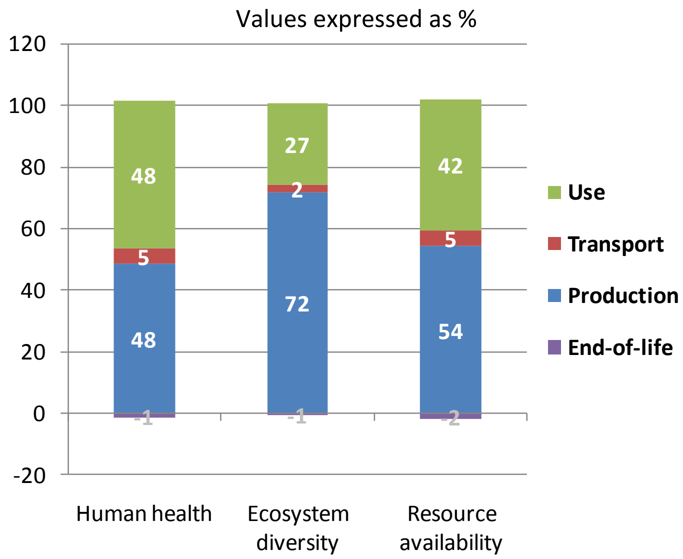


Figure 27: Environmental impacts of textile consumption in the EU-27 according to the endpoint indicators of ReCiPe

Production and use phases are the main contributors for all the indicators, contributing from 16 % to 96 % (production phase) and from 4 % to 84 % (use phase) to the overall impacts. The contributions of distribution and end-of-life phases appear less significant, with the latter one being in some case negative because of credits due to energy and material recovery. Despite the apparent small contribution of the end-of-life stage, it should be however remarked that this only takes into account recycling and disposal activities. The reuse of textile products, indeed, was included in the calculation of the real consumption of textiles, and that a discount was therefore implicitly assigned to the impacts from the production stage.

The production phase dominates with regard to eutrophication, agricultural land occupation and natural land transformation. This can be explained by the high share of cotton to produce textiles for the European market. Cotton (but also other natural fibres from crops) is produced using high amounts of fertilisers. Nitrogen, phosphorus and potassium, contained in fertilisers, contribute especially to the impact on eutrophication. The potential impact on land is a straightforward consequence of the cotton cultivation. Also the other crops contribute to land use and to the use of agrochemicals; nevertheless, a higher market share is associated with cotton.

With the exception of terrestrial ecotoxicity, most of the toxic emissions affecting human beings and aquatic ecosystems results associated with the use phase, mainly because of the use of laundry detergents. Regarding this matter, a specific category of household textiles such as bed, kitchen and toilet linens and casual clothes (tops, bottoms and underwear) are especially important contributors to impacts related to human health and biodiversity. It should be noted that these products can be either relatively heavy and sporadically washed (i.e. linens) or lighter but washed frequently (i.e. tops, bottoms, underwear); a high number of washing cycles is anyway required in comparison with other product categories that do not need the same care (e.g. jackets, coats, suits, blankets). The assumptions on the use phase were gathered from several sources: Marks & Spencer (2002), Ensait (2009), Ediptex (2007). They reveal that tops, bottoms and underwear are generally washed, dried and ironed more frequently than other clothes. Energy and water are demanded all along the value chain of each textile products, which explains a relative balance between production and use phases in categories related to water depletion and energy consumption (e.g. fossil fuel depletion climate change, ozone depletion, photochemical oxidant formation and particulate matter formation).

The impact share that is attributable to distribution is relatively low for most of the indicators. The highest contribution, 12%, is registered for photochemical oxidant formation (i.e. smog formation). The explanation is fairly straightforward, as vehicles (trucks, ships and planes) release particulate matter and exhaust gas directly into the atmosphere.

The end-of-life phase includes disposal treatments such as incineration (with and without energy recovery) and landfilling as well as recycling processes. The end-of-life phase only concerns end products in the LCA model: losses during fabrication have their own end-of-life scheme and they were included in the production phase (Section 2.2.1). The environmental impacts of the end-of-life phase are small compared to the other life cycle phases. Additionally, environmental credits are associated with recycling and energy recovery schemes, which can lead to negative contributions (see Figures 25 and 26).

With respect to the endpoint indicators, the use phase scores the highest contribution to the damage to ecosystems as a potential consequence of the significant contribution to freshwater and marine toxicity. The damage to human health and to resources is instead allocated almost equally between production and use phases, mainly because of the relatively balanced energy demands, which yield similar impacts in the indicators related to energy consumption.

A detailed description of the environmental impacts of the production and processing phase, disaggregated to the individual fibre types and cloth categories, is given in Section 3.2. Similarly, the use phase is detailed in Section 3.3.

3.2 Focus on the production phase

3.2.1 Breakdown of the environmental impacts by product types

The production phase encompasses raw material production processes, as well as the preparation of fibres until the manufacture of the final products (see Section 2.2.1). This phase ends when the textile product is ready to be used. Figure 28 presents the breakdown of the environmental impacts of the production and processing phase by product types.

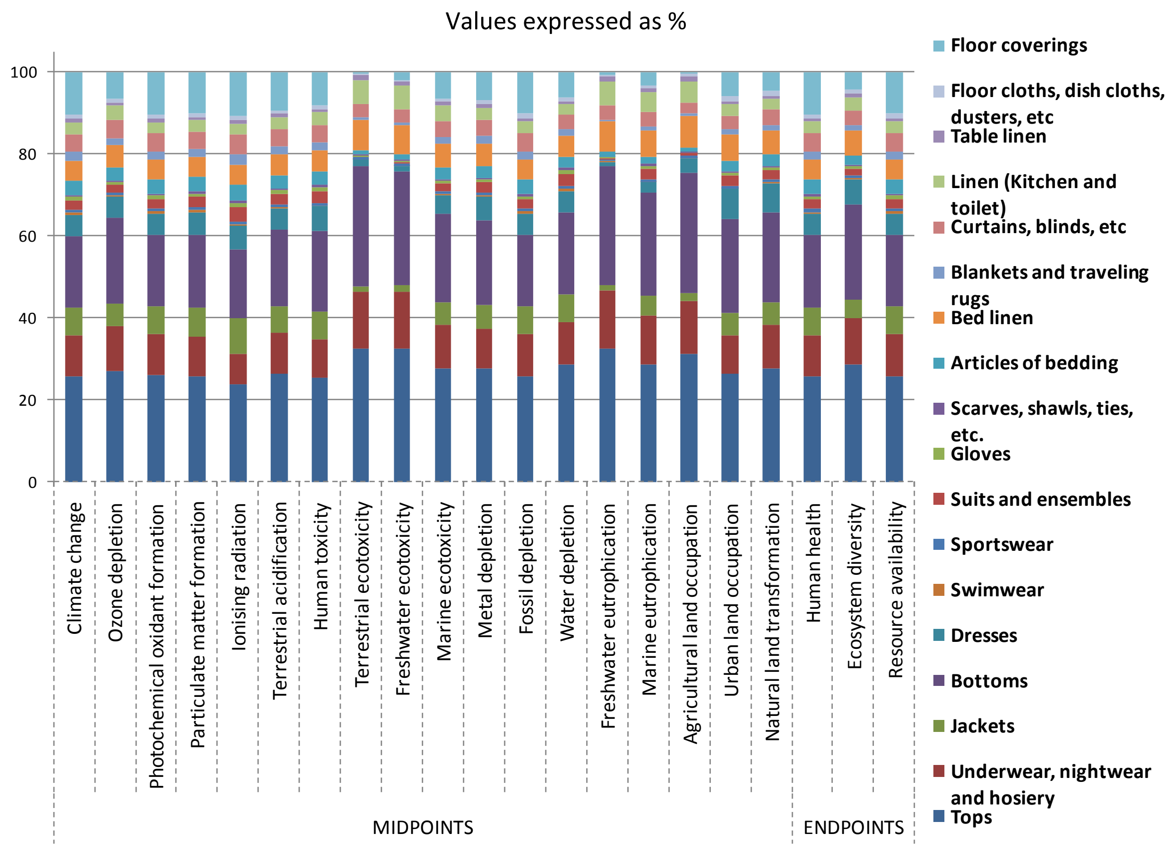


Figure 28: Breakdown by product types of the environmental impacts due to the production phase

The significant contributions to all the impacts are due to a few specific clothing categories. The three top categories are: tops (24–33 %), underwear (8–14 %) and bottoms (17–29 %). This is due to the fact that these everyday textile products are also the products which are consumed in the highest quantities in Europe (see Section 1.3). To the contrary, household textile (i.e. bedding, bed linens, blankets and travelling rugs, curtains, blinds, kitchen and toilet linens, table linens) production does not much contribute to the total impacts. Similar results are obtained with respect to the endpoint indicators of the ReCiPe method, where the main categories are: tops (26–29 %), underwear (10–11 %), bottoms (17–23 %), dresses (5–6 %) and floor coverings (4–10 %).

3.2.2 Breakdown of the environmental impacts by fibre types

Figure 29 shows the environmental impact of textile consumption in the EU-27 according to midpoint and endpoint categories and material.

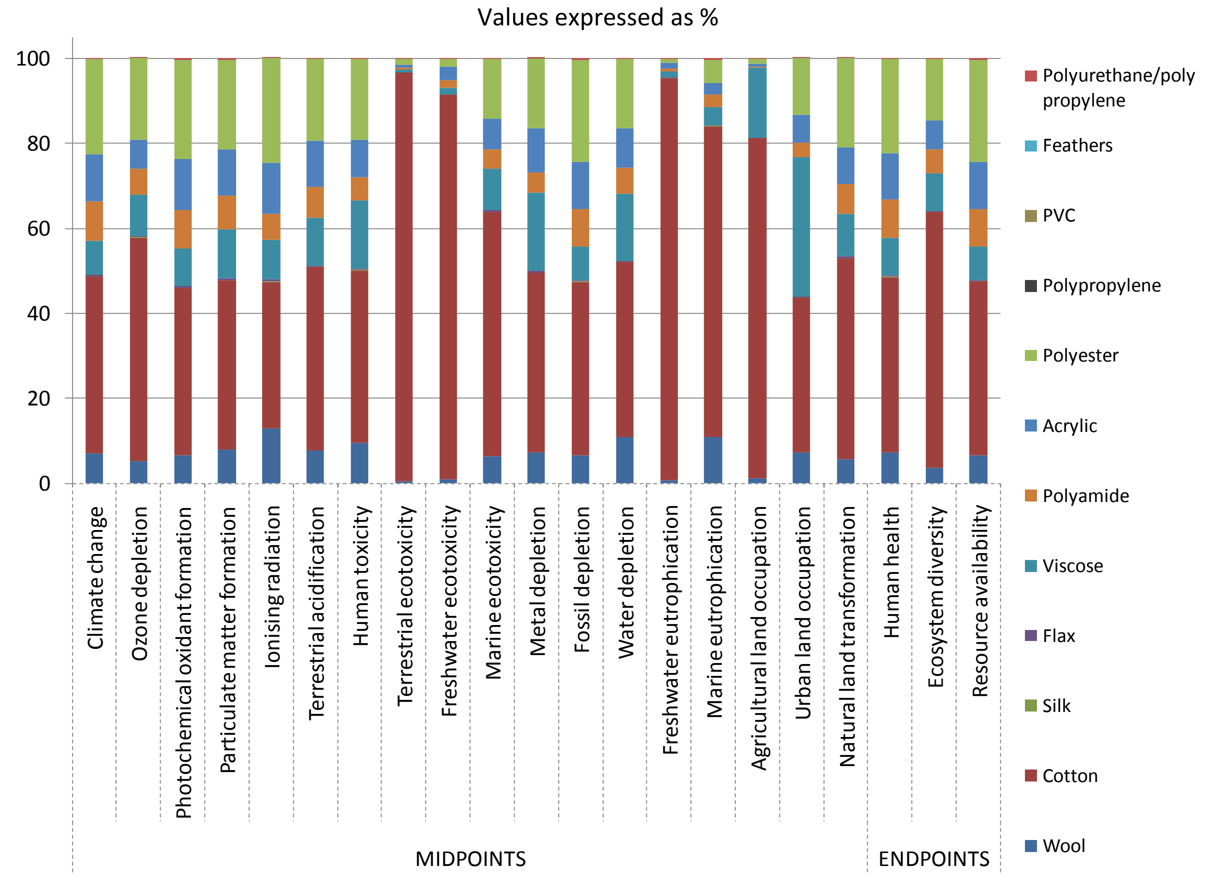


Figure 29: Breakdown by material of the environmental impacts due to the production phase

Cotton is the dominating fibre type in terms of environmental impacts (see Figure 29). This is because cotton fibre is the main fibre type used in textiles (more than one third of the fibre production). In addition, environmental impacts per kilogram of fibre are higher for cotton than for the other fibres (see Section 3.2.3).

The main environmental impacts from cotton production are due to the use of high amounts of fertilisers and pesticides. Insecticides can be released into the ground and the water (through leaching) and are significant contributors to ecotoxicity. Phosphorus and phosphate compounds from the raw material production process are responsible for most of the potential freshwater eutrophication impacts.

The second most significant contribution is generally associated with polyester. This is because polyester (1 968 kt) is the most consumed fibre type after cotton (3 733 kt) on the European consumption market for textiles (9 547 kt). As a synthetic fibre, polyester requires large amounts of energy to be produced. Polyester therefore is an important contributor to energy-related indicators, e.g. climate change and ionising radiation (nuclear energy is mainly used as electricity). The full life cycle of 1 kg of polyester fabric is responsible for the release of more than 30 kg CO_2 equivalents to the atmosphere (around 20 kg are associated with cotton). As no agricultural production is needed, the impacts on ecosystems are lower than for cotton.

Although it only represents 8 % of all fibres in mass (see Section 1.3), viscose also appears as a relatively high contributor for some impact categories, mainly for categories concerning with land occupation issues. Viscose is made from sulphate pulp, which is one of the main products from pulp and paper mills.

3.2.3 Comparison of different fibre types for selected environmental impact categories

Due to a large variety of fibre types available, it is interesting to compare the impacts of these fibre types in terms of weight.

Some of the midpoint and endpoint indicators were selected for comparison: climate change, as it is as a widely accepted and popular indicator; human toxicity and freshwater ecotoxicity, as they are indicators which are particularly affected by the compounds being used for the production of natural fibres; and the three endpoint indicators of ReCiPe.

The assessment focuses on the production of 1 kg of finished woven fabrics. Impacts are broken down into several phases: raw material production and processing, pre-treatment (only for natural fibres), sizing, spinning, desizing, warping sizing, fabric formation, finishing, printing and dyeing and the end-of-life treatment of stitching (a finishing sub-process) and warping.

Since the main contribution to the impacts of the production stage is due to cotton, displaying results per kg of fibre enhances the understanding as to whether this is due to its high mass share or to higher impacts per kg. It is however to be noted that the comparison of the fibre types will only give a better comprehension of the sources of environmental impacts for each fibre type. A direct comparison between fibre types might not be relevant as they differ in terms of use, quality and functionality. In addition, the impacts caused by the other life cycle phases (i.e. distribution, use, end-of-life of the fibre) are not taken into account here.

Polyurethane is only used when mixed with polypropylene for the induction of textile products, especially for the backing of carpets. It is then not a fibre, nor feathers. PVC (only used in table and bed linens) is not strictly a ‘fibre’ either, since this material is actually neither woven nor knitted. The 9 fibres considered in the following parts are the fibre types addressed in the baseline scenario: viscose, flax, silk, wool, cotton, polyester, polyamide, acrylic and polypropylene (see table 1).

The production & processing chain encompasses 10 processes, which are grouped into the following categories:

- fibre production
    - raw material production and processing
    - pretreatment
    - sizing
- yarn formation
    - spinning
    - desizing
- fabric formation
    - warping
    - fabric formation
- finishing phase and end-of-life
    - finishing
    - printing and dyeing
    - end-of-life of production losses.

➢ **Climate change (midpoint)**

Figure 29 shows the impact on climate change due to the production of one kg of fabric from different fibre types. Impact on climate change ranges from 14.9 to 35.7 kg CO_2 eq/kg_{fabric} (values corresponding to silk and acrylic, respectively).

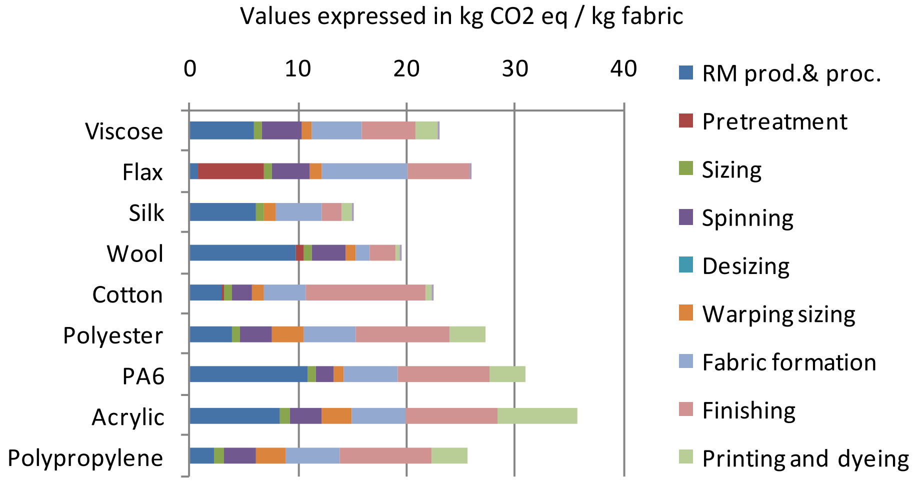


Figure 30: Impact on climate change due to the production of fabric from different fibre types

The most substantial impact, 35.7 kg CO_2 eq/kg, is generated by acrylic. Acrylic is followed by PA6 (30.9 kg CO_2 eq/kg) and polyester (27.2 kg CO_2 eq/kg). In general, synthetic fibres show a higher impact on climate change than natural fibres. This gap would result still higher if end-of-life emissions were included in the assessment since synthetic fibres are based on fossil feedstock.

Impacts are mainly due to the production of the raw materials but also to the combustion energy required in the finishing process. The most important processes after these are the formation, printing and dyeing of the fabric, which requires a high electricity demand. As far as dyeing is concerned, it is worth mentioning that dye is the next main contributor to the climate change impact after energy.

The finishing process is common to all the fibres. In the case of polyester, polypropylene, polyamide and acrylic, electricity and gas demand per kg of fabric is 3.9 kWh and 6.3 kWh, respectively. The loss rate is also the same for all of these fibre types. This is why synthetic fibres all have the same share of impacts allocable to finishing. Every other fibre considered in the model requires different amounts of energy in the finishing process.

Pre-treatment is only needed by cotton (scouring), wool and flax (bleaching) with the aim to remove matters and add-ons that could remain on the fibre during its growth (pesticides, colour, etc.). This process, requiring natural gas as input, can contribute significantly to the overall impact, as in the case of flax.

➢ Human toxicity (midpoint)

Figure 31 shows the impact on human toxicity due to the production of one kg of fabric from different fibre types. Impacts range from 0.39 (silk) to 0.99 (acrylic) kg 1.4-DB eq/kg of fabric.

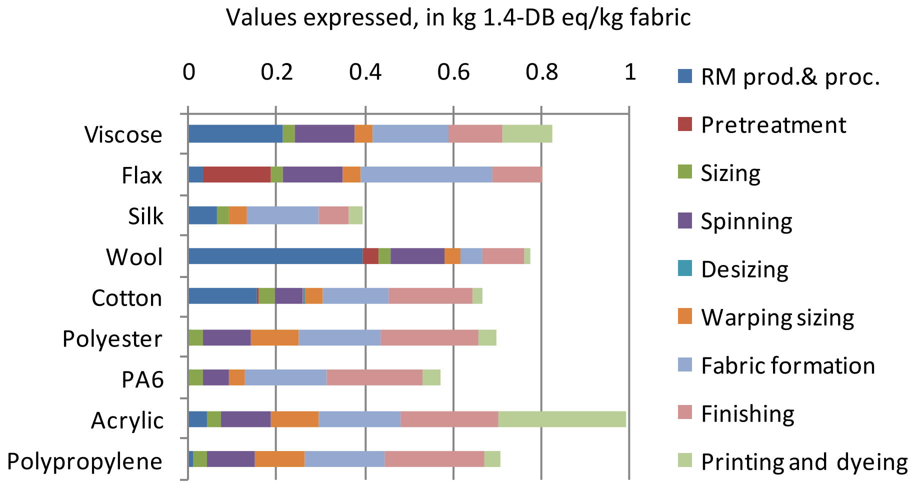


Figure 31: Impact on human toxicity due to the production of fabric from different fibre types

Acrylic is the fibre type that creates the greatest impact in terms of human toxicity, with 0.99 kg 1.4-DB eq/kg of fabric. Viscose and flax are the next two fibre types in terms of human toxicity potential per kg of fabric with 0.82 kg 1.4-DB eq/kg of fabric and 0.80 kg-DB eq/kg of fabric, respectively.

Finishing processes are the main contributors in the pathways leading to the production of synthetic fibres. The contribution of finishing and fabric formation is also significant in all the fibre types. The high requests of electricity are indeed responsible for high potential impact in terms of human toxicity due to the release of arsenic into the air. Emissions of arsenic are associated with the production of the copper wires used for the distribution of electricity.

Special attention is to be paid to wool and silk. Raw material production and processing is the most demanding step in the wool fabric production chain. This is due to a high level of material losses coupled with a high demand of energy and animal feed (the two main contributors for this process). With reference to silk, it is instead important to remark that the inclusion of the raw material production in the model has been not possible, so that the contribution due to this step is not quantifiable.

- **Freshwater ecotoxicity (midpoint)**

Figure 32 shows the impact on freshwater ecotoxicity due to the production of one kg of fabric from different fibre types. Impacts range from 15.7 (silk) to 360 (cotton) g 1.4-DB eq/kg.

The fibre type which creates the highest impact in terms of freshwater ecotoxicity is cotton, with 0.36 1.4-DB eq/kg of fabric. Cotton is followed by acrylic and polyamide, with 85 and 50 g 1.4-DB eq/kg of fabric, respectively.

The impact due to the production of 1 kg of cotton fabric is significantly higher compared to the other fibre types because of the high amount of fertilisers and agrochemicals used during the agricultural production. It should be however remarked that, while the life cycle inventory is very detailed for cotton, a lower level of detail was available for flax and hemp. Only generic agrochemicals have been used in the modelling of flax and hemp, while some harmful chemicals are included in the exhaustive LCI set found for cotton

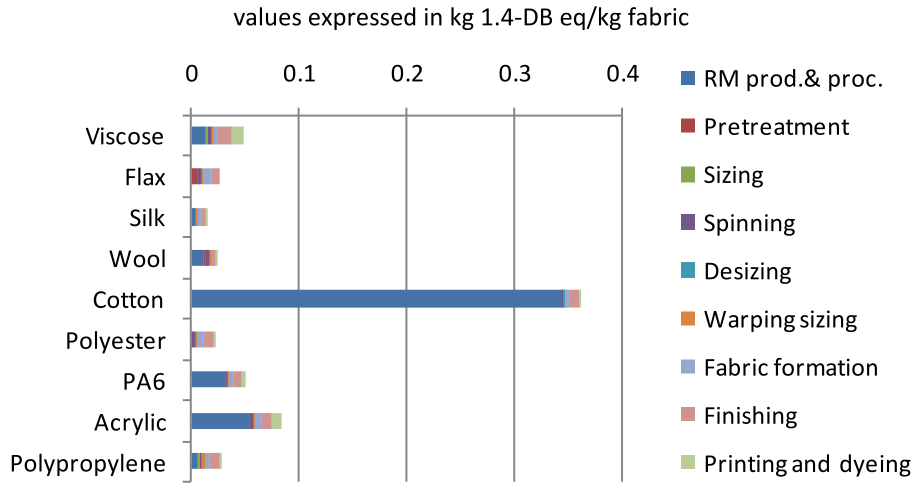


Figure 32: Impact on freshwater ecotoxicity due to the production of fabric from different fibre types

Relatively high impacts on freshwater ecotoxicity are also associated with acrylic and polyamide. This is in particular due to the raw material fabrication process, which releases substantial amounts of phosphorus directly into aquatic media.

Substantial amounts of dye are used in the production of fabrics from viscose and acrylic. These two fibre types then have a visible share of the impact on freshwater ecotoxicity allocated to the dyeing process.

- **Human health (endpoint)**

Figure 33 shows the impact on human health due to the production of one kg of fabric from different fibre types. Impacts range from 0.026 (silk) to 0.063 (acrylic) DALY/t.

Acrylic is the fibre which creates the highest impact on human health, with 0.063 DALY/t. Polyamide comes next, with 0.053 DALY/t, followed by flax, with 0.045 DALY/t.

On a general basis, synthetic fibres are worse than natural ones. The raw material production and the finishing process are of particular concern in this category. Fabric formation and finishing are energy-consuming processes. Energy inputs have high impacts on human health, mainly due to the combustion of fossil resources, which releases particles and other harmful substances and greenhouse gases into the atmosphere.

Silk still has the lowest impact, also because the raw material production step has not been modelled, due to a lack of relevant data.

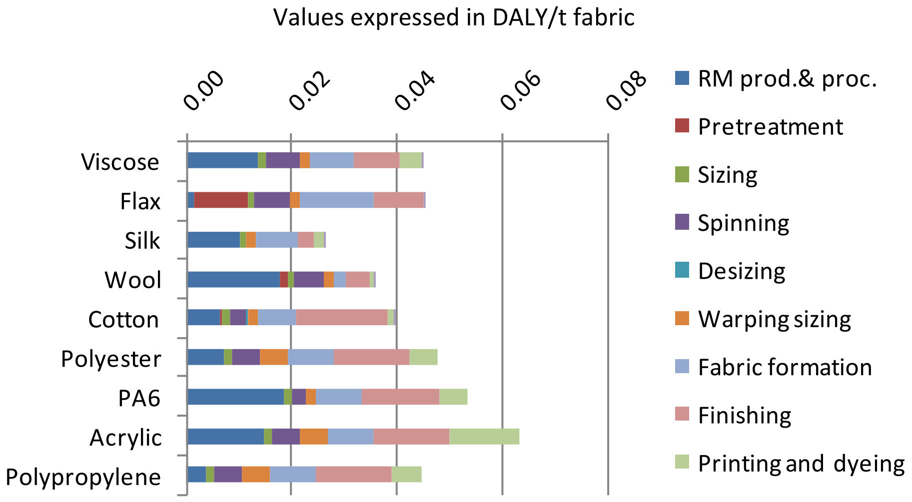


Figure 33: Impact on human health due to the production of fabric from different fibre types

➢ Ecosystem diversity (endpoint)

Figure 34 shows the impact on ecosystem diversity due to the production of one kg of fabric from different fibre types. Impacts range from 2.5×10^{-7} (wool) to 1.56×10^{-6} (viscose) species/yr/kg. More information about this indicator is available in the glossary (see Annex 4).

Of all the fibre types, viscose dominates with respect to the ecosystem diversity impact, with 1.6×10^{-6} species*yr/kg of fabric, followed by flax and cotton, with 6.8×10^{-7} and 6.6×10^{-7} species*yr/kg, respectively.

The finishing phase is responsible for a substantial share of impact for most of the fibre types, especially for viscose. The viscose finishing phase embodies many sub-processes (e.g. softening, streaming, fabric washing, water finishing, soaping) which are not necessarily energy demanding but which require soaps and softeners. The fatty alcohol sulfonate is for instance an oil-based product which is used in the fabric washing sub-process and which significantly contributes to tropical land transformation.

Concerning the raw material production phase, it can be observed that this step is particularly important for viscose- and cotton-based fabrics. Viscose requires sulphate pulp, which is a product of pulp and paper mills and thus has an impact on forests and ecosystem diversity. Cotton is a vegetable fibre and a substantial share of the impact is instead associated with the demand of land, which also applies, more in general, to the other fibre types of natural origin.

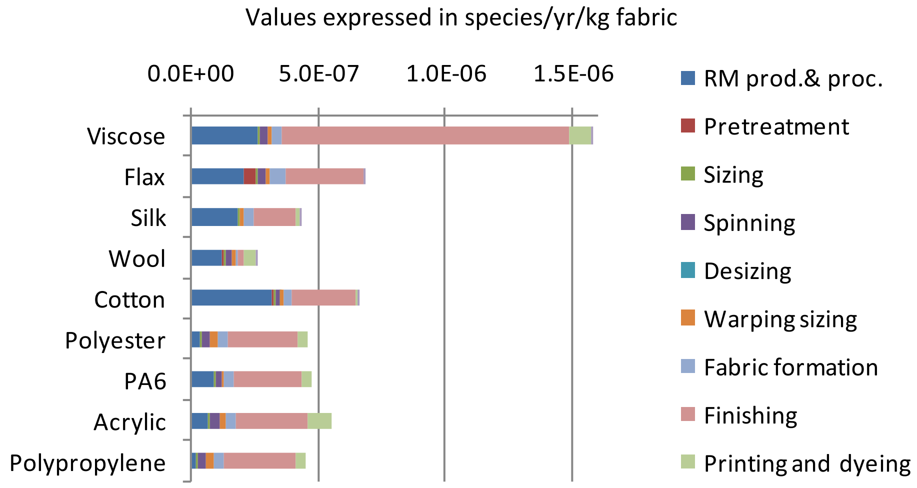


Figure 34: Impact on ecosystem diversity due to the production of fabric from different fibre types

➢ Resource availability (endpoint)

Figure 35 presents the impact on resource availability due to the production of one kg of fabric from different fibre types. Impacts range from USD 92 (silk) to 193 (acrylic), expressed as external costs per kg of fabric.

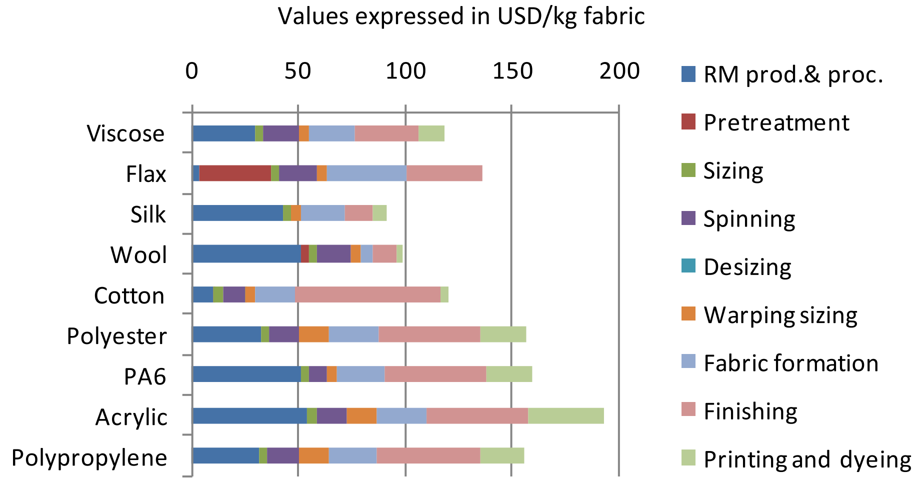


Figure 35: Impact on resource availability due to the production of fabric from different fibre types

Acrylic is the fibre type which creates the highest impact with respect to resource availability, with USD 193 per kg of fabric. Acrylic and polypropylene follow in terms of impact per kg of fabric with USD 160 and 156, respectively. It is possible to observe from the graph that substantial amounts of resources are demanded during the raw material production as well as the processing and the finishing of the fabric. Higher impacts are generally associated with synthetic fibres because they more intensively contribute to the depletion of fossil resource than fibres based on renewable-material-based materials. Silk and wool, which are from animal origin, have the lowest impact per kg of fabric.

3.3 Focus on the use phase

3.3.1 Environmental impacts of the use phase depending on the textile category

The environmental impacts of the use phase have been broken down by textile category in Figure 36, from which it is possible to observe that tops (25-28 %), underwear (12-21 %) and bottoms (28-31 %) are the most significant contributors. Compared to the production phase (see Figure 29), the contribution of these products is more pronounced for the use phase. This is basically due to two reasons: they have the highest market share in Europe in terms of quantity and they are used more than other clothes (see Section 3.1).

Interestingly, a substantial share of the impacts is also associated with bed linens, especially with reference to freshwater eutrophication and natural land transformation. Bed linens are indeed an important household textile category, composed of products which are washed, dried and ironed on a regular basis. Kitchen, toilet linens and curtains, which also are washed quite frequently, follows bed linens in importance.

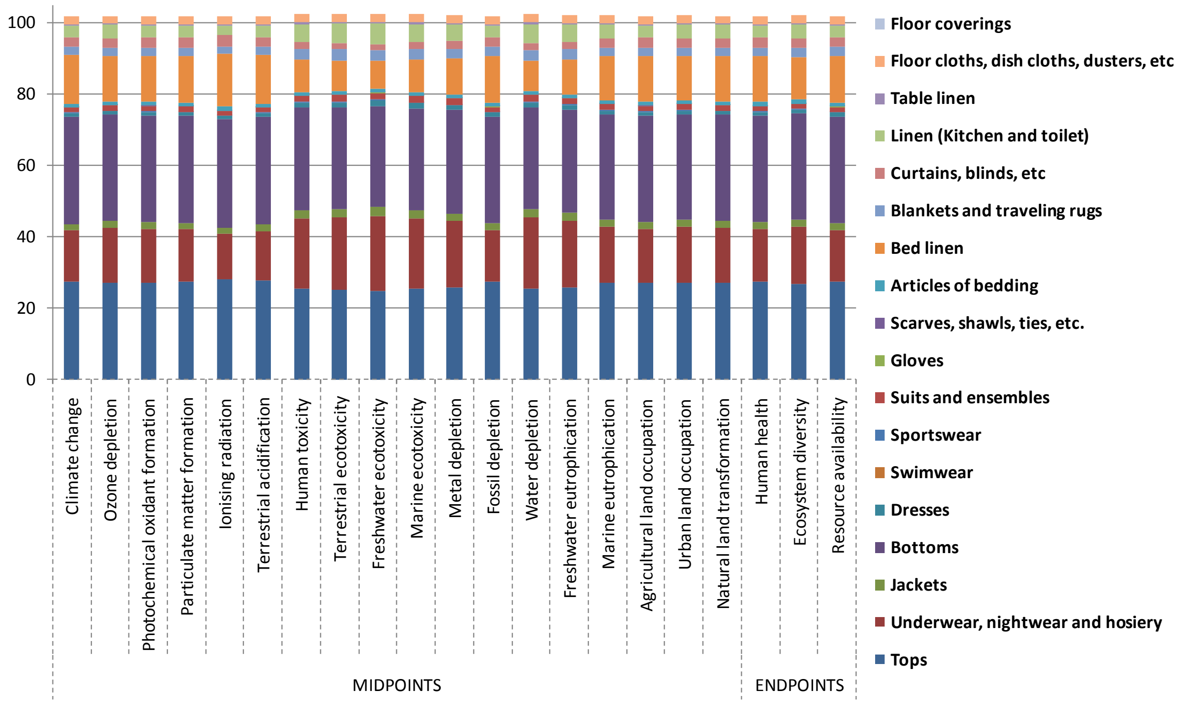


Figure 36: Impacts of textile consumption in the EU-27, for the use phase, broken down by textile category

3.3.2 Environmental impacts of the use phase depending on the process

The use phase encompasses four processes which are easily distinguishable: washing (excluding detergent use), detergent use during washing (including emissions to water), tumble drying and ironing (see Section 2.2.3). Figure 37 presents a breakdown of the potential impacts of the use phase based on the four processes previously identified.

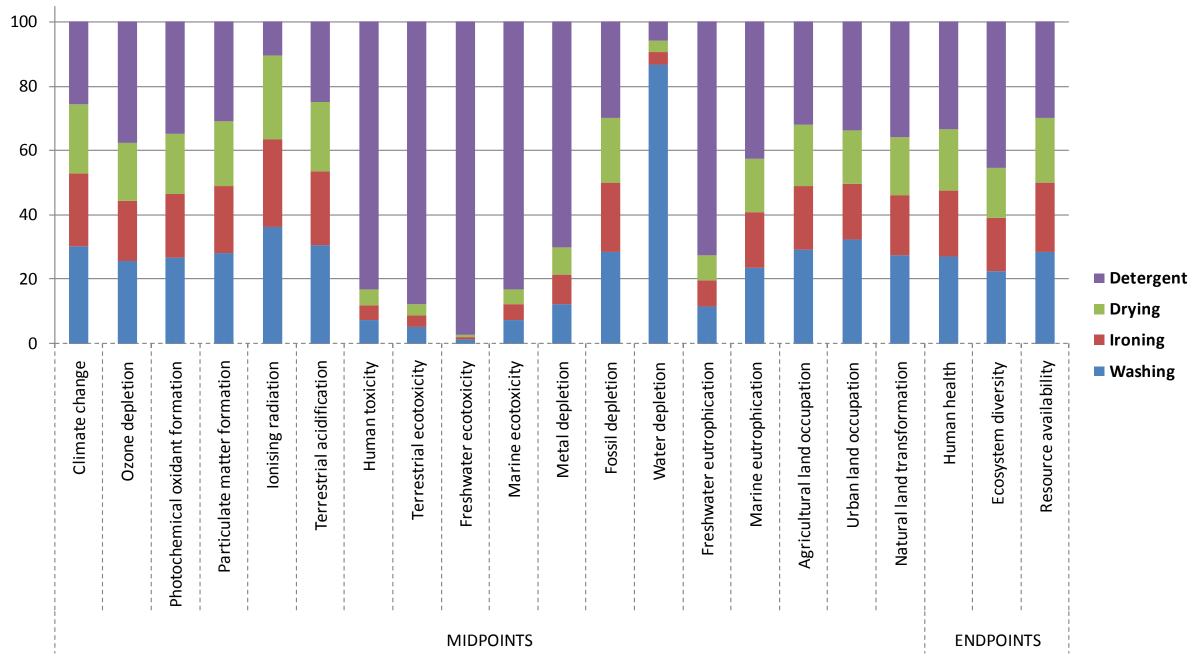


Figure 37: Impacts of the use phase of textile consumption in the EU-27, for the use phase, broken down by process

The four processes contribute almost equally to the environmental impacts, with the exception of the indicators related to toxicity, metal depletion, and freshwater eutrophication. With respect to these indicators, the detergent use clearly dominates the impacts. Detergent fabrication requires sodium compounds, as well as surfactants, which are potentially harmful for human health, water and terrestrial ecosystems. Another exception is the water depletion indicator. As a highly water-consuming process, washing is of course responsible for the largest contribution in this impact category.

4 IMPROVEMENT POTENTIAL OF THE EU-27 TEXTILES MARKET

4.1 Introduction and Methodology

To identify the improvement potential of the textile market in EU-27, improvement options were identified. A list of options was set-up further to a literature review and a consultation of experts. The number of options was reduced based on the following criteria:

- relevance in the context of IPP
- size of the environmental improvement potential
- coverage of the existing technical potential by the existing legislation
- availability and reliability of data to quantify the environmental impacts.

After the screening, 13 improvement options were selected and the improvement potential assessed for each of them (see 4.2). For the majority of options, the improvement potential was calculated on the basis of the textile LCA model. For one option (i.e. fibre blending), the improvement potential was instead quantified by carrying out further case studies as data in this case were limited to only a few or very specific fibre types. Changes in the methodological approach were thus necessary.

4.2 Preliminary technology and options review

In total, 52 options have been identified, including:

- 35 for the production phase
- 3 for the distribution phase
- 9 for the use phase
- 5 for the end-of-life phase.

The following tables (Table 38 to table 41) list the improvement options identified during the preliminary review and present an assessment of each option: environmental benefits which can be potentially gained with the option, availability of information, time horizon necessary to implement the option, final decision about the inclusion or exclusion of the option.

Table 38: Preliminary list of improvement options for the production and processing phase

Option	Environmental benefit	Data availability (1)	Time horizon (2)	Decision (3)
Reduce agrochemical use in cotton production	Reduction of pesticide and fertiliser use could result in easing of impacts on aquatic systems	+	ST	✓
Replace cotton with alternative natural fibres	Flax and hemp crops are less reliant on agrochemical use in comparison with cotton crops.	+	ST	✓
Reduce fibre blending to facilitate recycling	Potentially reduces impacts of disposal where landfilling is avoided	o	ST	✓
Reduce consumption of sizing chemicals	Reduced raw materials consumption and effluent treatment	o	ST	✓

Option	Environmental benefit	Data availability (1)	Time horizon (2)	Decision (3)
Use alternative knitting technologies	Potential reduction in energy consumption and fabric waste production	+	ST	✓
Replace chemicals with enzymes	Overall slight reduction of impacts, up to 1 % of savings for metal depletion	+	LT	✓
Exclude toxic agents during production steps	Overall reduction of impacts to human health and ecosystem quality	o	LT	✓
Recycle or reuse water during processing steps	Reduced water and energy consumption	o	ST	✓
Replace bleaching, rinsing and washing technologies	Reduced water and energy consumption	o	LT	✓
Recycle effluent water	Reduced water consumption	o	LT	✓
Use low liquor ratio dyeing machines	Reduced energy, steam and water consumption	o	ST	✓
Recover fabric waste during production	Reduced amount of waste disposed of	o	ST	✓
For wool fibre production, replace sheep dip chemicals	Replacing sheep dip chemicals with less toxic alternatives may reduce impacts on aquatic systems and human toxicity	–	ST	Excluded due to lack of data on sheep dipping pesticide alternatives rendering this option difficult to quantify
For wool fibre production, reuse Lanolin	Reusing lanolin could offset some of the impacts of disposal	–	ST	Excluded because data collected in the model does not specify whether lanolin reuse is considered, and further, inventory data for this substance were unavailable. Moreover, as lanolin is an expensive by-product, reusing it is already a current practice according to textile experts
Replace crude oil-based synthetic fibres with bio-sourced synthetic fibres	Reduced crude oil consumption and may have other overall environmental benefits	o	LT	This option will not be assessed further as little reliable and specific data are available due to industrial confidentiality hence making this option difficult to assess accurately
Horizontal washers versus vertical washers	Reduced water consumption	–	ST	This option will not be included because data do not allow for differentiating between different types of washers
Continuous versus non-continuous dyeing	Reduced water and chemical consumption	–	ST	Excluded because it would be difficult to determine how these two techniques would differ in terms of raw materials consumption

Option	Environmental benefit	Data availability (1)	Time horizon (2)	Decision (3)
Consider processes which are in concordance with REACH	Elimination of hazardous chemicals which could result in an overall reduction of impacts	–	LT	Option will not be assessed further because data are not readily available
Consider digital instead of pigment or traditional printing	Overall reduction of impacts	–	LT	Excluded because data were not available to quantify the improvement potential
Consider pulsating rinse technology	Reduced chemical use and overall reduction of impacts	–	ST	
Consider ultrasonic treatments and ozonation	Used in conjunction with other techniques such as enzyme replacement; could result in overall reduction of impacts	–	ST	Excluded because data were not available to quantify the improvement potential
Employ electrochemical dyeing	Replacement of environmentally harmful chemical reducing agents, reduction in water consumption and significant BOD reduction	–	LT	Excluded because data were not available to quantify the improvement potential
Employ plasma technology	Eliminates water consumption and therefore effluent treatment is not necessary. Also significantly reduces need for certain processing chemicals	–	+LT	Excluded because data were not available to quantify the improvement potential
Use of supercritical CO_2 for dyeing	Reduced or completely eliminated water consumption for dyeing step	–	LT	Excluded because data were not available to quantify the improvement potential
Favour low impact textile production where use phase impacts are high	Overall reduction of impacts	–	LT	Excluded because data were not available to quantify the improvement potential
Apply easy care treatments	Reduced impacts brought about during the use phase	–	LT	Excluded because data were not available to quantify the improvement potential
Quality control for raw materials before finishing	Reduction of waste generated during processing stages	–	ST	Excluded because data were not available to quantify the improvement potential
Improve yarn quality to increase lifetime	Reduced need for disposal	–	ST	Excluded because data were not available to quantify the improvement potential
Increase tolerance for colour changes	Less fading, resulting in longer product lifetime	–	ST	Excluded because data were not available to quantify the improvement potential
Reduce energy use or recycle calorific energy	Reduced energy consumption	–	ST	Excluded because data were not available to quantify the improvement potential

Option	Environmental benefit	Data availability ([1])	Time horizon ([2])	Decision ([3])
Combine processes (e.g. bleaching and scouring)	Reduced water and energy consumption	–	**ST**	Excluded because data were not available to quantify the improvement potential
Consider cold pad batch dyeing	Reduced energy consumption	–	**+ST**	Excluded because data were not available to quantify the improvement potential
Improve machine maintenance	Overall reduction of impacts	–	**+ST**	Excluded because data were not available to quantify the improvement potential
Use automated chemical dosing systems	Prevention of excess chemical use or inefficient application	–	**+ST**	Excluded because data were not available to quantify the improvement potential
Use dye machine controllers	Prevention of excess chemical use or inefficient application	–	**+ST**	Excluded because data were not available to quantify the improvement potential
Use on-line monitoring or fuzzy logic	Better control of materials and energy consumption	–	**LT**	Excluded because data were not available to quantify the improvement potential

([1]) + = many data / o = little data / – = no data.
([2]) +ST = Very short term / ST = Short term / LT = Long term / +LT = Very long term.
([3]) ✓ = included.

Table 39: Preliminary list of improvement options for the distribution phase

Option	Environmental benefit	Data availability ([1])	Time horizon ([2])	Decision ([3])
Adjust the partition of distribution methods for imported textile	Reduced overall impacts related to transportation, in particular CO_2 emissions	–	**LT**	✓
Reduce the percentage of unsold or returned products	Reduced waste generation	–	**LT/+LT**	The percentage of unsold products can vary greatly depending on market conditions, seasons and popularity of stores they come from. As no data were available, this option has been excluded
Reduce the packaging and paper advertising	Reduced raw materials consumption and waste generation	–	**ST**	This option will not be investigated further. Packaging of products and advertisement has not been included in the base case model

( ) + = many data / o = little data / – = no data.
([2]) +ST = Very short term / ST = Short term / LT = Long term / +LT = Very long term.
([3]) ✓ = included.

Table 40: Preliminary list of improvement options for the use phase

Option	Environmental benefit	Data availability ([1])	Time horizon ([2])	Decision ([3])
Reduce number of washes through better loading of the appliances	Reduced detergent, energy and water consumption	o	LT	✓
Avoid or reduce tumble drying frequency	Reduced energy consumption	o	LT	✓
Use energy efficient washing machines, tumble dryers and irons	Reduced energy consumption	+	LT	✓
Wash at lower temperatures	Reduced energy consumption	–	LT	✓
Use eco-friendly washing detergents	Reduced impacts of detergent use (e.g. lower BOD and COD)	–	LT	Lack of data means this option cannot be quantified. It has therefore been excluded from further analysis
Buy more durable garments and textiles	Longer product lifetime and, therefore, reduction in textile waste generation	–	LT	The production phase cannot be quantified as it is difficult to determine the changes in production and processing inputs that would increase product lifetime and to model phenomenon of fast fashion reducing the potential lifetime of clothes
Promote purchase of eco-friendly textiles	Reduction of overall impacts	–	LT	This is dealt with, to an extent, during the production phase, where certain fibres replace high impacting fibres. However, it is difficult to quantify the use phase differences as little information is available on the washing and drying needs of eco-friendly textiles
Lease clothes	Prevents individual purchase, and therefore results in an overall reduction of impacts	–	LT	Data pertaining to the market share of clothes leasing are not available, therefore it is not possible to quantify how much the consumption of clothing products would be reduced by
Extend the life of clothing and textiles through repairs	Longer product lifetime and, therefore, reduction in textile waste generation	–	ST	This is dealt with, to an extent, increasing the reuse during the end-of-life phase because the impacts of repairs (e.g. sewing) are difficult to be quantified

([1]) + = many data / o = little data / – = no data.
([2]) +ST = Very short term / ST = Short term / LT = Long term / +LT = Very long term.
([3]) ✓ = included.

Table 41: Preliminary list of improvement options for the end-of-life phase

Option	Environmental benefit	Data availability (1)	Time horizon (2)	Decision (3)
Promote textile recycling, reuse and second-hand purchase by increasing collection	Reduction of textile waste generated	o	+LT	✓
Develop textile recovery technologies	Reduction of textile waste generated	–	LT	It is uncertain what the impact of these technologies will be and by how much they will be able to increase the recovery of textiles waste
Develop recycling methods for fibre blends	Reduction of textile waste generated	–	ST	As fibre blends are not directly accounted for in the model, it would be difficult to determine the effects of introducing this technology. As it is not yet available, it is also difficult to determine the impact of the use of this technology
Melting or depolymerisation of recycled fibres of polyester or product into filaments	Reduction of textile waste generated	0	ST	It is difficult to quantify the impacts of using this technology.
Encourage production of 100 % synthetic textiles (no fibre blend) for easier recycling	Reduction of textile waste generated	–	LT	Fibre blends have not been modelled in the base case: the model only includes 100 % synthetic fibres and therefore the reduction of fibre blends cannot be quantified for the entire market

(1) + = many data / o = little data / – = no data.
(2) +ST = Very short term / ST = Short term / LT = Long term / +LT = Very long term.
(3) ✓ = included.

All in all, 13 improvement options were selected:

- **production and processing phase**
  1. reducing agrochemical use
  2. developing easy-to-grow crop cultivations by replacing cotton with hemp or flax
  3. reducing consumption of sizing chemicals
  4. replacing chemicals with enzymes
  5. using alternative knitting techniques (e.g. fully-fashioned knitting or integral knitting)
  6. using dye controllers and low liquor ratio dyeing machines
  7. water recycling

- **distribution phase**
    8. reducing air freight
- **use phase:**
    9. reducing washing temperature
    10. reducing tumble drying
    11. optimising the load of appliances
    12. improvement of washing/drying appliances efficiency
- **end-of-life phase**
    13. promotion of reuse and recycling

In addition, an analysis of fibre blending and its potential improvement potential is presented in this section. This case study is slightly different as it focuses on only one product (T-shirts) and implied some changes in the methodological approach. Thus, the results from this analysis cannot be compared with the other improvement options.

4.3 Improvement options for the production and processing phase

In total, 7 improvement options were assessed for the production and processing phase. They can be gathered into four categories:

- **alternative agricultural practices**
    1. reducing agrochemical use
    2. developing easy-to-grow crop cultivations by replacing cotton with hemp or flax
- **alternative chemicals:**
    3. reducing sizing chemicals
    4. replacing chemicals with enzymes
- **alternative knitting techniques**
    5. using alternative knitting techniques (e.g. fully-fashioned knitting or integral knitting)
- **reducing water use**
    6. using dye controllers and low liquor ratio dyeing machines
    7. water recycling.

For each option and indicator of ReCiPe, improvement potentials are showed with reference to the baseline scenario. A more detailed analysis of the single options is carried out with reference to a selected set of indicators (climate change and the 3 endpoint indicators of ReCiPe are always shown, 4 further indicators are sometimes added in order to ease the understanding of the analysis).

4.3.1 Reducing agrochemical use

4.3.1.1 Context

Agrochemicals play an important part in the cultivation of crops for natural fibre production. Cotton in particular has received much attention over the last two decades (Khan *et al*., 2002). In particular, pesticides use in cotton cultivation has been associated with impacts on the health of workers and surrounding populations, environmental problems, pest resistance, and other indirect impacts. Crops such as cotton are often susceptible to insect pests which infect crops and significantly reduce yield. However, more recently, studies are beginning to show that it is in fact the improper application of pesticides that has led to an increase in pest resistance. In addition, the reduction of crop yields due to resistance might induce farmers to increase the intensity and frequency of crop spraying. A study carried out in Pakistan has shown that although cotton crop yields had decreased slightly over the last decade, pesticide use has tripled (Khan *et al*., 2002).

As a result of the problems related to cotton cultivation, alternatives such as genetically modified (GM) crop cultivation are coming to the fore (Transgen, 2007). Since the beginnings of its development in the 1990s, GM cotton has received much attention due to the controversy surrounding the genetic modification of living organisms, though more related to food crops. This is clearly visible through the apparition of anti-GMO associations and websites such as 'Say no to GMOs'([1]). Following its introduction, GM cotton has had some success, not only in reducing the pesticide load, but also in increasing yields and reducing costs. In countries such as China or India, GM cotton cultivation is becoming more and more widespread (Transgen, 2007). Bt cotton and herbicide-tolerant cotton are the two main types of GM cotton plants currently grown, although new strains are constantly being developed.

Another growing trend is the growth of organic cotton crops due to increasing sustainability consciousness (Martins & Vascouto, 2007). Unlike conventional and GM cotton, organic cotton crops use no pesticides at all. Organic cotton does have some benefits for the environment with respect to toxicity issues, however, it also comes with some disadvantages, in particular, crop yields might be lower (Swezey *et al*., 2007).

4.3.1.2 Improvement potential

➢ **Baseline and improvement assumptions**

The parameters related to yields and agrochemical consumption were changed to quantify the effects of changing the crop type from conventional to organic or GM. Table 42 shows which specific values were used.

In the literature, there is some controversy with respect to the yields of GM crops. Some studies showed a significant increase in crop yield (Qaim, 2003), while others showed that yield tends to decrease over time. A 2002 study of Bt cotton in the Warangal district of Andhra Pradesh found a 35 % reduction in the total yield of Bt cotton (ISIS, 2005). In this study, a moderate increase of yields was assumed.

Table 42: Parameters considered for the cotton cultivation scenarios

Cultivation type	Yield		Pesticide use	Fertiliser use
	Ratio	kg/ha	Ratio	Ratio
Conventional cotton	1	775	1	1
Organic cotton	0.82	635.5	0	1
GM cotton	1.24	961	0.5	1

Cotton cultivation is composed of seven processes. The LCI of these processes were adjusted according to the parameters considered for the different types of cultivation. The scaling factors used to adjust the LCI are shown in table 43.

([1]) Available at http://www.saynotogmos.org/

Table 43: Scaling parameters for the life cycle inventories

<table>
<tr><th colspan="2">Process
(referred to one kg of fibre)</th><th>Scaling factor</th></tr>
<tr><td colspan="2">Transport from field to barn(t*km)</td><td>1</td></tr>
<tr><td colspan="2">Provision and application of pesticides (kg)</td><td>pesticide use ratio / yield variation</td></tr>
<tr><td colspan="2">Irrigation (kg)</td><td>1 / yield variation</td></tr>
<tr><td colspan="2">Provision and application of fertilisers (kg)</td><td>1 / yield variation</td></tr>
<tr><td rowspan="8">Agricultural processes</td><td>Mulching (ha)</td><td rowspan="8">1 / yield variation</td></tr>
<tr><td>Sowing (ha)</td></tr>
<tr><td>Chiselling (ha)</td></tr>
<tr><td>Harrowing (rotary harrow, ha)</td></tr>
<tr><td>Harrowing (spring tine harrow, ha)</td></tr>
<tr><td>Fertilising (ha)</td></tr>
<tr><td>Combine harvesting (ha)</td></tr>
<tr><td>Baling (ha)</td></tr>
<tr><td colspan="2">Provision and sewing of seeds (kg)</td><td>1 / yield variation</td></tr>
<tr><td rowspan="2">Direct emissions</td><td>CO_2 (kg)</td><td>1 / yield variation</td></tr>
<tr><td>Others (kg)</td><td>pesticide use ratio / yield variation / 2</td></tr>
</table>

(*) the ½ factor assumes that half of the emissions are allocable to pesticides and half to fertilisers.

➢ Results

Figure 38 shows how the overall life cycle impacts changes further to the assumptions considered for organic cotton and GM cotton.

Agricultural land occupation is increased in case of organic cotton. This is directly related to the reduction of yield which is the main drawback of organic cotton. However, total ecotoxicity impacts are reduced significantly by organic cotton. Compared to conventional cotton, organic cotton is favourable also in the 'eutrophication' impact category. The main reason why these indicators show significant impact reductions is the reduction of pesticide use.

No trade-offs are instead associated with GM cotton. GM cotton requires fewer pesticides than a conventional crop but still more than organic crops. However, as GM cotton is produced at a higher yield, impacts on a mass basis are notably lowered. 'Eutrophication', 'terrestrial ecotoxicity' and 'land occupation' are the impact categories that are more sensitive to the cultivation shift.

For all other impact categories, there is little difference between the cotton types. This is due to the fact that the material production and the agricultural processing phases are contributing to, roughly, half of life cycle impacts. Variations are mainly associated with the combustion of fossil fuels in tractors which has been assumed to be proportional only to the yield (smaller change if compared to the change in pesticide use).

However, it should be noted that the previous results are valid only under the assumptions considered in the assessment. Not all benefits and potential drawbacks of GMO from a broader point of view were indeed included. For instance, GMO crops may transmit seeds to other crops, a concern which is not specific to cotton (Hoyle, 2007). Genetically modified organisms are relatively recent on the majority of markets (food, energy crops, etc.) and all the risks (principally long-term risks) for human health and biodiversity have not been assessed yet.

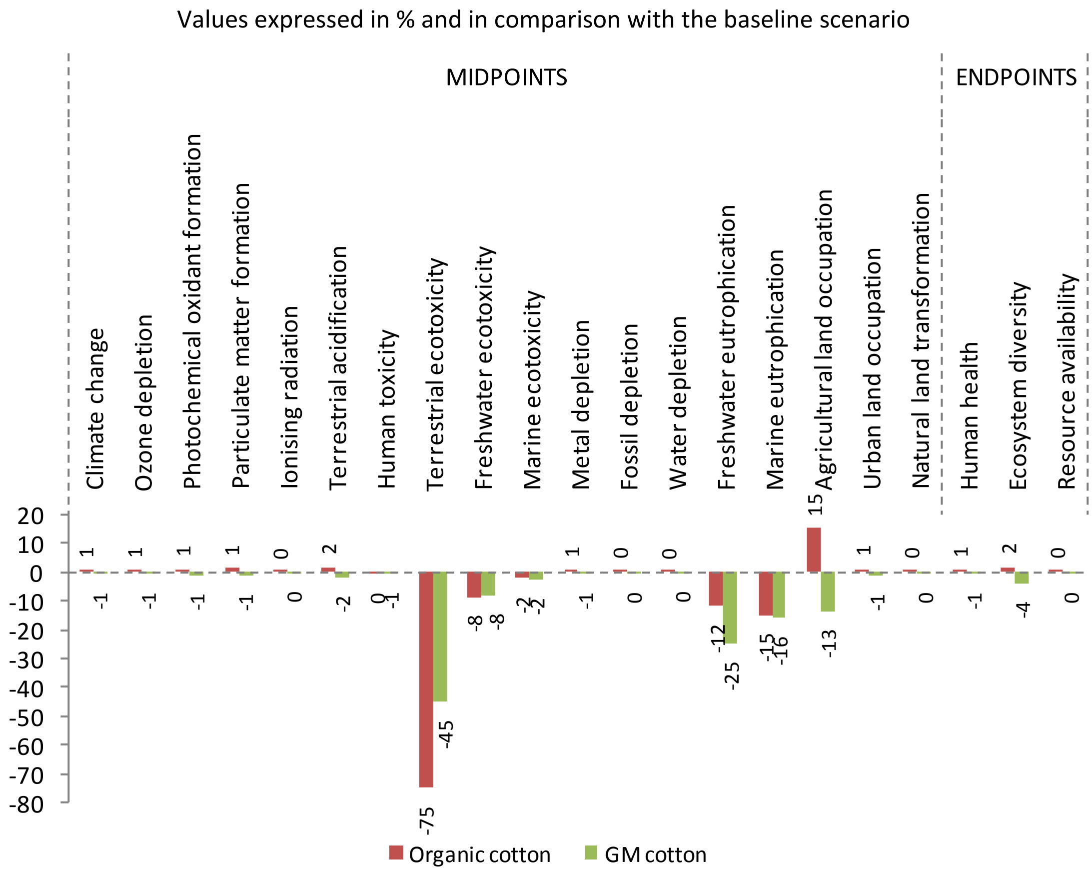


Figure 38: Changes in the life cycle impacts of textiles in the EU-27 resulting from different cotton types

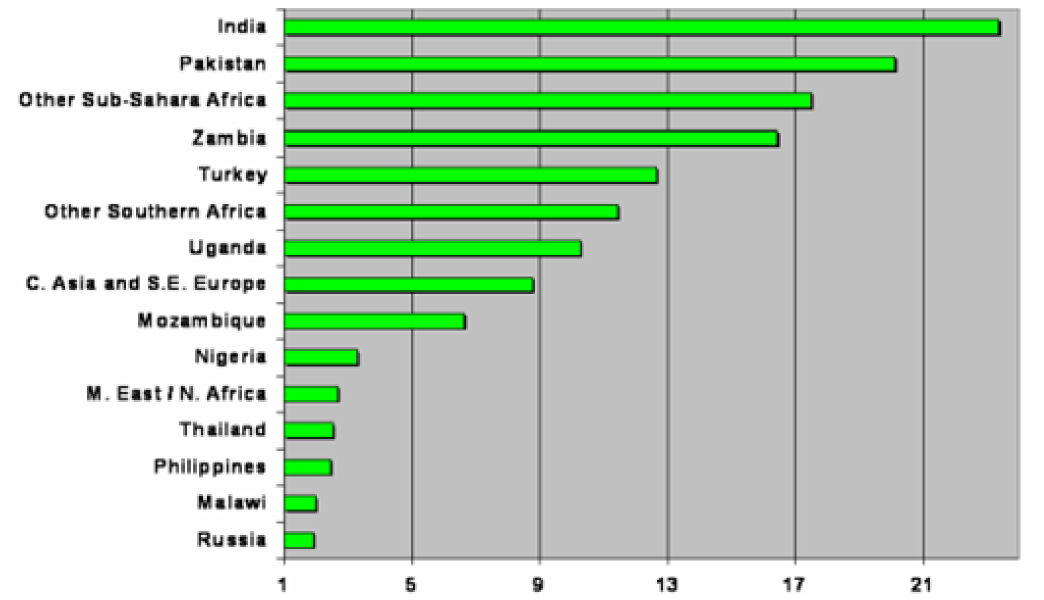
4.3.1.3 Barriers and opportunities

Conventional cotton crops depend on the use of agrochemicals. Thus, alternative crops are becoming an increasingly attractive alternative (Kant, 2007). Although seemingly an expensive option, GM cotton has experienced a dramatic increase in cultivation since its introduction, augmenting in global production by approximately 44 % from 2002 to 2005 (see table 44). Transgenic crops offer the benefit of increased yields and lower costs due to the reduced application of agrochemicals (Anderson *et al.*, 2006).

Table 44: Global uptake of cotton transgenic crops between 2002 and 2005

	2002	2003	2004	2005
Global area of GM cotton crops (million hectare)	6.8	7.2	9.0	9.8
Source: Anderson et al., 2006				

A recent World Bank study has estimated that welfare gains from the increased adoption of GM cotton could be higher than 20 % of total global GDP welfare gain in some developing countries (see Figure 39). The global benefit in monetary terms has been estimated at USD 2.3 billion (Anderson *et al*., 2006).



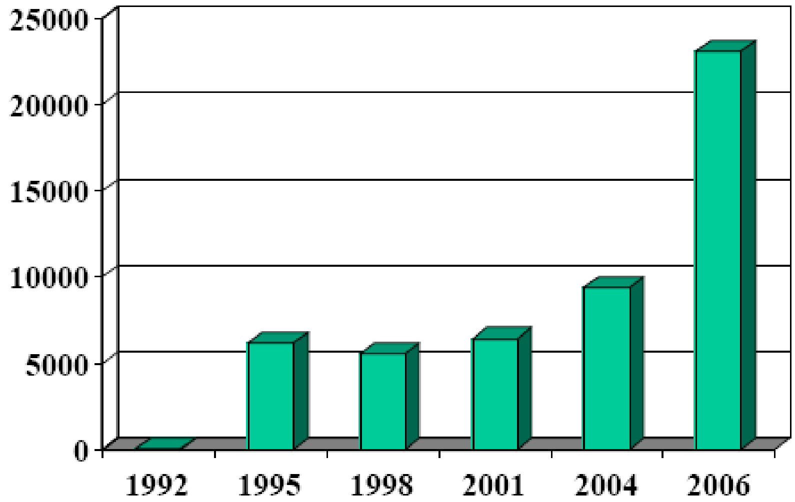
Source: Anderson et al., 2006

Figure 39: Welfare gain from GM cotton as a percentage of total world GDP welfare gain

With these estimated yield increases, it seems that GM cotton might be an economical replacement for conventional cotton crops. However, one issue that has come to light in recent years is the decrease in marginal returns from GM crop cultivation due to stagnating or even decreasing yields in the long run (Eyhorn *et al*., 2007). Pest resistance to some GM crop defences (such as those in Bt cotton crops) is also a concern, however, and some cases have already been confirmed ([1]). The cultivation of organic cotton is also increasing, however, at a lower level than the cultivation of GM cotton. In a two-year comparative study in central India, covering 170 fields, it was shown that production costs could be lowered by 10–20 %, and a 20 % organic price premium could be achieved when compared with conventional cotton crops (International Trade Centre, 2007). This translates to an income increase of 10–20 % for organic cotton growers (International Trade Centre, 2007).

Although organic cotton cultivation has seen some growth in the past years (see Figure 40), its uptake has been relatively modest and relatively insignificant in comparison with global cotton production (Baffes, 2004). Some important barriers hinder organic cotton cultivation. Certification and monitoring of organic crop cultivation is a costly procedure, which may ultimately offset the economic benefits due to less use of chemicals and higher returns from organic crop sales. It is also challenging to persuade consumers to opt for organic cotton items. Concerns over brand, style, colour, quality, care instructions and size may have a greater influence on consumer choice than ecological issues. More importantly, the price of products has a significant effect on consumer decisions. In an age of fast fashion, many companies are competing on price factors only by reducing production costs or balancing out product quality. Whereas organic food attracts consumers due to health as well as ethical benefits, the ethical incentives of organic cotton may not be enough to persuade consumers to switch.

([1]) 'First documented case of pest resistance to biotech cotton.' PHYSorg.com. 7 Feb 2008. www.physorg.com/news121614449.html



Source: International Trade Centre, 2007

Figure 40: Global organic cotton production and trade in tonnes of fibres

More recently, larger international textile producers and retailers are increasingly using organic cotton. Increased consumer awareness and demand has resulted in a niche market for 100 % organic or blended organic cotton products. Growing consumer awareness of environmental and ethical issues, as well as growing interest in corporate social responsibility, could lead to an even greater increase in organic crop production. However, until then, the costs of production, processing and purchase still remain a major threat to the organic cotton industry.

4.3.2 Alternative crop cultivation

4.3.2.1 Context

Today, cotton is the most popular type of natural plant-based fibre used for textiles (see Ffigure 9). However, it is becoming increasingly popular to use other plants such as flax, hemp, bamboo, ramie and soy. Certain properties such as texture, durability and strength, and also user comfort, differ by fibre type. Thus, replacing cotton fibres with other fibre types might not be feasible in all cases. The assumptions of this improvement option thus might be more of a hypothetical nature; however, the scenario will provide a general idea of the impact of switching away from cotton to the use of other natural fibre types.

4.3.2.2 Improvement potential

- **Baseline and improvement assumptions**

This improvement option was investigated comparing cotton to flax and to hemp, respectively. In woven applications, it was assumed that either flax or hemp was used in substitution of cotton. Knitted cotton fabric was instead considered to be irreplaceable, so that the crop was still present in the assessment.

The majority of data for early processing steps in the hemp fibre production are unique to this type. However, later steps, such as yarn production and finishing were based on figures for linen production. The key assumptions for each fibre type are given in table 45.

Table 45: Key assumptions for the modelling of flax and hemp cultivation, annual values

Parameter	Cotton	Flax		Hemp	
		Value	Source	Value	Source
Yield (kg/ha)	775	1200	BIO (2007a)	7750	Boutin, *et al.* (2005)
Fertiliser use (kg N/P/K per ha)	104/56/89	86/146/117	BIO (2007a)	66/29/110	Boutin, *et al.* (2005)
Pesticide use (kg/ha)	0.0216	2.09 (incl. 1.58 kg bentazone)	BIO (2007a)	9.5	Boutin, *et al.* (2005)

➢ **Results**

Figure 41 shows the results obtained in the life cycle assessment of the ‘alternative crop cultivation’ improvement option.

Midpoint indicators show similar environmental patterns for hemp and flax, whose cultivations could lead to significant environmental improvements with respect to ecotoxicity, eutrophication and agricultural land occupation. Pesticides such as aldicarb or cypermethrin, which are used for cotton cultivation, do not have to be applied in the case of hemp and flax. Flax and hemp also need less amounts per kg of nitrogen-based fertilisers (see table 45), which are the main contributors to eutrophication. However, environmental benefits are not registered in all the impact categories because fabric formation is more energy-demanding than for cotton.

Hemp has a slight advantage compared to flax in all the midpoint impact categories and it scores better than cotton in all the endpoint indicators while flax does worse. Nevertheless, it has to be noted that the improvement evaluation scenarios do not consider either the effects of a shift from cotton to flax or hemp on the distribution and use phases or technical aspects related to hemp production and processing (e.g. hemp yields short fibres and is much slower to grow).

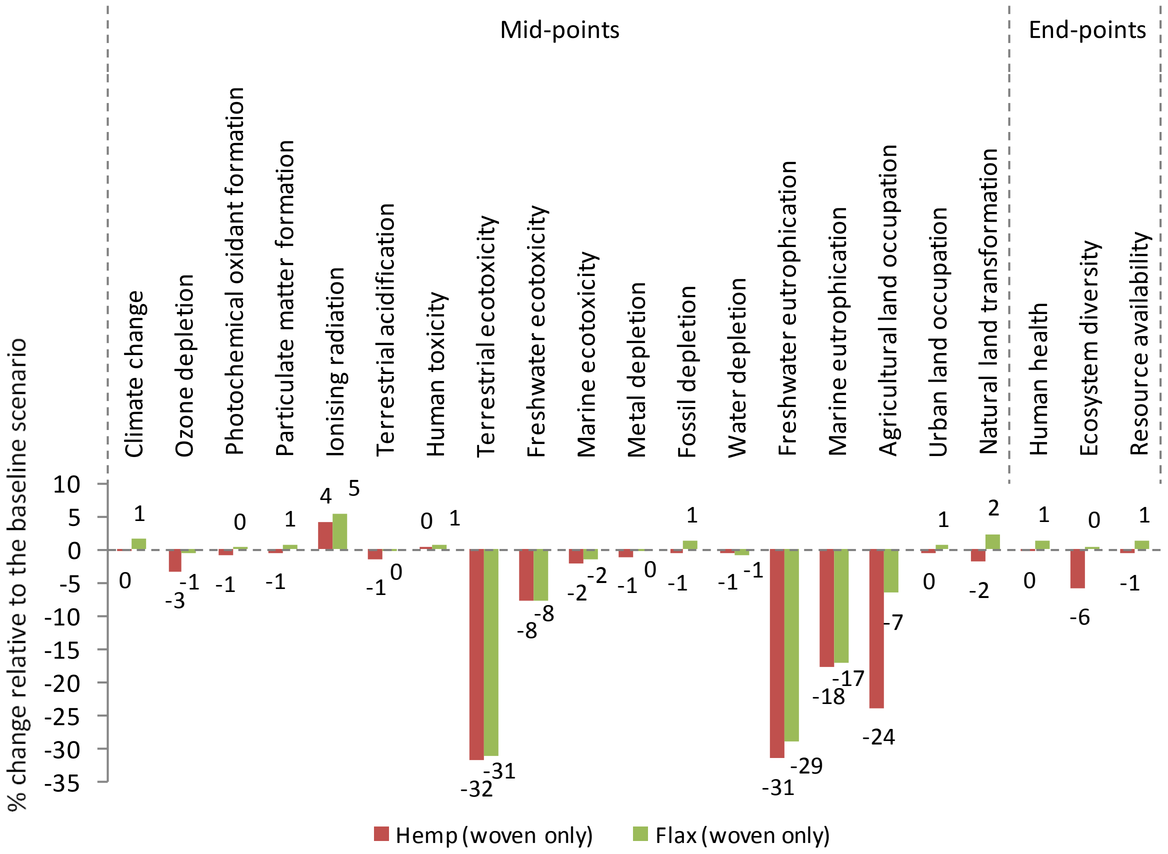


Figure 41: Changes in the life cycle impacts of textiles in the EU-27 resulting from cotton substitution

4.3.2.3 Barriers and opportunities

With increasing prices of cotton production (Huang *et al.*, 2003), and concerns for the environment, some manufacturers are beginning to consider alternative fibre sources for fabric production. This is especially true for cotton, which, despite its unique qualities, is one of the types of fibres with the highest potential of producing environmental impacts (see Section 3.2.3). Other natural fibre sources such as flax, hemp and bamboo are viable alternatives to cotton.

For many years, flax and hemp fibre production in the EU have benefited from agricultural support subsidies (ADAS, 2005). Recent changes have been introduced however, which have replaced direct crop-based support payments (Arable Area Payment Scheme or AAPS) with a single payment scheme (SPS) designed to aid farmers in environmental stewardship (ADAS, 2005). The reduction in crop-based subsidies could have a dramatic effect on flax and hemp production, depending on the level of crop yield, production costs and fibre extraction rates. In 2005 it was reported that through decoupling of support subsidies, flax production suffered a significant loss in gross margin, from approximately EUR 370 to -6 per hectare (ADAS, 2005). In addition to this, the decoupling of flax and hemp processing subsidies, as stipulated in EC Regulation 1673/2000, would further reduce the gross margin to approximately EUR -48 per hectare (ADAS, 2005). Decoupling of funding would provide a level playing field among global markets, although this could possibly lead to a reduction of flax and hemp cultivation in the EU. However, it was noted that through technological advances and adequate management, the gross margins of flax and hemp cultivation could be increased (ADAS, 2005).

There is another challenge in stimulating hemp markets: despite its heritage as one of the oldest fibres in the world (Liberalato, 2003), hemp remains one of the most controversial fibres for industrial production. Until recently, heavy restrictions were placed on the commercial production of this crop in some countries ([1]), due to its intrinsic psychoactive properties ([2])([3])([4]). Industrial grade hemp, however, can be produced without such properties, thus providing a legal alternative for other natural fibres. Despite some of its superior properties (such as high durability and strength) and its potentially lower environmental impact, hemp is an expensive fibre to produce in comparison with other alternatives. With the advent of cheap and fast fashion, the hemp market has suffered a significant decrease in production over the last few years (BioRegional, 2004; Vantreese, 2001). Inability to compete with low-cost producers could threaten the use of hemp in textiles production, although demand for hemp-based products gradually continues to rise, which should support the growth of this market in future.

Bamboo, soy or ramie are other fibres presumed to be environmentally friendly. Little information on the potential benefits of soy and ramie has been found and they represent a limited market share but bamboo has received some attention recently (Devi *et al*., 2007). Bamboo fabric is soft and smooth and the use of bamboo seems also to provide many environmental benefits (Uni-SunTextile, 2007). It is a fast growing crop which is not heavily reliant on pesticides (Ecotextiles, 2009). It also improves soil quality due to its extensive root system (Purdew, 2007). Unlike most other natural plant-based fibres, bamboo does not require replanting as its root system is able to produce new shoots continually. However, one of the biggest limitations of bamboo-based fibres is the method of converting crop to fibres. Although bamboo can be processed in the same manner as flax and hemp, the preferred process is similar to that of viscose fibre extraction, which can also have significant environmental impacts. The types of dyes and chemicals used in fibre processing can also offset the environmental benefits of using bamboo fibres. Newly introduced environmentally friendly processing measures might be an alternative (Ecotextiles, 2009).

4.3.3 Reducing consumption of sizing chemicals

4.3.3.1 Context

Sizing is a centuries old process which can have a considerable impact on the environment (European Commission, 2003). Sizing recipes contain molecules with high TOC (Total Organic Carbon) content, which can contribute to water eutrophication during the desizing process and can also be costly if applied incorrectly.

The sizing of fibres and yarns for weaving is especially important during natural fibre processing. Sizing chemicals are applied to bind fibres together and stiffen yarn for weaving (Celanese Acetate, 2001) and ultimately reduce breakage. Sizing chemicals can differ depending on which fibres they are applied to. Typical sizing chemicals include starch, gelatine, oil, wax and polymers. Conversely, desizing is the process of removing sizing compounds before finishing steps are carried out. The quality of yarn is greatly increased by the application of sizing chemicals. Yarn quality, however, also depends on properties of the yarn itself, independent of whether sizing is used or not. These qualities affect the tensile strength, abrasion resistance, and elongation of yarn during weaving. For example, abrasion resistance can be raised greatly where sizing is used. However, yarn property also suffers when the quantity of sizing is too high or too low. Choosing the correct amount of sizing for each fabric type is a difficult process as a thorough analysis of fibre type and quality is required.

To conclude, the need for sizing depends on the yarn quality, the nature of the fibre and the weaving loom used. For example, high performance polyester fibres often do not need sizing during the weaving process because the fibres are resistant enough and should not break during the weaving process (Sawhney *et al*., 2008). Decreasing size amount could be achieved by pre-wetting (Sejri *et al*., 2008) before sizing and using special sizing box (Asian Textile Journal, 2004). Pre-wetting not only improves the weaving efficiency, it also increases sizing performance. The use of sizes with less

([1]) Arizona Industrial Hemp Council, http://www.azhemp.org/Archive/Package/Countries/countries.html
([2]) Vantreese, V.L. *Industrial hemp: Global markets and prices*, June 1997, http://votehemp.com/PDF/hemp97.pdf
([3]) Hemp Industries Association, http://www.thehia.org/facts.html#Countries
([4]) The House of Hemp, *Agricultural hemp: A solution to creating a diverse rural economy?* http://www.thehouseofhemp.co.uk/hemp.html

environmental impact is another improvement option (Thomas, 1996; Sakharkhar *et al*., 2003). In recent years, new technology is being developed which will eliminate the need for sizing chemicals. Testing was recently carried out on a high speed weaving machine which demonstrated the mechanical feasibility of producing woven cotton fabric without the need for a sizing application. However, to achieve this, yarn of very high quality with the highest possible uniformity and consistency is needed (Sawhney *et al*., 2005; Sawhney *et al*., 2007; Sawhney *et al.*, 2006). The last improvement option consists of the recovery of sizing chemicals (Robinson, 1996).

4.3.3.2 Improvement potential

- **Baseline and improvement assumptions**

To demonstrate the potential improvements due to removing sizing from the production and processing phase, the use of sizing chemicals (starch and oil) was set to zero. The scenario thus shows the maximum potential that can be achieved by this option.

- **Results**

Figure 42 shows the potential environmental benefits which results from the new scenario, in which the use of sizing chemicals was completely avoided.

Apart from the impacts on marine eutrophication, which can be reduced by about 8 % if no sizing chemicals are used, slight environmental improvements seems to be associated with this option. The benefits mainly come from the avoided use of starch, which was requiring fertilizers in the LCA model for the potato production process.

4.3.3.3 Barriers and opportunities

The results have shown that a reduction of the amount of sizing used or the removal of the sizing process is environmentally friendly. With good quality yarn, sizing would be less important (Pahrik *et al*., 2006; Sawhney *et al*., 2006); however in today's market the tendency is to manufacture with poor quality yarns which makes sizing necessary (Pahrik *et al*., 2006). Size recovery is a cost effective procedure that reduces the environmental impact of sizing (MIGA, 2007) while improving slashing and weaving performance (ITJ, 2007).

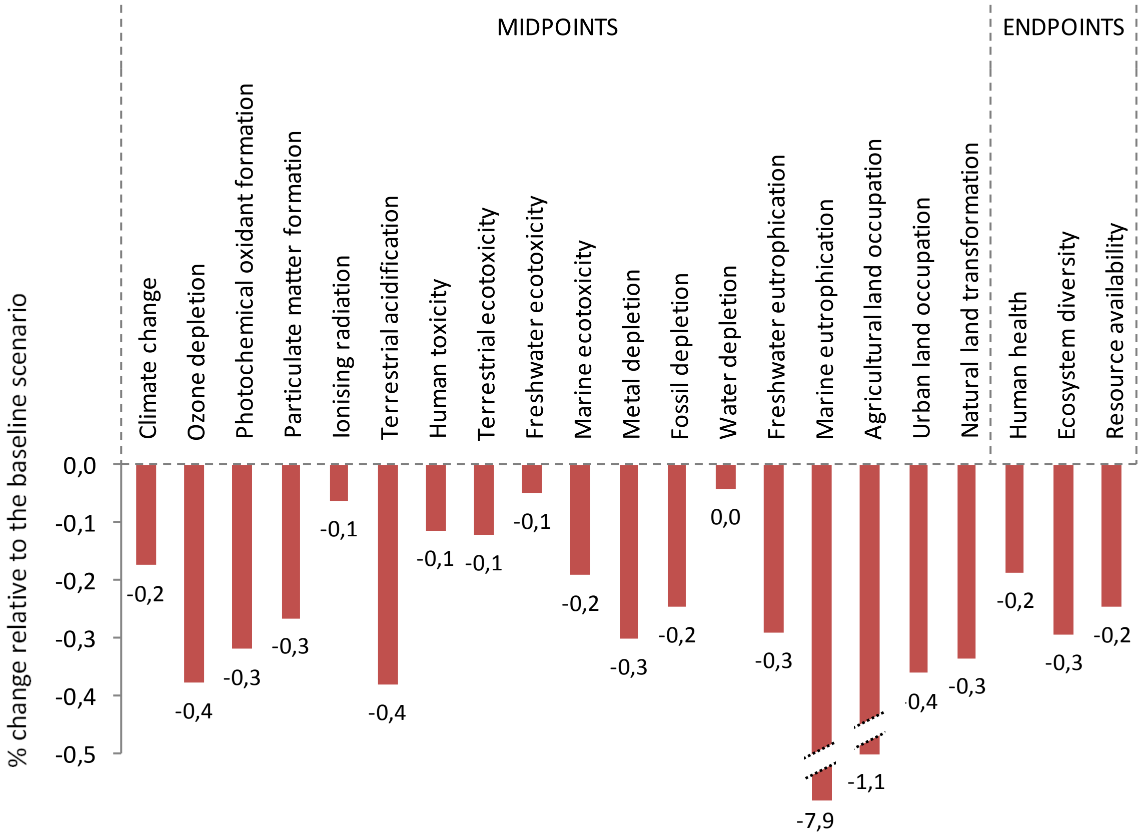


Figure 42: Changes in the life cycle impacts of textiles in the EU27 resulting from sizing chemical use reduction

4.3.4 Replacing chemicals with enzymes

4.3.4.1 Context

Enzymes have a long history of use in the textiles industry, the first enzyme desizing practices being applied as early as 1912 (Aehle, 2004). Enzymes are proteins and are used to catalyse chemical reactions. In the textile industry context, they can be used in several processes and replace regular chemicals. Since the early use of amylases, also for desizing, many other enzymes have been developed for different processes. Some of the most important enzymes, along with their respective applications, are listed in table 46.

Table 46: Important enzymes for textile application

Process	Type of enzyme
Desizing	Amylase
Scouring	Pectinase
Bleaching H_2O_2 preparation Bleach cleaner	Glucose oxide Catalase
Reactive dyeing wash off	Laccase
Bio wash	Laccase and cellulose
Bio polish	Catalase
Flax retting	Flaxzym and ultrazym
Wool and silk Shrink-resistant wool Antifelting of wool Degumming of silk	Protease
Wrinkle recover of linen	Polygalactoranase
Absorbency and surface modification of polyester	Lipase
Waste cotton treatment	Cellulase

Source: TheSmartTime, 2008

4.3.4.2 Improvement potential

➢ **Baseline and improvement assumptions**

Some of the advantages attributed to enzyme use in textiles processing include reduced process time, improved quality, as well as energy and water savings. A scenario has been included in the model in order to quantify the improvement potential of enzyme use in two process steps: the desizing and scouring of cotton by enzymes instead of regular chemicals, as shown in table 47. Consequently, this option only concerns cotton. The other fibres were excluded because of a lack of data on the enzyme use associated with them.

The impacts related to the enzyme production have not been included in the model due to lack of data. Enzymes can theoretically be reused as many times as needed, hence suggesting that the impacts of enzyme production are low when scaled to their lifetime.

The parameters that are used for the baseline and the enzyme replacement scenarios are shown in table 47, from which it can be observed that also other chemicals are to be used with enzymes. This is of importance because the initial savings obtained through the enzyme use might be offset by the use of new chemicals which have been included in the life cycle model. Data have been gathered from ENSAIT (2009).

Table 47: Input parameters of the 'baseline' and 'enzyme' scenarios

Substance ('kg' is 'kg yarn')	Scouring		Desizing	
	Baseline	*Enzyme*	*Baseline*	*Enzyme*
Water (l/kg)	80	60	7	6
Caustic soda (g/kg)	26	-	40	-
Enzymes (g/kg)	-	20	-	9
Soda ash (g/kg)	-	10	-	-
Acetic acid (g/kg)	-	6	-	1
Sodium carbonate (g/kg)	32	-	0.1	-
Surfactant (g/kg)	-	20	0.7	15
Detergent with wetting agent (g/kg)	40	-	-	-
HCl (g/kg)	2	-	0.1	-
Hydrogen peroxide (g/kg)	-	-	-	3.4
Oxalic acid (g/kg)	-	-	0.5	-

Source: ENSAIT, 2009

➢ **Results**

Figure 43 compares the environmental impacts of the textile life cycle in the EU-27 for the enzyme scenarios and the baseline scenario.
The use of enzymes could reduce the environmental impacts in almost all the categories, nevertheless impact variations associated with this option are almost negligible (below 1 %, in absolute value for all the indicators).

The limit of this improvement option is that cotton was the only fibre included in the analysis because it was not possible to gather information on the other fibres. Moreover, the improvement potential does not look very significant also because enzymes inevitably involves the use of compounds which are not originally included in the scouring and desizing processes, such as surfactant and acetic acid. As a consequence, the potential benefits of this option are reduced, even worsening some indicators.

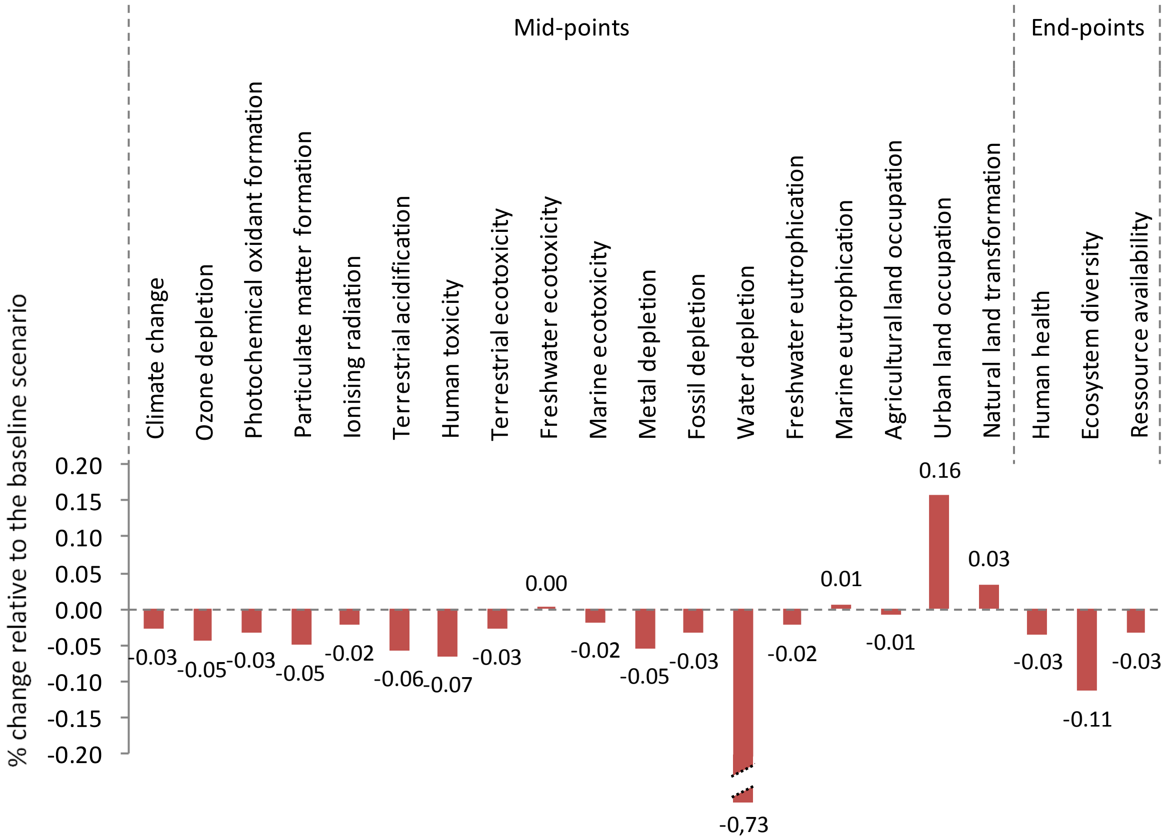


Figure 43: Changes in life cycle impacts of textiles in the EU-27 resulting from the enzyme use scenario

4.3.4.3 Barriers and opportunities

As an alternative to conventional processes which create a high level of impact, technical enzymes may be a viable possibility. However, this technique faced some challenges within the last decade. Although major enzyme manufacturers predicted a growth in enzyme sales for the textile market, growth has been modest, and in some cases, decreasing (Novozymes, 2008). For example, sales of textile enzymes for abrasion of denim fell in 2008 as the result of a fashion trend in favour of darker denims and a slowing US denim demand. This resulted in a falling demand for enzymes that carry out these processes. Enzyme manufacturers are however continuing to work on penetrating the textiles market and some are confident that this is an area for significant growth (Novozymes, 2008).

4.3.5 Alternative knitting techniques

4.3.5.1 Context

Knitting is a subprocess of the process called ‘fabric formation’. Fabric can be either woven or knitted. The process of knitting fabrics has experienced a series of technological improvements. Knitted items can now be made quickly and efficiently, and the process has also allowed for innovations such as three-dimensional and seamless whole garment knitting. Data have been gathered based on a previous study which considered the impacts of different knitting techniques (BIO, 2006). The three main knitting techniques are:

- straight knitting (flat or circular, flat panel knitting is used in the baseline scenario)
- fully-fashioned knitting
- integral knitting.

- **Straight (flat or circular) knitting**

Knitting, whether by hand or on a machine, is usually done by using warp and weft knitting techniques. Straight knitting most commonly relies on the weft technique which consists of using one continuous yarn which is fed to and looped in rows by one or more needles at a time. Two common forms of straight weft knitting machines exist:

- *Flat knitting machine* – also known as the cut and sew technique, flat knitting creates rectangular panels of fabric. Once made, these panels are cut into the desired size, and subsequently sewn to create the garment. These machines are quite versatile as they can create fabrics with different colours, patterns and knitting textures. The size of the fabric panel is dependent on the size of the frame, which can be as wide as 2.5 metres. Taking this consideration into account, two flat knitting methods have been considered in the model – large and measured panel knitting.
- *Circular knitting machine* – as the name suggests, circular knitting can be used to create cylindrical panels of knitted fabric. This method is often used for the creation of socks and sweaters. As with flat knitting, circular knitting machines are also able to create different textures and patterns, such as ribbing.

- **Fully fashioned knitting**

The fully fashioned knitting technique is a relatively recent knitting technique, which is essentially an advancement of the straight knitting technique. The distinguishing characteristic of the technique is that instead of knitting large rectangular panels, the machine can knit a custom-shaped two dimensional sheet of fabric. One of the advantages of this machine is that there is little or no need for cutting panels, and therefore little or no fabric is discarded in the process. Although it can reduce material and labour costs significantly, this type of technique requires significant investment (The Textile Institute, 2002).

- **Integral knitting**

Integral knitting is a further advancement of the fully fashioned knitting technique. An integral knitting machine is able to add additional trimmings as an integrated part of the fabric panel (e.g. pockets, collars, V-necks). Along with the advantage of reducing fabric loss from cutting, this technique then also reduces sewing requirements (Peterson, 2007).

State-of-the-art integral knitting machines are now available which are able to knit complete garments, and therefore eliminate cutting and sewing steps altogether. This type of technology is becoming increasingly attractive as it eliminates the costs of expensive post-knitting steps, decreases raw materials consumption, and also produces higher-quality garments (Mowbray, 2002).

4.3.5.2 Improvement potential

- **Baseline and improvement assumptions**

In the baseline of the model, flat, large panel knitting has been assumed. The two other techniques considered as alternatives are: fully fashioned and integral knitting. These techniques avoid cutting losses, but the flip side is the fact that they need much higher energy inputs. The energy inputs and fabric losses considered in the model have been based on the parameters presented in table 48. In the improvement scenario, the alternative knitting options have been applied to all knitted clothes for the following fibres: cotton, viscose, wool, silk, polyester, and acrylic which are the only knitted fibres.

Table 48: Energy inputs and fabric losses for different knitting techniques

Energy use and fabric losses (per 400 g pullover)		Type of knitting technique		
		Flat (large panel), baseline scenario	Fully fashioned	Integral
Knitting	Energy (Wh)	120	1200	3250
	Losses (%)	6	6	6
Cutting	Energy (Wh)	112	-	-
	Losses (%)	21	-	-
Confection and finishing	Energy (Wh)	176	176	0
	Losses (%)	5	3-5	3

➢ Results

Figure 44 present the results of the comparison between the baseline scenario and the two knitting alternatives.

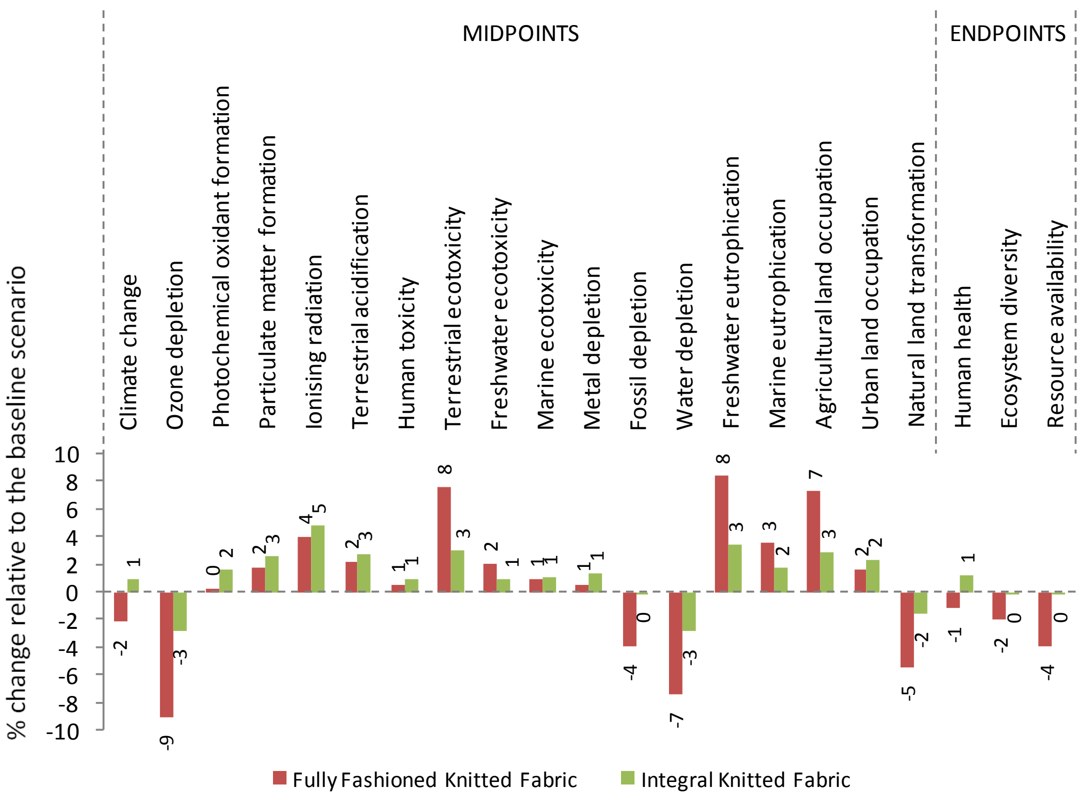


Figure 44: Changes in the life cycle impacts of textiles in the EU-27 resulting from alternative knitting techniques

The influence of different knitting techniques shows significant changes in the environmental impacts of the total textile chain in the EU. For some impact categories the change in technology leads to improvements, while in other categories the environmental burdens increase. The trade-off is due to the increased energy use and to the reduced material losses associated with the alternative knitting technologies. Loss rates have a strong influence and their reduction results in significant environmental improvements, while energy input could be considered as a secondary parameter, with lower effects on the environmental profiles of knitting techniques.

Impact categories as ionising radiation and particulate matter formation are particularly sensitive to energy demand variations (i.e. electricity and natural gas). Nevertheless, even if the energy consumption increases considerably with the alternative knitting techniques, the effects due to this variation seems to be much more limited. For example, in the case of integral knitting, an increase of the energy consumption by 2600 % is associated with an increase of the ionising radiation indicator by 5 %.

Other impact categories are instead so much influenced by the reduced loss of fabric pieces that a negative indicator results. Credits due to avoided material losses are in particular related to natural fibres, which dominate the EU-27 market. The highest net benefit (9 %) is registered for the ozone depletion impact category in case of fully fashioned knitted fabric. Significant improvements could be also achieved for water depletion, natural land transformation and fossil depletion.

With respect to the endpoints indicators, results show an overall improvement for all the categories of the ReCiPe method, except for the impact on human health in case of integral knitted fabric, for which energy inputs slightly outweigh the potential improvement due to the reduction of material losses. In comparison with the baseline scenario, from the point of view of the endpoint indicators, the fully fashioned knitting technique appears to be the best available option.

4.3.5.3 Barriers and opportunities

With the introduction of fully fashioned machines in the late 19th century, many producers favoured innovative fully fashioned technologies over conventional knitting machines (such as circular machines). Fully fashioned machines cut down labour and resource costs, and also produced a higher quality knit. However, towards the turn of the 19th century, competition among knit producers grew and manufacturers preferred working with circular knit machines, as they were much less expensive than fully fashioned machines (The Textile Institute, 2002). Also in the future, companies could, as they have in the past, opt to invest in cheaper but less efficient techniques. As mentioned earlier, fully fashioned, integral or full garment knitting machines require a significant amount of initial capital investment. However, these costs can be offset by long term savings in labour and resource costs. Replacing older inefficient machines is more a question of time and not a decision that is made rashly.

In the period between 2003 and 2007, the knitting industry experienced a high number of investments in new circular and flat knitting machines causing an increase in the number of machines as well as technological improvements (Knitting Industry, 2008) However, in 2008, the shipment of these machines fell by 21 % and 7 % respectively in comparison with 2007 (Knitting Industry, 2008). Falling sales of knitting machines could, however, motivate manufacturers to invest in new technologies to remain competitive. Continuing developments in this area are likely to lead to reduced costs and savings in resources. This could have a positive knock-on effect on the environmental performance of these industries. However, in countries where manual labour is still inexpensive, manufacturers may have less incentive to invest in expensive but efficient technology. However, there is a growing interest in computerised machines which not only produce at higher efficiencies, but also at much higher outputs and greater speeds, and allow for greater flexibility in design.

4.3.6 Dye controller and low liquor ratio dyeing machines

With legislative pressures mounting on businesses to adopt methods which produce a lower environmental impact, it is in the interest of most to adopt cleaner technologies. Concerning the textiles sector, an important Directive is the EU Water Framework Directive (WFD), which will govern the quality of effluent discharged from industry. Passed in December 2000, the WFD aims to achieve its goals of restoring river basins to a 'good chemical and ecological status' according to standards set in River Basin Management Plans (European Commission, 2007b). A key principle of the WFD is the use of the 'polluter pays' principle (Chave, 2001). This means that those companies with discharge permits will have to bear the costs of waste water treatment, in order to reach the desired water quality. The collection and treatment of water may be charged to the producer in accordance with the amount of waste water produced. It is expected that this will make most waste water-producing industries recycle or reuse water before discharging. Tax incentives and credits could also potentially be used to reward those who employ clean technologies (Van Berkel, 1999).

The introduction of the Water Framework Directive has been called revolutionary in terms of environmental protection. It is likely to affect the textiles production industry which is one of the greatest waste water generators. The requirements set under the WFD are likely to provide a strong incentive for change. However, it should be taken into account that the terms of the WFD extend only to waterways in the EU. A significant amount of textiles consumed in the EU are not produced within its boundaries. Furthermore, with greater concern for the environment and human rights, water quality will continue to be an area of development over years to come.

4.3.6.1 Context

Dyeing textiles can greatly affect the environment, as the process often generates various pollutants. The concentration of waste chemicals in discharge can be dependent on the dye liquor ratio. The liquor ratio is defined as the mass of dye-bath used per mass of material being dyed. Another important factor is exhaustion, which is defined as the degree to which dye is transferred to the textile during the dyeing process. The higher the degree of exhaustion, the more dye has been taken up by the fabric. One of the main contributors to effluent chemicals from dyeing is the low degree of exhaustion. The latest jet machines, which are able to dye textiles at low liquor ratios, are able to overcome this problem (Lidyard *et al*., 2008). The textile is fed through a closed tube and a jet of dye solution is applied to the textile. Turbulence created by the jet also aids in penetration of the dye. Due to the higher efficiency of this method compared to conventional ratios, its use results in reduced consumption of water and chemicals.

Dye machine controllers can successfully regulate various aspects of the dyeing process. The controllers work via a feedback system, rapidly analysing process conditions and altering parameters to reach optimum conditions for dyeing. They are able to control parameters such as pH, salt, colour, chemical levels based on liquor ratio and temperature. One particular advantage of dye machine controllers is that they are capable of controlling the amount of water utilised in the dyeing process, and therefore also control the amount of effluent produced.

Both the implementation of controllers and the use of low liquor dyeing machines have been considered simultaneously as they address the same issue. Additionally, individual assessment revealed that few benefits can be observed if those options are assessed separately.

4.3.6.2 Improvement potential

- **Baseline and improvement assumptions**

The improvement potential of dye machine controllers and low liquor ratio dyeing machines has been based on the reduction of water and chemicals use for all dyeing stages. Results of the literature review have shown that the installation of this type of technologies results in an average water consumption reduction of approximately 69.6 % and 28 % for the dyeing process (DANCED, undated). The estimated values are shown in Table 49. It is apparent that both options make substantial savings possible for this dyeing phase.

Table 49: Parameters for water and chemical inputs in the dyeing phase

Process change	Reduction due to controllers implementation	Reduction due to the use of low liquor dyeing machines
Water use	69.6 %	28 %
Chemical use	59.4 %	-

Source: DANCED, undated

➢ Results

The environmental improvement potential due to installing dye machine controllers was assessed against the baseline scenario (see Figure 45).

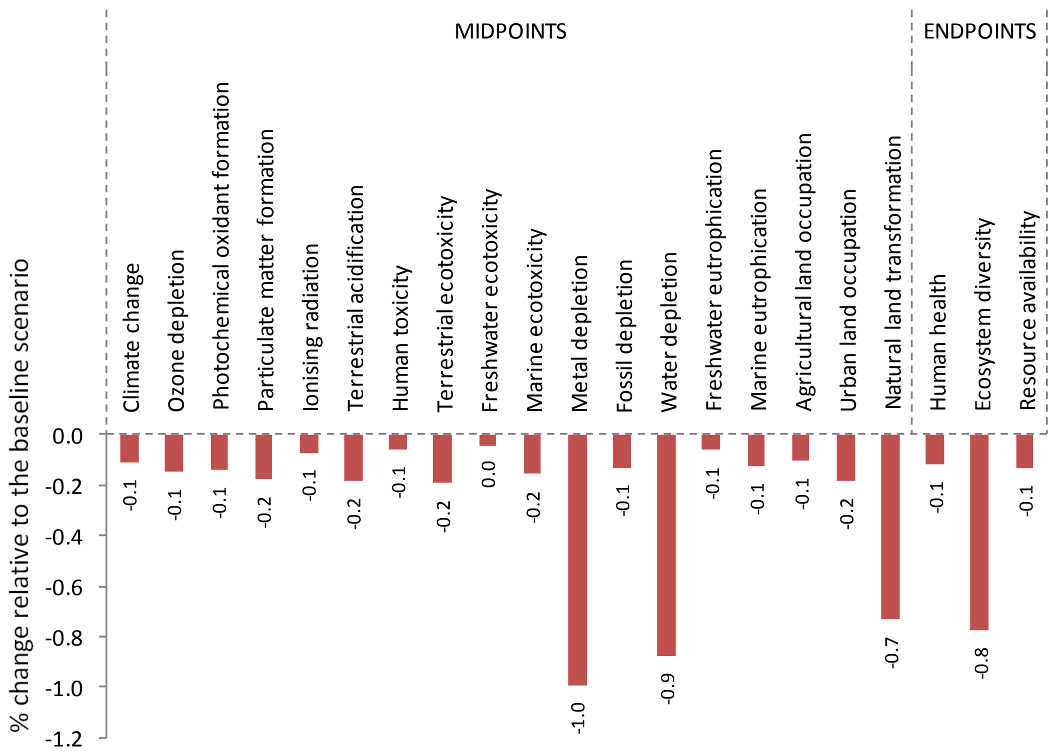


Figure 45: Changes in life cycle impacts of textiles in the EU-27 resulting from water consumption reduction scenario in the dyeing process

Limited environmental benefits (lower than 1 %) seem possible for all the indicators. This is due to the fact that the improvement options addressed here are only related to a small share of total water consumption of the whole fabric production chain. Raw material production is, in comparison, much more water consuming, in general. For example, one kilogram of cotton fabric requires 120 litres of water, while dyeing 1 kg of cotton fabric only requires 2 litres of water.

The highest reduction of the impacts can be observed for metal and water depletion, as well as for natural land transformation. From the point of view of the endpoint indicators, ecosystem diversity is the one showing the highest potential of improvement (0.8 %). Avoiding the use of dye has beneficial effects on natural land transformation because dye production requires raw materials which are extracted in mines.

4.3.6.3 Barriers and opportunities

As low liquor ratio techniques contribute to reducing water consumption and effluent production, it may be of interest to companies who will be affected by the WFD. However, the consumption of water will ultimately also be dependent on the amount of water used in subsequent washing stages. If more water has to be used at these points, it could offset the reduction provided by low-liquor ratio dyeing machines. Low-liquor ratio dyeing machines can not only improve the environmental performance of the dyeing stage, but provide also high economic benefits, despite the need for a significant initial investment (see Table 50). If operated efficiently, low liquor ratio dyeing machines have an average payback period of approximately 1.9 years for a medium-sized dyeing plant (Marbek Resource Consultants, 2001).

Concerning dye machine controller, initial capital investment is lower than for low-liquor ratio dyeing machines (see Table 50). Also, water savings are smaller (about half). Based on a recent study carried out in the US, operating cost savings are much lower, and the payback period for these machines is estimated to be 3.5 years (Marbek Resource Consultants, 2001). However, these devices have a significant advantage over installing low-liquor ratio dyeing machines: they can be retrofitted to most types of dye machines.

With the increasing costs of operation across all industries, dye machine controllers are a lower cost option which may be advantageous for many textile mills.

Table 50: Costs related to installing the low liquor ratio dyeing technique or a dye machine controller in a medium sized plant

Cost item (average per plant)	Low liquor ratio dyeing technique	Dye machine controller
Capital cost in USD	3 370 000	450 000
Net annual operating savings in USD	1 790 000	128 000
Simple payback period in years	1.9	3.5

Source: Marbek Resource Consultants, 2001

4.3.7 Water recycling

4.3.7.1 Context

The finishing and wet processing steps of textiles production often produce a large amount of effluent, which contains a number of environmental pollutants. A direct reuse of the water-based effluent is not possible for most steps during textiles production due to technical limitations. However, a significant volume of water can be recovered by the use of in-house effluent treatment systems. With the advent of stricter effluent discharge legislation, there is some incentive for industries to recycle water and reduce the toxicity of the effluent they produce. Many novel technologies are now available to treat industrial effluent (Entec, undated). We will assess the improvement potential of two techniques (described below in greater detail) that can lead to higher reuse of water.

4.3.7.2 Improvement potential

➢ **Baseline and improvement assumptions**

Non-biodegradable chemical polymers are often present in significant quantities in effluents due to the use of surfactants, dyeing chemicals, etc. (Das, undated). Preliminary, primary and secondary water treatment systems are often unable to treat them. Thus, tertiary treatments are necessary. The two types of tertiary systems investigated here are reverse osmosis and ion exchange. Note that these techniques are quite recent and are energy-consuming. Today, they are still very expensive to implement at a commercial scale.

In the comparison, energy inputs were not included, due to the lack of data available on these high-technology processes. Only improvements from water reduction will thus be assessed via the two scenarios.

- **Reverse osmosis**. Reverse osmosis is an example of a membrane filtration process used to remove total dissolved solids from effluent water (Remco, 2008). During this process, water is demineralised using a semi-permeable membrane. The two main compartments on either side hold different concentrations of water and electrolytes. The side containing a high electrolyte concentration is subjected to high pressure, which forces water across to the opposite chamber. As more water is displaced, the pressure must be increased to remove the remaining water. Applying reverse osmosis in a textile mill can result in the recovery of approximately 81 % of waste water for reuse.
- **Ion exchange**. As with reverse osmosis, this technique is used to remove undesirable electrolytes from waste water (APEC, 2008). Water is fed through a matrix of ion exchange resins, where undesirable electrolytes are exchanged for sodium and hydrogen ions contained in the resin. As the ions in the resin are increasingly exchanged with ions from waste water, the matrix must be regenerated in order to work effectively. The matrix must be washed through with a highly concentrated solution containing sodium and hydrogen ions. With the ion exchange technology, approximately 95 % of waste water can be recovered for reuse.

➢ **Results**

Figure 46 presents the overall improvements reached with either reversed osmosis or ion exchange technologies.

A reduction of the impacts is registered in all the midpoint and, consequently, in all the endpoint indicators. The water depletion indicator is significantly diminished, by about 22% and 25% for reversed osmosis and ion exchange, respectively. This impact is dependent on water consumption, and is related to the amount of water that is recycled.

The impact on natural land transformation is also noticeably reduced (by about 10 % to 12 %) while the rest of the indicators show improvements to a lesser extent (up to 3 %). The only substantial benefits in terms of endpoint indicators are registered for the ecosystem diversity indicator.

This improvement options could thus be of particular interest in geographical areas where water is not an easily available resource. Nevertheless, it should be remarked that it was not possible to assess the impacts due to the different amount of energy required in reverse osmosis and in ion exchange

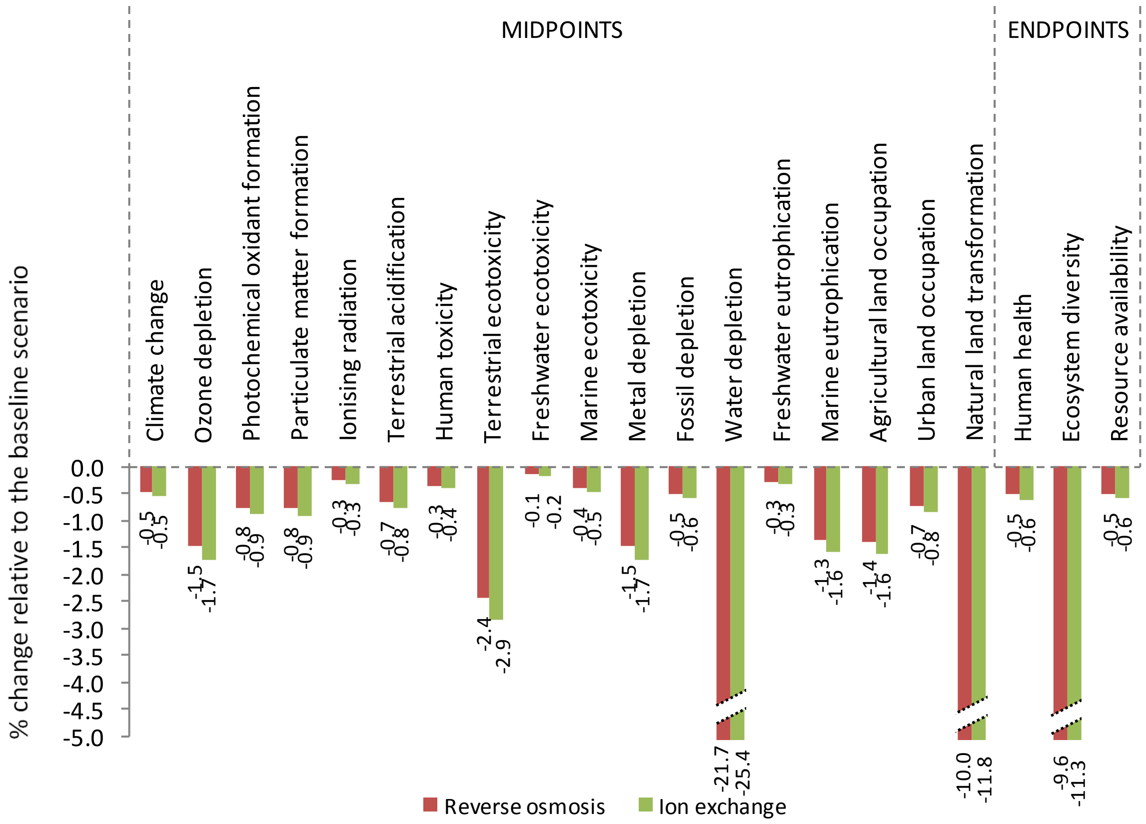


Figure 46: Changes in life cycle impacts of textiles in the EU-27 resulting from the water recycling scenario

4.3.7.3 Barriers and opportunities

There are some advantages and disadvantages when reverse osmosis or ion exchange technologies are used for waste water treatment. Because of its membrane system, the reverse osmosis membrane can remove larger particles instead of exclusively removing non-biodegradable chemicals. It also requires minimal maintenance over a short period of time. However, in the textiles industry, the membrane can become clogged with dyes over time. Other disadvantages include the high initial capital investment (Subrata, 2000) and a slow rate of filtration, when compared to other types of techniques. Ion exchange systems are able to remove dissolved substances efficiently from effluent, require a relatively low initial capital investment, and the resin can be reused again after regeneration ([1]). However, the running costs for this type of equipment can be high as it requires the addition of chemicals for regeneration. Unlike reverse osmosis, it is also unable to remove larger particles which could interfere with equipment and processes in the textiles mill. Despite the drawbacks, it could be of interest for textile mills to include the two technologies assessed due to the significant water savings that can be achieved.

([1]) Free drinking water, *Different filtration methods explained*, http://www.freedrinkingwater.com/water-education/quality-water-filtration-method.htm#Anchor-Reverse-23240

4.4 Improvement options for the distribution phase

Only one option was analysed for the distribution phase: 'less air freight'.

4.4.1 Reducing air freight

4.4.1.1 Context

In recent years, due to the lower cost of production outside the EU, offshore sources of textile products have an increasing appeal for EU retailers. Thus, long distance transportation has become an important and necessary part of the textiles market. The transportation of goods can be carried out by four major means – air, water, rail and road. The baseline model has considered air and sea freight to be the most significant methods of long distance shipment of textiles. In the baseline scenario, the shipping is broken down as follows: 92 % by sea freight and 8 % by air freight. In the improvement scenario, the share of sea freight is increased up to 100 %.

4.4.1.2 Improvement potential

In the baseline scenario, the distribution phase is responsible for about 10 % of the overall impacts (see Section 3.1). In the same scenario, it was assumed that long distance shipment is dominated by shipping (92 %). Air transportation was assumed to be 8 %. According to the Ecoinvent 2.0 inventories, impact on climate change is 100 times greater for air transportation than for ship transportation, approximately. Two scenarios have been modelled: the first one takes into account a 4 % share of air transportation, which corresponds to 50 % of the baseline scenario. Alternatively, the second scenario considers 100 % shipping. Figure 47 presents the changes in overall impacts for the different transportation scenarios.

Air freight is a significant source of environmental burdens. It is by far the most polluting means of transportation, releasing much more greenhouse gases and air pollutants than trucks and ships, according to the inventories gathered from the Ecoinvent 2.0 database. Consequently, substantial improvements can be reached if air transportation is reduced.

By reducing or avoiding air transportation, the environmental impacts of the textile chain of the EU can be reduced for all environmental categories. Significant reductions could be achieved for climate change, particulate matter formation, ozone depletion and photochemical oxidant formation (from about 2 % to 8 %, depending on the indicators and the ship/air freight ratio).

Land use impacts are mainly due to the transportation of oil in pipelines. Air freight uses more energy per km and tonne of transported goods. The impacts due to this transportation mode are then higher than the impacts resulting from trucks or ships.

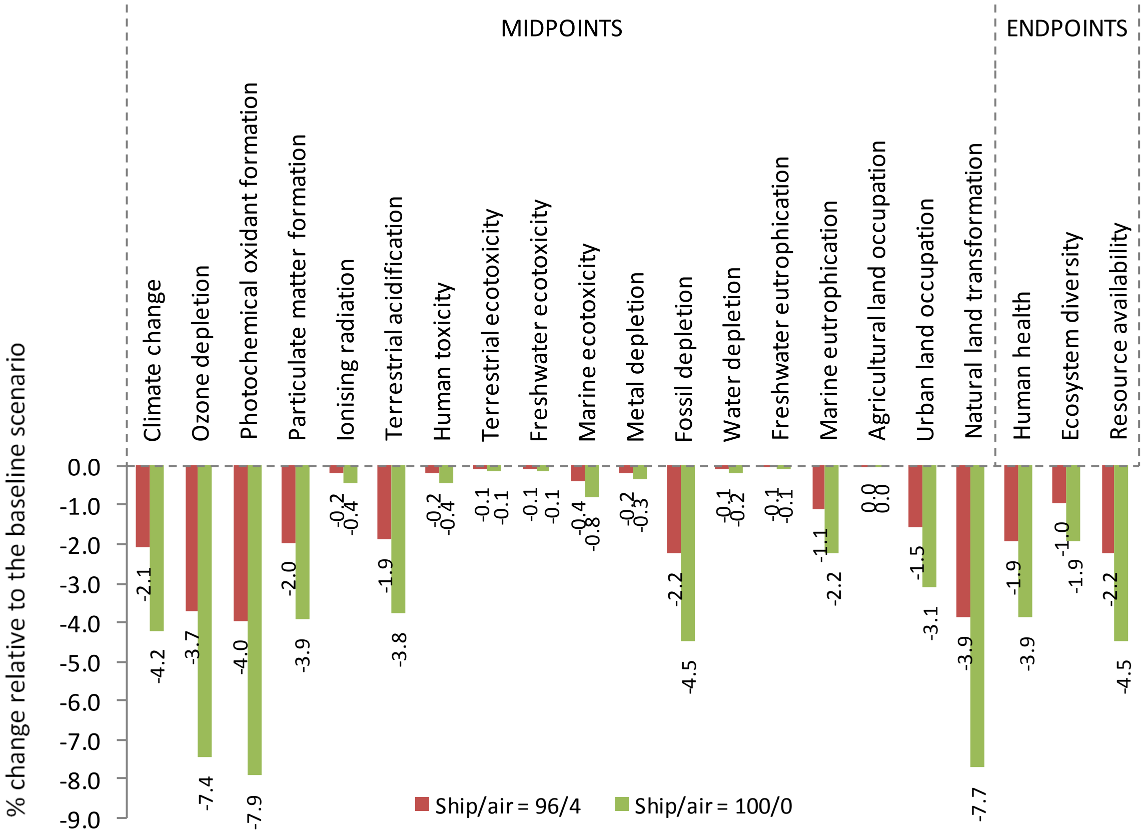


Figure 47: Changes in the life cycle impacts of textiles in the EU-27 resulting from the different transportation scenarios

4.4.1.3 Barriers and opportunities

Shifts between different freight modes occur naturally within the distribution sector. In relation to air shipments, they can be strongly influenced by market conditions and changing trade legislation (Seabury, 2009). Between the years 2002 and 2007, the majority of shipments to Europe experienced a positive mode shift towards air freight (Seabury, 2009). This is likely attributed to the decrease in unit prices and the increased deregulation of air cargo (Euro-CASE, 2000). There were however, some exceptions, most notably from China. Early in the decade, the global air freight sector was subject to rapid growth, stimulated by a fall in unit prices and air cargo deregulation (Euro-CASE, 2000).

Air freight is often seen as a less advantageous method of transport due to its inevitably high costs, which may ensure that sea freight remains competitive. Air transport is, however, vital for transporting goods which require fast shipment, and may in some cases be cost effective. In particular, air freight is not subject to high storage costs sometimes associated with sea freight. Once a ship has docked, products are often held in storage before redistribution on land. As airports may be closer to final destinations, storage is not as significant a necessity for air freight. As well as economic factors, changing environmental legislation, and concerns over resource depletion and resulting rises in costs are likely to affect the air freight industry in the future. In order to remain competitive, this sector may need to concentrate on reducing costs and reducing the environmental impacts related to air transport.

4.5 Improvement options for the use phase

With regard to data availability and in accordance to the scope of this project, two main areas of improvement are analysed in this section. In total, four improvement options were assessed:

- changing consumer behaviour:
    - reducing washing temperature
    - reducing tumble drying
    - better loading of washing machine
- changing appliance efficiency:
    - improvement of washing and drying appliances efficiency.

First, life cycle impact variations associated with each improvement option are shown. Then, the focus is shifted to the life cycle phase related to the improvement option and to a selection of indicators: climate change, the three endpoint indicators of ReCiPe and a set of other four sensitive indicators for the improvement option.

4.5.1 Changing consumer behaviour

4.5.1.1 Context

There are many parameters associated with clothes cleaning that influence their environmental impacts. These factors can be significantly determined by consumer choices; among which one can consider:

- **washing**: washing frequency, selected programme/options, programme temperature and load size
- **drying**: drying frequency, selected programme/options, programme temperature and load size
- **ironing**: ironing frequency, ironing time and ironing temperature.

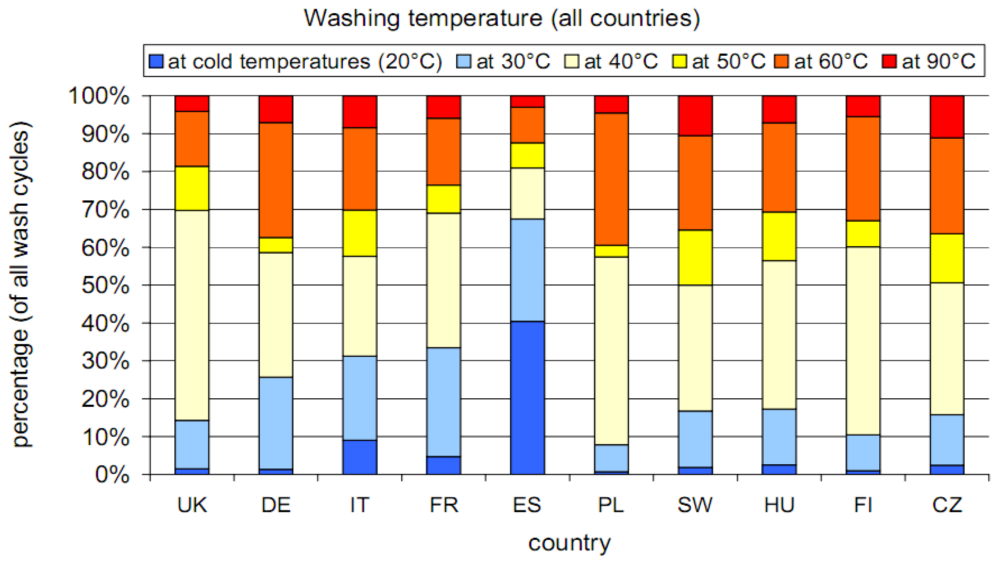
Each of these parameters can differ for each product depending on its fibre nature, as well as its practical functions. Household textiles, for example, are often washed less frequently than apparel. Similarly, garments made of synthetic fibres are likely to be washed at lower temperatures in order to avoid dimensional changes. Most of the use phase parameters can be adjusted to adopt more environmentally friendly practices, without compromising cleaning and drying quality. In this section, the analysis focuses on three measures for improving environmental performance:

- reducing washing temperature
- reducing tumble drying frequency
- optimising load capacity of washing and drying machines.

4.5.1.2 Improvement potential for reducing washing temperature

➢ **Baseline and improvement assumptions**

The selected program temperature has a high influence on the energy consumption of a washing machine (Presutto *et al*., 2007). The average washing temperature was 45.8 °C in the EU in 2005. However, average washing temperatures vary between countries (see Figure 51).



Source: Presutto et al., 2007

Figure 48: Temperature settings of washing machines in European countries

The above figure illustrates that there is a potential for reducing the average washing temperature in Europe. Therefore two improvement scenarios have been considered:

- A shift to washing at 30 °C rather than 40 °C and at 40 °C instead of 50 °C for routine cycles and at 60 °C instead of 90 °C for high temperature cycles. The resulting average washing temperature in this 'conservative scenario' of improvement would be 39.3 °C.
- an 'optimistic scenario' of improvement corresponding to the situation in Spain, where the average washing temperature is 32.9 °C

Table 51 presents the setting of washing temperatures in the various scenarios.

Electricity use has been calculated according to the methodology presented in Section 2.2.3.1: 0.21 kWh/kg in the baseline scenario, 0.17 kWh/kg in the 'conservative scenario' and 0.13 kWh/kg in the 'optimistic scenario'.

Table 51: Share of washing temperatures for the various scenarios considered in the analysis

Washing temperature (°C)	Baseline scenario (%)	Conservative scenario (%)	Optimistic scenario (%)
20	6	6	40
30	18	55	29
40	37	9	12
50	9	0	6
60	23	30	11
90	7	0	2
Average temperature	**45.8 °C**	**39.3 °C**	**32.9 °C**

➢ **Results**

The comparison between the improvement options and the baseline scenario is shown in Figure 49. Environmental benefits can be observed in all the indicators.

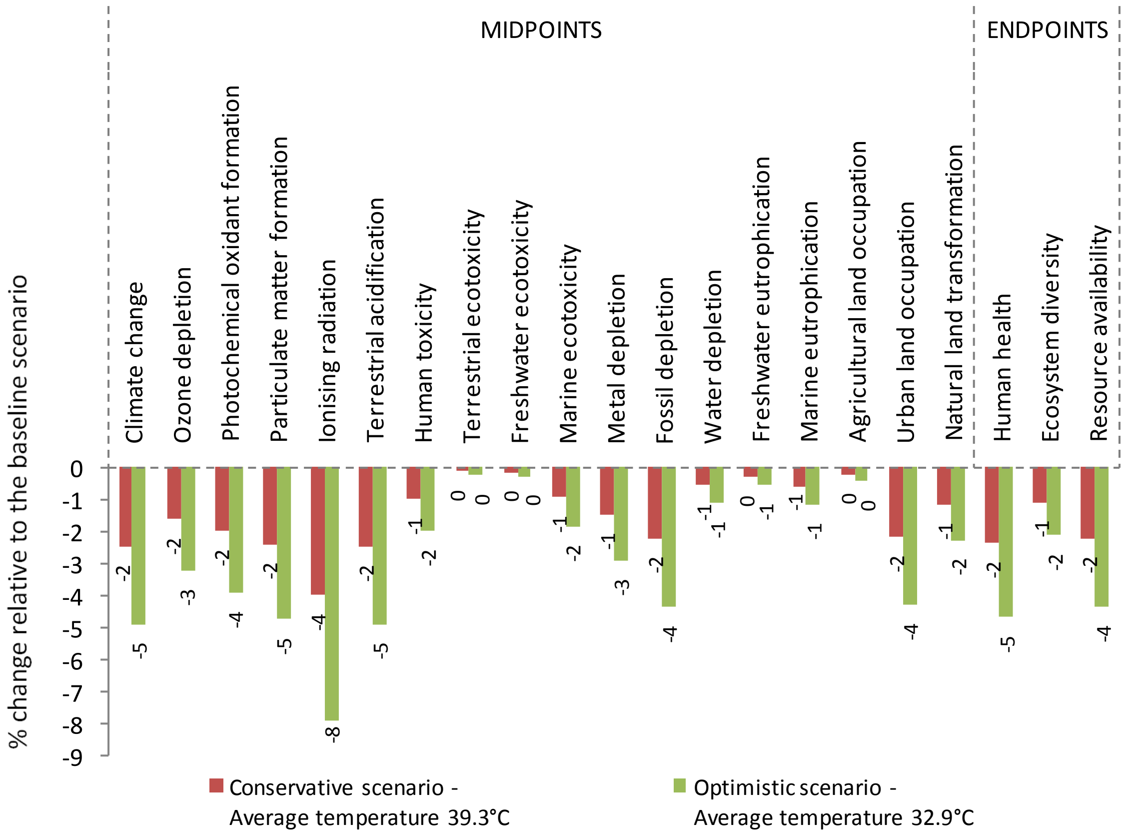


Figure 49: Changes in life cycle impacts of textiles in the EU-27 resulting from reduced washing temperatures

The highest reduction can be obtained for ionising radiation: 4 % in the conservative scenario and 8 % in the optimistic scenario. Other midpoint indicators that are affected significantly are: climate change, particulate matter formation, terrestrial acidification. For all of them, reductions of 2 % (conservative scenario) and 5 % (optimistic scenario) could be reached.

Regarding the endpoints, reducing the washing temperature is more beneficial for human health and resource availability, with a decrease by about 5 % in the optimistic scenario, while the decrease which can be reached for ecosystem diversity seems to be small (2 % in the optimistic scenario).

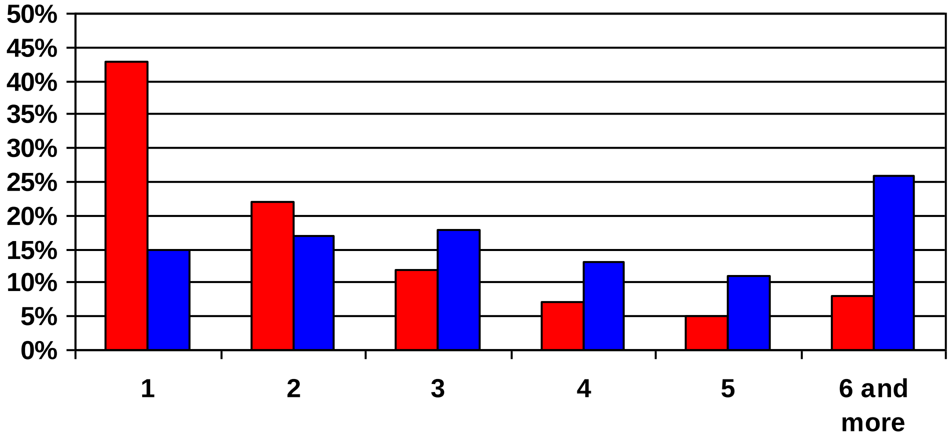
4.5.1.3 Improvement potential for reducing tumble drying

➢ **Baseline and improvement assumptions**

The tumble drying frequency is highly dependent on the season (see Figure 50). Indeed, during the summer period most users dry their laundry outside while in winter tumble drying is the most widespread way of drying (PriceWaterHouse Coopers, 2009). Other drying possibilities are indoor line drying in heated or unheated rooms. Based on the EuP study on tumble dryers (PriceWaterHouse Coopers, 2009), the baseline scenario considered that the average number of drying cycles per week and per household is 2.3 in summer and 3.6 in winter.

In the improvement options, it has been considered that it is during summer that the greatest possibilities for reducing tumble drying can be found since the laundry can be dried outside. Reducing tumble drying during winter time is more problematic. Therefore two scenarios for tumble drying reduction have been considered:

- A first scenario assuming a 30 % reduction of the use of tumble drying during summer.
- A second scenario assuming a 50 % reduction of the use of tumble drying during summer and a 15 % reduction during winter. It should be noted that, if the laundry is dried in rooms during the winter season, additional energy would be required for this purpose. However, this contribution has not been considered in the model because of difficult evaluation and reasonably limited impact.



Source: PriceWaterHouse Coopers, 2009
NB: summer in red and winter in blue

Figure 50: Number of drying cycles per week in summer and winter in the EU-27

The assumptions chosen for the different scenarios are summarised in Table 52. It is assumed in all scenarios that 35 % of consumers in the EU are equipped with tumble dryers (see Section 2.2.3.2).

➢ **Results**

The comparison between the results of improvement and baseline scenarios are shown in Figure 23.

A decrease of all the indicators can be observed as a consequence of the electrical energy saved in the improvement scenarios. The highest impact reduction is obtained for ionising radiation, with a reduction of 2.7 % in the case of 50 % reduction of tumble drying in summer and 15 % reduction in winter. The contribution to ionising radiation is due to the electricity production mix, which partly relies on nuclear power. The reduction does not exceed 1.7 % for the other indicators, including the endpoint indicators. The reductions remain limited due to the small share of tumble drying on the total impacts of the use phase (see Section 2.2.3).

Table 52: Parameters affected by the reduction of the use of tumble drying

Parameter	Scenario		
	Baseline scenario	Conservative scenario	Optimistic scenario
Number of cycles per week per household in summer	2.3	1.6	1.2
Number of cycles per week per household in winter	3.6	3.6	3.1
Frequency of tumble drying among dryer owners (in % of washes)	71	**63**	**50**
% penetration ratio of dryers	35	35	35
% of washes tumble dried	**25**	**22**	**18**

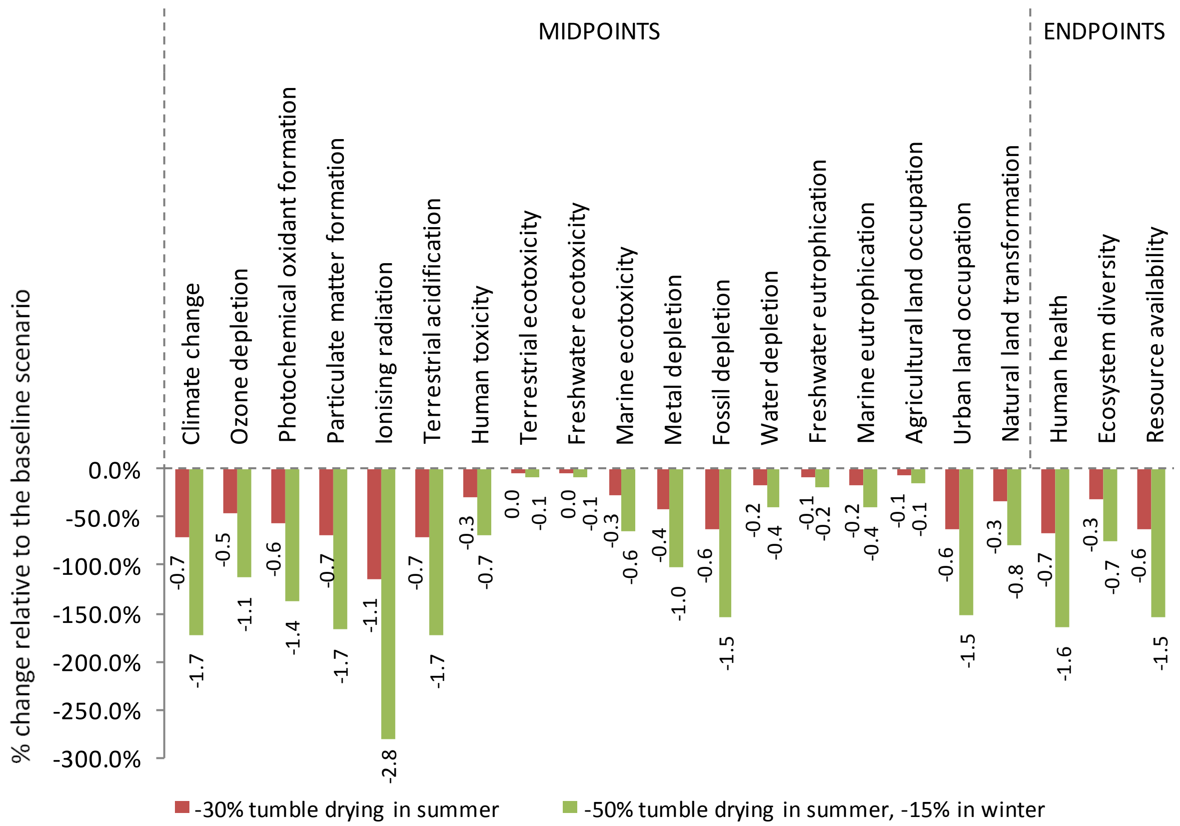


Figure 51: Changes in life cycle impacts of textiles in the EU-27 resulting from tumble drying reduction

4.5.1.4 Improvement potential for optimising the load of appliances

➢ **Baseline and improvement assumptions**

In the baseline scenario, a standard load capacity of 5.36 kg for washing machines was assumed (see Section 2.2.3.1) which corresponds to the most frequent sold washing capacity. However, in reality loads are often smaller. On average, 64 % of the standard capacity (3.4 kg) is usually loaded. This was used for the baseline (see Section 2.2.3.1). In all scenarios, the load for tumble drying is assumed to be similar to the one for washing since drying and washing usually take place in a row.
Two improvement scenarios have been assessed.

- A first scenario assuming that 69 % of the standard capacity is used, instead of 64 %. This corresponds to a load of 3.7 kg per washing and drying cycle, instead of 3.4 kg.
- A second scenario assuming that 74 % of the standard capacity is used, corresponding to a load of 4 kg per washing and drying cycle.

Parameters related to load capacity are indicated in Table 53.

Table 53: Load capacity parameters in the different load capacity scenarios

Parameter	Load capacity scenario		
	Baseline scenario	Conservative scenario	Optimistic scenario
Average theoretical washing machine load capacity in kg/cycle	5.36	5.36	5.36
% capacity use under real conditions	64	69	74
Average load capacity under real conditions in kg/cycle	3.4	3.7	4.0
Washing energy consumption in kWh/kg	0.21	0.20	0.19
Washing water consumption in l/kg	13.5	12.7	12.0
Drying energy consumption in kWh/kg	0.59 kWh	0.57 kWh	0.56 kWh

➢ **Results**

The comparison between the results for the improvement and baseline scenarios are shown over the page in Figure 52.

It is possible to observe that optimising the load capacity can reduce all the indicators. In particular, the impact on toxicity can be significantly decreased: the overall impacts on human toxicity, freshwater and marine ecotoxicity are indeed decreased by about 10 % in the optimistic scenario. In addition, the reduced water consumption for washing leads to a 6 % decrease in the water depletion indicator. The influence on the three endpoint indicators is instead lower since the reduction does not exceed 4 %.

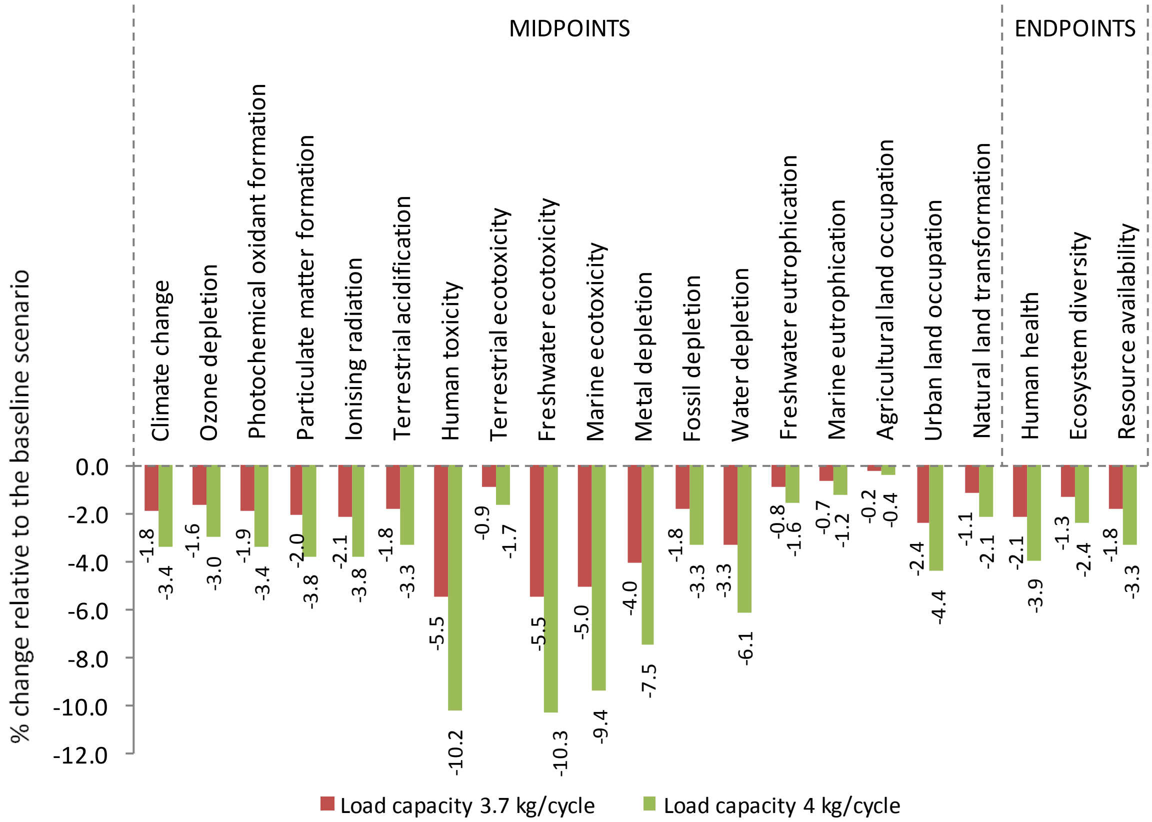


Figure 52: Changes in life cycle impacts of textiles in the EU-27 resulting from increased load capacity

4.5.1.5 Barriers and opportunities

The adoption of sustainable practices depends on different aspects. Results of the Public Understanding of Sustainable Clothing (Fisher *et al*., 2008) study have shown that some parts of consumer laundering behaviour can be more susceptible to change than others. The perception of 'cleanliness' was found to be a strongly influencing factor on consumer laundering behaviour. The study showed that consumers are reluctant to reduce the frequency of washing and drying, due to concerns over the 'freshness' of items or smell. The study found that some consumers are apt to wash and tumble dry below the load capacity as they dislike items 'sitting around' unwashed. The perception of cleanliness can also influence the temperature at which consumers wash items. It is more difficult to encourage a consumer to use reduced temperatures where items are more heavily soiled. To an extent, encouraging consumers to wear clothes for longer periods could result in heavier soiling of items, and could therefore encourage high temperature washing. Some may reduce the temperature but, ultimately, it would be compensated by an increased detergent use (Fisher *et al*., 2008).

There seems to be some potential for change, however. A recent survey lead in the UK by a leading detergent manufacturer found that in 2002, 2 % of respondents washed primarily at 30 °C, whereas in 2007, this number increased to 17 % (IPSOS, 2007). One factor that influenced the trend towards colder temperature washing is the availability of washing detergents made specifically for this purpose. Research has shown that low temperature detergents have no significantly higher environmental impacts than regular formulations, even when used at the other temperatures (P&G, 2006). A potential drawback of routinely washing at low temperature is the possible accumulation of bio-films in the washing machine. Using the correct dose of detergent, leaving the door open between washes and carrying out a service wash at 60 °C are strategies that can be used to prevent bio-films (BIO, 2009).

Although certain individuals have internalised sustainability into their thinking, they can be constrained by factors such as physical space, time and weather (BIO, 2009). Conversely, those individuals that behave in a pro-environmental manner may do so due to economic pressures. This is especially the case for tumble drying, where tumble drying may not be affordable, or high energy costs encourage line drying over tumble drying. Increasing consumer awareness could to some extent promote behaviour which lowers the impact on the environment. However, it appears that even for consumers with a good level of awareness, convenience and cost play a greater role in influencing choice (BIO, 2009).

4.5.2 Improvement of washing/drying appliances efficiency

4.5.2.1 Context

Along with consumer behaviour, it is also important to assess the efficiency of equipment. Washing and drying appliances available on the market have different efficiencies depending on the technology they rely on. The following assessment takes into account the current average energy consumption patterns and determines the magnitude of improvement brought about by increasing appliance efficiency.

4.5.2.2 Improvement potential

- **Baseline and improvement assumptions**

The average energy and water consumption of washing machines in the baseline scenario was modelled according to the average energy and water consumptions under standard conditions in Europe, i.e. 0.998 kWh/cycle and 50.7 l/cycle (see Section 2.2.3.1). In order to test the influence of improving the efficiency of washing appliances, minimum energy and water consumption values were assumed, i.e. 0.92 kWh/cycle and 39 l/cycle under standard conditions (Presutto *et al.*, 2007). Similar calculations to the baseline scenario were then used to determine the energy and water consumption under real conditions.

Regarding the efficiency of tumble dryers, the assumed energy consumption in the baseline scenario was based on an average C class air vented tumble dryer. It was assumed that the tumble dryer consumes 0.73 kWh per kg textiles under standard conditions (see Section 2.2.3.2). In order to assess the influence of a more efficient technology, the use of class A heat pump dryers was assumed instead. These dryers consume up to 50 % less energy than conventional condenser dryers, thanks to their efficient heat pump technology. The average energy consumption of these dryers under standard conditions is 0.55 kWh per kg (Topten.info, 2009), corresponding to an energy savings of 30 % compared to the baseline. This reduction is in line with the finding of the EuP study on laundry dryers (PriceWaterHouse Coopers, 2009) in which the use of a heat pump condenser dryer was found to allow for reducing the energy consumption by 24 % on average.

Two scenarios were included in the analysis: a first scenario for which only the efficiency of washing machines is assumed to be improved, and a second scenario for which an increased efficiency is assumed for both washing machines and tumble dryers.

For both scenarios, the washing load is unchanged compared to the baseline scenario, i.e. an average washing load of 3.4 kg per cycle is assumed. Table 54 sums up the parameters taken into account for both improvement scenarios.

Table 54: Parameters affected by the use of energy efficient washing machines and tumble dryers

Parameter	Scenario alternatives		
	Baseline scenario	Improved efficiency of washing machines	Improved efficiency of washing machines and dryers
Energy consumption of washing machines in kWh/kg	0.21	0.19	0.19
Water consumption of washing machines in l/kg	13.49	10.38	10.38
Energy consumption of tumble dryers in kWh/kg	0.59	0.59	0.44

➢ **Results**

The comparison between the results of improvement and baseline scenarios are shown in Figure 53, from which it can be observed that impacts can be reduced for all the indicators. The results revealed that the highest benefits concern the water depletion indicator because of the water saved during washing. For the other indicators, the impact reductions are lower but still appreciable. It can also be noted that, except for water depletion, the improvement of the efficiency of tumble dryers brings more benefits than the improvement of the efficiency of washing machines.

4.5.2.3 Barriers and opportunities

Recent legislation is expected to have a significant impact on the performance of certain appliances, in particular washing machines and clothes dryers. The Ecodesign Framework Directive 2009/125/EC provides a framework for implementing minimum Ecodesign requirements for Energy Using Products (EuP). The aim of the Directive is to reduce the environmental impact of energy using products, contributing to sustainable development whilst ensuring businesses do not experience heavy impacts. The measures are mandatory and will therefore affect the parameters of all appliances to be sold in the EU.

As regards washing machines, the draft implementing measure (BIO, 2009) was issued in April 2009, before being approved by the EuP regulatory committee. The Commission Regulation (EU) No 1015/2010 on the ecodesign of washing machines was adopted in November 2010. The specific requirements of the implementing measure will be introduced progressively between December 2012 to December 2013, with the requirements to be reviewed again in 2014.

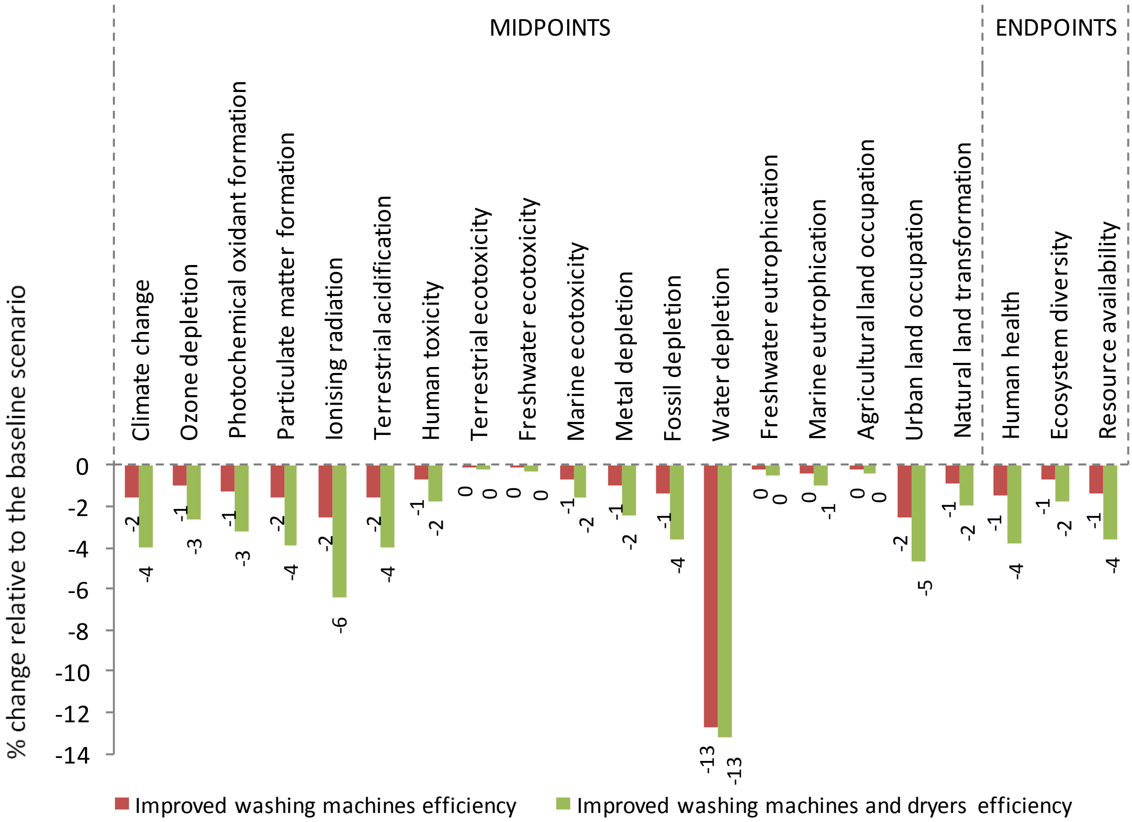


Figure 53: Changes in life cycle impacts of textiles in the EU-27 resulting from increased efficiency of washing machines and dryers

The requirements are as follows: from December 2011, minimum standards have required that all washing machines with a rated capacity of greater than 3 kg have a minimum cleaning performance and energy efficiency equivalent to A class performance on the current EU Energy Label. From December 2012, the performance of washing machines has had to take into account standby power which is to be measured with respect to different washing conditions, which are intended to be representative of consumer use. This requirement is expected to drive improvements in performance particularly where the washing machine is not loaded to full capacity.

From December 2013, the minimum standards introduced in 2011 will be tightened and washing machines will be required to have a cooler 20 °C programme. Many washing machines already have a cold wash programme (usually 30 °C) but in most cases this is only intended for items which cannot withstand higher temperatures. It is important to note that there is no requirement for this programme to be suitable for washing cotton fabric. The expected energy savings across Europe from these measures is 2 000 GWh per year by 2020 (BIO, 2009).

The Regulation also sets requirements for the water consumption of washing machines. In the case of washing machines, the requirements for a standard 60 °C cotton programme are (European Commission, 2010) given below:

- From December 2011 the water consumption per cycle at full load has had to be lower than $(5 \times c) + 35$ (where c is the rated capacity at full load). This corresponds to 12 l/kg for 5 kg of load.
- From December 2013 the water consumption per cycle at full load shall be lower than $(2.5 \times c) + 35$ (where c is the rated capacity at full load). This corresponds to 6 l/kg for 5 kg of load).

Water consumption benchmarks are also set for machines of different capacities (European Commission, 2009):

- 39 l/cycle (5 kg) or 5.6 l/kg
- 43 l/cycle (7 kg) or 6.1 l/kg
- 56 l/cycle (8 kg) or 7.0 l/kg.

Concerning tumble dryers, the preliminary EuP study was published in March 2009 (Pricewaterhouse Coopers, 2009). The preparatory study considers a number of technical options for improving energy efficiency. The analysis has shown that for the majority of options, the reduction of energy consumption is quite modest, in comparison with the "Business As Usual" scenario (BAU). Ambitious introduction of BAT appears to provide the greatest improvement, however this is the best case scenario for improvement.

4.6 Improvement options for the end-of-life phase

Only one improvement option was considered for the end-of-life phase: the promotion of recycling and reuse (see Section 2.2.4).

A first set of results show the impact variation from a life cycle point of view for all the indicators. Then, a focus is placed on the life cycle phase related to the option, with a selection of indicators: climate change and the three endpoint indicators are always shown, extended with a set of the other four most sensitive indicators in order to facilitate the understanding of the analysis.

4.6.1 Promotion of recycling and reuse

4.6.1.1 Context

Clothes are often discarded before the end of their lifetime (Salvation Army, 2008). Across Europe, many charitable organisations, such as the Salvation Army or the Red Cross, collect used clothing in order to recycle it or to resale it as second-hand clothing. The principle is that people bring the clothes they do not want to wear anymore to 'drop-off' containers belonging to charitable organisations or to local charity shops. Door-to-door collection is also in use in some areas. The collected clothes are then sorted and routed to different destinations depending on their quality and condition. Usually, best quality items are sold in second-hand shops in the country of collection. Low-quality and torn or stained clothes are sold to the textile recycling industry to be shredded and converted into wipers or carded and mixed with other fibres to be re-spun into yarn. However, most clothes are baled and shipped for resale in Eastern Europe, the Middle East or Africa. Second-hand garment bales are sold via a commodity market to traders and then to stall merchants for resale at local markets. The money from the sale of the donated clothes provides funds to charities for financing development projects while it provides a source of cheap clothing particularly appreciated in developing countries (ERM, 2007; ERM & AEA Technology 2005).

The improvement options for the end-of-life phase therefore lie in the promotion of reuse and recycling. This means than consumers need to be encouraged to donate the clothes they want to get rid of. Across Europe, about 20 % of the clothing waste is collected, of which about 40 % are reused, 50 % are recycled, and 10 % are disposed of by incineration or landfilling (these values were chosen for the baseline scenario, see Section 2.2.4).

4.6.1.2 Improvement potential

➢ **Baseline and improvement assumptions**

As said before, a collection of 20 % of the clothing waste was assumed as an average in Europe. However, practices in this area vary greatly from one country to another. For instance, in Germany, about 70 % of the potential tonnage is collected, while the population in Eastern countries like Poland or the Baltic countries is not familiar at all with the collection of used clothes (Textile Recycling Association, 2005).

In order to assess the potential benefits of increased recycling and reuse, two scenarios have been analysed.

- A first, conservative, scenario for which a collection rate of 40 % of used clothes is assumed (corresponding to the average collection rate in Scandinavia countries);
- A second, optimistic, scenario assuming a collection rate of 70 % (based on German performances).

However, a significant part of the clothes collected in Western countries are routed to Eastern countries for reuse as second-hand clothes. If these countries would reach a collection rate as high as in Germany, a significant part of the reuse market might be at stake. In that case, the optimistic scenario may thus not be realistic.

The fate of the clothes after collection has not been changed compared to the baseline scenario. Therefore, 50 % of the collected clothes are still assumed to be recycled, while 40 % are reused either in the EU or in developing countries. The remaining 10 % are incinerated or disposed in landfills. This repartition between the different routes depends on the quality and conditions of the collected clothes for which no improvement area can be easily pointed out.

The collection rates and the proportion of clothes recycled and reused are summarised in table 55 according to the scenarios.

Table 55: Setting of parameters for promotion of recycling and reuse scenarios

Parameter	Promotion of recycling and reuse scenarios		
	Baseline scenario	Conservative scenario	Optimistic scenario
% of textile clothing waste being collected	**20**	**40**	**70**
% of total clothing waste being recycled	10	20	35
% of total clothing waste being reused	8	16	28
% of total clothing waste being landfilled or incinerated	2	4	7

➢ **Results**

The comparison between the improvement and the baseline scenarios is shown in Figure 54 and it highlights that environmental benefits occur for all the indicators and for both the improvement options.

The environmental benefits associated with an increase of the collection rates from 20 % to 40 % (conservative scenario) are limited between 0 % and 4 %. Environmental improvement potentials are significantly higher in the optimistic scenario.

The highest benefits are obtained for the impact category 'ionising radiation' (i.e. 4% and 12 % for conservative and optimistic scenarios, respectively) and mainly come from the prevented production of new items. It is assumed that every item used second-hand prevents the production of a similar item from virgin materials. This results in high savings in the production and processing stages, in particular in terms of energy (explaining the high reduction obtained for ionising radiation).

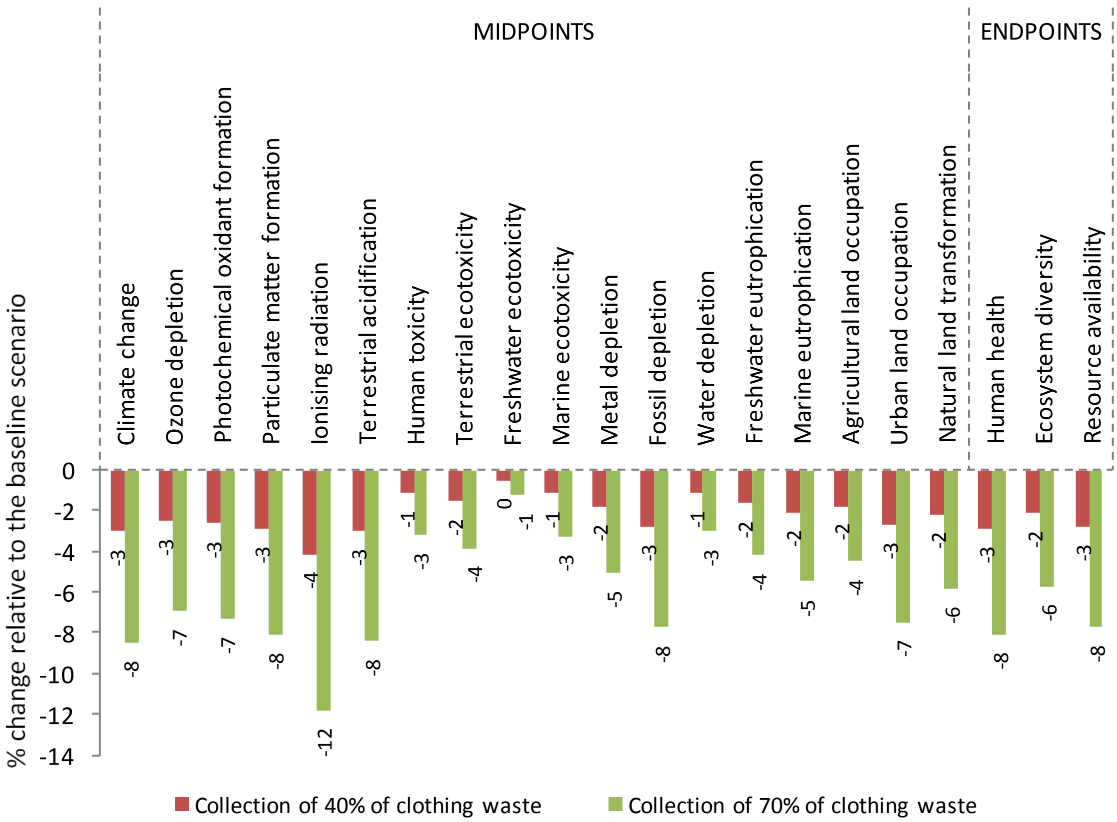


Figure 54: Changes in life cycle impacts of textile in the EU-27 resulting from increased collection of clothing waste

4.6.1.3 Barriers and opportunities

The promotion of reuse and recycling is in line with the European Landfill Directive that aims at reducing biodegradable waste including organic textiles going to landfill to 75 % of the 1995 figures by 2010 and to 35 % by 2020 (Environmental Information Exchange, 2009). In order to reach these targets, the Directive has been transposed into national laws. For example, in the UK, landfill tax regulations were implemented in 1996 to promote the 'polluter pays' principle, by increasing the costs of disposal to landfill, thus reflecting the environmental impact of this option ([1]). However, the promotion of used clothing only makes sense if recycling and second-hand businesses are viable. Regarding the second-hand use business, while the demand is still high (Hansen K., 2004), the sector currently faces some challenges on the donor side. The current 'fast fashion' trend results in cheap low quality clothing that is often not suitable for reuse (ERM, 2007) and could lead to a decrease in the availability of second-hand clothing. If a smaller fraction of the collected clothes can be sold as

([1]) HM Revenue and Customes, *Landfill tax guidance*, http://www.hmrc.gov.uk/landfill-tax/index.htm second-hand clothes the whole business profitability will be affected. In addition, the second-hand clothing business is threatened by the low price of Asian textile imports since the economic advantage in buying second-hand clothes thus tends to disappear.

For the recycling of items unsuitable for reuse, the barriers are mostly technological. Recycling certain types of textiles, such as plasticised prints on clothes, composite materials, and clothes treated to be waterproof, is indeed problematic. However, as recycling technology is progressing, the means may be developed to recycle such fibres, as has been the case with plastics recycling technologies in the last decade (ERM & AEA Technology 2005).

Lastly, if the recycling and reuse business is to be developed at a larger scale, the infrastructures for clothes collection and sorting will have to be adapted. Some support from authorities would be needed to improve the infrastructure of clothing collection. But then of course cost effectiveness issues also enter into the picture.

4.7 Case study on fibre blending

A case study was also carried-out in order to evaluate the environmental impact of fibre blending and the potential benefits associated with it. A complete analysis of fibre blending would involve changes in many parameters of the model, both with reference to the life cycle stages of each textile product and to the functional unit itself (e.g. a difference in cloth quality implies a different lifetime). A simplified case-study dealing with T-shirts was thus implemented.

4.7.1 Fibre blends

4.7.1.1 Context

A fibre blend is any combination of fibre types, whether they occur as different filaments or staple fibres in the same yarn, or as different yarns assembled in the same fabric or garment. The components are generally two different fibrous polymers each with their own characteristic properties: cotton and polyester.

In the baseline scenario, the textile LCA model does not differentiate between single fibre fabrics and fibre blends because the number of possible blends for a given item is too large to define specific life cycle properties (e.g. washing temperature and lifetime) for each fibre blend. However, these types of fabrics play an important part in the textiles market. Many types of clothing and household textile products are produced from fibre blends. The most common types of blends include:

- polyester/cotton
- polyester/viscose
- polyester/wool
- wool/acrylic
- polyamide/wool.

Polyester and cotton blends (also called polycotton) are considered one of the most important and common fibre blends. Often used for clothing products, blending these two fibres brings many advantages compared to the use of only one fibre type. The blend is similar to cotton in terms of breathability and also offers stretchability (due to the polyester component) therefore offering a more comfortable fit. The blend may also be more crease resistant, durable and stronger than its single components. One of the greatest disadvantages of fibre blends is that it is not always possible to recycle them due to the differing properties of their constituent fibres. The equipment used to shred and convert clothes back into fibres is not suitable for blended fibres and it is difficult to make new yarns out of mixed fibres.

4.7.1.2 Improvement potential

➢ **Baseline and fibre-blending assumptions**

In the baseline scenario, products made from blended fibres are included in the textiles LCA model but they cannot be distinguished from products made from 'pure' ones (see Section 2.2). The model therefore does not allow characteristics of blended textiles such as longer lifetime, different care instructions and different end-of-life due to reduced recyclability to be fully caught,

In order to evaluate the environmental consequences associated with fibre blending, a case study focusing on T-shirts was carried-out. 'Wearing one T-shirt for one day' was selected as functional unit of the study. Three fibre types were considered: 100 % cotton (CO), 100 % polyester (PES), and a 50:50 cotton-polyester blend (CO/PES).

The following differences exist between the different fibre types: cotton and polyester fabrics are dyed using direct and disperse dyes, respectively. The blend, however, relies on two successive dyeing steps using direct and disperse dyes. Other differences exist which are related to the use phase. Washing temperatures and tumble drying depend on fibre type. Polyester can also be ironed, so that ironing assumptions remain the same for every case. Table 56 shows the assumptions made on the use phase.

Table 56: Product parameters according to fibre type

Fibre type	Washing temperature (°C)	Tumble drying	End-of-life
100 % cotton	45.8 °C (Baseline)	Baseline	Baseline
100 % polyester	40 °C	None	Baseline
50 % cotton/50 % polyester	40 °C	Baseline	No recycling

Products made from blended fibres often cannot be recycled, and therefore disposal routes differ from those of non-blended fibres. The recycling route has therefore been removed for blended polyester and the T-shirts are assumed to be disposed of instead.

The lifetime of fibre blends might differ between the three fibres used in this case study due to differing durability and strength. No reliable information is publicly available on this topic therefore testing was conducted by Ensait to determine the lifetime of each fibre type. Determination of the abrasion resistance of fabrics was carried out by the Martindale method ([1]), determination of colour fastness to rubbing with Crock Meter ([2]) and determination of colour fastness to machine washing with soap or soap/soda ([3]). The results are displayed in Table 57.

In the case study, it is assumed that T-shirts are washed after each use for all three fibre types. it is also considered that the distribution phase remains the same for all three fibre types.

([1]) ISO 12 947-2.
([2]) ISO 105-X12.
([3]) ISO 105-C10:2006- Part 10.

Table 57: Ratio of product lifetime in relation to fibre type

Fibre type	Lifetime ratio in years	Corresponding number of washes during lifetime
100 % cotton	1	50
100 % polyester	1.9	95
50 % cotton/50 % polyester	1.6	80

➢ Results

Figure 55 shows the results of the comparative assessment of the cotton/polyester and polyester T-shirts compared to a cotton T-shirt. Note that the results refer to the functional unit 'wearing a T-shirt for one day' and not to the total textile life cycle in the EU-27.

The T-shirt made of the cotton/polyester fibre blend and the T-shirt made of polyester show lower environmental impacts than the cotton T-shirt for all the indicators. In particular, in most impact categories polyester scores sensitively lower that the fibre blend.

The main explanation for this pattern is the longer lifetime of polyester and of cotton/polyester fibre blend. In addition, the lower temperature for washing (40 °C for the T-shirt containing some polyester compared to 45.8 °C for cotton) reduces the impact of the use phase, which is a critical stage of the life cycle (see Section 4.1). The differences observed between the T-shirt made of the blend and the T-shirt made of polyester are instead mostly related to the production stage.

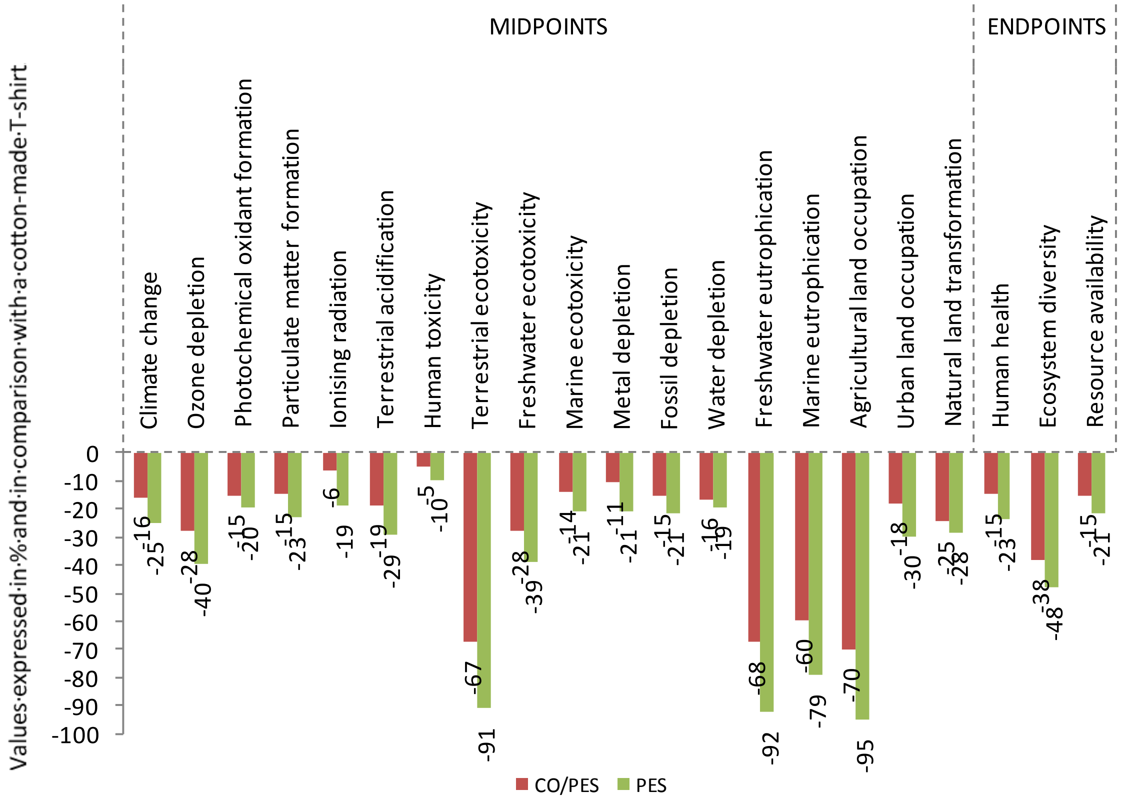


Figure 55: Change in life cycle impacts resulting from wearing a T-shirt made of a 50:50 fibre blend of cotton and polyester (CO/PES) or a T-shirt made of polyester (PES)

➢ Barriers and opportunities

There are many advantages when fibre types are replaced by fibre blends:

1. economy: the dilution of an expensive fibre by blending with a cheaper substitute;
2. durability: the incorporation of a more durable component can extend the useful life of a relatively fragile fibre;
3. physical properties: a compromise to take advantage of desirable performance characteristics contributed by both fibre components;
4. appearance: the attainment of an attractive appearance and tactile qualities using combinations of yarns of different lustre, crimp or denier, which still differ in appearance even when dyed uniformly to the same colour.

For example, silk fibre-based products are very desirable, albeit expensive. To achieve the attractive qualities of these fibres in an economical way, these fibres have been blended with other cheaper fibre types which have increased their market share in the last few years. This provides both an economic solution, as well as increasing durability as shown above. As shown earlier, polyester improves cotton tear strength, crease resistance, and abrasion resistance. The blended fibres exhibit, depending on the blend, lower moisture regain, lower liquid water absorption, increased flammability and greater susceptibility to pilling. Approximately 7 million tonnes of cotton and polyester are blended every year (Ford, 1994). Currently there are no other fibre blends capable of yielding such compatible properties, nor is any blend likely to be for years to come. From a life cycle perspective, the blending of fibre types seems to offer a significant environmental improvement potential.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 The most promising improvement options

5.1.1 Environmental improvement potential of the options

table 58 presents the maximum benefits which can be achieved with each of the improvement options evaluated. Improvement potentials are referred to the three endpoint categories of ReCiPe and to the full life cycle of textiles. In the case where several scenarios were examined for a given improvement option, the results from the most optimistic scenario have been chosen. The full table for all the indicators of ReCiPe is given in Annex 2.

Table 58: Environmental improvement potentials of the different options considered in the study and for the endpoint indicators of ReCiPe. Values expressed in % and in comparison with the baseline scenario

Phase	Option	ENDPOINTS		
		Human health	Ecosystem diversity	Resource availability
Production	Reducing agrochemical use	0.7	3.7	0.4
	Replacing cotton with hemp or flax	0.3	5.8	0.7
	Reducing consumption of sizing chemicals	0.2	0.3	0.2
	Replacing chemicals with enzymes	0.03	0.11	0.03
	Using alternative knitting techniques	1.2	2.0	4.0
	Using dye controllers and low liquor ratio dyeing machines	0.1	0.8	0.1
	Water recycling	0.6	11.3	0.6
Distribution	Reducing air freight	3.9	1.9	4.5
Use	Reducing washing temperature	4.7	2.1	4.3
	Optimising the load of appliances	3.9	2.4	3.3
	Reducing tumble drying	1.6	0.7	1.5
	Improvement of washing/drying appliances efficiency	3.8	1.7	3.6
End-of-life	Promotion of reuse and recycling	8.1	5.7	7.7

It can first be noted that the maximum improvement potential for all options and all endpoint indicators is an 11 % reduction which is reached for ecosystem diversity in the case of the use of the ion exchange technology to recycle the effluent water. Increasing the collection of used clothing for recycling and reuse appears as the most promising option to reduce the impacts on human health and resource availability by about 8 %. This option, which also allows for a significant reduction of the 'ecosystem diversity' indicator (-5.7 %), appear the most effective strategy, among the ones investigated in the study.

With reference to the implementation of the other options, lower but still appreciable environmental benefits seem obtainable. As a general rule, options concerning with distribution and use phases should be more beneficial for human health and resource availability, while interventions at agricultural level should be more effective for ecosystem diversity.

Concerning with midpoint indicators, the most promising option for each indicator is presented in table 59 (see Annex 2 for the complete results). The options that come out as the most efficient are:

- reducing agrochemical use in traditional cotton crops (particularly beneficial with respect to the impact categories related to ecotoxicity and eutrophication);
- substituting cotton with hemp (particularly beneficial with respect to the impact categories related to ecotoxicity, eutrophication, agricultural land occupation);
- using the ion exchange technology to recycle the effluent water during the production phase (particularly beneficial with respect to the impact categories related to water depletion and natural land transformation);
- avoiding air transportation (particularly beneficial with respect to the impact categories related to ozone depletion, photochemical oxidant formation, natural land transformation);
- reducing the end product washing temperature (particularly beneficial with respect to the impact category related to ionising radiation);
- increasing the load of capacity of washing and drying appliances (particularly beneficial with respect to the impact categories related to human toxicity, freshwater and marine ecotoxicity, metal and water depletion);
- increasing the efficiency of washing and drying appliances (particularly beneficial with respect to the impact categories related to water depletion and ionising radiation);
- increasing the collection of used clothing to develop recycling and reuse (particularly beneficial with respect to the impact categories related to climate change, ozone depletion, photochemical oxidant formation, particulate matter formation, ionising radiation, terrestrial acidification, fossil depletion, urban land occupation).

Interestingly, it can be noted that for 10 out of 18 indicators the most promising options are consumer-oriented, which further emphasised the key role of the consumer behaviour.

In addition to this global overview, it is interesting to evaluate the options that are the most promising within each life cycle phase.
Within the production and processing phase, high reduction potentials could be obtained by replacing traditional cotton cultivation, as illustrated in Figure 56, which present the three most sensitive indicators.

In addition, the contribution to water depletion can be decreased by 25 % by using the ion exchange technology to recycle the effluent water. This option also brings a 12 % reduction in the contribution to natural land transformation.

Table 59: Most promising options for reducing the environmental impacts of textiles according to the midpoint indicators of ReCiPe

Midpoint Indicator	Most promising option to decrease the contribution to the indicator	% reduction reached
Climate change	Increase of the collection of used clothing for reuse and recycling	8
Particulate matter formation		8
Ionising radiation		12
Terrestrial acidification		8
Fossil depletion		8
Urban land occupation		7
Freshwater ecotoxicity	Increase of the load capacity of washing and drying appliances	10
Marine ecotoxicity		9
Metal depletion		7
Human toxicity		10
Freshwater eutrophication	Substitution of cotton by hemp	31
Marine eutrophication		18
Agricultural land occupation		24
Water depletion	Recycling of effluent water by ion exchange technology	25
Natural land transformation		12
Ozone depletion	Use of fully fashioned knitting	9
Photochemical oxidant formation	Avoidance of air transportation	8
Terrestrial ecotoxicity	Replacement of traditional cotton by GM cotton	45

Table 60: Highest reduction potentials for the improvement options that concern the production and processing phase

Midpoint indicator	Impact reduction assessed over the whole life cycle (%)	
	Replacing traditional cotton by genetically modified cotton	Replacing cotton by hemp
Terrestrial ecotoxicity	45	32
Freshwater eutrophication	25	31
Agricultural land occupation	13	24

For the use phase, the reductions observed over the whole life cycle do not exceed 12 %. From a global point of view, of the four improvement options assessed for the use phase, increasing the load capacity of washing and drying appliances appears as the most promising option, followed by reducing the washing temperature and improving the efficiency of washing machines and dryers. The reduction of the tumble drying frequency does not appear to bring any significant benefits. Figure 56 presents the highest reduction potentials that could be obtained for the three most promising options.

Figure 56: Highest reduction potentials for improvement options that concern the use phase

Impact reduction assessed over the whole life cycle (%)					
Increasing the load capacity of washing and drying appliances		Reducing the washing temperature		Improving washing machines and dryers efficiencies	
Human toxicity	10	Ionising radiation	8	Water depletion	12
Freshwater ecotoxicity	10	Terrestrial acidification	5	Ionising radiation	6
Marine ecotoxicity	9	Climate change	5	Terrestrial acidification	4

For the distribution and end-of-life phases, only one option has been assessed within each phase. The highest reduction potentials of avoiding air transportation bring a maximum reduction of 8 % for the category photochemical oxidant formation. Increasing the collection rate of used clothing is instead the most efficient option for reducing the impacts due to ionising radiations (by up to 12 %).

It should be however noted that not all the impact categories have the same environmental significance. In other words, a higher/lower concern could be given to some environmental issues. This evaluation, which is in any case a subjectivity matter, could be for example apparent after the indicators are normalised, as shown in Annex 2.

Table 61 and table 62 present the highest reduction potentials for the most efficient improvement options for the distribution and the end-of-life phases.

Table 61: Highest reduction potentials for the improvement option that concerns the distribution phase

Impact reduction assessed over the whole life cycle (%)	
Avoiding air transportation	
Photochemical oxidant formation	8
Natural land transformation	8
Ozone depletion	7

Table 62: Highest reduction potentials for the improvement option that concerns the end-of-life phase

Impact reduction assessed over the whole life cycle (%)	
Increasing the collection of used clothing for reuse and recycling	
Ionising radiation	12
Climate change	8
Terrestrial acidification	8

It is apparent from the analysis of the improvement options that it is not possible to objectively select a single strategy effectively capable to reduce the environmental burdens of the textile sectors because the options investigated for each life cycle phase can yield benefits with respect to different impact categories.

5.1.2 Combination of improvement options

In order to evaluate the maximum benefits that could be gained, the environmental impacts of a scenario combining all the compatible options has been assessed. The options combined within this scenario are presented in Figure 57 which shows the environmental improvement potential due to the combination of the improvement options compared to the baseline scenario. Significant reductions can be obtained. the contribution to each indicator is decreased by at least 17 %. The contribution to the three endpoint indicators are reduced by between 21 % and 27 %. In addition, terrestrial ecotoxicity and water depletion appear as the midpoint indicators for which the reduction potential is the highest, i.e. 51 % and 35 %, respectively. The next most important reduction is in relation to marine eutrophication, with 34 %. The impacts of the textile life cycle on climate change could be reduced by 22 %.

The hypothetical replacement of traditional cotton by GM cotton has been included in the analysis, while the substitution of cotton for hemp has been left out of the combined scenario. The replacement of chemicals with enzymes has also been excluded because data was missing to fully model this option (see Section 4.3.4).

Figure 57 shows the environmental improvement potential due to the combination of the improvement options compared to the baseline scenario. Significant reductions can be obtained. The contribution to each indicator is decreased by at least 17 %. The contribution to the three endpoint indicators is reduced by 21 % to 27 %. In addition, terrestrial ecotoxicity and water depletion appear as the midpoint indicators for which the reduction potential is the highest, i.e. 51 % and 35 %, respectively. The next most important reduction is in terms of marine eutrophication, with 34 %. The impacts of the textile life cycle on climate change could be instead reduced by 22 %.

Table 63: Overview of the improvement options included in the scenario combining different improvement options

Phase	Option	Included in the scenario combining improvement options
Production	Replacement of traditional cotton by GM cotton	✓
	Substitution of cotton with flax or hemp	
	Reducing the consumption of sizing chemicals	✓
	Replacement of chemicals with enzymes	
	Use of fully fashioned knitting	✓
	Use low liquor ratio dyeing machines and dye machine controllers	✓
	Recycling of effluent water by ion exchange technology	✓
Distribution	Avoidance of air transportation	✓
Use	Reduction of the washing temperature	✓
	Increase of the load capacity of washing and drying appliances	✓
	Reduction of the use of tumble drying	✓
	Improvement of washing machines and dryers efficiencies	✓
End-of-life	Increase of the collection of used clothing for reuse and recycling	✓

It should be noted that the options have been assessed based on current trends without taking into consideration the possible future evolution of some parameters that could affect the achieved benefits. For example, for the use stage, the improvement option concerning the efficiency of appliances has been modelled based on best available techniques. However, thanks to technical progress, the efficiency of appliances will be continually improved. In addition, the analysis of the effects due to a reduction of the drying frequency does not take into account the possible evolution of the proportion of the EU population equipped with dryers. This parameter would also play a role in the evaluation of the influence of an increased load capacity.

Taking into consideration future trends could also suggest alternative options that have not been assessed in the present study. For instance, concerning transport, the share of alternative transportation means might increase. It could be for example imagined that in future textiles will be more frequently transported by rail than by trucks.

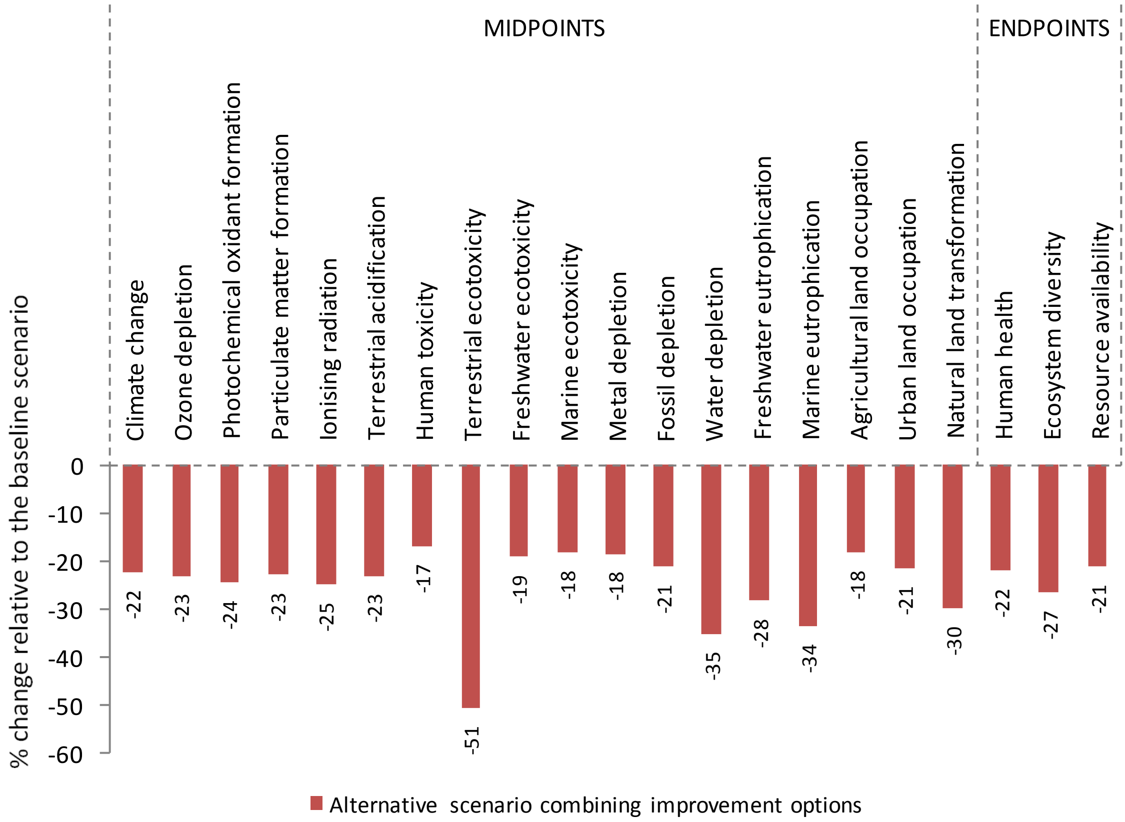


Figure 57: Changes in life cycle impacts of textile use in the EU-27 for combined improvement options

5.2 Conclusion

The textile industry is characterised by one of the longest and most complicated industrial chains in the manufacturing industry, bringing into play actors from the agricultural, chemical fibre, textile, apparel, retail, services and waste treatment sectors. This fragmented and heterogeneous industry is dominated by small and medium enterprises.

A key challenge of this project was to cope with the lack of consistent and reliable data on both structural (e.g. intermediary product flows, end-of-life routes) and technological (e.g. demand of energy, raw materials and chemicals) issues. Some assumptions have been necessary in order to perform the environmental assessment of the textiles lifecycle.

The key conclusion of the project is that the life cycle environmental impacts of the textiles market are mainly influenced by production and use phases. Within the production and processing phase, the use of agrochemicals to produce natural fibres contributes significantly to eutrophication, ecotoxicity and land use. The production of synthetic fibres rather raises some concerns due to the consumption of fossil resources. Reuse and recycle of old textiles appears to lead to significant positive effects on the impacts from the production phase. In the use phase, detergents are responsible for a high share of toxicological impacts, while the energy needs associated with washing and drying contribute to indicators such as climate change, ozone depletion, photochemical oxidant formation and particulate matter formation.

In general, the impacts of textile consumption can be classified under two headings: supply factors and demand factors. Supply factors encompass drivers such as: agricultural practices, production processes of the textile industry, product design and functionalities of household appliances, and the existence of sorting and recycling schemes. Concerning demand factors, the impacts are mostly driven by social parameters, including: choice of products/fibres, care practices (washing, drying, and ironing), lifetime

of product in the context of fast fashion, and disposal practices. Efforts to reduce the overall impact of the EU-27 textiles market should concentrate both on the production and on the use phases.
The assessment of improvement options in this study suggests that a significant reduction of impacts can be achieved by targeting consumers. Practical actions could focus on: reducing washing temperature, washing at full load, favour line drying whenever possible, purchasing eco-friendly fibres, and donating clothes instead of throwing them away. To achieve such changes it is necessary for consumers to be aware of these issues, and it is imperative that infrastructural requirements can be met. Raising awareness and dissemination therefore become important drivers of change. Promotion of ecolabels, and examples of best practice cases could be used as tools to improve the environmental performance.

Overall, concerning improvement options related to supply factors, it is challenging to accurately assess and compare the improvement potential offered by single actions due to a lack of experience with emerging techniques. Nevertheless, the analysis suggests that significant improvement can be achieved by appropriately encouraging practices in the textile industry with a lesser environmental impact, such as replacing traditional cotton with more eco-friendly crops, recycling the effluent water during the production phase, avoiding air transportation.

Environmental policy intervention can address both the supply and demand of textiles. At the European level, the initiatives launched so far have mostly focused on the production phase. One can for instance mention the directives and voluntary schemes promoting cleaner production such as the REACH legislation or the EMAS voluntary instrument that have a strong influence on the industry. Other notable actions include product targeted measures such as the Ecodesign Directive which is a key EU strategy. However, when it comes to the textile industry, the field of action of European policies and legislations could be limited by the fact that most of the production takes place outside of the EU borders. Therefore, one way to tackle this limitation is to further develop the use of market and policy instruments which are more consumer-oriented, such as the European Ecolabel scheme.

5.3 Recommendations

To be able to cope with the complexity of the textile sector, some simplifications have been necessary. Average European data were therefore used to model the environmental impacts of textile products consumed in EU-27. However, the study highlights that there are significant data gaps in the textile sector. This section identifies the key issues for which data gaps were identified and suggests how they could be tackled to improve the reliability of the assessment.

➢ **Lack of market and flow data**

In order to build a consistent life cycle model of the textiles consumed in Europe, it is necessary to gather specific life cycle data for all textile products included in the model. This implies a strong need for detailed information on product quantities, composition, and transportation flows. In order to improve the model, improved statistical data are required in order to carry out the following items.

- Better integrate end products made of blended fibres and take into account relationships between processes, quality and durability. No data was found to distinguish pure products from blended ones and therefore it was not possible to include in the model some of their specific characteristics, for instance related to processes, care habits, disposal routes.
- Improve the modelling of the end-of-life phase by better matching product characteristics with disposal routes.
- Take into account that most life cycle processes take place in different locations. This implies technological variability and complex transportation schemes of fibres, yarns, intermediary or end products.

➢ **Lack of environmental data**

When performing an LCA, gathering reliable environmental data for the different life cycle steps is often the most critical step. The following aspects could be further analysed and improved.

- For some fibres, e.g. hemp or silk, life cycle inventory data for production and processing is very scarce. Extrapolation of data from common fibres such as cotton or polyester has therefore been necessary. For more accuracy, more data for the production and processing of these less widespread fibres would be required to ensure similar representativeness between fibres. The lack of data for some fibres also imposed some simplifications in the modelling of the end-of-life phase.
- The study highlights that the use phase is a key contributor to the environmental impacts of the textile life cycle. In particular, detergents are responsible for a high share of toxicological impacts. First of all, it should be kept in mind that, due to the complexity of the mechanisms involved, some further development of the LCA indicators related to toxicity is possible. Moreover, detergent formulations and formats (powder, liquid, tablet, etc.) have evolved over the last few years but LCA data is scarce. More research in this area is required.
- No environmental data was found to assess 'closed loop' recycling whereby recycled fibres are used in the manufacture of new clothing. This would be an interesting issue to investigate since it could bring more benefits than using textile waste to replace low quality products such as cleaning rags as assumed in the model. Data on the end-of-life of textiles is scarce, particularly for the various recycling routes.
- One of the key aspects of the textile industry is the dispersion of many actors in various geographical areas. There is therefore a strong need for area-specific life cycle data in order to improve the representativeness of the textile LCA model. Indeed, in order to overcome this limitation, it is assumed that EU processes are representative of global practices.

➢ **Lack of social data**

Individuals have a key role in determining the environmental impacts of the use phase of textiles. With consideration to these aspects, reliable social data are needed in order to carry out the items listed below.

- Improve the consideration of clothing reuse in the model. Indeed, benefits from reusing clothes come from the fact that this may prevent the production of new clothes from virgin materials. Investigating the substitution ratio between reused and new product is a key element for improving the assessment of these potential benefits.
- Integrate in the model fashion effects, as it can have impacts on the textile lifetime.
- Improve the reliability of parameters such as washing temperature, drying method, ironing or disposal practices which are ultimately decided by the individual consumer. An area of improvement would thus be to differentiate consumer behaviour according to geographical zones or to consumer profiles.

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ANNEXES

Four annexes are embodied in this chapter with the aim of providing with more detailed information about the assumptions and the results of the study, as well as further technical specifications.

- **Annex 1**
  - classification and breakdown by broad categories and fibre type for clothing textiles
  - classification and breakdown by end product and fibre type for household textiles
  - breakdown into total weights per end product and fibre type for clothing textiles
  - breakdown into total weights per end product and fibre type for household textiles
  - confection losses and user washing behaviour related to clothing textiles
  - confection losses and user washing behaviour related to household textiles
- **Annex 2**
  - normalisation of the environmental impacts of the textiles life cycle in the baseline scenario
- **Annex 3**
  - detailed results for maximum and minimum clothing weights
  - detailed results for all the improvement options assessed in the study
- **Annex 4**
  - glossary.

Annex 1: Market data

This section presents the exhaustive list of assumptions that have been taken into account in the life cycle model as follows:

- classification and breakdown by broad categories and fibre type for clothing textiles
- classification and breakdown by end product and fibre type for household textiles
- breakdown into total weights per end product and fibre type for clothing textiles
- breakdown into total weights per end product and fibre type for household textiles
- confection losses and user washing behaviour related to clothing textiles
- confection losses and user washing behaviour related to household textiles.

➢ **Classification and breakdown by broad categories (further disaggregated into end product categories) and fibre type for clothing textiles**

	EU-27 TOTALS (units or pairs)	Processes	Process types			Percentage breakdown	Breakdown of consumption (%)								
			Woven	Knitted	Waterproofing		WO	CO	SI	FL	VI	PA	PAC	PU/PP	PES
TOPS															
T-shirts, vests, singlets, etc.	3.8E+09			x			0	55	0	0	10	5	10	0	20
Shirts or blouses (knitted or crocheted)	7.8E+08		x				0	62	0	0	18	1	3	0	16
Shirts or blouses (excluding knitted or crocheted)	1.1E+09			x			0	64	0	0	18	1	3	0	14
Jerseys, jumpers, pullovers, etc. (cotton)	7.6E+08			x			0	100	0	0	0	0	0	0	0
Jerseys, jumpers, pullovers, etc. (MMF)	8.9E+08			x			0	0	0	0	10	11	75	0	4
Jerseys, jumpers, pullovers, etc. (wool or fine animal hair)	2.8E+08			x			100	0	0	0	0	0	0	0	0
UNDERWEAR, NIGHTWEAR AND HOSIERY															
Briefs, panties, underpants, etc. (knitted or chrochetted)	2.7E+09			x			0	46	0	0	7	26	3	10	8
Briefs, panties, underpants, etc. (excluding knitted or crocheted)	1.2E+08		x				0	46	0	0	7	26	3	10	8
Hosiery (knitted or crocheted)	6.4E+09			x			5	41	0	0	7	26	3	10	8
Hosiery (excluding knitted or crocheted)	1.5E+08			x			5	41	0	0	7	26	3	10	8
Slips, petticoats and girdles (other)	6.2E+07		x				0	46	0	0	7	26	3	10	8
Slips, petticoats and girdles (knitted or crocheted)	2.1E+07			x			0	46	0	0	7	26	3	10	8
Slips, petticoats and girdles (excluding knitted or crocheted)	9.9E+06		x				0	46	0	0	7	26	3	10	8
Brassieres	6.3E+08		x	x			0	23	0	0	7	24	0	12	34
Nightwear (knitted or crocheted)	4.6E+08			x			0	83	0	0	4	5	0	0	8
Nightwear (excluding knitted or crocheted)	1.3E+08		x				0	83	0	0	4	5	0	0	8
Negligees, bathrobes, dressing gowns, etc. (knitted or crocheted)	6.6E+07			x			0	80	0	0	3	5	0	0	12
Negligees, bathrobes, dressing gowns, etc. (excluding knitted or crocheted)	1.6E+07		x				0	80	0	0	3	5	2	0	10
Other underwear, nightwear and hosiery (cotton, knitted or crocheted)	1.1E+08			x			0	100	0	0	0	0	0	0	0

	EU-27 TOTALS (units or pairs)	Process types			Breakdown of consumption (%)								
		Woven	Knitted	Waterproofing	WO	CO	SI	FL	VI	PA	PAC	PU/PP	PES
Other underwear, nightwear and hosiery (excluding cotton, MMF, knitted or crocheted)	2.1E+07		x		100	0	0	0	0	0	0	0	0
Other underwear, nightwear and hosiery (excluding knitted or crocheted)	2.7E+07	x			0	46	0	0	7	26	3	10	8
Other underwear, nightwear and hosiery (other)	6.7E+06	x	x		0	46	0	0	7	26	3	10	8
JACKETS													
Anoraks, ski jackets, etc.	3.3E+08	x		x	0	10	0	0	0	30	0	0	60
Anoraks, ski jackets, etc. (knitted or crocheted)	6.0E+07		x	x	0	10	0	0	0	30	0	0	60
Jackets and blazers (knitted or crocheted)	7.9E+07		x		76	0	0	0	8	0	0	0	16
Jackets and blazers (excluding knitted or crocheted)	1.9E+08	x			76	0	0	0	8	0	0	0	16
Jackets and blazers (cotton or MMF)	3.2E+07	x			0	22	0	0	0	0	10	0	68
Raincoats	7.8E+07	x		x	0	0	0	0	5	45	0	0	50
Overcoats, car coats, capes (other)	6.3E+07	x		x	32	5	0	0	0	5	33	0	25
Overcoats, car coats, capes (knitted or crocheted)	3.6E+07		x	x	32	5	0	0	0	5	33	0	25
BOTTOMS													
Trousers, breeches, overalls, etc. (cotton, excluding denim)	4.2E+08	x			0	100	0	0	0	0	0	0	0
Trousers, breeches, overalls, etc. (cotton, excluding denim, knitted or crocheted)	3.5E+08		x		0	100	0	0	0	0	0	0	0
Trousers, breeches, overalls, etc. (cotton, excluding knitted or crocheted)	7.7E+06	x			0	100	0	0	0	0	0	0	0
Trousers, breeches, overalls, etc. (MMF, excluding knitted or crocheted)	1.0E+08	x			0	0	0	0	40	4	5	0	51
Trousers, breeches, overalls, etc. (cotton or MMF)	1.0E+08	x			0	55	0	0	23	2	2	0	18
Trousers, breeches, overalls, etc. (excluding knitted or crocheted)	3.5E+07	x			100	0	0	0	0	0	0	0	0
Trousers, breeches, overalls, etc. (excluding cotton, wool or fine animal hair, MMF, knitted or crocheted)	1.1E+08		x		0	0	0	0	100	0	0	0	0
Trousers, breeches, overalls, etc. (knitted or crocheted)	5.6E+08		x		8	45	0	0	25	2	2	0	18
Trousers, breeches, overalls, etc. (other)	3.1E+06	x			17	0	0	0	33	4	4	0	42
Trousers, breeches, overalls, etc. (denim)	4.6E+08	x			0	96	0	0	0	0	0	0	4
Shorts (MMF)	5.8E+07	x			0	0	0	0	40	5	5	0	50
Shorts (cotton)	8.5E+07	x			0	100	0	0	0	0	0	0	0
Shorts (cotton and MMF)	9.1E+07	x			0	55	0	0	23	2	2	0	18
Skirts (excluding knitted or crocheted)	3.1E+08	x			3	7	2	2	25	0	3	0	58
Skirts (knitted or crocheted)	5.5E+07		x		3	9	0	0	25	1	3	1	58
Skirts (excluding wool or fine animal hair, MMF, knitted or crocheted)	2.2E+08		x		0	100	0	0	0	0	0	0	0
DRESSES													
Dresses (excluding knitted or crocheted)	2.1E+08	x			0	6	0	0	25	0	1	0	68
Dresses (knitted or crocheted)	1.4E+08		x		0	6	0	0	25	0	1	0	68
SWIMWEAR													
Swimwear (knitted or crocheted)	2.2E+08		x		0	0	0	0	0	75	0	25	0
Swimwear (excluding knitted or crocheted)	7.5E+07	x			0	0	0	0	0	75	0	25	0
SPORTWEAR													
Tracksuits	1.3E+08	x	x		0	26	0	0	9	26	0	7	32

	EU-27 TOTALS (units or pairs)	Process types			Breakdown of consumption (%)								
		Woven	Knitted	Waterproofing	WO	CO	SI	FL	VI	PA	PAC	PU/PP	PES
Ski suits (knitted or crocheted)	1.8E+05		x	x	0	0	0	0	0	50	0	0	50
Ski suits (excluding knitted or crocheted)	4.2E+06	x		x	0	0	0	0	0	50	0	0	50
SUITS AND ENSEMBLES													
Suits and ensembles (knitted or crocheted)	1.0E+08		x		75	0	0	0	6	0	2	0	17
Suits and ensembles (excluding knitted or crocheted)	9.4E+07	x			75	0	0	0	0	0	1	0	24
Suits and ensembles (cotton of MMF)	2.5E+07	x			0	5	0	0	20	0	5	0	70
GLOVES													
Gloves (knitted or crocheted)	1.2E+09		x		54	6	0	0	0	5	30	0	5
Gloves (excluding knitted or crocheted)	1.7E+08	x			54	6	0	0	0	5	30	0	5
SCARVES, SHAWLS, TIES, ETC.													
Scarves, shawls, etc. (knitted or crocheted)	3.5E+07		x		75	15	5	0	0	0	5	0	0
Scarves, shawls, etc. (excluding knitted or crocheted)	1.8E+07	x			75	15	5	0	0	0	5	0	0
Scarves, shawls, etc. (excluding articles of silk or silk waste, knitted or crocheted)	2.2E+08		x		65	25	0	0	0	0	10	0	0
Ties, bow ties and cravats (excluding knitted or crocheted)	8.9E+07	x			0	0	77	0	0	0	0	0	23
Ties, bow ties and cravats (excluding articles of silk or silk waste, knitted or crocheted)	5.5E+07		x		0	0	0	0	12	0	0	0	88

WO	Wool or other animal hair
CO	Cotton
SI	Silk
FL	Flax and ramie
VI	Viscose
PA	Polyamide (nylon)
PAC	Acrylic
PU/PP	Polyurethane (Lycra Spandex)/polypropylene
PES	Polyester

Biermann *et al.*, 1998

Cotton Incorporated, 2000

Average figures provided by Ensait

x Process chosen

➤ Classification and breakdown by end product and fibre type for household textiles

			Process types				Breakdown of consumption (%)										
	EU-27 TOTALS (units or pairs)	Processes	Woven	Knitted	Non-woven	Percentage Breakdown	WO	CO	FL	VI	PES	PU	PP	PA	PVC	PAC	FEA
Articles of bedding																	
Articles of bedding filled other than with feathers or down (including quilts and eiderdown comforters, cushions, pouffes, pillows; excluding mattresses, sleeping bags)	1.6E+08			x			0	10	2	0	60	10	0	13	5	0	0
Articles of bedding of feathers or down (including quilts and eiderdown comforters, cushions, pouffes, pillows; excluding mattresses, sleeping bags), in pairs/amounts	1.9E+07			x			0	20	2	0	10	0	0	0	0	0	68
Bed linens																	
Bed linens of cotton (excluding knitted or crocheted), in kg	2.8E+08			x			0	100	0	0	0	0	0	0	0	0	0
Bed linens of woven textiles (excluding of cotton, flax or ramie), in kg	9.5E+07			x			0	0	0	60	37	0	0	3	0	0	0
Bed linens of knitted or crocheted textiles	5.3E+07		x				0	38	0	32	30	0	0	0	0	0	0
Bed linens of non-woven synthetic fibres (excluding knitted or crocheted), in kg	8.1E+06				x		0	0	0	32	60	0	0	8	0	0	0
Bed linens of flax or ramie (excluding knitted or crocheted), in kg	1.0E+06			x			0	0	100	0	0	0	0	0	0	0	0
Blankets and travelling rugs																	
Blankets and travelling rugs of synthetic fibres (excluding electric blankets), in pairs/amounts	1.0E+08			x			0	0	0	0	20	0	0	28	0	52	0
Blankets (excluding electric blankets) and travelling rugs of textile materials (excluding of wool or fine animal hair, synthetic fibres), in pairs/amounts	2.0E+07			x			0	60	40	0	0	0	0	0	0	0	0
Blankets and travelling rugs of wool or fine animal hair (excluding electric blankets), in pairs/amounts	5.0E+06		x	x			100	0	0	0	0	0	0	0	0	0	0
Floor cloths, dishcloths, dusters, etc.																	
Floor-cloths, dishcloths, dusters and similar cleaning cloths (excluding knitted or crocheted, articles of non-woven textiles), in kg	6.8E+07			x			0	11	0	18	31	0	18	22	0	0	0
Floor-cloths, dishcloths, dusters and similar cleaning cloths, of non-woven textiles, in kg	3.8E+07				x		0	0	0	16	24	0	38	22	0	0	0
Curtains, blinds, etc.																	
Curtains and interior blinds, curtain or bed valances, of woven materials, in m^2	7.0E+08			x			0	35	0	0	59	0	0	6	0	0	0
Curtains and interior blinds, curtain or bed valances, of knitted or crocheted materials, in m^2	9.2E+07		x				0	35	0	0	44	0	0	21	0	0	0
Curtains and interior blinds, curtain or bed valances, of non-woven materials	2.9E+07				x		0	29	0	0	51	0	0	20	0	0	0
Floor coverings																	
Tufted carpets and other tufted textile floor coverings , in m^2	6.5E+08				Tufted		0	0	0	0	24	0	22	48	0	6	0
Needle felt carpets and other needle felt textile floor coverings (excluding tufted or flocked), in m^2	1.9E+08				x		0	0	0	0	20	0	26	54	0	0	0
Carpets and other textile floor coverings (excluding knotted, woven, tufted, needle felt), in m^2	1.6E+08		x				0	0	0	0	22	0	26	44	0	8	0
Knotted carpets and other knotted textile floor coverings, in m^2	2.1E+07				Knotted		44	16	2	0	20	0	0	10	0	8	0

	EU-27 TOTALS (units or pairs)		Process types				Breakdown of consumption (%)										
			Woven	Knitted	Non-woven		WO	CO	FL	VI	PES	PU	PP	PA	PVC	PAC	FEA
Kitchen and toilet linens																	
Kitchen and toilet linens, of terry towelling or similar terry fabrics of cotton, in kg	**2.3E+08**			**x**			0	100	0	0	0	0	0	0	0	0	0
Woven kitchen and toilet linens, of textiles (excluding terry towelling or similar terry fabrics of cotton), in kg	**3.7E+07**			**x**			0	70	0	20	10	0	0	0	0	0	0
Kitchen and toilet linens, of non-woven synthetic fibres, in kg	**1.9E+06**				**x**		0	0	0	40	26	0	34	0	0	0	0
Table linens																	
Table linens of cotton (excluding knitted or crocheted), in kg	**4.1E+07**			**x**			0	100	0	0	0	0	0	0	0	0	0
Table linens of woven synthetic fibres and of other woven or non-woven textiles (excluding of cotton, flax), in kg	**1.6E+07**			**x**			0	0	0	33	37	0	0	24	6	0	0
Table linens of flax (excluding knitted or crocheted), in kg	**3.8E+06**			**x**			0	0	100	0	0	0	0	0	0	0	0
Table linens of knitted or crocheted textiles, in kg	**3.5E+06**		**x**				0	44	0	6	35	0	0	15	0	0	0
Table linens of non-woven synthetic fibres, in kg	**2.7E+06**				**x**		0	0	0	0	23	0	24	37	16	0	0

WO	Wool or other animal hair
CO	Cotton
FL	Flax and ramie
VI	Viscose
PES	Polyester
PU	Polyurethane (Lycra Spandex)
PP	Polypropylene
PA	Polyamide (nylon)
PVC	Poly vinyl chloride
PAC	Acrylic
FEA	Feathers

Own assumption

Cotton incorporated, 2001

Rugs and carpets, 2009

Average figures provided by Ensait

x Process chosen

➢ Breakdown into total weights per end product and fibre type for clothing textiles

Product	Specific consumption	Weight (in g)			Total average weight (in 1000 tonnes)	Total weight per fibre type (in 1000 tonnes)								
		Avg	Min	Max		WO	CO	SI	FL	VI	PA	PAC	PU/PP	PES
TOPS														
T-shirts, vests, singlets, etc.	**3.8E+09**	210	170	250	873.8	0	480.6	0	0	87.4	43.7	87.4	0	174.8
Shirts or blouses (knitted or crocheted)	**7.8E+08**	197	93	225	167.8	0	104.0	0	0	30.2	1.7	5.0	0	26.8
Shirts or blouses (excluding knitted or crocheted)	**1.1E+09**	197	93	225	243.8	0	156.0	0	0	43.9	2.4	7.3	0	34.1
Jerseys, jumpers, pullovers, etc. (cotton)	**7.6E+08**	575	250	900	476.2	0	476.2	0	0	0	0	0	0	0
Jerseys, jumpers, pullovers, etc. (MMF)	**8.9E+08**	575	250	900	556.8	0	0	0	0	55.7	61.3	417.6	0	22.3
Jerseys, jumpers, pullovers, etc. (wool or fine animal hair)	**2.8E+08**	575	250	900	174.0	174.0	0	0	0	0	0	0	0	0
UNDERWEAR														
Briefs, panties, underpants, etc. (knitted or crocheted)	**2.7E+09**	125	25	150	365.0	0	167.9	0	0	25.6	94.9	11.0	36.5	29.2
Briefs, panties, underpants, etc. (excluding knitted or crocheted)	**1.2E+08**	125	25	150	16.6	0	7.6	0	0	1.2	4.3	0.5	1.7	1.3
Hosiery (knitted or crocheted)	**6.4E+09**	60	20	100	420.0	21.0	172.2	0	0	29.4	109.2	12.6	42.0	33.6
Hosiery (excluding knitted or crocheted)	**1.5E+08**	60	20	100	9.7	0.5	4.0	0	0	0.7	2.5	0.3	1.0	0.8
Slips, petticoats and girdles (other)	**6.2E+07**	100	50	150	6.8	0	3.1	0	0	0.5	1.8	0.2	0.7	0.5
Slips, petticoats and girdles (knitted or crocheted)	**2.1E+07**	100	50	150	2.3	0	1.1	0	0	0.2	0.6	0.1	0.2	0.2
Slips, petticoats and girdles (excluding knitted or crocheted)	**9.9E+06**	100	50	150	1.1	0	0.5	0	0	0.1	0.3	0	0.1	0.1
Brassieres	**6.3E+08**	100	30	170	68.9	0	15.8	0	0	4.8	16.5	0	8.3	23.4
Nightwear (knitted or crocheted)	**4.6E+08**	210	120	300	105.3	0	87.4	0	0	4.2	5.3	0	0	8.4
Nightwear (excluding knitted or crocheted)	**1.3E+08**	210	120	300	29.0	0	24.1	0	0	1.2	1.5	0	0	2.3
Negligees, bathrobes, dressing gowns, etc. (knitted or crocheted)	**6.6E+07**	525	150	900	37.6	0	30.1	0	0	1.1	1.9	0	0	4.5
Negligees, bathrobes, dressing gowns, etc. (excluding knitted or crocheted)	**1.6E+07**	525	150	900	8.9	0	7.1	0	0	0.3	0.4	0.2	0	0.9
Other underwear, nightwear and hosiery (cotton, knitted or crocheted)	**1.1E+08**	163	25	300	20.3	0	20.3	0	0	0	0	0	0	0
Other underwear, nightwear and hosiery (excluding cotton, MMF, knitted or crocheted)	**2.1E+07**	163	25	300	3.6	3.6	0	0	0	0	0	0	0	0
Other underwear, nightwear and hosiery (excluding knitted or crocheted)	**2.7E+07**	163	25	300	4.7	0	2.2	0	0	0.3	1.2	0.1	0.5	0.4
Other underwear, nightwear and hosiery (other)	**6.7E+06**	163	25	300	1.2	0	0.5	0	0	0.1	0.3	0	0.1	0.1
JACKETS														
Anoraks, ski jackets, etc.	**3.3E+08**	434	300	900	154.1	0	15.4	0	0	0	46.2	0	0	92.5
Anoraks, ski jackets, etc. (knitted or crocheted)	**6.0E+07**	434	300	900	28.3	0	2.8	0	0	0	8.5	0	0	17.0
Jackets and blazers (knitted or crocheted)	**7.9E+07**	700	300	1700	60.2	45.8	0	0	0	4.8	0	0	0	9.6
Jackets and blazers (excluding knitted or crocheted)	**1.9E+08**	700	300	1700	145.8	110.8	0	0	0	11.7	0	0	0	23.3
Jackets and blazers (cotton or MMF)	**3.2E+07**	700	300	1700	24.2	0	5.3	0	0	0	0	2.4	0	16.5
Raincoats	**7.8E+07**	600	500	800	50.7	0	0	0	0	2.5	22.8	0	0	25.3
Overcoats, car coats, capes, other	**6.3E+07**	1500	780	2000	103.3	33.1	5.2	0	0	0	5.2	34.1	0	25.8

Product	Specific consumption	Weight (in g)			Total average weight (in 1000 tonnes)	Total weight per fibre type (in 1000 tonnes)								
		Avg	Min	Max		WO	CO	SI	FL	VI	PA	PAC	PU/PP	PES
Overcoats, car coats, capes (knitted or crocheted)	**3.6E+07**	1500	780	2000	58.5	18.7	2.9	0	0	0	2.9	19.3	0	14.6
BOTTOMS														
Trousers, breeches, overalls, etc. (cotton, excluding denim)	**4.2E+08**	568	320	800	260.4	0	260.4	0	0	0	0	0	0	0
Trousers, breeches, overalls, etc. (cotton, excluding denim, knitted or crocheted)	**3.5E+08**	568	320	800	217.0	0	217.0	0	0	0	0	0	0	0
Trousers, breeches, overalls, etc. (cotton, excluding knitted or crocheted)	**7.7E+06**	568	320	800	4.7	0	4.7	0	0	0	0	0	0	0
Trousers, breeches, overalls, etc. (MMF, excluding knitted or crocheted)	**1.0E+08**	568	320	800	64.3	0	0	0	0	25.7	2.6	3.2	0	32.8
Trousers, breeches, overalls, etc. (cotton or MMF)	**1.0E+08**	568	320	800	64.3	0	35.4	0	0	14.8	1.3	1.3	0	11.6
Trousers, breeches, overalls, etc. (excluding knitted or crocheted)	**3.5E+07**	568	320	800	21.7	21.7	0	0	0	0	0	0	0	0
Trousers, breeches, overalls, etc. (excluding cotton, wool or fine animal hair, MMF, knitted or crocheted)	**1.1E+08**	568	320	800	65.7	0	0	0	0	65.7	0	0	0	0
Trousers, breeches, overalls, etc (knitted or crocheted)	**5.6E+08**	568	320	800	344.7	27.6	155.1	0	0	86.2	6.9	6.9	0	62.0
Trousers, breeches, overalls, etc. (other)	**3.1E+06**	568	320	800	1.9	0.3	0	0	0	0.6	0.1	0.1	0	0.8
Trousers, breeches, overalls, etc. (denim)	**4.6E+08**	568	320	800	284.9	0	273.5	0	0	0	0	0	0	11.4
Shorts (MMF)	**5.8E+07**	300	200	400	19.0	0	0	0	0	7.6	1.0	1.0	0	9.5
Shorts (cotton)	**8.5E+07**	300	200	400	27.7	0	27.7	0	0	0	0	0	0	0
Shorts (cotton and MMF)	**9.1E+07**	300	200	400	29.6	0	16.3	0	0	6.8	0.6	0.6	0	5.3
Skirts (excluding knitted or crocheted)	**3.1E+08**	385	250	480	128.0	3.8	9.0	2.6	2.6	32.0	0	3.8	0	74.2
Skirts (knitted or crocheted)	**5.5E+07**	385	250	480	22.9	0.7	2.1	0	0	5.7	0.2	0.7	0.2	13.3
Skirts (excluding wool or fine animal hair, MMF, knitted or crocheted)	**2.2E+08**	385	250	480	90.5	0	90.5	0	0	0	0	0	0	0
DRESSED														
Dresses (excluding knitted or crocheted)	**2.1E+08**	1125	250	2000	256.9	0	15.4	0	0	64.2	0	2.6	0	174.7
Dresses (knitted or crocheted)	**1.4E+08**	1125	250	2000	171.1	0	10.3	0	0	42.8	0	1.7	0	116.3
SWIMWEAR														
Swimwear (knitted or crocheted)	**2.2E+08**	140	80	200	33.7	0	0	0	0	0	25.2	0	8.4	0
Swimwear (excluding knitted or crocheted)	**7.5E+07**	140	80	200	11.4	0	0	0	0	0	8.6	0	2.9	0
SPORTSWEAR														
Tracksuits	**1.3E+08**	475	380	600	65.9	0	17.1	0	0	5.9	17.1	0	4.6	21.1
Ski suits (knitted or crocheted)	**1.8E+05**	1703	1400	2005	0.3	0	0	0	0	0	0.2	0	0	0.2
Ski suits (excluding knitted or crocheted)	**4.2E+06**	1703	1400	2005	7.7	0	0	0	0	0	3.8	0	0	3.8
SUITS AND ENSEMBLES														
Suits and ensembles (knitted or crocheted)	**1.0E+08**	921	790	1400	103.8	77.9	0	0	0	6.2	0	2.1	0	17.6
Suits and ensembles (excluding knitted or crocheted)	**9.4E+07**	921	790	1400	94.5	70.9	0	0	0	0	0	0.9	0	22.7
Suits and ensembles (cotton of MMF)	**2.5E+07**	921	790	1400	25.2	0	1.3	0	0	5.0	0	1.3	0	17.6
GLOVES														
Gloves (knitted or crocheted)	**1.2E+09**	48	25	70	60.8	32.9	3.7	0	0	0	3.0	18.3	0	3.0
Gloves (excluding knitted or crocheted)	**1.7E+08**	55	25	70	9.9	5.3	0.6	0	0	0	0.5	3.0	0	0.5

Product	Specific consumption	Weight (in g)			Total average weight (in 1000 tonnes)	Total weight per fibre type (in 1000 tonnes)								
		Avg	Min	Max		WO	CO	SI	FL	VI	PA	PAC	PU/PP	PES
SCARVES, SHAWLS														
Scarves, shawls, etc. (knitted or crocheted)	**3.5E+07**	121	65	176	4.6	3.4	0.7	0.2	0	0	0	0.2	0	0
Scarves, shawls, etc. (excluding knitted or crocheted)	**1.8E+07**	121	65	176	2.4	1.8	0.4	0.1	0	0	0	0.1	0	0
Scarves, shawls, etc. (excluding articles of silk or silk waste, knitted or crocheted)	**2.2E+08**	121	65	176	28.3	18.4	7.1	0	0	0	0	2.8	0	0
Ties, bow ties and cravats (excluding knitted or crocheted)	**8.9E+07**	75	40	110	7.3	0	0	5.6	0	0	0	0	0	1.7
Ties, bow ties and cravats (excluding articles of silk or silk waste, knitted or crocheted)	**5.5E+07**	75	40	110	4.5	0	0	0	0	0.5	0	0	0	4.0

WO	Wool or other animal hair
CO	Cotton
SI	Silk
FL	Flax and ramie
VI	Viscose
PA	Polyamide (nylon)
PAC	Acrylic
PU/PP	Polyurethane (Lycra Spandex) / Polypropylene
PES	Polyester

Estimation
Weight data from Bhalla, 2005

➢ Breakdown into total weights per end product and fibre type for household textiles

Product	Specific consumption	Average weight (in g)	Total average weight (in 1000 tonnes)	Total weight per fibre type (in 1000 tonnes)										
				WO	CO	FL	VI	PES	PU	PP	PA	PVC	PAC	FEA
Articles of bedding														
Articles of bedding filled other than with feathers or down (including quilts and eiderdown comforters, cushions, pouffes, pillows; excluding mattresses, sleeping bags) in pairs/amounts	**1.6E+08**													
Articles of bedding of feathers or down (including quilts and eiderdown comforters, cushions, pouffes, pillows; excluding mattresses, sleeping bags), in pairs/amounts	**1.9E+07**	2000	310.1	0	31	6	0	186	31	0	40	16	0	0
Bed linens														
Bed linens of cotton (excluding knitted or crocheted), in kg	**2.8E+08**			0	0	0	0	0	0	0	0	0	0	0
Bed linens of woven textiles (excluding of cotton, of flax or ramie), in kg	**9.5E+07**		281.4	0	281	0	0	0	0	0	0	0	0	0
Bed linens of knitted or crocheted textiles, in kg	**5.3E+07**		94.7	0	0	0	57	35	0	0	3	0	0	0
Bed linens of non-woven synthetic fibres (excluding knitted or crocheted), in kg	**8.1E+06**		53.3	0	20	0	17	16	0	0	0	0	0	0
Bed linens of flax or ramie (excluding knitted or crocheted) in kg	**1.0E+06**		8.1											
Blankets and travelling rugs														
Blankets and travelling rugs of synthetic fibres (excluding electric blankets), in pairs/amounts	**1.0E+08**			0	0	0	0	0	0	0	0	0	0	0
Blankets (excluding electric blankets) and travelling rugs of textile materials (excluding of wool or fine animal hair, of synthetic fibres), in pairs/amounts	**2.0E+07**	1150	117.0	0	0	0	0	23	0	0	33	0	61	0
Blankets and travelling rugs of wool or fine animal hair (excluding electric blankets), in pairs/amounts	**5.0E+06**	1150	22.8	0	14	9	0	0	0	0	0	0	0	0
Floor cloths, dishcloths, dusters, etc.														
Floor cloths, dishcloths, dusters and similar cleaning cloths (excluding knitted or crocheted, articles of non-woven textiles), in kg	**6.8E+07**			0	0	0	0	0	0	0	0	0	0	0
Floor cloths, dishcloths, dusters and similar cleaning cloths, of non-woven textiles, in kg	**3.8E+07**		68.4	0	8	0	12	21	0	12	15	0	0	0
Curtains, blinds, etc.														
Curtains and interior blinds, curtain or bed valances, of woven materials, in m^2	**7.0E+08**			0	0	0	0	0	0	0	0	0	0	0
Curtains and interior blinds, curtain or bed valances, of knitted or crocheted materials, in m^2	**9.2E+07**	458	321.9	0	0	0	0	0	0	0	0	0	0	0
Curtains and interior blinds, curtain or bed valances, of non-woven materials, in m^2	**2.9E+07**	458	42.1	0	0	0	0	0	0	0	0	0	0	0
Floor coverings														

Product	Specific consumption	Average weight (in g)	Total average weight (in 1000 tonnes)	Total weight per fibre type (in 1000 tonnes)										
				WO	CO	FL	VI	PES	PU	PP	PA	PVC	PAC	FEA
Tufted carpets and other tufted textile floor coverings, in m^2	**6.5E+08**			0	0	0	0	0	0	0	0	0	0	0
Needle felt carpets and other needle felt textile floor coverings (excluding tufted or flocked), in m^2	**1.9E+08**	1185	771.1	0	0	0	0	185	0	170	370	0	46	0
Carpets and other textile floor coverings (excluding knotted, woven, tufted, needle felt), in m^2	**1.6E+08**	400	77.3	0	0	0	0	15	0	20	42	0	0	0
Knotted carpets and other knotted textile floor coverings, in m^2	**2.1E+07**	1185	190.6	0	0	0	0	42	0	50	84	0	15	0
Kitchen and toilet linens														
Kitchen and toilet linens, of terry towelling or similar terry fabrics of cotton, in kg	**2.3E+08**			0	0	0	0	0	0	0	0	0	0	0
Woven kitchen and toilet linens, of textiles (excluding terry towelling or similar terry fabrics of cotton), in kg	**3.7E+07**		226.2	0	226	0	0	0	0	0	0	0	0	0
Kitchen and toilet linens, of non-woven synthetic fibres, in kg	**1.9E+06**		37.4	0	26	0	7	4	0	0	0	0	0	0
Table linens														
Table linens of cotton (excluding knitted or crocheted), in kg	**4.1E+07**			0	0	0	0	0	0	0	0	0	0	0
Table linens of woven synthetic fibres and of other woven or non-woven textiles (excluding of cotton, of flax) in kg	**1.6E+07**		40.8	0	41	0	0	0	0	0	0	0	0	0
Table linens of flax (excluding knitted or crocheted) in kg	**3.8E+06**		16.3	0	0	0	5	6	0	0	4	1	0	0
Table linens of knitted or crocheted textiles, in kg	**3.5E+06**		3.8	0	0	4	0	0	0	0	0	0	0	0
Table linen of non-woven synthetic fibres, in kg	**2.7E+06**		3.5											

WO	Wool or other animal hair
CO	Cotton
FL	Flax and ramie
VI	Viscose
PES	Polyester
PU	Polyurethane (Lycra Spandex)
PP	Polypropylene
PA	Polyamide (nylon)
PVC	Poly vinyl chloride
PAC	Acrylic
FEA	Feathers

Estimation

➢ Confection losses and user washing behaviour related to clothing textiles

PRODUCT	Lifetime Number of washes	Ratio machine wash/handwash	Ratio dry/wash in %	Ratio iron/wash	Ironing time (in minutes)	Confection losses in %
TOPS						
T-shirts, vests, singlets, etc.	50	100	25	100	3	13
Shirts or blouses (knitted or crocheted)	25	100	25	100	3	13
Shirts or blouses (excluding knitted or crocheted)	25	100	25	100	3	13
Jerseys, jumpers, pullovers, etc. (cotton)	50	100	25	100	3	10
Jerseys, jumpers, pullovers, etc. (MMF)	50	100	25	100	3	10
Jerseys, jumpers, pullovers, etc. (wool or fine animal hair)	50	100	25	0	1	10
UNDERWEAR, NIGHTWEAR AND HOSIERY						
Briefs, panties, underpants, etc. (knitted or crocheted)	104	100	25	0	1	16
Briefs, panties, underpants, etc. (excluding knitted or crocheted)	104	100	25	0	3	16
Hosiery (knitted or crocheted)	104	100	0	0	0	0
Hosiery (excluding knitted or crocheted)	104	100	0	0	0	0
Slips, petticoats and girdles (other)	104	100	25	0	1	18
Slips, petticoats and girdles (knitted or crocheted)	104	100	25	0	1	18
Slips, petticoats and girdles (excluding knitted or crocheted)	104	100	25	0	1	18
Brassieres	40	100	0	0	0	18
Nightwear (knitted or crocheted)	50	100	25	0	6	13
Nightwear (excluding knitted or crocheted)	50	100	25	0	6	13
Negligees, bathrobes, dressing gowns, etc. (knitted or crocheted)	24	100	0	0	6	15
Negligees, bathrobes, dressing gowns, etc. (excluding knitted or crocheted)	24	100	0	0	10	15
Other underwear, nightwear and hosiery (cotton, knitted or crocheted)	52	100	25	0	6	18
Other underwear, nightwear and hosiery (excluding cotton, MMF, knitted or crocheted)	52	100	25	0	6	18
Other underwear, nightwear and hosiery (excluding knitted or crocheted)	52	100	25	0	4	18
Other underwear, nightwear and hosiery (other)	52	100	25	0	4	18
JACKETS						

PRODUCT	Lifetime Number of washes	Ratio machine wash/handwash	Ratio dry/wash in %	Ratio iron/wash	Ironing time (in minutes)	Confection losses in %
Anoraks, ski jackets, etc.	10	100	25	0	0	12
Anoraks, ski jackets, etc. (knitted or crocheted)	10	100	25	0	0	12
Jackets and blazers (knitted or crocheted)	40	100	25	0	3	16
Jackets and blazers (excluding knitted or crocheted)	40	100	25	0	5	16
Jackets and blazers (cotton or MMF)	40	100	25	0	5	16
Raincoats	0	0	0	0	0	14
Overcoats, car coats, capes (other)	1	0	0	0	3	14
Overcoats, car coats, capes (knitted or crocheted)	1	0	0	0	3	14
BOTTOMS						
Trousers, breeches, overalls, etc. (cotton, excluding denim)	92	100	25	100	6	14
Trousers, breeches, overalls, etc. (cotton, excluding denim, knitted or crocheted)	92	100	25	100	3	14
Trousers, breeches, overalls, etc. (cotton, excluding knitted or crocheted)	92	100	25	100	6	14
Trousers, breeches, overalls, etc. (MMF, excluding knitted or crocheted)	92	100	25	100	3	14
Trousers, breeches, overalls, etc. (cotton or MMF)	92	100	25	100	6	14
Trousers, breeches, overalls, etc. (excluding knitted or crocheted)	92	100	25	100	6	14
Trousers, breeches, overalls, etc. (excluding cotton, wool or fine animal hair, MMF, knitted or crocheted)	92	100	25	100	3	14
Trousers, breeches, overalls, etc. (knitted or crocheted)	92	100	25	100	3	14
Trousers, breeches, overalls, etc. (other)	92	100	25	100	3	14
Trousers, breeches, overalls, etc. (denim)	92	100	25	100	6	14
Shorts (MMF)	24	100	25	100	3	15
Shorts (cotton)	24	100	25	100	6	15
Shorts (cotton and MMF)	24	100	25	100	3	15
Skirts (excluding knitted or crocheted)	24	100	25	100	3	14
Skirts (knitted or crocheted)	24	100	25	100	6	14
Skirts (excluding wool or fine animal hair, MMF, knitted or crocheted)	24	100	25	100	3	14
DRESSES						

PRODUCT	Lifetime Number of washes	Ratio machine wash/handwash	Ratio dry/wash in %	Ratio iron/wash	Ironing time (in minutes)	Confection losses in %
Dresses (excluding knitted or crocheted)	15	100	0	100	6	18
Dresses (knitted or crocheted)	15	100	0	100	3	18
SWIMWEAR						
Swimwear (knitted or crocheted)	0	0	0	0	0	18
Swimwear (excluding knitted or crocheted)	0	0	0	0	0	18
SPORTWEAR						
Tracksuits	24	100	0	0	6	15
Ski suits (knitted or crocheted)	6	100	0	0	0	14
Ski suits (excluding knitted or crocheted)	6	100	0	0	0	14
SUITS AND ENSEMBLES						
Suits and ensembles (knitted or crocheted)	40	100	0	100	3	14
Suits and ensembles (excluding knitted or crocheted)	40	100	0	100	3	14
Suits and ensembles (cotton of MMF)	40	100	0	100	3	14
GLOVES						
Gloves (knitted or crocheted)	4	100	0	0	0	18
Gloves (excluding knitted or crocheted)	4	100	0	0	0	18
SCARVES, SHAWLS, TIES, ETC.						
Scarves, shawls, etc. (knitted or crocheted)	12	0	0	0	1	4
Scarves, shawls, etc. (excluding knitted or crocheted)	12	0	0	0	4	4
Scarves, shawls, etc. (excluding articles of silk or silk waste, knitted or crocheted)	12	0	0	0	1	4
Ties, bow ties and cravats (excluding knitted or crocheted)	0	0	0	0	4	5
Ties, bow ties and cravats (excluding articles of silk or silk waste, knitted or crocheted)	0	0	0	0	2	5

Laursen *et al.*, 2007
Allwood *et al.*, 2006
Own estimate
Collins & Aumônier, 2002

➤ Confection losses and user washing behaviour related to household textiles

PRODUCT	Lifetime	Ratio	Ratio dry/wash in %	Ratio iron/wash in %	Ironing time (in minutes)	Confection losses (in %)
	Number of washes	machine wash/handwash in %				
ARTICLES OF BEDDING						
Articles of bedding filled other than with feathers or down (including quilts and eiderdown comforters, cushions, pouffes, pillows; excluding mattresses, sleeping bags)	10	100	80	0	0	4
Articles of bedding of feathers or down (including quilts and eiderdown comforters, cushions, pouffes, pillows; excluding mattresses, sleeping bags), in pairs/amounts	30	100	80	0	0	4
BED LINENS						
Bed linens of cotton (excluding knitted or crocheted), in kg	80	100	100	100	10	3
Bed linens of woven textiles (excluding of cotton, of flax or ramie) in kg	80	100	100	100	10	3
Bed linens of knitted or crocheted textiles	80	100	20	0	10	3
Bed linens of non-woven synthetic fibres (excluding knitted or crocheted; in kg	80	100	100	100	10	3
Bed linens of flax or ramie (excluding knitted or crocheted), in kg	80	100	100	100	10	3
BLANKETS AND TRAVELLING RUGS						
Blankets and travelling rugs of synthetic fibres (excluding electric blankets), in pairs/amounts	100	100	20	0	0	3
Blankets (excluding electric blankets) and travelling rugs of textile materials (excluding wool or fine animal hair, of synthetic fibres), in pairs/amounts	100	100	20	0	0	3
Blankets and travelling rugs of wool or fine animal hair (excluding electric blankets), in pairs/amounts	100	100	0	0	0	3
FLOOR CLOTHS, DISHCLOTHS, DUSTERS, ETC.						
Floor cloths, dishcloths, dusters and similar cleaning cloths (excluding knitted or crocheted, articles of non-woven textiles), in kg	100	100	45	100	3	5
Floor cloths, dishcloths, dusters and similar cleaning cloths, of non-woven textiles, in kg	100	100	45	100	3	5
CURTAINS, BLINDS, ETC.						
Curtains and interior blinds, curtain or bed valances, of woven materials, in m^2	20	100	45	100	10	3
Curtains and interior blinds, curtain or bed valances, of knitted or crocheted materials, in m^2	20	100	45	100	10	3
Curtains and interior blinds, curtain or bed valances, of non-woven materials	20	100	45	100	10	3
FLOOR COVERINGS						
Tufted carpets and other tufted textile floor coverings, in m^2	0	0	0	0	0	0
Needle felt carpets and other needle felt textile floor coverings (excluding tufted or flocked), in m^2	0	0	0	0	0	0

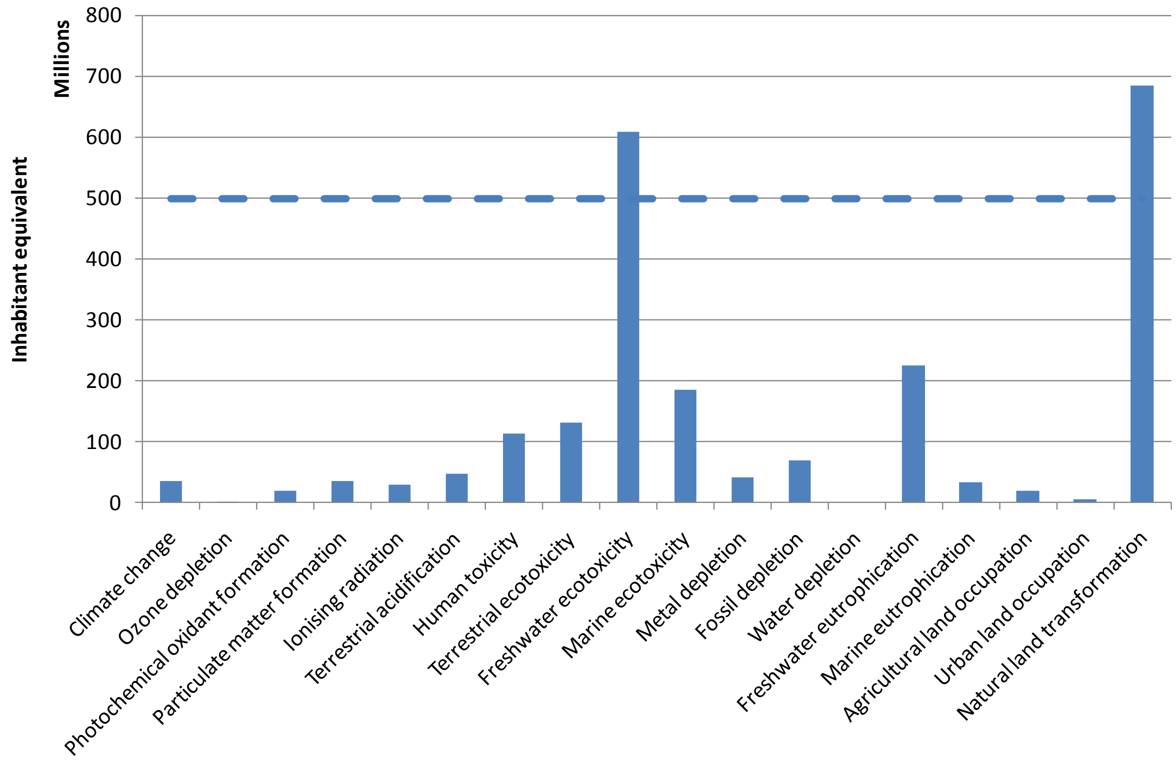
PRODUCT	Lifetime Number of washes	Ratio machine wash/handwash in %	Ratio dry/wash in %	Ratio iron/wash in %	Ironing time (in minutes)	Confection losses (in %)
Carpets and other textile floor coverings (excluding knotted, woven, tufted, needle felt), in m^2	0	0	0	0	0	0
Knotted carpets and other knotted textile floor coverings, in m^2	0	0	0	0	0	0
KITCHEN AND TOILET LINENS						
Kitchen and toilet linens of terry towelling or similar terry fabrics of cotton, in kg	100	100	0	0	0	5
Woven kitchen and toilet linens of textiles (excluding terry towelling or similar terry fabrics of cotton), in kg	100	100	0	0	0	5
Kitchen and toilet linens of non-woven synthetic fibres, in kg	100	100	0	0	0	5
TABLE LINENS						
Table linens of cotton (excluding knitted or crocheted), in kg	25	100	0	100	10	9
Table linens of woven synthetic fibres and of other woven or non-woven textiles (excluding of cotton, of flax), in kg	25	100	0	100	10	9
Table linens of flax (excluding knitted or crocheted), in kg	25	100	0	100	10	9
Table linens of knitted or crocheted textiles, in kg	25	100	0	100	10	9
Table linens of non-woven synthetic fibres, in kg	25	100	0	100	10	9

Laursen *et al.*, 2007.
Own estimate.
RCSC (2004) Life cycle analysis of cotton towels.

Annex 2: Normalisation of the environmental impacts of the textile life cycle for the baseline scenario

According to the ISO 14040 and ISO 14044 standards, the results of an LCA study can be normalised by benchmark values and referred to a common unit with the aim of easing their interpretation.
In this study, the environmental impacts of the textiles life cycle are normalised to 'inhabitant equivalents' (Wegener *et al.*, 2008). One 'inhabitant equivalent' corresponds to the yearly environmental impact of one ‘average’ citizen of a given geographic area with respect to a given indicator. A global geographical scale was considered in this study.

Figure 58 presents the normalised indicators for the baseline scenario. Natural land transformation, toxicity-related indicators and freshwater eutrophication appear as the most critical indicators of the system modelled. This is due to the important impacts of detergent use and fibre cultivation. It should however be noted that the normalisation scores, which are used as a reference basis, are calculated taking into account for a limited number of flows at the macroscopic level (national/regional inventories). This tends to overestimate normalised results, especially when more flows are included in the LCA model than in the reference score, which is particularly true, for example, for indicators related to toxicity. Considering the uncertainty related to the normalisation procedure, results from Figure 58 should be thus interpreted with care.



Source: UN, January 2009

Figure 58: Impacts of textile consumption in the EU-27, midpoint indicators, normalised with respect to the estimated burdens generated by an 'average' citizen of the world. EU-27 population: 499.8 million

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Annex 3: Detailed results

CLOTHING MINIMUM AND MAXIMUM WEIGHTS

			Production					Transport					Use					End-of-life					Total				
	Indicator	Unit	Baseline scenario	minimum weights	% change compared to baseline	maximum weights	% change compared to baseline	Baseline scenario	minimum weights	% change compared to baseline	maximum weights	% change compared to baseline	Baseline scenario	minimum weights	% change compared to baseline	maximum weights	% change compared to baseline	Baseline scenario	minimum weights	% change compared to baseline	maximum weights	% change compared to baseline	Baseline scenario	minimum weights	% change compared to baseline	maximum weights	% change compared to baseline
MIDPOINTS	Climate change	kg CO2 eq	2.13E+11	1.42E+11	-33.5	2.86E+11	33.9	2.07E+10	1.22E+10	-41.2	2.92E+10	40.9	1.85E+11	1.33E+11	-28.2	2.28E+11	23.3	-6.38E+09	-3.23E+09	-49.4	-9.51E+09	49.0	4.13E+11	2.83E+11	-31.3	5.33E+11	29.3
	Ozone depletion	kg CFC-11 eq	1.65E+04	1.07E+04	-35.0	2.21E+04	34.1	2.63E+03	1.54E+03	-41.4	3.70E+03	41.0	1.04E+04	7.25E+03	-30.0	1.29E+04	24.9	-3.48E+01	1.14E+01	-132.6	-8.41E+01	141.3	2.94E+04	1.95E+04	-33.7	3.86E+04	31.3
	Photochemical oxidant formation	kg NMVOC	5.21E+08	3.45E+08	-33.8	6.99E+08	34.2	1.27E+08	7.47E+07	-41.3	1.79E+08	40.9	4.47E+08	3.15E+08	-29.6	5.56E+08	24.5	-7.60E+06	-2.88E+06	-62.1	-1.23E+07	61.5	1.09E+09	7.31E+08	-32.8	1.42E+09	30.8
	Particulate matter formation	kg PM10 eq	2.63E+08	1.74E+08	-34.0	3.54E+08	34.5	3.74E+07	2.20E+07	-41.2	5.27E+07	40.8	2.60E+08	1.85E+08	-29.0	3.23E+08	24.0	-8.36E+06	-4.17E+06	-50.1	-1.25E+07	49.4	5.52E+08	3.76E+08	-31.9	7.17E+08	29.8
	Ionising radiation	kg U235 eq	7.99E+10	5.37E+10	-32.7	1.08E+11	35.6	1.20E+09	7.02E+08	-41.6	1.70E+09	41.2	1.14E+11	8.46E+10	-26.0	1.39E+11	21.3	-6.04E+09	-3.20E+09	-47.1	-8.84E+09	46.4	1.89E+11	1.36E+11	-28.2	2.40E+11	26.7
	Terrestrial acidification	kg SO2 eq	8.51E+08	5.59E+08	-34.3	1.15E+09	34.6	1.12E+08	6.61E+07	-41.1	1.58E+08	40.8	7.47E+08	5.37E+08	-28.1	9.20E+08	23.2	-2.72E+07	-1.37E+07	-49.5	-4.05E+07	48.9	1.68E+09	1.15E+09	-31.7	2.18E+09	29.7
	Human toxicity	kg 1,4-DB eq	1.25E+10	8.16E+09	-34.6	1.69E+10	35.4	4.43E+08	2.58E+08	-41.7	6.26E+08	41.3	6.35E+10	4.01E+10	-36.7	8.30E+10	30.9	-5.68E+08	-2.97E+08	-47.8	-8.36E+08	47.2	7.58E+10	4.83E+10	-36.3	9.97E+10	31.5
	Terrestrial ecotoxicity	kg 1,4-DB eq	9.43E+08	5.92E+08	-37.3	1.24E+09	31.7	1.91E+06	1.12E+06	-41.4	2.69E+06	41.0	1.44E+08	9.00E+07	-37.3	1.89E+08	31.4	-9.83E+05	-5.15E+05	-47.6	-1.44E+06	46.9	1.09E+09	6.82E+08	-37.3	1.43E+09	31.6
	Freshwater ecotoxicity	kg 1,4-DB eq	1.68E+09	1.06E+09	-36.8	2.22E+09	31.6	1.24E+07	7.24E+06	-41.8	1.76E+07	41.4	5.64E+09	3.45E+09	-38.8	7.48E+09	32.6	-7.13E+06	-3.73E+06	-47.7	-1.05E+07	47.1	7.33E+09	4.52E+09	-38.3	9.71E+09	32.4
	Marine ecotoxicity	kg 1,4-DB eq	3.76E+08	2.44E+08	-35.1	5.04E+08	34.1	2.32E+07	1.36E+07	-41.4	3.28E+07	41.0	1.28E+09	8.13E+08	-36.7	1.68E+09	30.8	-1.18E+07	-6.17E+06	-47.5	-1.73E+07	46.9	1.67E+09	1.06E+09	-36.4	2.20E+09	31.6
	Metal depletion	kg Fe eq	1.09E+10	7.05E+09	-35.6	1.48E+10	35.4	2.13E+08	1.21E+08	-43.1	3.04E+08	42.7	2.19E+10	1.43E+10	-34.8	2.83E+10	29.1	-3.74E+08	-1.97E+08	-47.3	-5.48E+08	46.6	3.27E+10	2.13E+10	-35.0	4.28E+10	31.1
	Fossil depletion	kg oil eq	7.30E+10	4.84E+10	-33.7	9.78E+10	34.0	7.21E+09	4.23E+09	-41.3	1.02E+10	40.9	5.70E+10	4.06E+10	-28.8	7.06E+10	23.8	-2.48E+09	-1.33E+09	-46.2	-3.61E+09	45.6	1.35E+11	9.19E+10	-31.8	1.75E+11	29.8
	Water depletion	m3	5.77E+09	3.65E+09	-36.7	7.92E+09	37.2	3.76E+07	2.19E+07	-41.8	5.32E+07	41.4	8.57E+09	5.38E+09	-37.3	1.13E+10	31.3	-6.00E+07	-3.13E+07	-47.8	-8.83E+07	47.2	1.43E+10	9.02E+09	-37.0	1.91E+10	33.6
	Freshwater eutrophication	kg P eq	4.95E+07	3.12E+07	-37.0	6.51E+07	31.5	1.09E+05	6.29E+04	-42.4	1.55E+05	42.0	7.94E+06	5.15E+06	-35.1	1.03E+07	29.4	-1.04E+05	-5.18E+04	-50.0	-1.55E+05	49.3	5.74E+07	3.63E+07	-36.8	7.54E+07	31.2
	Marine eutrophication	kg N eq	3.42E+08	2.18E+08	-36.4	4.62E+08	35.1	1.39E+07	8.17E+06	-41.2	1.96E+07	40.9	5.72E+07	3.96E+07	-30.7	7.18E+07	25.5	8.65E+06	6.07E+06	-29.8	1.12E+07	29.4	4.22E+08	2.71E+08	-35.6	5.65E+08	33.8
	Agricultural land occupation	m2a	8.12E+10	5.03E+10	-38.0	1.08E+11	32.9	3.47E+07	2.02E+07	-41.9	4.91E+07	41.5	3.72E+09	2.62E+09	-29.5	4.64E+09	24.5	-1.42E+08	-7.54E+07	-47.1	-2.09E+08	46.5	8.48E+10	5.29E+10	-37.6	1.12E+11	32.5
	Urban land occupation	m2a	9.39E+08	5.97E+08	-36.5	1.28E+09	36.0	8.97E+07	5.19E+07	-42.1	1.27E+08	41.7	1.03E+09	7.17E+08	-30.7	1.30E+09	25.5	-3.32E+07	-1.74E+07	-47.5	-4.88E+07	46.8	2.03E+09	1.35E+09	-33.6	2.65E+09	30.7
	Natural land transformation	m2	7.58E+07	4.77E+07	-37.1	1.03E+08	36.0	1.03E+07	6.07E+06	-41.2	1.46E+07	40.8	2.81E+07	1.97E+07	-30.0	3.51E+07	24.9	-1.07E+06	-5.80E+05	-45.9	-1.56E+06	45.3	1.13E+08	7.29E+07	-35.6	1.51E+08	33.6
ENDPOINTS	Human health	DALY	3.77E+05	2.50E+05	-33.7	5.06E+05	34.1	3.91E+04	2.29E+04	-41.2	5.50E+04	40.9	3.73E+05	2.63E+05	-29.4	4.64E+05	24.3	-1.16E+04	-5.86E+03	-49.5	-1.73E+04	49.0	7.77E+05	5.31E+05	-31.7	1.01E+06	29.5
	Ecosystem diversity	species.yr	5.74E+03	3.61E+03	-37.0	7.73E+03	34.8	1.82E+02	1.07E+02	-41.3	2.56E+02	40.9	2.12E+03	1.46E+03	-31.1	2.67E+03	25.9	-5.44E+01	-2.76E+01	-49.3	-8.09E+01	48.9	7.98E+03	5.15E+03	-35.5	1.06E+04	32.5
	Ressource availability	$	1.18E+12	7.80E+11	-33.7	1.58E+12	34.0	1.16E+11	6.80E+10	-41.3	1.63E+11	40.9	9.18E+11	6.54E+11	-28.8	1.14E+12	23.9	-3.99E+10	-2.15E+10	-46.2	-5.81E+10	45.6	2.17E+12	1.48E+12	-31.8	2.82E+12	29.8

IMPROVEMENT OPTIONS

➢ Organic and GM cotton cultivation

			Production					Transport					Use					End-of-life					Total				
	Indicator	Unit	Baseline scenario	Organic cotton	% change compared to baseline	GM cotton	% change compared to baseline	Baseline scenario	Organic cotton	% change compared to baseline	GM cotton	% change compared to baseline	Baseline scenario	Organic cotton	% change compared to baseline	GM cotton	% change compared to baseline	Baseline scenario	Organic cotton	% change compared to baseline	GM cotton	% change compared to baseline	Baseline scenario	Organic cotton	% change compared to baseline	GM cotton	% change compared to baseline
MIDPOINTS	Climate change	kg CO2 eq	2.13E+11	2.16E+11	1.2	2.11E+11	-1.1	2.07E+10	2.07E+10	0.0	2.07E+10	0.0	1.85E+11	1.85E+11	0.0	1.85E+11	0.0	-6.38E+09	-6.38E+09	0.0	-6.38E+09	0.0	4.13E+11	4.15E+11	0.6	4.10E+11	-0.6
	Ozone depletion	kg CFC-11 eq	1.65E+04	1.66E+04	0.9	1.63E+04	-1.1	2.63E+03	2.63E+03	0.0	2.63E+03	0.0	1.04E+04	1.04E+04	0.0	1.04E+04	0.0	-3.48E+01	-3.48E+01	0.0	-3.48E+01	0.0	2.94E+04	2.96E+04	0.5	2.92E+04	-0.6
	Photochemical oxidant formation	kg NMVOC	5.21E+08	5.33E+08	2.4	5.09E+08	-2.2	1.27E+08	1.27E+08	0.0	1.27E+08	0.0	4.47E+08	4.47E+08	0.0	4.47E+08	0.0	-7.60E+06	-7.60E+06	0.0	-7.60E+06	0.0	1.09E+09	1.10E+09	1.1	1.08E+09	-1.1
	Particulate matter formation	kg PM10 eq	2.63E+08	2.70E+08	2.7	2.57E+08	-2.6	3.74E+07	3.74E+07	0.0	3.74E+07	0.0	2.60E+08	2.60E+08	0.0	2.60E+08	0.0	-8.36E+06	-8.36E+06	0.0	-8.36E+06	0.0	5.52E+08	5.59E+08	1.3	5.46E+08	-1.2
	Ionising radiation	kg U235 eq	7.99E+10	7.99E+10	0.1	7.97E+10	-0.3	1.20E+09	1.20E+09	0.0	1.20E+09	0.0	1.14E+11	1.14E+11	0.0	1.14E+11	0.0	-6.04E+09	-6.04E+09	0.0	-6.04E+09	0.0	1.89E+11	1.89E+11	0.0	1.89E+11	-0.1
	Terrestrial acidification	kg SO2 eq	8.51E+08	8.81E+08	3.5	8.23E+08	-3.3	1.12E+08	1.12E+08	0.0	1.12E+08	0.0	7.47E+08	7.47E+08	0.0	7.47E+08	0.0	-2.72E+07	-2.72E+07	0.0	-2.72E+07	0.0	1.68E+09	1.71E+09	1.8	1.65E+09	-1.7
	Human toxicity	kg 1,4-DB eq	1.25E+10	1.21E+10	-2.8	1.21E+10	-3.2	4.43E+08	4.43E+08	0.0	4.43E+08	0.0	6.35E+10	6.35E+10	0.0	6.35E+10	0.0	-5.68E+08	-5.68E+08	0.0	-5.68E+08	0.0	7.58E+10	7.55E+10	-0.5	7.54E+10	-0.5
	Terrestrial ecotoxicity	kg 1,4-DB eq	9.43E+08	1.27E+08	-86.5	4.53E+08	-52.0	1.91E+06	1.91E+06	0.0	1.91E+06	0.0	1.44E+08	1.44E+08	0.0	1.44E+08	0.0	-9.83E+05	-9.83E+05	0.0	-9.83E+05	0.0	1.09E+09	2.72E+08	-75.0	5.97E+08	-45.1
	Freshwater ecotoxicity	kg 1,4-DB eq	1.68E+09	1.06E+09	-37.0	1.11E+09	-34.4	1.24E+07	1.24E+07	0.0	1.24E+07	0.0	5.64E+09	5.64E+09	0.0	5.64E+09	0.0	-7.13E+06	-7.13E+06	0.0	-7.13E+06	0.0	7.33E+09	6.71E+09	-8.5	6.75E+09	-7.9
	Marine ecotoxicity	kg 1,4-DB eq	3.76E+08	3.42E+08	-9.1	3.34E+08	-11.0	2.32E+07	2.32E+07	0.0	2.32E+07	0.0	1.28E+09	1.28E+09	0.0	1.28E+09	0.0	-1.18E+07	-1.18E+07	0.0	-1.18E+07	0.0	1.67E+09	1.64E+09	-2.0	1.63E+09	-2.5
	Metal depletion	kg Fe eq	1.09E+10	1.12E+10	2.0	1.07E+10	-1.9	2.13E+08	2.13E+08	0.0	2.13E+08	0.0	2.19E+10	2.19E+10	0.0	2.19E+10	0.0	-3.74E+08	-3.74E+08	0.0	-3.74E+08	0.0	3.27E+10	3.29E+10	0.7	3.25E+10	-0.6
	Fossil depletion	kg oil eq	7.30E+10	7.35E+10	0.6	7.25E+10	-0.7	7.21E+09	7.21E+09	0.0	7.21E+09	0.0	5.70E+10	5.70E+10	0.0	5.70E+10	0.0	-2.48E+09	-2.48E+09	0.0	-2.48E+09	0.0	1.35E+11	1.35E+11	0.3	1.34E+11	-0.4
	Water depletion	m3	5.77E+09	5.78E+09	0.3	5.75E+09	-0.3	3.76E+07	3.76E+07	0.0	3.76E+07	0.0	8.57E+09	8.57E+09	0.0	8.57E+09	0.0	-6.00E+07	-6.00E+07	0.0	-6.00E+07	0.0	1.43E+10	1.43E+10	0.1	1.43E+10	-0.1
	Freshwater eutrophication	kg P eq	4.95E+07	4.28E+07	-13.6	3.53E+07	-28.7	1.09E+05	1.09E+05	0.0	1.09E+05	0.0	7.94E+06	7.94E+06	0.0	7.94E+06	0.0	-1.04E+05	-1.04E+05	0.0	-1.04E+05	0.0	5.74E+07	5.07E+07	-11.7	4.33E+07	-24.7
	Marine eutrophication	kg N eq	3.42E+08	2.80E+08	-18.3	2.74E+08	-19.8	1.39E+07	1.39E+07	0.0	1.39E+07	0.0	5.72E+07	5.72E+07	0.0	5.72E+07	0.0	8.65E+06	8.65E+06	0.0	8.65E+06	0.0	4.22E+08	3.59E+08	-14.8	3.54E+08	-16.1
	Agricultural land occupation	m2a	8.12E+10	9.41E+10	15.9	6.98E+10	-14.0	3.47E+07	3.47E+07	0.0	3.47E+07	0.0	3.72E+09	3.72E+09	0.0	3.72E+09	0.0	-1.42E+08	-1.42E+08	0.0	-1.42E+08	0.0	8.48E+10	9.77E+10	15.2	7.34E+10	-13.4
	Urban land occupation	m2a	9.39E+08	9.64E+08	2.7	9.16E+08	-2.5	8.97E+07	8.97E+07	0.0	8.97E+07	0.0	1.03E+09	1.03E+09	0.0	1.03E+09	0.0	-3.32E+07	-3.32E+07	0.0	-3.32E+07	0.0	2.03E+09	2.06E+09	1.2	2.01E+09	-1.1
	Natural land transformation	m2	7.58E+07	7.62E+07	0.5	7.54E+07	-0.6	1.03E+07	1.03E+07	0.0	1.03E+07	0.0	2.81E+07	2.81E+07	0.0	2.81E+07	0.0	-1.07E+06	-1.07E+06	0.0	-1.07E+06	0.0	1.13E+08	1.14E+08	0.3	1.13E+08	-0.4
ENDPOINTS	Human health	DALY	3.77E+05	3.82E+05	1.3	3.72E+05	-1.4	3.91E+04	3.91E+04	0.0	3.91E+04	0.0	3.73E+05	3.73E+05	0.0	3.73E+05	0.0	-1.16E+04	-1.16E+04	0.0	-1.16E+04	0.0	7.77E+05	7.82E+05	0.7	7.72E+05	-0.7
	Ecosystem diversity	species.yr	5.74E+03	5.89E+03	2.7	5.44E+03	-5.1	1.82E+02	1.82E+02	0.0	1.82E+02	0.0	2.12E+03	2.12E+03	0.0	2.12E+03	0.0	-5.44E+01	-5.44E+01	0.0	-5.44E+01	0.0	7.98E+03	8.14E+03	1.9	7.69E+03	-3.7
	Resource availability	$	1.18E+12	1.18E+12	0.6	1.17E+12	-0.7	1.16E+11	1.16E+11	0.0	1.16E+11	0.0	9.18E+11	9.18E+11	0.0	9.18E+11	0.0	-3.99E+10	-3.99E+10	0.0	-3.99E+10	0.0	2.17E+12	2.18E+12	0.3	2.16E+12	-0.4

➢ Cotton substitution

			Production					Transport					Use					End-of-life					Total				
	Indicator	Unit	Baseline scenario	Hemp (woven only)	% change compared to baseline	Flax (woven only)	% change compared to baseline	Baseline scenario	Hemp (woven only)	% change compared to baseline	Flax (woven only)	% change compared to baseline	Baseline scenario	Hemp (woven only)	% change compared to baseline	Flax (woven only)	% change compared to baseline	Baseline scenario	Hemp (woven only)	% change compared to baseline	Flax (woven only)	% change compared to baseline	Baseline scenario	Hemp (woven only)	% change compared to baseline	Flax (woven only)	% change compared to baseline
MIDPOINTS	Climate change	kg CO2 eq	2.13E+11	2.12E+11	-0.7	2.19E+11	2.8	2.07E+10	2.07E+10	0.0	2.07E+10	0.0	1.85E+11	1.85E+11	0.0	1.85E+11	0.0	-6.38E+09	-6.38E+09	0.0	-6.38E+09	0.0	4.13E+11	4.11E+11	-0.4	4.18E+11	1.4
	Ozone depletion	kg CFC-11 eq	1.65E+04	1.55E+04	-6.0	1.63E+04	-1.1	2.63E+03	2.63E+03	0.0	2.63E+03	0.0	1.04E+04	1.04E+04	0.0	1.04E+04	0.0	-3.48E+01	-3.48E+01	0.0	-3.48E+01	0.0	2.94E+04	2.84E+04	-3.4	2.92E+04	-0.6
	Photochemical oxidant formation	kg NMVOC	5.21E+08	5.10E+08	-2.0	5.23E+08	0.4	1.27E+08	1.27E+08	0.0	1.27E+08	0.0	4.47E+08	4.47E+08	0.0	4.47E+08	0.0	-7.60E+06	-7.60E+06	0.0	-7.60E+06	0.0	1.09E+09	1.08E+09	-1.0	1.09E+09	0.2
	Particulate matter formation	kg PM10 eq	2.63E+08	2.60E+08	-1.1	2.67E+08	1.2	3.74E+07	3.74E+07	0.0	3.74E+07	0.0	2.60E+08	2.60E+08	0.0	2.60E+08	0.0	-8.36E+06	-8.36E+06	0.0	-8.36E+06	0.0	5.52E+08	5.49E+08	-0.5	5.56E+08	0.6
	Ionising radiation	kg U235 eq	7.99E+10	8.75E+10	9.6	8.99E+10	12.5	1.20E+09	1.20E+09	0.0	1.20E+09	0.0	1.14E+11	1.14E+11	0.0	1.14E+11	0.0	-6.04E+09	-6.04E+09	0.0	-6.04E+09	0.0	1.89E+11	1.97E+11	4.0	1.99E+11	5.3
	Terrestrial acidification	kg SO2 eq	8.51E+08	8.27E+08	-2.8	8.46E+08	-0.6	1.12E+08	1.12E+08	0.0	1.12E+08	0.0	7.47E+08	7.47E+08	0.0	7.47E+08	0.0	-2.72E+07	-2.72E+07	0.0	-2.72E+07	0.0	1.68E+09	1.66E+09	-1.4	1.68E+09	-0.3
	Human toxicity	kg 1,4-DB eq	1.25E+10	1.27E+10	1.9	1.31E+10	4.7	4.43E+08	4.43E+08	0.0	4.43E+08	0.0	6.35E+10	6.35E+10	0.0	6.35E+10	0.0	-5.68E+08	-5.68E+08	0.0	-5.68E+08	0.0	7.58E+10	7.60E+10	0.3	7.64E+10	0.8
	Terrestrial ecotoxicity	kg 1,4-DB eq	9.43E+08	5.98E+08	-36.6	6.05E+08	-35.8	1.91E+06	1.91E+06	0.0	1.91E+06	0.0	1.44E+08	1.44E+08	0.0	1.44E+08	0.0	-9.83E+05	-9.83E+05	0.0	-9.83E+05	0.0	1.09E+09	7.43E+08	-31.7	7.50E+08	-31.1
	Freshwater ecotoxicity	kg 1,4-DB eq	1.68E+09	1.11E+09	-34.3	1.11E+09	-34.0	1.24E+07	1.24E+07	0.0	1.24E+07	0.0	5.64E+09	5.64E+09	0.0	5.64E+09	0.0	-7.13E+06	-7.13E+06	0.0	-7.13E+06	0.0	7.33E+09	6.75E+09	-7.9	6.76E+09	-7.8
	Marine ecotoxicity	kg 1,4-DB eq	3.76E+08	3.39E+08	-9.7	3.48E+08	-7.5	2.32E+07	2.32E+07	0.0	2.32E+07	0.0	1.28E+09	1.28E+09	0.0	1.28E+09	0.0	-1.18E+07	-1.18E+07	0.0	-1.18E+07	0.0	1.67E+09	1.64E+09	-2.2	1.64E+09	-1.7
	Metal depletion	kg Fe eq	1.09E+10	1.06E+10	-3.3	1.08E+10	-1.1	2.13E+08	2.13E+08	0.0	2.13E+08	0.0	2.19E+10	2.19E+10	0.0	2.19E+10	0.0	-3.74E+08	-3.74E+08	0.0	-3.74E+08	0.0	3.27E+10	3.23E+10	-1.1	3.26E+10	-0.4
	Fossil depletion	kg oil eq	7.30E+10	7.21E+10	-1.3	7.47E+10	2.3	7.21E+09	7.21E+09	0.0	7.21E+09	0.0	5.70E+10	5.70E+10	0.0	5.70E+10	0.0	-2.48E+09	-2.48E+09	0.0	-2.48E+09	0.0	1.35E+11	1.34E+11	-0.7	1.36E+11	1.2
	Water depletion	m3	5.77E+09	5.69E+09	-1.4	5.64E+09	-2.2	3.76E+07	3.76E+07	0.0	3.76E+07	0.0	8.57E+09	8.57E+09	0.0	8.57E+09	0.0	-6.00E+07	-6.00E+07	0.0	-6.00E+07	0.0	1.43E+10	1.42E+10	-0.6	1.42E+10	-0.9
	Freshwater eutrophication	kg P eq	4.95E+07	3.14E+07	-36.5	3.28E+07	-33.7	1.09E+05	1.09E+05	0.0	1.09E+05	0.0	7.94E+06	7.94E+06	0.0	7.94E+06	0.0	-1.04E+05	-1.04E+05	0.0	-1.04E+05	0.0	5.74E+07	3.94E+07	-31.5	4.08E+07	-29.1
	Marine eutrophication	kg N eq	3.42E+08	2.67E+08	-22.0	2.70E+08	-21.2	1.39E+07	1.39E+07	0.0	1.39E+07	0.0	5.72E+07	5.72E+07	0.0	5.72E+07	0.0	8.65E+06	8.65E+06	0.0	8.65E+06	0.0	4.22E+08	3.47E+08	-17.8	3.49E+08	-17.2
	Agricultural land occupation	m2a	8.12E+10	6.09E+10	-25.0	7.55E+10	-7.0	3.47E+07	3.47E+07	0.0	3.47E+07	0.0	3.72E+09	3.72E+09	0.0	3.72E+09	0.0	-1.42E+08	-1.42E+08	0.0	-1.42E+08	0.0	8.48E+10	6.45E+10	-23.9	7.92E+10	-6.7
	Urban land occupation	m2a	9.39E+08	9.30E+08	-1.0	9.50E+08	1.1	8.97E+07	8.97E+07	0.0	8.97E+07	0.0	1.03E+09	1.03E+09	0.0	1.03E+09	0.0	-3.32E+07	-3.32E+07	0.0	-3.32E+07	0.0	2.03E+09	2.02E+09	-0.5	2.04E+09	0.5
	Natural land transformation	m2	7.58E+07	7.37E+07	-2.8	7.84E+07	3.4	1.03E+07	1.03E+07	0.0	1.03E+07	0.0	2.81E+07	2.81E+07	0.0	2.81E+07	0.0	-1.07E+06	-1.07E+06	0.0	-1.07E+06	0.0	1.13E+08	1.11E+08	-1.9	1.16E+08	2.3
ENDPOINTS	Human health	DALY	3.77E+05	3.75E+05	-0.7	3.87E+05	2.6	3.91E+04	3.91E+04	0.0	3.91E+04	0.0	3.73E+05	3.73E+05	0.0	3.73E+05	0.0	-1.16E+04	-1.16E+04	0.0	-1.16E+04	0.0	7.77E+05	7.75E+05	-0.3	7.87E+05	1.2
	Ecosystem diversity	species.yr	5.74E+03	5.27E+03	-8.1	5.77E+03	0.7	1.82E+02	1.82E+02	0.0	1.82E+02	0.0	2.12E+03	2.12E+03	0.0	2.12E+03	0.0	-5.44E+01	-5.44E+01	0.0	-5.44E+01	0.0	7.98E+03	7.52E+03	-5.8	8.02E+03	0.5
	Ressource availability	$	1.18E+12	1.16E+12	-1.4	1.20E+12	2.3	1.16E+11	1.16E+11	0.0	1.16E+11	0.0	9.18E+11	9.18E+11	0.0	9.18E+11	0.0	-3.99E+10	-3.99E+10	0.0	-3.99E+10	0.0	2.17E+12	2.15E+12	-0.7	2.20E+12	1.2

➢ Reducing consumption of sizing chemicals

			Production			Transport			Use			End-of-life			Total		
	Indicator	Unit	Baseline scenario	Sizing oil use reduction	% change compared to baseline	Baseline scenario	Sizing oil use reduction	% change compared to baseline	Baseline scenario	Sizing oil use reduction	% change compared to baseline	Baseline scenario	Sizing oil use reduction	% change compared to baseline	Baseline scenario	Sizing oil use reduction	% change compared to baseline
MIDPOINTS	Climate change	kg CO2 eq	2,13E+11	2,12E+11	0%	1,87E+10	1,87E+10	0%	1,85E+11	1,85E+11	0%	-6,38E+09	-6,38E+09	0%	4,11E+11	4,10E+11	0%
	Ozone depletion	kg CFC-11 eq	1,65E+04	1,64E+04	-1%	2,38E+03	2,38E+03	0%	1,04E+04	1,04E+04	0%	-3,48E+01	-3,48E+01	0%	2,92E+04	2,91E+04	0%
	Photochemical oxidant formation	kg NMVOC	5,21E+08	5,17E+08	-1%	1,15E+08	1,15E+08	0%	4,47E+08	4,47E+08	0%	-7,60E+06	-7,60E+06	0%	1,07E+09	1,07E+09	0%
	Particulate matter formation	kg PM10 eq	2,63E+08	2,62E+08	-1%	3,38E+07	3,38E+07	0%	2,60E+08	2,60E+08	0%	-8,36E+06	-8,36E+06	0%	5,49E+08	5,47E+08	0%
	Ionising radiation	kg U235 eq	7,99E+10	7,98E+10	0%	1,09E+09	1,09E+09	0%	1,14E+11	1,14E+11	0%	-6,04E+09	-6,04E+09	0%	1,89E+11	1,89E+11	0%
	Terrestrial acidification	kg SO2 eq	8,51E+08	8,44E+08	-1%	1,01E+08	1,01E+08	0%	7,47E+08	7,47E+08	0%	-2,72E+07	-2,72E+07	0%	1,67E+09	1,66E+09	0%
	Human toxicity	kg 1,4-DB eq	1,25E+10	1,24E+10	-1%	4,03E+08	4,03E+08	0%	6,35E+10	6,35E+10	0%	-5,68E+08	-5,68E+08	0%	7,58E+10	7,57E+10	0%
	Terrestrial ecotoxicity	kg 1,4-DB eq	9,43E+08	9,42E+08	0%	1,73E+06	1,73E+06	0%	1,44E+08	1,44E+08	0%	-9,83E+05	-9,83E+05	0%	1,09E+09	1,09E+09	0%
	Freshwater ecotoxicity	kg 1,4-DB eq	1,68E+09	1,68E+09	0%	1,13E+07	1,13E+07	0%	5,64E+09	5,64E+09	0%	-7,13E+06	-7,13E+06	0%	7,33E+09	7,33E+09	0%
	Marine ecotoxicity	kg 1,4-DB eq	3,76E+08	3,73E+08	-1%	2,11E+07	2,11E+07	0%	1,28E+09	1,28E+09	0%	-1,18E+07	-1,18E+07	0%	1,67E+09	1,67E+09	0%
	Metal depletion	kg Fe eq	1,09E+10	1,08E+10	-1%	1,98E+08	1,98E+08	0%	2,19E+10	2,19E+10	0%	-3,74E+08	-3,74E+08	0%	3,27E+10	3,26E+10	0%
	Fossil depletion	kg oil eq	7,30E+10	7,27E+10	0%	6,52E+09	6,52E+09	0%	5,70E+10	5,70E+10	0%	-2,48E+09	-2,48E+09	0%	1,34E+11	1,34E+11	0%
	Water depletion	m3	5,77E+09	5,76E+09	0%	3,43E+07	3,43E+07	0%	8,57E+09	8,57E+09	0%	-6,00E+07	-6,00E+07	0%	1,43E+10	1,43E+10	0%
	Freshwater eutrophication	kg P eq	4,95E+07	4,93E+07	0%	1,00E+05	1,00E+05	0%	7,94E+06	7,94E+06	0%	-1,04E+05	-1,04E+05	0%	5,74E+07	5,73E+07	0%
	Marine eutrophication	kg N eq	3,42E+08	3,09E+08	-10%	1,26E+07	1,26E+07	0%	5,72E+07	5,72E+07	0%	8,65E+06	8,65E+06	0%	4,20E+08	3,87E+08	-8%
	Agricultural land occupation	m2a	8,12E+10	8,03E+10	-1%	3,17E+07	3,17E+07	0%	3,72E+09	3,72E+09	0%	-1,42E+08	-1,42E+08	0%	8,48E+10	8,39E+10	-1%
	Urban land occupation	m2a	9,39E+08	9,32E+08	-1%	8,22E+07	8,22E+07	0%	1,03E+09	1,03E+09	0%	-3,32E+07	-3,32E+07	0%	2,02E+09	2,02E+09	0%
	Natural land transformation	m2	7,58E+07	7,55E+07	-1%	9,34E+06	9,34E+06	0%	2,81E+07	2,81E+07	0%	-1,07E+06	-1,07E+06	0%	1,12E+08	1,12E+08	0%
ENDPOINTS	Human health	DALY	3,77E+05	3,76E+05	0%	3,53E+04	3,53E+04	0%	3,73E+05	3,73E+05	0%	-1,16E+04	-1,16E+04	0%	7,74E+05	7,72E+05	0%
	Ecosystem diversity	species.yr	5,74E+03	5,71E+03	0%	1,64E+02	1,64E+02	0%	2,12E+03	2,12E+03	0%	-5,44E+01	-5,44E+01	0%	7,96E+03	7,94E+03	0%
	Ressource availability	$	1,18E+12	1,17E+12	0%	1,05E+11	1,05E+11	0%	9,18E+11	9,18E+11	0%	-3,99E+10	-3,99E+10	0%	2,16E+12	2,15E+12	0%

➢ Alternative knitting technologies

			Production					Transport					Use					End-of-life					Total				
	Indicator	Unit	Baseline scenario	Fully Fashioned Knitted Fabric	% change compared to baseline	Integral Knitted Fabric	% change compared to baseline	Baseline scenario	Fully Fashioned Knitted Fabric	% change compared to baseline	Integral Knitted Fabric	% change compared to baseline	Baseline scenario	Fully Fashioned Knitted Fabric	% change compared to baseline	Integral Knitted Fabric	% change compared to baseline	Baseline scenario	Fully Fashioned Knitted Fabric	% change compared to baseline	Integral Knitted Fabric	% change compared to baseline	Baseline scenario	Fully Fashioned Knitted Fabric	% change compared to baseline	Integral Knitted Fabric	% change compared to baseline
MIDPOINTS	Climate change	kg CO2 eq	2.13E+11	2.09E+11	-1.9	2.17E+11	1.6	2.07E+10	2.07E+10	0.0	2.07E+10	0.0	1.85E+11	1.85E+11	0.0	1.85E+11	0.0	-6.38E+09	-6.38E+09	0.0	-6.38E+09	0.0	4.13E+11	4.09E+11	-1.0	4.16E+11	0.8
	Ozone depletion	kg CFC-11 eq	1.65E+04	1.53E+04	-7.2	1.56E+04	-5.1	2.63E+03	2.63E+03	0.0	2.63E+03	0.0	1.04E+04	1.04E+04	0.0	1.04E+04	0.0	-3.48E+01	-3.48E+01	0.0	-3.48E+01	0.0	2.94E+04	2.82E+04	-4.0	2.86E+04	-2.8
	Photochemical oxidant formation	kg NMVOC	5.21E+08	5.22E+08	0.3	5.38E+08	3.2	1.27E+08	1.27E+08	0.0	1.27E+08	0.0	4.47E+08	4.47E+08	0.0	4.47E+08	0.0	-7.60E+06	-7.60E+06	0.0	-7.60E+06	0.0	1.09E+09	1.09E+09	0.1	1.10E+09	1.6
	Particulate matter formation	kg PM10 eq	2.63E+08	2.68E+08	1.7	2.77E+08	5.3	3.74E+07	3.74E+07	0.0	3.74E+07	0.0	2.60E+08	2.60E+08	0.0	2.60E+08	0.0	-8.36E+06	-8.36E+06	0.0	-8.36E+06	0.0	5.52E+08	5.57E+08	0.8	5.66E+08	2.5
	Ionising radiation	kg U235 eq	7.99E+10	8.32E+10	4.2	8.89E+10	11.3	1.20E+09	1.20E+09	0.0	1.20E+09	0.0	1.14E+11	1.14E+11	0.0	1.14E+11	0.0	-6.04E+09	-6.04E+09	0.0	-6.04E+09	0.0	1.89E+11	1.93E+11	1.8	1.98E+11	4.8
	Terrestrial acidification	kg SO2 eq	8.51E+08	8.67E+08	1.9	8.97E+08	5.4	1.12E+08	1.12E+08	0.0	1.12E+08	0.0	7.47E+08	7.47E+08	0.0	7.47E+08	0.0	-2.72E+07	-2.72E+07	0.0	-2.72E+07	0.0	1.68E+09	1.70E+09	1.0	1.73E+09	2.8
	Human toxicity	kg 1,4-DB eq	1.25E+10	1.27E+10	1.4	1.32E+10	5.8	4.43E+08	4.43E+08	0.0	4.43E+08	0.0	6.35E+10	6.35E+10	0.0	6.35E+10	0.0	-5.68E+08	-5.68E+08	0.0	-5.68E+08	0.0	7.58E+10	7.60E+10	0.2	7.65E+10	1.0
	Terrestrial ecotoxicity	kg 1,4-DB eq	9.43E+08	9.80E+08	3.9	9.75E+08	3.4	1.91E+06	1.91E+06	0.0	1.91E+06	0.0	1.44E+08	1.44E+08	0.0	1.44E+08	0.0	-9.83E+05	-9.83E+05	0.0	-9.83E+05	0.0	1.09E+09	1.12E+09	3.4	1.12E+09	2.9
	Freshwater ecotoxicity	kg 1,4-DB eq	1.68E+09	1.75E+09	3.9	1.75E+09	3.7	1.24E+07	1.24E+07	0.0	1.24E+07	0.0	5.64E+09	5.64E+09	0.0	5.64E+09	0.0	-7.13E+06	-7.13E+06	0.0	-7.13E+06	0.0	7.33E+09	7.40E+09	0.9	7.39E+09	0.9
	Marine ecotoxicity	kg 1,4-DB eq	3.76E+08	3.83E+08	1.8	3.93E+08	4.7	2.32E+07	2.32E+07	0.0	2.32E+07	0.0	1.28E+09	1.28E+09	0.0	1.28E+09	0.0	-1.18E+07	-1.18E+07	0.0	-1.18E+07	0.0	1.67E+09	1.68E+09	0.4	1.69E+09	1.0
	Metal depletion	kg Fe eq	1.09E+10	1.10E+10	0.7	1.14E+10	3.9	2.13E+08	2.13E+08	0.0	2.13E+08	0.0	2.19E+10	2.19E+10	0.0	2.19E+10	0.0	-3.74E+08	-3.74E+08	0.0	-3.74E+08	0.0	3.27E+10	3.28E+10	0.2	3.31E+10	1.3
	Fossil depletion	kg oil eq	7.30E+10	7.07E+10	-3.3	7.28E+10	-0.3	7.21E+09	7.21E+09	0.0	7.21E+09	0.0	5.70E+10	5.70E+10	0.0	5.70E+10	0.0	-2.48E+09	-2.48E+09	0.0	-2.48E+09	0.0	1.35E+11	1.32E+11	-1.8	1.35E+11	-0.1
	Water depletion	m3	5.77E+09	5.30E+09	-8.2	5.36E+09	-7.2	3.76E+07	3.76E+07	0.0	3.76E+07	0.0	8.57E+09	8.57E+09	0.0	8.57E+09	0.0	-6.00E+07	-6.00E+07	0.0	-6.00E+07	0.0	1.43E+10	1.38E+10	-3.3	1.39E+10	-2.9
	Freshwater eutrophication	kg P eq	4.95E+07	5.16E+07	4.3	5.15E+07	4.0	1.09E+05	1.09E+05	0.0	1.09E+05	0.0	7.94E+06	7.94E+06	0.0	7.94E+06	0.0	-1.04E+05	-1.04E+05	0.0	-1.04E+05	0.0	5.74E+07	5.96E+07	3.7	5.94E+07	3.4
	Marine eutrophication	kg N eq	3.42E+08	3.49E+08	1.9	3.49E+08	2.1	1.39E+07	1.39E+07	0.0	1.39E+07	0.0	5.72E+07	5.72E+07	0.0	5.72E+07	0.0	8.65E+06	8.65E+06	0.0	8.65E+06	0.0	4.22E+08	4.28E+08	1.6	4.29E+08	1.7
	Agricultural land occupation	m2a	8.12E+10	8.39E+10	3.4	8.37E+10	3.0	3.47E+07	3.47E+07	0.0	3.47E+07	0.0	3.72E+09	3.72E+09	0.0	3.72E+09	0.0	-1.42E+08	-1.42E+08	0.0	-1.42E+08	0.0	8.48E+10	8.75E+10	3.2	8.73E+10	2.9
	Urban land occupation	m2a	9.39E+08	9.54E+08	1.6	9.86E+08	5.0	8.97E+07	8.97E+07	0.0	8.97E+07	0.0	1.03E+09	1.03E+09	0.0	1.03E+09	0.0	-3.32E+07	-3.32E+07	0.0	-3.32E+07	0.0	2.03E+09	2.04E+09	0.7	2.08E+09	2.3
	Natural land transformation	m2	7.58E+07	7.31E+07	-3.6	7.40E+07	-2.4	1.03E+07	1.03E+07	0.0	1.03E+07	0.0	2.81E+07	2.81E+07	0.0	2.81E+07	0.0	-1.07E+06	-1.07E+06	0.0	-1.07E+06	0.0	1.13E+08	1.10E+08	-2.4	1.11E+08	-1.6
ENDPOINTS	Human health	DALY	3.77E+05	3.73E+05	-1.1	3.86E+05	2.4	3.91E+04	3.91E+04	0.0	3.91E+04	0.0	3.73E+05	3.73E+05	0.0	3.73E+05	0.0	-1.16E+04	-1.16E+04	0.0	-1.16E+04	0.0	7.77E+05	7.73E+05	-0.6	7.87E+05	1.2
	Ecosystem diversity	species.yr	5.74E+03	5.67E+03	-1.2	5.72E+03	-0.3	1.82E+02	1.82E+02	0.0	1.82E+02	0.0	2.12E+03	2.12E+03	0.0	2.12E+03	0.0	-5.44E+01	-5.44E+01	0.0	-5.44E+01	0.0	7.98E+03	7.91E+03	-0.9	7.97E+03	-0.2
	Resource availability	$	1.18E+12	1.14E+12	-3.3	1.17E+12	-0.3	1.16E+11	1.16E+11	0.0	1.16E+11	0.0	9.18E+11	9.18E+11	0.0	9.18E+11	0.0	-3.99E+10	-3.99E+10	0.0	-3.99E+10	0.0	2.17E+12	2.13E+12	-1.8	2.17E+12	-0.1

➢ Replacing chemicals with enzymes

	Indicator	Unit	Production			Transport			Use			End-of-life			Total		
			Baseline scenario	Use of enzyme	% change compared to baseline	Baseline scenario	Use of enzyme	% change compared to baseline	Baseline scenario	Use of enzyme	% change compared to baseline	Baseline scenario	Use of enzyme	% change compared to baseline	Baseline scenario	Use of enzyme	% change compared to baseline
MIDPOINTS	Climate change	kg CO2 eq	2,13E+11	2,13E+11	0%	1,87E+10	1,87E+10	0%	1,85E+11	1,85E+11	0%	-6,38E+09	-6,38E+09	0%	4,11E+11	4,10E+11	0%
	Ozone depletion	kg CFC-11 eq	1,65E+04	1,65E+04	0%	2,38E+03	2,38E+03	0%	1,04E+04	1,04E+04	0%	-3,48E+01	-3,48E+01	0%	2,92E+04	2,92E+04	0%
	Photochemical oxidant formation	kg NMVOC	5,21E+08	5,20E+08	0%	1,15E+08	1,15E+08	0%	4,47E+08	4,47E+08	0%	-7,60E+06	-7,60E+06	0%	1,07E+09	1,07E+09	0%
	Particulate matter formation	kg PM10 eq	2,63E+08	2,63E+08	0%	3,38E+07	3,38E+07	0%	2,60E+08	2,60E+08	0%	-8,36E+06	-8,36E+06	0%	5,49E+08	5,48E+08	0%
	Ionising radiation	kg U235 eq	7,99E+10	7,98E+10	0%	1,09E+09	1,09E+09	0%	1,14E+11	1,14E+11	0%	-6,04E+09	-6,04E+09	0%	1,89E+11	1,89E+11	0%
	Terrestrial acidification	kg SO2 eq	8,51E+08	8,50E+08	0%	1,01E+08	1,01E+08	0%	7,47E+08	7,47E+08	0%	-2,72E+07	-2,72E+07	0%	1,67E+09	1,67E+09	0%
	Human toxicity	kg 1,4-DB eq	1,25E+10	1,24E+10	0%	4,03E+08	4,03E+08	0%	6,35E+10	6,35E+10	0%	-5,68E+08	-5,68E+08	0%	7,58E+10	7,57E+10	0%
	Terrestrial ecotoxicity	kg 1,4-DB eq	9,43E+08	9,43E+08	0%	1,73E+06	1,73E+06	0%	1,44E+08	1,44E+08	0%	-9,83E+05	-9,83E+05	0%	1,09E+09	1,09E+09	0%
	Freshwater ecotoxicity	kg 1,4-DB eq	1,68E+09	1,68E+09	0%	1,13E+07	1,13E+07	0%	5,64E+09	5,64E+09	0%	-7,13E+06	-7,13E+06	0%	7,33E+09	7,33E+09	0%
	Marine ecotoxicity	kg 1,4-DB eq	3,76E+08	3,76E+08	0%	2,11E+07	2,11E+07	0%	1,28E+09	1,28E+09	0%	-1,18E+07	-1,18E+07	0%	1,67E+09	1,67E+09	0%
	Metal depletion	kg Fe eq	1,09E+10	1,09E+10	0%	1,98E+08	1,98E+08	0%	2,19E+10	2,19E+10	0%	-3,74E+08	-3,74E+08	0%	3,27E+10	3,26E+10	0%
	Fossil depletion	kg oil eq	7,30E+10	7,30E+10	0%	6,52E+09	6,52E+09	0%	5,70E+10	5,70E+10	0%	-2,48E+09	-2,48E+09	0%	1,34E+11	1,34E+11	0%
	Water depletion	m3	5,77E+09	5,66E+09	-2%	3,43E+07	3,43E+07	0%	8,57E+09	8,57E+09	0%	-6,00E+07	-6,00E+07	0%	1,43E+10	1,42E+10	-1%
	Freshwater eutrophication	kg P eq	4,95E+07	4,95E+07	0%	1,00E+05	1,00E+05	0%	7,94E+06	7,94E+06	0%	-1,04E+05	-1,04E+05	0%	5,74E+07	5,74E+07	0%
	Marine eutrophication	kg N eq	3,42E+08	3,42E+08	0%	1,26E+07	1,26E+07	0%	5,72E+07	5,72E+07	0%	8,65E+06	8,65E+06	0%	4,20E+08	4,21E+08	0%
	Agricultural land occupation	m2a	8,12E+10	8,12E+10	0%	3,17E+07	3,17E+07	0%	3,72E+09	3,72E+09	0%	-1,42E+08	-1,42E+08	0%	8,48E+10	8,48E+10	0%
	Urban land occupation	m2a	9,39E+08	9,42E+08	0%	8,22E+07	8,22E+07	0%	1,03E+09	1,03E+09	0%	-3,32E+07	-3,32E+07	0%	2,02E+09	2,03E+09	0%
	Natural land transformation	m2	7,58E+07	7,59E+07	0%	9,34E+06	9,34E+06	0%	2,81E+07	2,81E+07	0%	-1,07E+06	-1,07E+06	0%	1,12E+08	1,12E+08	0%
ENDPOINT	Human health	DALY	3,77E+05	3,77E+05	0%	3,53E+04	3,53E+04	0%	3,73E+05	3,73E+05	0%	-1,16E+04	-1,16E+04	0%	7,74E+05	7,73E+05	0%
	Ecosystem diversity	species.yr	5,74E+03	5,73E+03	0%	1,64E+02	1,64E+02	0%	2,12E+03	2,12E+03	0%	-5,44E+01	-5,44E+01	0%	7,96E+03	7,96E+03	0%
	Ressource availability	$	1,18E+12	1,18E+12	0%	1,05E+11	1,05E+11	0%	9,18E+11	9,18E+11	0%	-3,99E+10	-3,99E+10	0%	2,16E+12	2,16E+12	0%

➢ Recycling effluent water

			Production					Transport					Use					End-of-life					Total				
	Indicator	Unit	Baseline scenario	Reverse osmosis	% change compared to baseline	Ion exchange	% change compared to baseline	Baseline scenario	Reverse osmosis	% change compared to baseline	Ion exchange	% change compared to baseline	Baseline scenario	Reverse osmosis	% change compared to baseline	Ion exchange	% change compared to baseline	Baseline scenario	Reverse osmosis	% change compared to baseline	Ion exchange	% change compared to baseline	Baseline scenario	Reverse osmosis	% change compared to baseline	Ion exchange	% change compared to baseline
Mid-points	Climate change	kg CO2 eq	2.13E+11	2.11E+11	-0.9	2.11E+11	-1.1	2.07E+10	2.07E+10	0.0	2.07E+10	0.0	1.85E+11	1.85E+11	0.0	1.85E+11	0.0	-6.38E+09	-6.38E+09	0.0	-6.38E+09	0.0	4.13E+11	4.11E+11	-0.5	4.10E+11	-0.5
	Ozone depletion	kg CFC-11 eq	1.65E+04	1.60E+04	-2.6	1.60E+04	-3.1	2.63E+03	2.63E+03	0.0	2.63E+03	0.0	1.04E+04	1.04E+04	0.0	1.04E+04	0.0	-3.48E+01	-3.48E+01	0.0	-3.48E+01	0.0	2.94E+04	2.90E+04	-1.5	2.89E+04	-1.7
	Photochemical oxidant formation	kg NMVOC	5.21E+08	5.13E+08	-1.6	5.11E+08	-1.8	1.27E+08	1.27E+08	0.0	1.27E+08	0.0	4.47E+08	4.47E+08	0.0	4.47E+08	0.0	-7.60E+06	-7.60E+06	0.0	-7.60E+06	0.0	1.09E+09	1.08E+09	-0.8	1.08E+09	-0.9
	Particulate matter formation	kg PM10 eq	2.63E+08	2.59E+08	-1.6	2.58E+08	-1.9	3.74E+07	3.74E+07	0.0	3.74E+07	0.0	2.60E+08	2.60E+08	0.0	2.60E+08	0.0	-8.36E+06	-8.36E+06	0.0	-8.36E+06	0.0	5.52E+08	5.48E+08	-0.8	5.47E+08	-0.9
	Ionising radiation	kg U235 eq	7.99E+10	7.94E+10	-0.6	7.93E+10	-0.7	1.20E+09	1.20E+09	0.0	1.20E+09	0.0	1.14E+11	1.14E+11	0.0	1.14E+11	0.0	-6.04E+09	-6.04E+09	0.0	-6.04E+09	0.0	1.89E+11	1.89E+11	-0.3	1.89E+11	-0.3
	Terrestrial acidification	kg SO2 eq	8.51E+08	8.40E+08	-1.3	8.38E+08	-1.5	1.12E+08	1.12E+08	0.0	1.12E+08	0.0	7.47E+08	7.47E+08	0.0	7.47E+08	0.0	-2.72E+07	-2.72E+07	0.0	-2.72E+07	0.0	1.68E+09	1.67E+09	-0.7	1.67E+09	-0.8
	Human toxicity	kg 1,4-DB eq	1.25E+10	1.22E+10	-2.1	1.22E+10	-2.5	4.43E+08	4.43E+08	0.0	4.43E+08	0.0	6.35E+10	6.35E+10	0.0	6.35E+10	0.0	-5.68E+08	-5.68E+08	0.0	-5.68E+08	0.0	7.58E+10	7.55E+10	-0.3	7.55E+10	-0.4
	Terrestrial ecotoxicity	kg 1,4-DB eq	9.43E+08	9.17E+08	-2.8	9.12E+08	-3.3	1.91E+06	1.91E+06	0.0	1.91E+06	0.0	1.44E+08	1.44E+08	0.0	1.44E+08	0.0	-9.83E+05	-9.83E+05	0.0	-9.83E+05	0.0	1.09E+09	1.06E+09	-2.4	1.06E+09	-2.9
	Freshwater ecotoxicity	kg 1,4-DB eq	1.68E+09	1.67E+09	-0.6	1.67E+09	-0.7	1.24E+07	1.24E+07	0.0	1.24E+07	0.0	5.64E+09	5.64E+09	0.0	5.64E+09	0.0	-7.13E+06	-7.13E+06	0.0	-7.13E+06	0.0	7.33E+09	7.32E+09	-0.1	7.32E+09	-0.2
	Marine ecotoxicity	kg 1,4-DB eq	3.76E+08	3.69E+08	-1.8	3.68E+08	-2.1	2.32E+07	2.32E+07	0.0	2.32E+07	0.0	1.28E+09	1.28E+09	0.0	1.28E+09	0.0	-1.18E+07	-1.18E+07	0.0	-1.18E+07	0.0	1.67E+09	1.66E+09	-0.4	1.66E+09	-0.5
	Metal depletion	kg Fe eq	1.09E+10	1.05E+10	-4.4	1.04E+10	-5.1	2.13E+08	2.13E+08	0.0	2.13E+08	0.0	2.19E+10	2.19E+10	0.0	2.19E+10	0.0	-3.74E+08	-3.74E+08	0.0	-3.74E+08	0.0	3.27E+10	3.22E+10	-1.5	3.21E+10	-1.7
	Fossil depletion	kg oil eq	7.30E+10	7.24E+10	-0.9	7.22E+10	-1.1	7.21E+09	7.21E+09	0.0	7.21E+09	0.0	5.70E+10	5.70E+10	0.0	5.70E+10	0.0	-2.48E+09	-2.48E+09	0.0	-2.48E+09	0.0	1.35E+11	1.34E+11	-0.5	1.34E+11	-0.6
	Water depletion	m3	5.77E+09	2.66E+09	-53.8	2.13E+09	-63.1	3.76E+07	3.76E+07	0.0	3.76E+07	0.0	8.57E+09	8.57E+09	0.0	8.57E+09	0.0	-6.00E+07	-6.00E+07	0.0	-6.00E+07	0.0	1.43E+10	1.12E+10	-21.7	1.07E+10	-25.4
	Freshwater eutrophication	kg P eq	4.95E+07	4.94E+07	-0.3	4.93E+07	-0.4	1.09E+05	1.09E+05	0.0	1.09E+05	0.0	7.94E+06	7.94E+06	0.0	7.94E+06	0.0	-1.04E+05	-1.04E+05	0.0	-1.04E+05	0.0	5.74E+07	5.73E+07	-0.3	5.73E+07	-0.3
	Marine eutrophication	kg N eq	3.42E+08	3.36E+08	-1.7	3.35E+08	-1.9	1.39E+07	1.39E+07	0.0	1.39E+07	0.0	5.72E+07	5.72E+07	0.0	5.72E+07	0.0	8.65E+06	8.65E+06	0.0	8.65E+06	0.0	4.22E+08	4.16E+08	-1.3	4.15E+08	-1.6
	Agricultural land occupation	m2a	8.12E+10	8.00E+10	-1.4	7.98E+10	-1.7	3.47E+07	3.47E+07	0.0	3.47E+07	0.0	3.72E+09	3.72E+09	0.0	3.72E+09	0.0	-1.42E+08	-1.42E+08	0.0	-1.42E+08	0.0	8.48E+10	8.36E+10	-1.4	8.34E+10	-1.6
	Urban land occupation	m2a	9.39E+08	9.25E+08	-1.6	9.22E+08	-1.8	8.97E+07	8.97E+07	0.0	8.97E+07	0.0	1.03E+09	1.03E+09	0.0	1.03E+09	0.0	-3.32E+07	-3.32E+07	0.0	-3.32E+07	0.0	2.03E+09	2.02E+09	-0.7	2.01E+09	-0.8
	Natural land transformation	m2	7.58E+07	6.45E+07	-15.0	6.25E+07	-17.6	1.03E+07	1.03E+07	0.0	1.03E+07	0.0	2.81E+07	2.81E+07	0.0	2.81E+07	0.0	-1.07E+06	-1.07E+06	0.0	-1.07E+06	0.0	1.13E+08	1.02E+08	-10.0	9.99E+07	-11.8
End-points	Human health	DALY	3.77E+05	3.73E+05	-1.1	3.72E+05	-1.2	3.91E+04	3.91E+04	0.0	3.91E+04	0.0	3.73E+05	3.73E+05	0.0	3.73E+05	0.0	-1.16E+04	-1.16E+04	0.0	-1.16E+04	0.0	7.77E+05	7.73E+05	-0.5	7.73E+05	-0.6
	Ecosystem diversity	species.yr	5.74E+03	4.97E+03	-13.4	4.84E+03	-15.7	1.82E+02	1.82E+02	0.0	1.82E+02	0.0	2.12E+03	2.12E+03	0.0	2.12E+03	0.0	-5.44E+01	-5.44E+01	0.0	-5.44E+01	0.0	7.98E+03	7.21E+03	-9.6	7.08E+03	-11.3
	Resource availability	$	1.18E+12	1.17E+12	-0.9	1.16E+12	-1.1	1.16E+11	1.16E+11	0.0	1.16E+11	0.0	9.18E+11	9.18E+11	0.0	9.18E+11	0.0	-3.99E+10	-3.99E+10	0.0	-3.99E+10	0.0	2.17E+12	2.16E+12	-0.5	2.16E+12	-0.6

➢ Use of low liquor dyeing machines and controllers

			Production					Transport					Use					End-of-life					Total				
	Indicator	Unit	Baseline scenario	Conservative scenario	% change compared to baseline	Optimistic scenario	% change compared to baseline	Baseline scenario	Conservative scenario	% change compared to baseline	Optimistic scenario	% change compared to baseline	Baseline scenario	Conservative scenario	% change compared to baseline	Optimistic scenario	% change compared to baseline	Baseline scenario	Conservative scenario	% change compared to baseline	Optimistic scenario	% change compared to baseline	Baseline scenario	Conservative scenario	% change compared to baseline	Optimistic scenario	% change compared to baseline
Mid-points	Climate change	kg CO2 eq	2.13E+11	2.13E+11	0.0	2.13E+11	0.0	1.87E+10	1.87E+10	0.0	1.87E+10	0.0	1.85E+11	1.81E+11	0.0	1.71E+11	-0.1	-6.38E+09	-6.38E+09	0.0	-6.38E+09	0.0	4.11E+11	4.06E+11	0.0	3.96E+11	0.0
	Ozone depletion	kg CFC-11 eq	1.65E+04	1.65E+04	0.0	1.65E+04	0.0	2.38E+03	2.38E+03	0.0	2.38E+03	0.0	1.04E+04	1.02E+04	0.0	9.68E+03	-0.1	-3.48E+01	-3.48E+01	0.0	-3.48E+01	0.0	2.92E+04	2.90E+04	0.0	2.85E+04	0.0
	Photochemical oxidant formation	kg NMVOC	5.21E+08	5.21E+08	0.0	5.21E+08	0.0	1.15E+08	1.15E+08	0.0	1.15E+08	0.0	4.47E+08	4.38E+08	0.0	4.16E+08	-0.1	-7.60E+06	-7.60E+06	0.0	-7.60E+06	0.0	1.07E+09	1.07E+09	0.0	1.04E+09	0.0
	Particulate matter formation	kg PM10 eq	2.63E+08	2.63E+08	0.0	2.63E+08	0.0	3.38E+07	3.38E+07	0.0	3.38E+07	0.0	2.60E+08	2.54E+08	0.0	2.41E+08	-0.1	-8.36E+06	-8.36E+06	0.0	-8.36E+06	0.0	5.49E+08	5.43E+08	0.0	5.30E+08	0.0
	Ionising radiation	kg U235 eq	7.99E+10	7.99E+10	0.0	7.99E+10	0.0	1.09E+09	1.09E+09	0.0	1.09E+09	0.0	1.14E+11	1.11E+11	0.0	1.04E+11	-0.1	-6.04E+09	-6.04E+09	0.0	-6.04E+09	0.0	1.89E+11	1.86E+11	0.0	1.79E+11	-0.1
	Terrestrial acidification	kg SO2 eq	8.51E+08	8.51E+08	0.0	8.51E+08	0.0	1.01E+08	1.01E+08	0.0	1.01E+08	0.0	7.47E+08	7.29E+08	0.0	6.88E+08	-0.1	-2.72E+07	-2.72E+07	0.0	-2.72E+07	0.0	1.67E+09	1.65E+09	0.0	1.61E+09	0.0
	Human toxicity	kg 1,4-DB eq	1.25E+10	1.25E+10	0.0	1.25E+10	0.0	4.03E+08	4.03E+08	0.0	4.03E+08	0.0	6.35E+10	6.31E+10	0.0	6.24E+10	0.0	-5.68E+08	-5.68E+08	0.0	-5.68E+08	0.0	7.58E+10	7.55E+10	0.0	7.47E+10	0.0
	Terrestrial ecotoxicity	kg 1,4-DB eq	9.43E+08	9.43E+08	0.0	9.43E+08	0.0	1.73E+06	1.73E+06	0.0	1.73E+06	0.0	1.44E+08	1.43E+08	0.0	1.42E+08	0.0	-9.83E+05	-9.83E+05	0.0	-9.83E+05	0.0	1.09E+09	1.09E+09	0.0	1.09E+09	0.0
	Freshwater ecotoxicity	kg 1,4-DB eq	1.68E+09	1.68E+09	0.0	1.68E+09	0.0	1.13E+07	1.13E+07	0.0	1.13E+07	0.0	5.64E+09	5.64E+09	0.0	5.63E+09	0.0	-7.13E+06	-7.13E+06	0.0	-7.13E+06	0.0	7.33E+09	7.33E+09	0.0	7.32E+09	0.0
	Marine ecotoxicity	kg 1,4-DB eq	3.76E+08	3.76E+08	0.0	3.76E+08	0.0	2.11E+07	2.11E+07	0.0	2.11E+07	0.0	1.28E+09	1.28E+09	0.0	1.26E+09	0.0	-1.18E+07	-1.18E+07	0.0	-1.18E+07	0.0	1.67E+09	1.66E+09	0.0	1.65E+09	0.0
	Metal depletion	kg Fe eq	1.09E+10	1.09E+10	0.0	1.09E+10	0.0	1.98E+08	1.98E+08	0.0	1.98E+08	0.0	2.19E+10	2.17E+10	0.0	2.12E+10	0.0	-3.74E+08	-3.74E+08	0.0	-3.74E+08	0.0	3.27E+10	3.25E+10	0.0	3.20E+10	0.0
	Fossil depletion	kg oil eq	7.30E+10	7.30E+10	0.0	7.30E+10	0.0	6.52E+09	6.52E+09	0.0	6.52E+09	0.0	5.70E+10	5.57E+10	0.0	5.28E+10	-0.1	-2.48E+09	-2.48E+09	0.0	-2.48E+09	0.0	1.34E+11	1.33E+11	0.0	1.30E+11	0.0
	Water depletion	m3	5.77E+09	5.77E+09	0.0	5.77E+09	0.0	3.43E+07	3.43E+07	0.0	3.43E+07	0.0	8.57E+09	8.54E+09	0.0	8.46E+09	0.0	-6.00E+07	-6.00E+07	0.0	-6.00E+07	0.0	1.43E+10	1.43E+10	0.0	1.42E+10	0.0
	Freshwater eutrophication	kg P eq	4.95E+07	4.95E+07	0.0	4.95E+07	0.0	1.00E+05	1.00E+05	0.0	1.00E+05	0.0	7.94E+06	7.87E+06	0.0	7.71E+06	0.0	-1.04E+05	-1.04E+05	0.0	-1.04E+05	0.0	5.74E+07	5.74E+07	0.0	5.72E+07	0.0
	Marine eutrophication	kg N eq	3.42E+08	3.42E+08	0.0	3.42E+08	0.0	1.26E+07	1.26E+07	0.0	1.26E+07	0.0	5.72E+07	5.62E+07	0.0	5.38E+07	-0.1	8.65E+06	8.65E+06	0.0	8.65E+06	0.0	4.20E+08	4.19E+08	0.0	4.17E+08	0.0
	Agricultural land occupation	m2a	8.12E+10	8.12E+10	0.0	8.12E+10	0.0	3.17E+07	3.17E+07	0.0	3.17E+07	0.0	3.72E+09	3.65E+09	0.0	3.47E+09	-0.1	-1.42E+08	-1.42E+08	0.0	-1.42E+08	0.0	8.48E+10	8.47E+10	0.0	8.46E+10	0.0
	Urban land occupation	m2a	9.39E+08	9.39E+08	0.0	9.39E+08	0.0	8.22E+07	8.22E+07	0.0	8.22E+07	0.0	1.03E+09	1.02E+09	0.0	9.72E+08	-0.1	-3.32E+07	-3.32E+07	0.0	-3.32E+07	0.0	2.02E+09	2.00E+09	0.0	1.96E+09	0.0
	Natural land transformation	m2	7.58E+07	7.58E+07	0.0	7.58E+07	0.0	9.34E+06	9.34E+06	0.0	9.34E+06	0.0	2.81E+07	2.76E+07	0.0	2.63E+07	-0.1	-1.07E+06	-1.07E+06	0.0	-1.07E+06	0.0	1.12E+08	1.12E+08	0.0	1.10E+08	0.0
End-points	Human health	DALY	3.77E+05	3.77E+05	0.0	3.77E+05	0.0	3.53E+04	3.53E+04	0.0	3.53E+04	0.0	3.73E+05	3.65E+05	0.0	3.47E+05	-0.1	-1.16E+04	-1.16E+04	0.0	-1.16E+04	0.0	7.74E+05	7.66E+05	0.0	7.48E+05	0.0
	Ecosystem diversity	species.yr	5.74E+03	5.74E+03	0.0	5.74E+03	0.0	1.64E+02	1.64E+02	0.0	1.64E+02	0.0	2.12E+03	2.08E+03	0.0	2.00E+03	-0.1	-5.44E+01	-5.44E+01	0.0	-5.44E+01	0.0	7.96E+03	7.93E+03	0.0	7.84E+03	0.0
	Resource availability	$	1.18E+12	1.18E+12	0.0	1.18E+12	0.0	1.05E+11	1.05E+11	0.0	1.05E+11	0.0	9.18E+11	8.98E+11	0.0	8.51E+11	-0.1	-3.99E+10	-3.99E+10	0.0	-3.99E+10	0.0	2.16E+12	2.14E+12	0.0	2.09E+12	0.0

➢ Means of transportation

			Production					Transport					Use					End-of-life					Total				
	Indicator	Unit	Baseline scenario	Ship/air = 96/4	% change compared to baseline	Ship/air = 100/0	% change compared to baseline	Baseline scenario	Ship/air = 96/4	% change compared to baseline	Ship/air = 100/0	% change compared to baseline	Baseline scenario	Ship/air = 96/4	% change compared to baseline	Ship/air = 100/0	% change compared to baseline	Baseline scenario	Ship/air = 96/4	% change compared to baseline	Ship/air = 100/0	% change compared to baseline	Baseline scenario	Ship/air = 96/4	% change compared to baseline	Ship/air = 100/0	% change compared to baseline
MIDPOINTS	Climate change	kg CO2 eq	2.13E+11	2.13E+11	0.0	2.13E+11	0.0	2.07E+10	1.20E+10	-41.8	3.38E+09	-83.7	1.85E+11	1.85E+11	0.0	1.85E+11	0.0	-6.38E+09	-6.38E+09	0.0	-6.38E+09	0.0	4.13E+11	4.04E+11	-2.1	3.95E+11	-4.2
	Ozone depletion	kg CFC-11 eq	1.65E+04	1.65E+04	0.0	1.65E+04	0.0	2.63E+03	1.53E+03	-41.6	4.39E+02	-83.3	1.04E+04	1.04E+04	0.0	1.04E+04	0.0	-3.48E+01	-3.48E+01	0.0	-3.48E+01	0.0	2.94E+04	2.83E+04	-3.7	2.72E+04	-7.4
	Photochemical oxidant formation	kg NMVOC	5.21E+08	5.21E+08	0.0	5.21E+08	0.0	1.27E+08	8.42E+07	-33.8	4.11E+07	-67.7	4.47E+08	4.47E+08	0.0	4.47E+08	0.0	-7.60E+06	-7.60E+06	0.0	-7.60E+06	0.0	1.09E+09	1.04E+09	-4.0	1.00E+09	-7.9
	Particulate matter formation	kg PM10 eq	2.63E+08	2.63E+08	0.0	2.63E+08	0.0	3.74E+07	2.66E+07	-28.9	1.58E+07	-57.8	2.60E+08	2.60E+08	0.0	2.60E+08	0.0	-8.36E+06	-8.36E+06	0.0	-8.36E+06	0.0	5.52E+08	5.41E+08	-2.0	5.31E+08	-3.9
	Ionising radiation	kg U235 eq	7.99E+10	7.99E+10	0.0	7.99E+10	0.0	1.20E+09	8.05E+08	-33.0	4.08E+08	-66.0	1.14E+11	1.14E+11	0.0	1.14E+11	0.0	-6.04E+09	-6.04E+09	0.0	-6.04E+09	0.0	1.89E+11	1.89E+11	-0.2	1.89E+11	-0.4
	Terrestrial acidification	kg SO2 eq	8.51E+08	8.51E+08	0.0	8.51E+08	0.0	1.12E+08	8.05E+07	-28.2	4.88E+07	-56.5	7.47E+08	7.47E+08	0.0	7.47E+08	0.0	-2.72E+07	-2.72E+07	0.0	-2.72E+07	0.0	1.68E+09	1.65E+09	-1.9	1.62E+09	-3.8
	Human toxicity	kg 1,4-DB eq	1.25E+10	1.25E+10	0.0	1.25E+10	0.0	4.43E+08	2.84E+08	-35.8	1.26E+08	-71.6	6.35E+10	6.35E+10	0.0	6.35E+10	0.0	-5.68E+08	-5.68E+08	0.0	-5.68E+08	0.0	7.58E+10	7.56E+10	-0.2	7.55E+10	-0.4
	Terrestrial ecotoxicity	kg 1,4-DB eq	9.43E+08	9.43E+08	0.0	9.43E+08	0.0	1.91E+06	1.13E+06	-40.6	3.60E+05	-81.2	1.44E+08	1.44E+08	0.0	1.44E+08	0.0	-9.83E+05	-9.83E+05	0.0	-9.83E+05	0.0	1.09E+09	1.09E+09	-0.1	1.09E+09	-0.1
	Freshwater ecotoxicity	kg 1,4-DB eq	1.68E+09	1.68E+09	0.0	1.68E+09	0.0	1.24E+07	7.82E+06	-37.1	3.21E+06	-74.2	5.64E+09	5.64E+09	0.0	5.64E+09	0.0	-7.13E+06	-7.13E+06	0.0	-7.13E+06	0.0	7.33E+09	7.33E+09	-0.1	7.32E+09	-0.1
	Marine ecotoxicity	kg 1,4-DB eq	3.76E+08	3.76E+08	0.0	3.76E+08	0.0	2.32E+07	1.64E+07	-29.6	9.48E+06	-59.2	1.28E+09	1.28E+09	0.0	1.28E+09	0.0	-1.18E+07	-1.18E+07	0.0	-1.18E+07	0.0	1.67E+09	1.66E+09	-0.4	1.66E+09	-0.8
	Metal depletion	kg Fe eq	1.09E+10	1.09E+10	0.0	1.09E+10	0.0	2.13E+08	1.57E+08	-26.3	1.01E+08	-52.5	2.19E+10	2.19E+10	0.0	2.19E+10	0.0	-3.74E+08	-3.74E+08	0.0	-3.74E+08	0.0	3.27E+10	3.26E+10	-0.2	3.26E+10	-0.3
	Fossil depletion	kg oil eq	7.30E+10	7.30E+10	0.0	7.30E+10	0.0	7.21E+09	4.20E+09	-41.8	1.19E+09	-83.5	5.70E+10	5.70E+10	0.0	5.70E+10	0.0	-2.48E+09	-2.48E+09	0.0	-2.48E+09	0.0	1.35E+11	1.32E+11	-2.2	1.29E+11	-4.5
	Water depletion	m3	5.77E+09	5.77E+09	0.0	5.77E+09	0.0	3.76E+07	2.38E+07	-36.8	9.96E+06	-73.6	8.57E+09	8.57E+09	0.0	8.57E+09	0.0	-6.00E+07	-6.00E+07	0.0	-6.00E+07	0.0	1.43E+10	1.43E+10	-0.1	1.43E+10	-0.2
	Freshwater eutrophication	kg P eq	4.95E+07	4.95E+07	0.0	4.95E+07	0.0	1.09E+05	7.86E+04	-28.0	4.80E+04	-56.0	7.94E+06	7.94E+06	0.0	7.94E+06	0.0	-1.04E+05	-1.04E+05	0.0	-1.04E+05	0.0	5.74E+07	5.74E+07	-0.1	5.74E+07	-0.1
	Marine eutrophication	kg N eq	3.42E+08	3.42E+08	0.0	3.42E+08	0.0	1.39E+07	9.23E+06	-33.6	4.56E+06	-67.2	5.72E+07	5.72E+07	0.0	5.72E+07	0.0	8.65E+06	8.65E+06	0.0	8.65E+06	0.0	4.22E+08	4.17E+08	-1.1	4.12E+08	-2.2
	Agricultural land occupation	m2a	8.12E+10	8.12E+10	0.0	8.12E+10	0.0	3.47E+07	2.29E+07	-34.1	1.11E+07	-68.1	3.72E+09	3.72E+09	0.0	3.72E+09	0.0	-1.42E+08	-1.42E+08	0.0	-1.42E+08	0.0	8.48E+10	8.48E+10	0.0	8.48E+10	0.0
	Urban land occupation	m2a	9.39E+08	9.39E+08	0.0	9.39E+08	0.0	8.97E+07	5.83E+07	-35.0	2.68E+07	-70.1	1.03E+09	1.03E+09	0.0	1.03E+09	0.0	-3.32E+07	-3.32E+07	0.0	-3.32E+07	0.0	2.03E+09	2.00E+09	-1.5	1.97E+09	-3.1
	Natural land transformation	m2	7.58E+07	7.58E+07	0.0	7.58E+07	0.0	1.03E+07	5.96E+06	-42.3	1.59E+06	-84.6	2.81E+07	2.81E+07	0.0	2.81E+07	0.0	-1.07E+06	-1.07E+06	0.0	-1.07E+06	0.0	1.13E+08	1.09E+08	-3.9	1.04E+08	-7.7
ENDPOINTS	Human health	DALY	3.77E+05	3.77E+05	0.0	3.77E+05	0.0	3.91E+04	2.40E+04	-38.6	8.93E+03	-77.1	3.73E+05	3.73E+05	0.0	3.73E+05	0.0	-1.16E+04	-1.16E+04	0.0	-1.16E+04	0.0	7.77E+05	7.62E+05	-1.9	7.47E+05	-3.9
	Ecosystem diversity	species.yr	5.74E+03	5.74E+03	0.0	5.74E+03	0.0	1.82E+02	1.06E+02	-41.7	3.01E+01	-83.4	2.12E+03	2.12E+03	0.0	2.12E+03	0.0	-5.44E+01	-5.44E+01	0.0	-5.44E+01	0.0	7.98E+03	7.91E+03	-1.0	7.83E+03	-1.9
	Resource availability	$	1.18E+12	1.18E+12	0.0	1.18E+12	0.0	1.16E+11	6.74E+10	-41.8	1.91E+10	-83.5	9.18E+11	9.18E+11	0.0	9.18E+11	0.0	-3.99E+10	-3.99E+10	0.0	-3.99E+10	0.0	2.17E+12	2.12E+12	-2.2	2.07E+12	-4.5

➢ Appliances Load capacity

			Production					Transport					Use					End-of-life					Total				
	Indicator	Unit	Baseline scenario	Load capacity 3.7 kg/cycle	% change compared to baseline	Load capacity 4 kg/cycle	% change compared to baseline	Baseline scenario	Load capacity 3.7 kg/cycle	% change compared to baseline	Load capacity 4 kg/cycle	% change compared to baseline	Baseline scenario	Load capacity 3.7 kg/cycle	% change compared to baseline	Load capacity 4 kg/cycle	% change compared to baseline	Baseline scenario	Load capacity 3.7 kg/cycle	% change compared to baseline	Load capacity 4 kg/cycle	% change compared to baseline	Baseline scenario	Load capacity 3.7 kg/cycle	% change compared to baseline	Load capacity 4 kg/cycle	% change compared to baseline
MIDPOINTS	Climate change	kg CO2 eq	2.13E+11	2.13E+11	0.0	2.13E+11	0.0	2.07E+10	2.07E+10	0.0	2.07E+10	0.0	1.85E+11	1.77E+11	-4.1	1.71E+11	-7.6	-6.38E+09	-6.38E+09	0.0	-6.38E+09	0.0	4.13E+11	4.05E+11	-1.8	3.99E+11	-3.4
	Ozone depletion	kg CFC-11 eq	1.65E+04	1.65E+04	0.0	1.65E+04	0.0	2.63E+03	2.63E+03	0.0	2.63E+03	0.0	1.04E+04	9.88E+03	-4.6	9.47E+03	-8.5	-3.48E+01	-3.48E+01	0.0	-3.48E+01	0.0	2.94E+04	2.89E+04	-1.6	2.85E+04	-3.0
	Photochemical oxidant formation	kg NMVOC	5.21E+08	5.21E+08	0.0	5.21E+08	0.0	1.27E+08	1.27E+08	0.0	1.27E+08	0.0	4.47E+08	4.27E+08	-4.5	4.10E+08	-8.3	-7.60E+06	-7.60E+06	0.0	-7.60E+06	0.0	1.09E+09	1.07E+09	-1.9	1.05E+09	-3.4
	Particulate matter formation	kg PM10 eq	2.63E+08	2.63E+08	0.0	2.63E+08	0.0	3.74E+07	3.74E+07	0.0	3.74E+07	0.0	2.60E+08	2.49E+08	-4.4	2.39E+08	-8.0	-8.36E+06	-8.36E+06	0.0	-8.36E+06	0.0	5.52E+08	5.41E+08	-2.0	5.32E+08	-3.8
	Ionising radiation	kg U235 eq	7.99E+10	7.99E+10	0.0	7.99E+10	0.0	1.20E+09	1.20E+09	0.0	1.20E+09	0.0	1.14E+11	1.10E+11	-3.5	1.07E+11	-6.3	-6.04E+09	-6.04E+09	0.0	-6.04E+09	0.0	1.89E+11	1.85E+11	-2.1	1.82E+11	-3.8
	Terrestrial acidification	kg SO2 eq	8.51E+08	8.51E+08	0.0	8.51E+08	0.0	1.12E+08	1.12E+08	0.0	1.12E+08	0.0	7.47E+08	7.16E+08	-4.1	6.91E+08	-7.5	-2.72E+07	-2.72E+07	0.0	-2.72E+07	0.0	1.68E+09	1.65E+09	-1.8	1.63E+09	-3.3
	Human toxicity	kg 1,4-DB eq	1.25E+10	1.25E+10	0.0	1.25E+10	0.0	4.43E+08	4.43E+08	0.0	4.43E+08	0.0	6.35E+10	5.93E+10	-6.6	5.57E+10	-12.2	-5.68E+08	-5.68E+08	0.0	-5.68E+08	0.0	7.58E+10	7.16E+10	-5.5	6.81E+10	-10.2
	Terrestrial ecotoxicity	kg 1,4-DB eq	9.43E+08	9.43E+08	0.0	9.43E+08	0.0	1.91E+06	1.91E+06	0.0	1.91E+06	0.0	1.44E+08	1.34E+08	-6.7	1.26E+08	-12.5	-9.83E+05	-9.83E+05	0.0	-9.83E+05	0.0	1.09E+09	1.08E+09	-0.9	1.07E+09	-1.7
	Freshwater ecotoxicity	kg 1,4-DB eq	1.68E+09	1.68E+09	0.0	1.68E+09	0.0	1.24E+07	1.24E+07	0.0	1.24E+07	0.0	5.64E+09	5.24E+09	-7.1	4.89E+09	-13.3	-7.13E+06	-7.13E+06	0.0	-7.13E+06	0.0	7.33E+09	6.93E+09	-5.5	6.58E+09	-10.3
	Marine ecotoxicity	kg 1,4-DB eq	3.76E+08	3.76E+08	0.0	3.76E+08	0.0	2.32E+07	2.32E+07	0.0	2.32E+07	0.0	1.28E+09	1.20E+09	-6.6	1.13E+09	-12.2	-1.18E+07	-1.18E+07	0.0	-1.18E+07	0.0	1.67E+09	1.59E+09	-5.0	1.52E+09	-9.4
	Metal depletion	kg Fe eq	1.09E+10	1.09E+10	0.0	1.09E+10	0.0	2.13E+08	2.13E+08	0.0	2.13E+08	0.0	2.19E+10	2.06E+10	-6.0	1.95E+10	-11.1	-3.74E+08	-3.74E+08	0.0	-3.74E+08	0.0	3.27E+10	3.14E+10	-4.0	3.02E+10	-7.5
	Fossil depletion	kg oil eq	7.30E+10	7.30E+10	0.0	7.30E+10	0.0	7.21E+09	7.21E+09	0.0	7.21E+09	0.0	5.70E+10	5.45E+10	-4.3	5.25E+10	-7.9	-2.48E+09	-2.48E+09	0.0	-2.48E+09	0.0	1.35E+11	1.32E+11	-1.8	1.30E+11	-3.3
	Water depletion	m3	5.77E+09	5.77E+09	0.0	5.77E+09	0.0	3.76E+07	3.76E+07	0.0	3.76E+07	0.0	8.57E+09	8.10E+09	-5.5	7.70E+09	-10.2	-6.00E+07	-6.00E+07	0.0	-6.00E+07	0.0	1.43E+10	1.38E+10	-3.3	1.34E+10	-6.1
	Freshwater eutrophication	kg P eq	4.95E+07	4.95E+07	0.0	4.95E+07	0.0	1.09E+05	1.09E+05	0.0	1.09E+05	0.0	7.94E+06	7.45E+06	-6.1	7.04E+06	-11.3	-1.04E+05	-1.04E+05	0.0	-1.04E+05	0.0	5.74E+07	5.70E+07	-0.8	5.65E+07	-1.6
	Marine eutrophication	kg N eq	3.42E+08	3.42E+08	0.0	3.42E+08	0.0	1.39E+07	1.39E+07	0.0	1.39E+07	0.0	5.72E+07	5.44E+07	-4.8	5.21E+07	-8.9	8.65E+06	8.65E+06	0.0	8.65E+06	0.0	4.22E+08	4.19E+08	-0.7	4.17E+08	-1.2
	Agricultural land occupation	m2a	8.12E+10	8.12E+10	0.0	8.12E+10	0.0	3.47E+07	3.47E+07	0.0	3.47E+07	0.0	3.72E+09	3.56E+09	-4.5	3.42E+09	-8.2	-1.42E+08	-1.42E+08	0.0	-1.42E+08	0.0	8.48E+10	8.47E+10	-0.2	8.45E+10	-0.4
	Urban land occupation	m2a	9.39E+08	9.39E+08	0.0	9.39E+08	0.0	8.97E+07	8.97E+07	0.0	8.97E+07	0.0	1.03E+09	9.86E+08	-4.7	9.45E+08	-8.7	-3.32E+07	-3.32E+07	0.0	-3.32E+07	0.0	2.03E+09	1.98E+09	-2.4	1.94E+09	-4.4
	Natural land transformation	m2	7.58E+07	7.58E+07	0.0	7.58E+07	0.0	1.03E+07	1.03E+07	0.0	1.03E+07	0.0	2.81E+07	2.68E+07	-4.6	2.58E+07	-8.5	-1.07E+06	-1.07E+06	0.0	-1.07E+06	0.0	1.13E+08	1.12E+08	-1.1	1.11E+08	-2.1
ENDPOINTS	Human health	DALY	3.77E+05	3.77E+05	0.0	3.77E+05	0.0	3.91E+04	3.91E+04	0.0	3.91E+04	0.0	3.73E+05	3.56E+05	-4.4	3.42E+05	-8.2	-1.16E+04	-1.16E+04	0.0	-1.16E+04	0.0	7.77E+05	7.61E+05	-2.1	7.47E+05	-3.9
	Ecosystem diversity	species.yr	5.74E+03	5.74E+03	0.0	5.74E+03	0.0	1.82E+02	1.82E+02	0.0	1.82E+02	0.0	2.12E+03	2.01E+03	-4.9	1.92E+03	-9.1	-5.44E+01	-5.44E+01	0.0	-5.44E+01	0.0	7.98E+03	7.88E+03	-1.3	7.79E+03	-2.4
	Resource availability	$	1.18E+12	1.18E+12	0.0	1.18E+12	0.0	1.16E+11	1.16E+11	0.0	1.16E+11	0.0	9.18E+11	8.79E+11	-4.3	8.46E+11	-7.9	-3.99E+10	-3.99E+10	0.0	-3.99E+10	0.0	2.17E+12	2.13E+12	-1.8	2.10E+12	-3.3

➢ Tumble drying reduction

			Production					Transport					Use					End-of-life					Total				
	Indicator	Unit	Baseline scenario	-30% tumble drying in summer	% change compared to baseline	-50% tumble drying in summer, 15% in winter	% change compared to baseline	Baseline scenario	-30% tumble drying in summer	% change compared to baseline	-50% tumble drying in summer, 15% in winter	% change compared to baseline	Baseline scenario	-30% tumble drying in summer	% change compared to baseline	-50% tumble drying in summer, 15% in winter	% change compared to baseline	Baseline scenario	-30% tumble drying in summer	% change compared to baseline	-50% tumble drying in summer, 15% in winter	% change compared to baseline	Baseline scenario	-30% tumble drying in summer	% change compared to baseline	-50% tumble drying in summer, 15% in winter	% change compared to baseline
MIDPOINTS	Climate change	kg CO2 eq	2.13E+11	2.13E+11	0.0	2.13E+11	0.0	2.07E+10	2.07E+10	0.0	2.07E+10	0.0	1.85E+11	1.82E+11	-1.6	1.78E+11	-3.8	-6.38E+09	-6.38E+09	0.0	-6.38E+09	0.0	4.13E+11	4.10E+11	-0.7	4.05E+11	-1.7
	Ozone depletion	kg CFC-11 eq	1.65E+04	1.65E+04	0.0	1.65E+04	0.0	2.63E+03	2.63E+03	0.0	2.63E+03	0.0	1.04E+04	1.02E+04	-1.3	1.00E+04	-3.2	-3.48E+01	-3.48E+01	0.0	-3.48E+01	0.0	2.94E+04	2.93E+04	-0.5	2.91E+04	-1.1
	Photochemical oxidant formation	kg NMVOC	5.21E+08	5.21E+08	0.0	5.21E+08	0.0	1.27E+08	1.27E+08	0.0	1.27E+08	0.0	4.47E+08	4.41E+08	-1.4	4.32E+08	-3.4	-7.60E+06	-7.60E+06	0.0	-7.60E+06	0.0	1.09E+09	1.08E+09	-0.6	1.07E+09	-1.4
	Particulate matter formation	kg PM10 eq	2.63E+08	2.63E+08	0.0	2.63E+08	0.0	3.74E+07	3.74E+07	0.0	3.74E+07	0.0	2.60E+08	2.56E+08	-1.5	2.51E+08	-3.6	-8.36E+06	-8.36E+06	0.0	-8.36E+06	0.0	5.52E+08	5.49E+08	-0.7	5.43E+08	-1.7
	Ionising radiation	kg U235 eq	7.99E+10	7.99E+10	0.0	7.99E+10	0.0	1.20E+09	1.20E+09	0.0	1.20E+09	0.0	1.14E+11	1.12E+11	-1.9	1.09E+11	-4.6	-6.04E+09	-6.04E+09	0.0	-6.04E+09	0.0	1.89E+11	1.87E+11	-1.1	1.84E+11	-2.8
	Terrestrial acidification	kg SO2 eq	8.51E+08	8.51E+08	0.0	8.51E+08	0.0	1.12E+08	1.12E+08	0.0	1.12E+08	0.0	7.47E+08	7.35E+08	-1.6	7.17E+08	-3.9	-2.72E+07	-2.72E+07	0.0	-2.72E+07	0.0	1.68E+09	1.67E+09	-0.7	1.65E+09	-1.7
	Human toxicity	kg 1,4-DB eq	1.25E+10	1.25E+10	0.0	1.25E+10	0.0	4.43E+08	4.43E+08	0.0	4.43E+08	0.0	6.35E+10	6.32E+10	-0.3	6.29E+10	-0.8	-5.68E+08	-5.68E+08	0.0	-5.68E+08	0.0	7.58E+10	7.56E+10	-0.3	7.53E+10	-0.7
	Terrestrial ecotoxicity	kg 1,4-DB eq	9.43E+08	9.43E+08	0.0	9.43E+08	0.0	1.91E+06	1.91E+06	0.0	1.91E+06	0.0	1.44E+08	1.43E+08	-0.3	1.43E+08	-0.6	-9.83E+05	-9.83E+05	0.0	-9.83E+05	0.0	1.09E+09	1.09E+09	0.0	1.09E+09	-0.1
	Freshwater ecotoxicity	kg 1,4-DB eq	1.68E+09	1.68E+09	0.0	1.68E+09	0.0	1.24E+07	1.24E+07	0.0	1.24E+07	0.0	5.64E+09	5.64E+09	0.0	5.64E+09	-0.1	-7.13E+06	-7.13E+06	0.0	-7.13E+06	0.0	7.33E+09	7.33E+09	0.0	7.32E+09	-0.1
	Marine ecotoxicity	kg 1,4-DB eq	3.76E+08	3.76E+08	0.0	3.76E+08	0.0	2.32E+07	2.32E+07	0.0	2.32E+07	0.0	1.28E+09	1.28E+09	-0.3	1.27E+09	-0.8	-1.18E+07	-1.18E+07	0.0	-1.18E+07	0.0	1.67E+09	1.67E+09	-0.3	1.66E+09	-0.6
	Metal depletion	kg Fe eq	1.09E+10	1.09E+10	0.0	1.09E+10	0.0	2.13E+08	2.13E+08	0.0	2.13E+08	0.0	2.19E+10	2.18E+10	-0.6	2.16E+10	-1.5	-3.74E+08	-3.74E+08	0.0	-3.74E+08	0.0	3.27E+10	3.25E+10	-0.4	3.23E+10	-1.0
	Fossil depletion	kg oil eq	7.30E+10	7.30E+10	0.0	7.30E+10	0.0	7.21E+09	7.21E+09	0.0	7.21E+09	0.0	5.70E+10	5.61E+10	-1.5	5.49E+10	-3.6	-2.48E+09	-2.48E+09	0.0	-2.48E+09	0.0	1.35E+11	1.34E+11	-0.6	1.33E+11	-1.5
	Water depletion	m3	5.77E+09	5.77E+09	0.0	5.77E+09	0.0	3.76E+07	3.76E+07	0.0	3.76E+07	0.0	8.57E+09	8.55E+09	-0.3	8.52E+09	-0.7	-6.00E+07	-6.00E+07	0.0	-6.00E+07	0.0	1.43E+10	1.43E+10	-0.2	1.43E+10	-0.4
	Freshwater eutrophication	kg P eq	4.95E+07	4.95E+07	0.0	4.95E+07	0.0	1.09E+05	1.09E+05	0.0	1.09E+05	0.0	7.94E+06	7.89E+06	-0.6	7.83E+06	-1.4	-1.04E+05	-1.04E+05	0.0	-1.04E+05	0.0	5.74E+07	5.74E+07	-0.1	5.73E+07	-0.2
	Marine eutrophication	kg N eq	3.42E+08	3.42E+08	0.0	3.42E+08	0.0	1.39E+07	1.39E+07	0.0	1.39E+07	0.0	5.72E+07	5.65E+07	-1.2	5.55E+07	-3.0	8.65E+06	8.65E+06	0.0	8.65E+06	0.0	4.22E+08	4.21E+08	-0.2	4.20E+08	-0.4
	Agricultural land occupation	m2a	8.12E+10	8.12E+10	0.0	8.12E+10	0.0	3.47E+07	3.47E+07	0.0	3.47E+07	0.0	3.72E+09	3.67E+09	-1.4	3.60E+09	-3.4	-1.42E+08	-1.42E+08	0.0	-1.42E+08	0.0	8.48E+10	8.48E+10	-0.1	8.47E+10	-0.1
	Urban land occupation	m2a	9.39E+08	9.39E+08	0.0	9.39E+08	0.0	8.97E+07	8.97E+07	0.0	8.97E+07	0.0	1.03E+09	1.02E+09	-1.2	1.00E+09	-3.0	-3.32E+07	-3.32E+07	0.0	-3.32E+07	0.0	2.03E+09	2.02E+09	-0.6	2.00E+09	-1.5
	Natural land transformation	m2	7.58E+07	7.58E+07	0.0	7.58E+07	0.0	1.03E+07	1.03E+07	0.0	1.03E+07	0.0	2.81E+07	2.78E+07	-1.3	2.72E+07	-3.2	-1.07E+06	-1.07E+06	0.0	-1.07E+06	0.0	1.13E+08	1.13E+08	-0.3	1.12E+08	-0.8
ENDPOINTS	Human health	DALY	3.77E+05	3.77E+05	0.0	3.77E+05	0.0	3.91E+04	3.91E+04	0.0	3.91E+04	0.0	3.73E+05	3.68E+05	-1.4	3.60E+05	-3.4	-1.16E+04	-1.16E+04	0.0	-1.16E+04	0.0	7.77E+05	7.72E+05	-0.7	7.65E+05	-1.6
	Ecosystem diversity	species.yr	5.74E+03	5.74E+03	0.0	5.74E+03	0.0	1.82E+02	1.82E+02	0.0	1.82E+02	0.0	2.12E+03	2.09E+03	-1.2	2.06E+03	-2.8	-5.44E+01	-5.44E+01	0.0	-5.44E+01	0.0	7.98E+03	7.96E+03	-0.3	7.92E+03	-0.7
	Resource availability	$	1.18E+12	1.18E+12	0.0	1.18E+12	0.0	1.16E+11	1.16E+11	0.0	1.16E+11	0.0	9.18E+11	9.04E+11	-1.5	8.85E+11	-3.6	-3.99E+10	-3.99E+10	0.0	-3.99E+10	0.0	2.17E+12	2.16E+12	-0.6	2.14E+12	-1.5

➢ Appliance efficiency

	Indicator	Unit	Production					Transport					Use					End-of-life					Total				
			Baseline scenario	Improved washing machines efficiency	% change compared to baseline	Improved washing machines and dryers efficiency	% change compared to baseline	Baseline scenario	Improved washing machines efficiency	% change compared to baseline	Improved washing machines and dryers efficiency	% change compared to baseline	Baseline scenario	Improved washing machines efficiency	% change compared to baseline	Improved washing machines and dryers efficiency	% change compared to baseline	Baseline scenario	Improved washing machines efficiency	% change compared to baseline	Improved washing machines and dryers efficiency	% change compared to baseline	Baseline scenario	Improved washing machines efficiency	% change compared to baseline	Improved washing machines and dryers efficiency	% change compared to baseline
Mid-points	Climate change	kg CO2 eq	2.13E+11	2.13E+11	0.0	2.13E+11	0.0	2.07E+10	2.07E+10	0.0	2.07E+10	0.0	1.85E+11	1.79E+11	-3.5	1.68E+11	-8.9	-6.38E+09	-6.38E+09	0.0	-6.38E+09	0.0	4.13E+11	4.06E+11	-1.5	3.96E+11	-4.0
Mid-points	Ozone depletion	kg CFC-11 eq	1.65E+04	1.65E+04	0.0	1.65E+04	0.0	2.63E+03	2.63E+03	0.0	2.63E+03	0.0	1.04E+04	1.01E+04	-2.9	9.58E+03	-7.5	-3.48E+01	-3.48E+01	0.0	-3.48E+01	0.0	2.94E+04	2.91E+04	-1.0	2.86E+04	-2.6
Mid-points	Photochemical oxidant formation	kg NMVOC	5.21E+08	5.21E+08	0.0	5.21E+08	0.0	1.27E+08	1.27E+08	0.0	1.27E+08	0.0	4.47E+08	4.33E+08	-3.1	4.12E+08	-7.9	-7.60E+06	-7.60E+06	0.0	-7.60E+06	0.0	1.09E+09	1.07E+09	-1.3	1.05E+09	-3.2
Mid-points	Particulate matter formation	kg PM10 eq	2.63E+08	2.63E+08	0.0	2.63E+08	0.0	3.74E+07	3.74E+07	0.0	3.74E+07	0.0	2.60E+08	2.52E+08	-3.2	2.38E+08	-8.3	-8.36E+06	-8.36E+06	0.0	-8.36E+06	0.0	5.52E+08	5.44E+08	-1.5	5.31E+08	-3.9
Mid-points	Ionising radiation	kg U235 eq	7.99E+10	7.99E+10	0.0	7.99E+10	0.0	1.20E+09	1.20E+09	0.0	1.20E+09	0.0	1.14E+11	1.10E+11	-4.1	1.02E+11	-10.7	-6.04E+09	-6.04E+09	0.0	-6.04E+09	0.0	1.89E+11	1.85E+11	-2.5	1.77E+11	-6.5
Mid-points	Terrestrial acidification	kg SO2 eq	8.51E+08	8.51E+08	0.0	8.51E+08	0.0	1.12E+08	1.12E+08	0.0	1.12E+08	0.0	7.47E+08	7.21E+08	-3.5	6.79E+08	-9.0	-2.72E+07	-2.72E+07	0.0	-2.72E+07	0.0	1.68E+09	1.66E+09	-1.5	1.62E+09	-4.0
Mid-points	Human toxicity	kg 1,4-DB eq	1.25E+10	1.25E+10	0.0	1.25E+10	0.0	4.43E+08	4.43E+08	0.0	4.43E+08	0.0	6.35E+10	6.29E+10	-0.9	6.21E+10	-2.1	-5.68E+08	-5.68E+08	0.0	-5.68E+08	0.0	7.58E+10	7.53E+10	-0.7	7.45E+10	-1.7
Mid-points	Terrestrial ecotoxicity	kg 1,4-DB eq	9.43E+08	9.43E+08	0.0	9.43E+08	0.0	1.91E+06	1.91E+06	0.0	1.91E+06	0.0	1.44E+08	1.43E+08	-0.6	1.42E+08	-1.5	-9.83E+05	-9.83E+05	0.0	-9.83E+05	0.0	1.09E+09	1.09E+09	-0.1	1.09E+09	-0.2
Mid-points	Freshwater ecotoxicity	kg 1,4-DB eq	1.68E+09	1.68E+09	0.0	1.68E+09	0.0	1.24E+07	1.24E+07	0.0	1.24E+07	0.0	5.64E+09	5.63E+09	-0.2	5.62E+09	-0.3	-7.13E+06	-7.13E+06	0.0	-7.13E+06	0.0	7.33E+09	7.32E+09	-0.1	7.31E+09	-0.3
Mid-points	Marine ecotoxicity	kg 1,4-DB eq	3.76E+08	3.76E+08	0.0	3.76E+08	0.0	2.32E+07	2.32E+07	0.0	2.32E+07	0.0	1.28E+09	1.27E+09	-0.9	1.26E+09	-2.1	-1.18E+07	-1.18E+07	0.0	-1.18E+07	0.0	1.67E+09	1.66E+09	-0.7	1.64E+09	-1.6
Mid-points	Metal depletion	kg Fe eq	1.09E+10	1.09E+10	0.0	1.09E+10	0.0	2.13E+08	2.13E+08	0.0	2.13E+08	0.0	2.19E+10	2.16E+10	-1.4	2.11E+10	-3.6	-3.74E+08	-3.74E+08	0.0	-3.74E+08	0.0	3.27E+10	3.24E+10	-1.0	3.19E+10	-2.4
Mid-points	Fossil depletion	kg oil eq	7.30E+10	7.30E+10	0.0	7.30E+10	0.0	7.21E+09	7.21E+09	0.0	7.21E+09	0.0	5.70E+10	5.51E+10	-3.2	5.22E+10	-8.4	-2.48E+09	-2.48E+09	0.0	-2.48E+09	0.0	1.35E+11	1.33E+11	-1.4	1.30E+11	-3.6
Mid-points	Water depletion	m3	5.77E+09	5.77E+09	0.0	5.77E+09	0.0	3.76E+07	3.76E+07	0.0	3.76E+07	0.0	8.57E+09	6.75E+09	-21.2	6.67E+09	-22.1	-6.00E+07	-6.00E+07	0.0	-6.00E+07	0.0	1.43E+10	1.25E+10	-12.7	1.24E+10	-13.3
Mid-points	Freshwater eutrophication	kg P eq	4.95E+07	4.95E+07	0.0	4.95E+07	0.0	1.09E+05	1.09E+05	0.0	1.09E+05	0.0	7.94E+06	7.83E+06	-1.3	7.67E+06	-3.3	-1.04E+05	-1.04E+05	0.0	-1.04E+05	0.0	5.74E+07	5.73E+07	-0.2	5.72E+07	-0.5
Mid-points	Marine eutrophication	kg N eq	3.42E+08	3.42E+08	0.0	3.42E+08	0.0	1.39E+07	1.39E+07	0.0	1.39E+07	0.0	5.72E+07	5.57E+07	-2.7	5.32E+07	-6.9	8.65E+06	8.65E+06	0.0	8.65E+06	0.0	4.22E+08	4.20E+08	-0.4	4.18E+08	-0.9
Mid-points	Agricultural land occupation	m2a	8.12E+10	8.12E+10	0.0	8.12E+10	0.0	3.47E+07	3.47E+07	0.0	3.47E+07	0.0	3.72E+09	3.59E+09	-3.7	3.41E+09	-8.5	-1.42E+08	-1.42E+08	0.0	-1.42E+08	0.0	8.48E+10	8.47E+10	-0.2	8.45E+10	-0.4
Mid-points	Urban land occupation	m2a	9.39E+08	9.39E+08	0.0	9.39E+08	0.0	8.97E+07	8.97E+07	0.0	8.97E+07	0.0	1.03E+09	9.84E+08	-4.9	9.40E+08	-9.1	-3.32E+07	-3.32E+07	0.0	-3.32E+07	0.0	2.03E+09	1.98E+09	-2.5	1.94E+09	-4.6
Mid-points	Natural land transformation	m2	7.58E+07	7.58E+07	0.0	7.58E+07	0.0	1.03E+07	1.03E+07	0.0	1.03E+07	0.0	2.81E+07	2.72E+07	-3.4	2.59E+07	-7.9	-1.07E+06	-1.07E+06	0.0	-1.07E+06	0.0	1.13E+08	1.12E+08	-0.8	1.11E+08	-2.0
End-points	Human health	DALY	3.77E+05	3.77E+05	0.0	3.77E+05	0.0	3.91E+04	3.91E+04	0.0	3.91E+04	0.0	3.73E+05	3.61E+05	-3.1	3.43E+05	-8.0	-1.16E+04	-1.16E+04	0.0	-1.16E+04	0.0	7.77E+05	7.66E+05	-1.5	7.48E+05	-3.8
End-points	Ecosystem diversity	species.yr	5.74E+03	5.74E+03	0.0	5.74E+03	0.0	1.82E+02	1.82E+02	0.0	1.82E+02	0.0	2.12E+03	2.06E+03	-2.6	1.98E+03	-6.6	-5.44E+01	-5.44E+01	0.0	-5.44E+01	0.0	7.98E+03	7.93E+03	-0.7	7.84E+03	-1.7
End-points	Resource availability	$	1.18E+12	1.18E+12	0.0	1.18E+12	0.0	1.16E+11	1.16E+11	0.0	1.16E+11	0.0	9.18E+11	8.88E+11	-3.2	8.41E+11	-8.4	-3.99E+10	-3.99E+10	0.0	-3.99E+10	0.0	2.17E+12	2.14E+12	-1.4	2.09E+12	-3.6

➢ Low temperature

	Indicator	Unit	Production					Transport					Use					End-of-life					Total				
			Baseline scenario	Conservative scenario - Average temperature 39.3°C	% change compared to baseline	Optimistic scenario - Average temperature 32.9°C	% change compared to baseline	Baseline scenario	Conservative scenario - Average temperature 39.3°C	% change compared to baseline	Optimistic scenario - Average temperature 32.9°C	% change compared to baseline	Baseline scenario	Conservative scenario - Average temperature 39.3°C	% change compared to baseline	Optimistic scenario - Average temperature 32.9°C	% change compared to baseline	Baseline scenario	Conservative scenario - Average temperature 39.3°C	% change compared to baseline	Optimistic scenario - Average temperature 32.9°C	% change compared to baseline	Baseline scenario	Conservative scenario - Average temperature 39.3°C	% change compared to baseline	Optimistic scenario - Average temperature 32.9°C	% change compared to baseline
Mid-points	Climate change	kg CO2 eq	2.13E+11	2.13E+11	0.0	2.13E+11	0.0	2.07E+10	2.07E+10	0.0	2.07E+10	0.0	1.85E+11	1.75E+11	-5.5	1.65E+11	-10.9	-6.38E+09	-6.38E+09	0.0	-6.38E+09	0.0	4.13E+11	4.02E+11	-2.5	3.92E+11	-4.9
	Ozone depletion	kg CFC-11 eq	1.65E+04	1.65E+04	0.0	1.65E+04	0.0	2.63E+03	2.63E+03	0.0	2.63E+03	0.0	1.04E+04	9.88E+03	-4.6	9.42E+03	-9.1	-3.48E+01	-3.48E+01	0.0	-3.48E+01	0.0	2.94E+04	2.89E+04	-1.6	2.85E+04	-3.2
	Photochemical oxidant formation	kg NMVOC	5.21E+08	5.21E+08	0.0	5.21E+08	0.0	1.27E+08	1.27E+08	0.0	1.27E+08	0.0	4.47E+08	4.25E+08	-4.8	4.04E+08	-9.5	-7.60E+06	-7.60E+06	0.0	-7.60E+06	0.0	1.09E+09	1.07E+09	-2.0	1.04E+09	-3.9
	Particulate matter formation	kg PM10 eq	2.63E+08	2.63E+08	0.0	2.63E+08	0.0	3.74E+07	3.74E+07	0.0	3.74E+07	0.0	2.60E+08	2.47E+08	-5.1	2.34E+08	-10.1	-8.36E+06	-8.36E+06	0.0	-8.36E+06	0.0	5.52E+08	5.39E+08	-2.4	5.26E+08	-4.7
	Ionising radiation	kg U235 eq	7.99E+10	7.99E+10	0.0	7.99E+10	0.0	1.20E+09	1.20E+09	0.0	1.20E+09	0.0	1.14E+11	1.07E+11	-6.6	9.93E+10	-13.1	-6.04E+09	-6.04E+09	0.0	-6.04E+09	0.0	1.89E+11	1.82E+11	-4.0	1.74E+11	-7.9
	Terrestrial acidification	kg SO2 eq	8.51E+08	8.51E+08	0.0	8.51E+08	0.0	1.12E+08	1.12E+08	0.0	1.12E+08	0.0	7.47E+08	7.05E+08	-5.5	6.64E+08	-11.0	-2.72E+07	-2.72E+07	0.0	-2.72E+07	0.0	1.68E+09	1.64E+09	-2.5	1.60E+09	-4.9
	Human toxicity	kg 1,4-DB eq	1.25E+10	1.25E+10	0.0	1.25E+10	0.0	4.43E+08	4.43E+08	0.0	4.43E+08	0.0	6.35E+10	6.27E+10	-1.2	6.20E+10	-2.4	-5.68E+08	-5.68E+08	0.0	-5.68E+08	0.0	7.58E+10	7.51E+10	-1.0	7.43E+10	-2.0
	Terrestrial ecotoxicity	kg 1,4-DB eq	9.43E+08	9.43E+08	0.0	9.43E+08	0.0	1.91E+06	1.91E+06	0.0	1.91E+06	0.0	1.44E+08	1.42E+08	-0.9	1.41E+08	-1.8	-9.83E+05	-9.83E+05	0.0	-9.83E+05	0.0	1.09E+09	1.09E+09	-0.1	1.09E+09	-0.2
	Freshwater ecotoxicity	kg 1,4-DB eq	1.68E+09	1.68E+09	0.0	1.68E+09	0.0	1.24E+07	1.24E+07	0.0	1.24E+07	0.0	5.64E+09	5.63E+09	-0.2	5.62E+09	-0.3	-7.13E+06	-7.13E+06	0.0	-7.13E+06	0.0	7.33E+09	7.32E+09	-0.1	7.31E+09	-0.3
	Marine ecotoxicity	kg 1,4-DB eq	3.76E+08	3.76E+08	0.0	3.76E+08	0.0	2.32E+07	2.32E+07	0.0	2.32E+07	0.0	1.28E+09	1.27E+09	-1.2	1.25E+09	-2.4	-1.18E+07	-1.18E+07	0.0	-1.18E+07	0.0	1.67E+09	1.66E+09	-0.9	1.64E+09	-1.8
	Metal depletion	kg Fe eq	1.09E+10	1.09E+10	0.0	1.09E+10	0.0	2.13E+08	2.13E+08	0.0	2.13E+08	0.0	2.19E+10	2.14E+10	-2.2	2.09E+10	-4.3	-3.74E+08	-3.74E+08	0.0	-3.74E+08	0.0	3.27E+10	3.22E+10	-1.5	3.17E+10	-2.9
	Fossil depletion	kg oil eq	7.30E+10	7.30E+10	0.0	7.30E+10	0.0	7.21E+09	7.21E+09	0.0	7.21E+09	0.0	5.70E+10	5.40E+10	-5.2	5.11E+10	-10.3	-2.48E+09	-2.48E+09	0.0	-2.48E+09	0.0	1.35E+11	1.32E+11	-2.2	1.29E+11	-4.4
	Water depletion	m3	5.77E+09	5.77E+09	0.0	5.77E+09	0.0	3.76E+07	3.76E+07	0.0	3.76E+07	0.0	8.57E+09	8.49E+09	-0.9	8.42E+09	-1.8	-6.00E+07	-6.00E+07	0.0	-6.00E+07	0.0	1.43E+10	1.42E+10	-0.6	1.42E+10	-1.1
	Freshwater eutrophication	kg P eq	4.95E+07	4.95E+07	0.0	4.95E+07	0.0	1.09E+05	1.09E+05	0.0	1.09E+05	0.0	7.94E+06	7.78E+06	-2.0	7.62E+06	-4.0	-1.04E+05	-1.04E+05	0.0	-1.04E+05	0.0	5.74E+07	5.73E+07	-0.3	5.71E+07	-0.5
	Marine eutrophication	kg N eq	3.42E+08	3.42E+08	0.0	3.42E+08	0.0	1.39E+07	1.39E+07	0.0	1.39E+07	0.0	5.72E+07	5.48E+07	-4.2	5.24E+07	-8.4	8.65E+06	8.65E+06	0.0	8.65E+06	0.0	4.22E+08	4.19E+08	-0.6	4.17E+08	-1.1
	Agricultural land occupation	m2a	8.12E+10	8.12E+10	0.0	8.12E+10	0.0	3.47E+07	3.47E+07	0.0	3.47E+07	0.0	3.72E+09	3.54E+09	-4.8	3.37E+09	-9.5	-1.42E+08	-1.42E+08	0.0	-1.42E+08	0.0	8.48E+10	8.46E+10	-0.2	8.45E+10	-0.4
	Urban land occupation	m2a	9.39E+08	9.39E+08	0.0	9.39E+08	0.0	8.97E+07	8.97E+07	0.0	8.97E+07	0.0	1.03E+09	9.90E+08	-4.2	9.47E+08	-8.4	-3.32E+07	-3.32E+07	0.0	-3.32E+07	0.0	2.03E+09	1.99E+09	-2.2	1.94E+09	-4.3
	Natural land transformation	m2	7.58E+07	7.58E+07	0.0	7.58E+07	0.0	1.03E+07	1.03E+07	0.0	1.03E+07	0.0	2.81E+07	2.68E+07	-4.6	2.56E+07	-9.1	-1.07E+06	-1.07E+06	0.0	-1.07E+06	0.0	1.13E+08	1.12E+08	-1.1	1.11E+08	-2.3
End-points	Human health	DALY	3.77E+05	3.77E+05	0.0	3.77E+05	0.0	3.91E+04	3.91E+04	0.0	3.91E+04	0.0	3.73E+05	3.55E+05	-4.9	3.37E+05	-9.7	-1.16E+04	-1.16E+04	0.0	-1.16E+04	0.0	7.77E+05	7.59E+05	-2.4	7.41E+05	-4.7
	Ecosystem diversity	species.yr	5.74E+03	5.74E+03	0.0	5.74E+03	0.0	1.82E+02	1.82E+02	0.0	1.82E+02	0.0	2.12E+03	2.03E+03	-4.0	1.95E+03	-8.0	-5.44E+01	-5.44E+01	0.0	-5.44E+01	0.0	7.98E+03	7.90E+03	-1.1	7.81E+03	-2.1
	Resource availability	$	1.18E+12	1.18E+12	0.0	1.18E+12	0.0	1.16E+11	1.16E+11	0.0	1.16E+11	0.0	9.18E+11	8.70E+11	-5.2	8.24E+11	-10.3	-3.99E+10	-3.99E+10	0.0	-3.99E+10	0.0	2.17E+12	2.12E+12	-2.2	2.08E+12	-4.3

➢ Used clothing recycling

			Production					Transport					Use					End-of-life					Total				
	Indicator	Unit	Baseline scenario	Collection of 40% of clothing waste	% change compared to baseline	Collection of 70% of clothing waste	% change compared to baseline	Baseline scenario	Collection of 40% of clothing waste	% change compared to baseline	Collection of 70% of clothing waste	% change compared to baseline	Baseline scenario	Collection of 40% of clothing waste	% change compared to baseline	Collection of 70% of clothing waste	% change compared to baseline	Baseline scenario	Collection of 40% of clothing waste	% change compared to baseline	Collection of 70% of clothing waste	% change compared to baseline	Baseline scenario	Collection of 40% of clothing waste	% change compared to baseline	Collection of 70% of clothing waste	% change compared to baseline
MIDPOINTS	Climate change	kg CO2 eq	2.13E+11	2.10E+11	-1.4	2.06E+11	-3.6	2.07E+10	2.03E+10	-1.8	1.98E+10	-4.4	1.85E+11	1.85E+11	0.0	1.85E+11	0.0	-6.38E+09	-1.55E+10	142.2	-3.29E+10	415.4	4.13E+11	4.00E+11	-3.0	3.77E+11	-8.5
	Ozone depletion	kg CFC-11 eq	1.65E+04	1.62E+04	-1.5	1.59E+04	-3.8	2.63E+03	2.58E+03	-1.8	2.51E+03	-4.4	1.04E+04	1.04E+04	0.0	1.04E+04	0.0	-3.48E+01	-4.82E+02	1283.2	-1.34E+03	3758.0	2.94E+04	2.87E+04	-2.5	2.74E+04	-6.9
	Photochemical oxidant formation	kg NMVOC	5.21E+08	5.13E+08	-1.4	5.02E+08	-3.6	1.27E+08	1.25E+08	-1.8	1.22E+08	-4.4	4.47E+08	4.47E+08	0.0	4.47E+08	0.0	-7.60E+06	-2.64E+07	247.4	-6.29E+07	727.0	1.09E+09	1.06E+09	-2.6	1.01E+09	-7.3
	Particulate matter formation	kg PM10 eq	2.63E+08	2.59E+08	-1.4	2.54E+08	-3.6	3.74E+07	3.68E+07	-1.8	3.58E+07	-4.4	2.60E+08	2.60E+08	0.0	2.60E+08	0.0	-8.36E+06	-1.98E+07	137.4	-4.20E+07	402.6	5.52E+08	5.36E+08	-2.9	5.07E+08	-8.1
	Ionising radiation	kg U235 eq	7.99E+10	7.88E+10	-1.4	7.71E+10	-3.5	1.20E+09	1.18E+09	-1.8	1.15E+09	-4.4	1.14E+11	1.14E+11	0.0	1.14E+11	0.0	-6.04E+09	-1.27E+10	110.6	-2.55E+10	322.7	1.89E+11	1.82E+11	-4.1	1.67E+11	-11.8
	Terrestrial acidification	kg SO2 eq	8.51E+08	8.38E+08	-1.5	8.20E+08	-3.7	1.12E+08	1.10E+08	-1.7	1.07E+08	-4.4	7.47E+08	7.47E+08	0.0	7.47E+08	0.0	-2.72E+07	-6.33E+07	132.4	-1.33E+08	387.8	1.68E+09	1.63E+09	-3.0	1.54E+09	-8.4
	Human toxicity	kg 1,4-DB eq	1.25E+10	1.23E+10	-1.5	1.20E+10	-3.7	4.43E+08	4.35E+08	-1.8	4.24E+08	-4.4	6.35E+10	6.35E+10	0.0	6.35E+10	0.0	-5.68E+08	-1.24E+09	117.4	-2.52E+09	342.8	7.58E+10	7.49E+10	-1.1	7.34E+10	-3.2
	Terrestrial ecotoxicity	kg 1,4-DB eq	9.43E+08	9.28E+08	-1.6	9.05E+08	-4.1	1.91E+06	1.88E+06	-1.8	1.83E+06	-4.4	1.44E+08	1.44E+08	0.0	1.44E+08	0.0	-9.83E+05	-2.11E+06	115.0	-4.28E+06	336.0	1.09E+09	1.07E+09	-1.5	1.05E+09	-3.8
	Freshwater ecotoxicity	kg 1,4-DB eq	1.68E+09	1.66E+09	-1.6	1.62E+09	-4.0	1.24E+07	1.22E+07	-1.8	1.19E+07	-4.4	5.64E+09	5.64E+09	0.0	5.64E+09	0.0	-7.13E+06	-1.54E+07	116.6	-3.14E+07	340.5	7.33E+09	7.30E+09	-0.5	7.24E+09	-1.3
	Marine ecotoxicity	kg 1,4-DB eq	3.76E+08	3.70E+08	-1.5	3.62E+08	-3.8	2.32E+07	2.28E+07	-1.8	2.22E+07	-4.4	1.28E+09	1.28E+09	0.0	1.28E+09	0.0	-1.18E+07	-2.52E+07	114.7	-5.12E+07	335.3	1.67E+09	1.65E+09	-1.2	1.62E+09	-3.3
	Metal depletion	kg Fe eq	1.09E+10	1.08E+10	-1.5	1.05E+10	-3.8	2.13E+08	2.09E+08	-1.8	2.03E+08	-4.6	2.19E+10	2.19E+10	0.0	2.19E+10	0.0	-3.74E+08	-7.93E+08	112.4	-1.60E+09	328.2	3.27E+10	3.21E+10	-1.8	3.10E+10	-5.1
	Fossil depletion	kg oil eq	7.30E+10	7.20E+10	-1.4	7.04E+10	-3.6	7.21E+09	7.08E+09	-1.8	6.89E+09	-4.4	5.70E+10	5.70E+10	0.0	5.70E+10	0.0	-2.48E+09	-5.05E+09	103.7	-9.99E+09	302.9	1.35E+11	1.31E+11	-2.8	1.24E+11	-7.7
	Water depletion	m3	5.77E+09	5.68E+09	-1.6	5.54E+09	-3.9	3.76E+07	3.70E+07	-1.8	3.60E+07	-4.4	8.57E+09	8.57E+09	0.0	8.57E+09	0.0	-6.00E+07	-1.30E+08	117.3	-2.65E+08	342.3	1.43E+10	1.42E+10	-1.1	1.39E+10	-3.0
	Freshwater eutrophication	kg P eq	4.95E+07	4.87E+07	-1.6	4.75E+07	-4.1	1.09E+05	1.07E+05	-1.8	1.04E+05	-4.5	7.94E+06	7.94E+06	0.0	7.94E+06	0.0	-1.04E+05	-2.44E+05	135.7	-5.14E+05	396.4	5.74E+07	5.65E+07	-1.6	5.50E+07	-4.2
	Marine eutrophication	kg N eq	3.42E+08	3.37E+08	-1.6	3.29E+08	-4.0	1.39E+07	1.37E+07	-1.8	1.33E+07	-4.4	5.72E+07	5.72E+07	0.0	5.72E+07	0.0	8.65E+06	5.57E+06	-35.6	-3.66E+05	-104.2	4.22E+08	4.13E+08	-2.1	3.99E+08	-5.5
	Agricultural land occupation	m2a	8.12E+10	7.99E+10	-1.6	7.79E+10	-4.1	3.47E+07	3.41E+07	-1.8	3.32E+07	-4.4	3.72E+09	3.72E+09	0.0	3.72E+09	0.0	-1.42E+08	-3.01E+08	111.1	-6.04E+08	324.1	8.48E+10	8.33E+10	-1.8	8.10E+10	-4.5
	Urban land occupation	m2a	9.39E+08	9.25E+08	-1.5	9.03E+08	-3.9	8.97E+07	8.81E+07	-1.8	8.57E+07	-4.5	1.03E+09	1.03E+09	0.0	1.03E+09	0.0	-3.32E+07	-7.12E+07	114.5	-1.45E+08	335.1	2.03E+09	1.98E+09	-2.7	1.88E+09	-7.5
	Natural land transformation	m2	7.58E+07	7.46E+07	-1.6	7.29E+07	-3.9	1.03E+07	1.02E+07	-1.8	9.88E+06	-4.4	2.81E+07	2.81E+07	0.0	2.81E+07	0.0	-1.07E+06	-2.16E+06	101.6	-4.27E+06	298.2	1.13E+08	1.11E+08	-2.2	1.07E+08	-5.9
ENDPOINTS	Human health	DALY	3.77E+05	3.72E+05	-1.4	3.64E+05	-3.6	3.91E+04	3.84E+04	-1.8	3.73E+04	-4.4	3.73E+05	3.73E+05	0.0	3.73E+05	0.0	-1.16E+04	-2.79E+04	140.2	-5.92E+04	409.7	7.77E+05	7.55E+05	-2.9	7.15E+05	-8.1
	Ecosystem diversity	species.yr	5.74E+03	5.65E+03	-1.6	5.51E+03	-3.9	1.82E+02	1.79E+02	-1.8	1.74E+02	-4.4	2.12E+03	2.12E+03	0.0	2.12E+03	0.0	-5.44E+01	-1.30E+02	140.0	-2.77E+02	408.9	7.98E+03	7.81E+03	-2.1	7.53E+03	-5.7
	Resource availability	$	1.18E+12	1.16E+12	-1.4	1.13E+12	-3.6	1.16E+11	1.14E+11	-1.8	1.11E+11	-4.4	9.18E+11	9.18E+11	0.0	9.18E+11	0.0	-3.99E+10	-8.12E+10	103.7	-1.61E+11	302.9	2.17E+12	2.11E+12	-2.8	2.00E+12	-7.7

➢ Combined scenario

			Production			Transport			Use			End-of-life			Total		
	Indicator	Unit	Baseline scenario	Combined scenario	% change compared to baseline	Baseline scenario	Combined scenario	% change compared to baseline	Baseline scenario	Combined scenario	% change compared to baseline	Baseline scenario	Combined scenario	% change compared to baseline	Baseline scenario	Combined scenario	% change compared to baseline
MIDPOINTS	Climate change	kg CO2 eq	2.13E+11	2.00E+11	-6	2.07E+10	3.22E+09	-84	1.85E+11	1.42E+11	-23	-6.38E+09	-3.29E+10	415	4.13E+11	3.12E+11	-24
	Ozone depletion	kg CFC-11 eq	1.65E+04	1.33E+04	-19	2.63E+03	4.19E+02	-84	1.04E+04	8.12E+03	-22	-3.48E+01	-1.34E+03	3758	2.94E+04	2.05E+04	-30
	Photochemical oxidant formation	kg NMVOC	5.21E+08	4.94E+08	-5	1.27E+08	3.93E+07	-69	4.47E+08	3.48E+08	-22	-7.60E+06	-6.29E+07	727	1.09E+09	8.19E+08	-25
	Particulate matter formation	kg PM10 eq	2.63E+08	2.62E+08	-1	3.74E+07	1.51E+07	-60	2.60E+08	2.02E+08	-22	-8.36E+06	-4.20E+07	403	5.52E+08	4.36E+08	-21
	Ionising radiation	kg U235 eq	7.99E+10	8.95E+10	12	1.20E+09	3.89E+08	-68	1.14E+11	8.54E+10	-25	-6.04E+09	-2.55E+10	323	1.89E+11	1.50E+11	-21
	Terrestrial acidification	kg SO2 eq	8.51E+08	8.54E+08	0	1.12E+08	4.67E+07	-58	7.47E+08	5.72E+08	-23	-2.72E+07	-1.33E+08	388	1.68E+09	1.34E+09	-20
	Human toxicity	kg 1,4-DB eq	1.25E+10	1.23E+10	-1	4.43E+08	1.20E+08	-73	6.35E+10	5.36E+10	-16	-5.68E+08	-2.52E+09	343	7.58E+10	6.35E+10	-16
	Terrestrial ecotoxicity	kg 1,4-DB eq	9.43E+08	5.61E+08	-40	1.91E+06	3.43E+05	-82	1.44E+08	1.22E+08	-15	-9.83E+05	-4.28E+06	336	1.09E+09	6.80E+08	-38
	Freshwater ecotoxicity	kg 1,4-DB eq	1.68E+09	1.39E+09	-17	1.24E+07	3.06E+06	-75	5.64E+09	4.86E+09	-14	-7.13E+06	-3.14E+07	341	7.33E+09	6.23E+09	-15
	Marine ecotoxicity	kg 1,4-DB eq	3.76E+08	3.54E+08	-6	2.32E+07	9.06E+06	-61	1.28E+09	1.08E+09	-16	-1.18E+07	-5.12E+07	335	1.67E+09	1.39E+09	-17
	Metal depletion	kg Fe eq	1.09E+10	1.05E+10	-4	2.13E+08	9.62E+07	-55	2.19E+10	1.81E+10	-17	-3.74E+08	-1.60E+09	328	3.27E+10	2.70E+10	-17
	Fossil depletion	kg oil eq	7.30E+10	6.56E+10	-10	7.21E+09	1.13E+09	-84	5.70E+10	4.41E+10	-23	-2.48E+09	-9.99E+09	303	1.35E+11	1.01E+11	-25
	Water depletion	m3	5.77E+09	1.06E+09	-82	3.76E+07	9.49E+06	-75	8.57E+09	7.47E+09	-13	-6.00E+07	-2.65E+08	342	1.43E+10	8.28E+09	-42
	Freshwater eutrophication	kg P eq	4.95E+07	4.56E+07	-8	1.09E+05	4.57E+04	-58	7.94E+06	6.59E+06	-17	-1.04E+05	-5.14E+05	396	5.74E+07	5.17E+07	-10
	Marine eutrophication	kg N eq	3.42E+08	2.66E+08	-22	1.39E+07	4.36E+06	-69	5.72E+07	4.52E+07	-21	8.65E+06	-3.66E+05	-104	4.22E+08	3.15E+08	-25
	Agricultural land occupation	m2a	8.12E+10	8.20E+10	1	3.47E+07	1.06E+07	-70	3.72E+09	2.91E+09	-22	-1.42E+08	-6.04E+08	324	8.48E+10	8.43E+10	-1
	Urban land occupation	m2a	9.39E+08	9.47E+08	1	8.97E+07	2.56E+07	-72	1.03E+09	8.19E+08	-21	-3.32E+07	-1.45E+08	335	2.03E+09	1.65E+09	-19
	Natural land transformation	m2	7.58E+07	5.40E+07	-29	1.03E+07	1.52E+06	-85	2.81E+07	2.21E+07	-22	-1.07E+06	-4.27E+06	298	1.13E+08	7.33E+07	-35
ENDPOINTS	Human health	DALY	3.77E+05	3.58E+05	-5	3.91E+04	8.52E+03	-78	3.73E+05	2.90E+05	-22	-1.16E+04	-5.92E+04	410	7.77E+05	5.98E+05	-23
	Ecosystem diversity	species.yr	5.74E+03	4.41E+03	-23	1.82E+02	2.87E+01	-84	2.12E+03	1.68E+03	-21	-5.44E+01	-2.77E+02	409	7.98E+03	5.85E+03	-27
	Resource availability	$	1.18E+12	1.06E+12	-10	1.16E+11	1.82E+10	-84	9.18E+11	7.10E+11	-23	-3.99E+10	-1.61E+11	303	2.17E+12	1.62E+12	-25

Annex 4: Glossary

Term	Definition
Acidification	This midpoint impact category refers to the accumulation of acidifying substances (e.g. sulphuric acid, hydrochloric acid) in the water particles in suspension in the atmosphere. Deposited onto the ground by rain, acidifying pollutants have a wide variety of impacts on soil, groundwater, surface waters, biological organisms, ecosystems and materials (buildings).
Agricultural land occupation	This midpoint impact category refers to the amount of agricultural area occupied multiplied by the time of occupation.
Animal fibres	Fibres of animal origin such as wool, alpaca, camel hair, and silk.
Bleaching	Processes to remove the natural and artificial impurities in fabrics to obtain clear whites for finished fabric or in preparation for dyeing and finishing.
Blend	A yarn obtained when two or more staple fibres are combined in a textile process for producing spun yarns (e.g. at opening, carding, or drawing) or a fabric that contains a blended yarn (of the same fibre content) in the warp and filling.
Bt (Bacillus thuringiensis)	A spore forming bacterium that produces crystals of proteins which are toxic to many species of insects.
Carbonisation	Process that wool must undergo prior to spinning into woollen yarn. During the wool carbonising process all vegetable matter contained in the wool will be removed in preparation for carding and spinning into yarn.
Caustic soda	Sodium hydroxide.
Chelating agent	Chemical that combines with metal ions and removes them from their sphere of action, also called sequestrant.
Climate change	This midpoint impact category is also referred to as 'global warming'. Global warming refers to the increase of the average temperature of the Earth's surface which is widely accepted to be caused by the increased concentration of greenhouse gases (i.e. carbon dioxide, methane, nitrous oxide, fluorocarbons (e.g. CFCs and HCFCs), and others) in the atmosphere as a result of human activities.
Damage to ecosystem diversity	This endpoint category corresponds to the aggregation of the following midpoint impact categories: climate change, terrestrial acidification, freshwater eutrophication, marine eutrophication, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, agricultural land occupation, urban land occupation and natural land transformation. The unit of the corresponding indicator is 'species*yr', which is a measure of the number of species that potentially becomes extinct and the time span of this extinction. In other words, a value of '*x* species*yr' could quantify a threat to biodiversity as, for example, *x* species disappearing for 1 year, 2*x* species for 6 months, *x*/2 species for 2 years.
Damage to human health	This endpoint category corresponds to the aggregation of the following midpoint impact categories: climate change, ozone depletion, photochemical oxidant formation, particulate matter formation, ionising radiation and human toxicity. The unit of the corresponding indicator is 'disability-adjusted life year' (DALY)' which is a measure of the overall number of years lost due to ill, disability or early death.

Term	Definition
Damage to resource availability	This endpoint category corresponds to the aggregation of the following midpoint impact categories: water depletion, metal depletion and fossil fuel depletion. The corresponding indicator is expressed as the surplus cost which will be necessary in future to have access to the basket of limited resources that are currently exploited by human kind.
Desizing	The process of eliminating sizing, generally starch, from gray goods prior to applying special finishes or bleaches.
Detergent	A synthetic cleaning agent containing surfactants that do not precipitate in hard water and have the ability to emulsify oil and suspend dirt.
Dyeing	A process of colouring fibres, yarns, or fabrics with either natural or synthetic dyes.
Ecotoxicity	This midpoint impact category refers to how chemicals affect the environment and the organisms living in it. Ecotoxicity indicators assess when chemical releases are likely to result in toxic doses that exceed acceptable levels.
Enzymes	Proteins that catalyse chemical reactions.
Eutrophication	This midpoint impact category refers to processes that lead to water bodies, such as lakes or rivers, receiving excess chemical nutrients – typically compounds containing nitrogen or phosphorus – that stimulate excessive plant growth (e.g. algae). Nutrients can come from many sources, such as fertilisers applied to agricultural fields and golf courses, deposition of nitrogen from the atmosphere, erosion of soil containing nutrients, and sewage treatment plant discharges.
Flax	The plant from which the cellulosic fibre linen is obtained.
Fossil fuel depletion	This midpoint impact category measures the demand of fossil fuel resources.
Fully-fashioned	A term applied to fabrics produced on a flat-knitting machine, such as hosiery, sweaters, and underwear, which have been shaped by adding or reducing stitches.
Hemp	A coarse, durable bast fibre of *Cannabis sativa* found all over the world. Used primarily for twines, cordage, halyards, and tarred riggings.
Human toxicity	This midpoint impact category characterises health risks to humans by quantitatively assessing the risks posed by chemicals to human health and the environment. This indicator is based on 'risk characterisation ratios' that indicate when chemical releases are likely to result in toxic doses that exceed acceptable levels.
Ionising radiation	This midpoint impact category assesses the formation of ionising radiations emitted from radioactive materials.
Jet dyeing	High temperature piece dyeing in which the dye liquor is circulated via a Venturi jet thus providing the driving force to move the loop of fabric.
Kier boiling	Process of boiling cellulosic materials in alkaline liquors in a kier at or above atmospheric pressure.
Knitting	A method of constructing fabric by interlocking series of loops of one or more yarns.

Term	Definition
Linen	Cellulosic fibres derived from the stem of the flax plant or a fabric made from these fibres. Linen fibres are much stronger and more lustrous than cotton; they yield cool, absorbent fabrics that wrinkle easily. Fabrics with linen-like texture and coolness but with good wrinkle resistance can be produced from manufactured fibres and blends.
Liquor ratio	In wet processing the ratio of the weight of liquid used to the weight of goods treated.
Lubricant	An oil or emulsion finish applied to fibres to prevent damage during textile processing or to knitting yarns to make them more pliable.
Metal depletion	This midpoint impact category refers to the decreasing availability of metal resources.
Natural land transformation	This midpoint impact category refers to the natural land transformed as a consequence of anthropogenic activities.
NMVOC	NMVOC is the abbreviation for non-methane volatile organic compounds. It is a generic term for a large variety of chemically different compounds, like for example, benzene, ethanol, formaldehyde, cyclohexane, 1,1,1-trichloroethane or acetone. Essentially, NMVOCs are identical to VOCs, but with methane excluded. Sometimes NMVOC is also used as a sum parameter for emissions, where all NMVOC emissions are added up per weight into one figure. In absence of more detailed data, this can be a very coarse parameter for pollution, e.g. for summer smog or indoor air pollution.
Ozone depletion	This midpoint impact category refers to the thinning of the ozone layer, as know as 'ozone hole'. This mechanism is mainly due to the anthropogenic emission of brominated and chlorinated substances like CFCs.
Particulate matter formation	This midpoint impact category tracks the emissions of primary particulate matter less than 10 µm (PM_{10}) and secondary particulate matter precursors like nitrogen oxides (NO_X), ammonia (NH_3), and sulphur dioxide (SO_2).
Photochemical oxidant formation	This midpoint impact category refers to chemical reactions induced by solar light between nitrogen oxides and volatile organic compounds (VOC), commonly emitted in the combustion of fossil fuels. It provokes high levels of ozone and other chemicals toxic for humans and the environment.
Polyester fibre	A manufactured fibre in which the fibre-forming substance is any long chain synthetic polymer composed of at least 85 % by weight of an ester of dihydric alcohol and terephthalic acid (FTC definition).
Polypropylene fibre	A manufactured, olefin fibre made from polymers or copolymers of propylene.
Printing	A process for producing a pattern on yarns, warp, fabric, or carpet by any of a large number of printing methods.
Scouring	An operation to remove the sizing and tint used on the warp yarn in weaving and, in general, to clean the fabric prior to dyeing.
Silk fibre	A fine, strong, continuous filament produced by the larva of certain insects, especially the silkworm, when constructing its cocoons.

Term	Definition
Singeing	The process of burning off protruding fibres from yarn or fabric by passing it over a flame or heated copper plates. Singeing gives the fabric a smooth surface and is necessary for fabrics that are to be printed and for fabrics where smooth finishes are desired.
Sizing	A generic term for compounds that are applied to warp yarn to bind the fibre together and stiffen the yarn to provide abrasion resistance during weaving.
Sodium hydroxide	Caustic metallic base used in soap production.
Softener	A product designed to impart a soft mellowness to the fabric.
Spinning	The process or processes used in the production of single yarns or of fabrics generated directly from polymer.
Stitching	The process of passing a fibre or thread through the thickness of fabric layers to secure them. In composite manufacture, stitching is used to make preforms or to improve damage tolerance of complex-shaped parts.
Surfactant	A material that can greatly reduce the surface tension of water when used in very low concentrations.
Textile	Any type of material made from fibres or other extended linear materials such as thread or yarn.
Top making	Process of converting raw wool into a yarn suitable for spinning.
Tuft	A cluster of soft yarns drawn through a fabric and projecting from the surface in the form of cut yarns or loops.
Tufted carpet	Carpet produced by a tufting machine instead of a loom. It is an outgrowth of hand-tufted bedspreads.
Urban land transformation	This midpoint impact category refers to the urban area transformed as a consequence of anthropogenic activities.
Vegetable fibre	A textile fibre of vegetable origin, such as cotton, kapok, jute, ramie, and flax.
Viscose (a type of rayon)	A manufactured fibre composed of regenerated cellulose, as well as manufactured fibres composed of regenerated cellulose in which substituents have replaced not more than 15 % of the hydrogens of the hydroxyl groups (FTC definition).
Warp knitting	A type of knitting in which the yarns generally run lengthwise in the fabric.
Water depletion	This midpoint impact category refers to the withdrawal of water from the different sources (rivers, seas, groundwater) for use by humans. This water is not returned to the source.
Weaving	The method or process of interlacing two yarns of similar materials so that they cross each other at right angles to produce woven fabric. The warp yarns, or ends, run lengthwise in the fabric, and the filling threads (weft), or picks, run from side to side.
Weft knitting	A common type of knitting, in which one continuous thread runs crosswise in the fabric making all of the loops in one course. Weft knitting types are circular and flat knitting.

Term	Definition
Woven fabric	Generally used to refer to fabric composed of two sets of yarns, warp and filling, that is formed weaving, which is the interlacing of these sets of yarns.
Yarn	A generic term for a continuous strand of textile fibres, filaments, or material in a form suitable for knitting, weaving, or otherwise intertwining to form a textile fabric.

From Celanese Acetate (2001) for the textile terms.

European Commission
Joint Research Centre
Institute for Prospective Technological Studies (IPTS)

Title: Environmental Improvement Potential of textiles (IMPRO Textiles)

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Luxembourg: Publications Office of the European Union

2014, 187 pp. , 21.0 x 29.7 cm

EUR – Scientific and Technical Research series – ISSN 1831-9424 (online)

ISBN 978-92-79-34554-8 (pdf)

doi:10.2791/52624

Abstract

Completed in May 2006 by the European Commission's Joint Research Centre (JRC), the Environmental Impact of Products (EIPRO) study was conducted from a life cycle perspective. The EIPRO study indentified food and drink, transport and private housing as the highest areas of impact. Together they account for 70–80 % of the environmental impact of consumption. Of the remaining areas, clothing dominated across all impact categories with a contribution of 2–10 %.

A study on the Environmental Improvement of Products (IMPRO) for textiles was developed in order to identify technically and socio-economically feasible means of improving the environmental performance of textile products. The objectives of the study were to:

- identify the market share and consumption of textile products in the EU-27;
- estimate and compare the potential environmental impacts of textile products consumed in the EU-27, taking into account the entire value chain (life cycle) of these products;
- identify the main environmental improvement options and estimate their potential;
- assess the socioeconomic impacts of the identified options.

The analysis of the possible improvement options suggest that a significant reduction of impacts can potentially be achieved by targeting consumers. In particular, some of these options would require small behavioural changes. Examples for such changes are: reducing washing temperature, washing at full load, avoiding tumble-drying whenever possible, purchasing eco-friendly fibres, and donating clothes being not used anymore. To achieve such changes it is necessary for consumers to be aware of these issues, and it is imperative that infrastructural requirements can be met. Raising awareness and dissemination therefore become important drivers of change. Promotion of ecolabels, and examples of best practice cases, could therefore be used as tools for the overall improvement of environmental performance.

Concerning improvement options related to supply factors, it is more challenging to the accurate assessment and comparison of the improvement potential of single actions is more challenging due to a lack of experience with emerging techniques. Nevertheless, the analysis suggests that significant improvements could be achieved by appropriately encouraging practices which can produce less environment impacts, such as the recycling of effluent water.

LF-NA-26316-EN-N

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Publications Office

ISBN 978-92-79-34554-8 (pdf)