



Lifecycle environmental impact assessment of textiles

For priority streams in Dutch
lifecycle-based waste policy

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Authors:
Gerdien van de Vreede
Maartje Sevenster



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Gerdien van de Vreede, Maartje Sevenster
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For more information on this study, contact project leader Gerdien van de Vreede.

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Summary

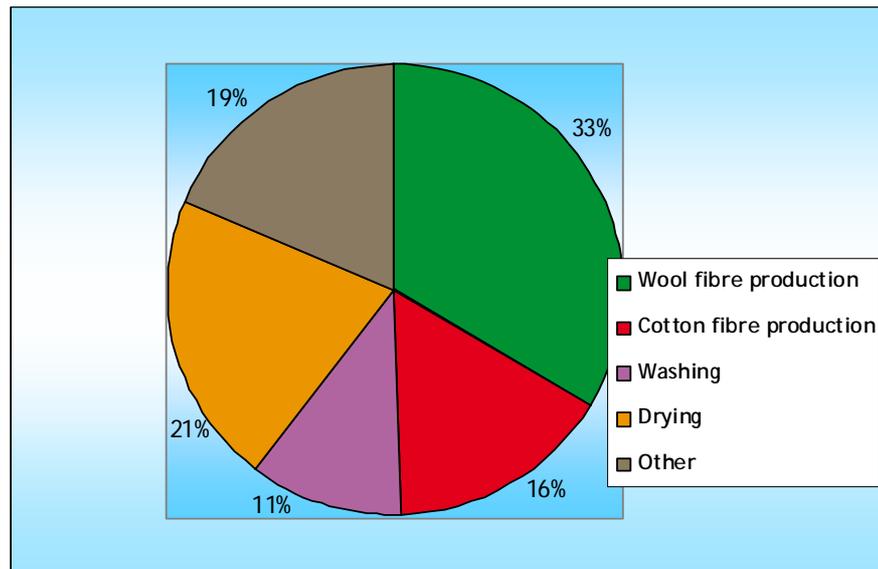
In the Netherlands' Second National Waste Management Programme (LAP2) a lifecycle-based approach has been adopted as a new policy framework. During the second planning period (2009-2015) this approach is to be further elaborated for seven priority material flows, one of which is textiles. A ballpark figure of 20% reduction of lifecycle environmental burden has been adopted as the target to be achieved by 2015.

In support of these policy intentions an environmental lifecycle assessment has been carried out for both the current situation, as a reference, and to estimate the available scope for improvement. The reference analysis covers the entire product chain from raw materials acquisition all the way through to final waste disposal, to determine not only the magnitude of the aggregate lifecycle impact, but also the precise activities contributing most to that impact. Based on the reference analysis, a series of options for improvement are identified and an assessment made of the potential environmental gains to be achieved.

For the purpose of this study the textiles stream has been limited to clothing (including work wear), household textiles and interior textiles, thus ignoring engineering textiles and carpeting. From an analysis of the aggregate lifecycle environmental impact of the textiles chain it emerges that the bulk of that impact is due to the production of wool fibre, cultivation and production of cotton fibre, and home washing and drying by consumers (Figure 1). Although the volume of wool used in the Netherlands is comparatively low, kilo for kilo it has a major impact because of the substantial areas of land required for sheep-farming and because sheep emit substantial quantities of methane by belching. It should be noted, though, that there are quite a few uncertainties about the precise impact of wool. Cotton is used a great deal (2/3 of Dutch textiles throughput consists of cotton) and has a slightly higher unit environmental impact than most other types of fibre. That impact is due largely to the land use requirements of cotton growing. Washing and drying are also responsible for a significant share of lifecycle environmental impact, owing mainly to energy (i.e. electricity) consumption, which leads to high scores on the impact categories 'climate change' and 'fossil depletion'.



Figure 1 Breakdown of environmental impacts of the textiles chain



There are number of options for reducing the lifecycle environmental impact of textiles consumption:

1. *Volume reduction*, by reducing textiles consumption or controlling material losses down the product chain.
2. *Process improvement*, with respect to production of the various fibres as well as the other lifecycle phases, for example by adopting alternative modes of cotton cultivation, through energy efficiency measures, by deploying cleaner energy sources in production processes, or by consumers switching from a conventional laundry dryer to a heat pump dryer or gas dryer.
3. *Switching to processes/materials with a lower environmental impact*, for example using alternative fibres with less environmental impact in the production phase and/or leading to more energy-efficient washing or drying in the use phase.

Of the options cited, the greatest potential lies in the realm of energy efficiency measures and use of cleaner energy sources in the upstream part of the supply chain, a shift in material choice from wool and cotton to other fibres, more efficient washing and drying by consumers and, finally, increased recycling in the waste disposal phase. Together, these options provide scope for over 30% improvement in lifecycle environmental performance.

1 Introduction

1.1 Background

In the context of the Netherlands' new lifecycle-based approach to waste management, as set out in the Second National Waste Management Programme (LAP2), a series of priority waste streams have been identified. During the second planning period (2009-2015) this approach is to be further elaborated for seven priority material flows. For each of these flows a strategy is to be drawn up to achieve a 20% reduction in lifecycle environmental impact by 2015.

In support of these policy intentions an environmental lifecycle assessment is required of both the current situation (as a reference) and as a means of assessing the potential for improvement. The reference analysis obviously needs to provide a picture of the current status quo, but in doing so can also yield insights into areas offering scope for improvement.

One of these seven priority flows is textiles, production and use of which are putting major pressure on the planet's environment. This is due among other things to land use and the greenhouse gas emissions accompanying production, but also to the energy consumption associated with textiles maintenance (i.e. washing and drying). The present study provides a reference analysis and an assessment, for the Netherlands, of the current environmental burden due to the production of textiles for Dutch consumption, their maintenance and their ultimate disposal as waste.

1.2 Aim

The central aim of this project was to undertake a reference analysis of the environmental impact of Dutch textiles throughput. This reference analysis covers the entire lifecycle from raw materials acquisition through to final waste disposal, to determine not only the magnitude of the overall impact, but also the precise activities contributing most to that impact. Based on the reference analysis, a series of options for improvement are identified and an assessment made of the potential environmental gains to be achieved.

1.3 Report outline

This report presents a reference analysis of the lifecycle environmental impacts of Dutch textiles throughput. Chapter 2 explains the general methodology, which has also been adopted for the other six priority flows. A description is provided of the scope and constraints of the present study, the data sources used, the environmental policy themes that have been included and the weighting methods employed. Chapter 3 provides a full description of the data used. Chapter 4 presents the results of the reference analysis: the environmental impact of the aggregate textiles flow, but also that of the various individual phases of the product chains as well as unit impacts. Chapter 5 discusses a number of areas providing scope for improvement and estimates the reduction potential relative to the reference analysis. Chapter 6 concludes by presenting a series of conclusions and recommendations.





2 Method

2.1 Procedure

It was originally the intention to analyse the environmental impact of a number of textile sub chains, to assess the scope for improvement in each of these and then upscale the results to yield an estimate of the scope for improvement for the entire textiles stream. During the kick-off meeting with the Advisory Committee on Textiles, however, it emerged that this was not the handiest approach for this particular stream. With the consent of the commissioning party it was therefore decided to adopt a different strategy.

Rather than employing a bottom-up method, with the impact of sub chains being scaled up to the entire textiles stream, a matrix method was used. This method proceeds on the premise that in each step of the production chain there are various alternatives available. In fibre production, for example, there is a choice from among a range of fibres, including cotton, linen, acryl and polyester, while in fabrics production there is a choice between woven, knitted and non-woven fabrics.

The overall matrix is summarised in Table 1, in which each column represents an individual step in the process. It starts with the cultivation and production of raw fibre (e.g. cotton, wool or hemp) or production of granulate (e.g. synthetic fibres like acryl, PLA and PET). These fibres are generally processed to yarn, which is then usually woven or knitted. With most types of textile there is also a pre-treatment step¹, a colouration step and/or a finishing step². There then usually follows a 'make-up' step in which the fabric is cut and sown to produce clothing or household textiles. In the consumption phase there is maintenance in the form of washing, drying, dry-cleaning and/or ironing. Ultimately, the product is discarded, at which stage it may be collected for reuse, incinerated, land filled or composted. To establish the lifecycle impact of a polycotton T-shirt, for example, one needs to know its composition (50% cotton, 50% polyester), its weight (e.g. 200 grams), the number of times it will be washed (e.g. 20) and the mode of waste disposal adopted (e.g. in a municipal waste incinerator). By multiplying the per-kg impact of each link in the chain by the number of kilos per link (in this fictional example: 100 grams of cotton fibre, 100 grams of polyester fibre, 200 grams knitted, $20 \times 0.2 = 4$ kg washed, etc.) the lifecycle impact of the T-shirt can be calculated. In Section 4.5 a version of Table 1 is provided which, in addition to the options available for each link in the supply chain, also reports the environmental impacts of each option.

In order to assess the environmental impact of the entire textiles stream, then, in each cell in the matrix two types of data are required:

- The unit environmental impact.
- The number of units.

¹ For example, bleaching or reinforcement.

² With most synthetic fibres, colouration takes place at the start of the process, prior to the granulate being extruded to yarn.



By multiplying these data for each cell and then summing the cells, a figure is obtained for the aggregate environmental impact of the entire textiles stream. The assumption is thereby made that the environmental impact of each cell is reasonably independent of that of the other cells. It is assumed, for example, that the weaving of cotton yarn requires approximately the same amount of energy as the weaving of linen or acryl. If there is reason to assume that the impact of certain processes depends very much on the type of fibre (or on some other variable), this can be easily remedied by adding an extra cell ('linen weaving', for example).

The advantage of adopting this kind of procedure is that it is very straightforward to add new fibres, production methods or maintenance activities. This means there is due scope for newly developed fibres or production methods, but also for calculations at a greater level of detail. All that is required for adding a new cell is a satisfactory understanding of the environmental impact of the fibre involved in the process in the cell and information on the size of the flow.



Table 1 Chain matrix

Fibre/granulate	Yarn production	Pre-treatment	Processing	Colouration	Finishing	Make-up	Maintenance	Waste disposal
Cotton	Spinning (various options)	Cotton pre-treatment	Weaving	Dyeing	Cotton finishing	* Sewing	Washing	Waste incinerator
Organic cotton	(n.a.)	Polyester pre-treatment	Knitting	Printing	Polyester finishing	(n.a.)	Dry cleaning	Separate collection for reuse various options
Linen			Non-woven	(n.a.)	(n.a.)		Ironing	Landfill
Acryl			(n.a.)				Drying	Composting (e.g. PLA)
Wool							Industrial washing	(n.a.)
Tencel							(n.a.)	
Bamboo								
Nylon/polyamide								
PLA								
PET (=polyester)								
Recycled PET								
Poly-olefins (PE/PP)								
Viscose								
Kenaf ³								
Jute								
Hemp								
Other								

³ Kenaf is made from the fibres of *Hibiscus cannabinus* and has similar properties to jute.

2.2 Scope and constraints

Although the purpose of this reference analysis is to elaborate a lifecycle-based approach to waste management policy, it takes as its starting point not the volume of textile waste arising annually in the Netherlands, but rather annual Dutch textiles consumption. The analysis encompasses the entire lifecycle, i.e. from raw materials production all the way through to waste disposal.

Engineering textiles and carpeting are not included in the definition of the textile stream as intended in this project on lifecycle-based waste policy. We are thus concerned with the following categories of textiles:

- Clothing.
- Work clothing ('workwear').
- Interior textiles (e.g. curtains).
- Household textiles (e.g. towels, duvet covers, etc.).

In addition, a number of prior choices were made regarding allocation, land use, short-cycle CO₂ and so-called LULUCF emissions⁴. These are now discussed.

Allocation

In Life Cycle Assessment (LCA) there is a need to decide on the appropriate procedure for impact allocation in the case of three types of processes:

- Multi-input processes, such as waste processing.
- Multi-output processes, such as processes in agricultural supply chains (wool/meat, cotton fibre/cotton oil, etc.).
- In the case of recycling, avoided emissions or production.

In the present reference analysis, economic allocation has been adopted for multi-input and multi-output processes. This means environmental impacts have been allocated to the various outputs on the basis of economic value: if product A represents 70% of the value of the outputs and product B 30%, then 70% of the environmental impact has been allocated to product A and 30% to product B. Although there may be a certain amount of variability over time as prices fluctuate, when long-term averages are considered this is generally only limited (cf. Blonk & Ponsioen, 2009). Only in the case of highly volatile markets (as in recent years for rapeseed used to produce fuel (biodiesel) rather than 'mash' for animal feed) is there a likelihood of major shifts occurring.

Allocation of avoided emissions or production is of relevance in the case of open-cycle materials recycling. If material from chain A is used in chain B, then this usually implies a degree of avoided production (and attendant emissions), but it is not immediately clear which chain is 'responsible'. In LCA, 'system expansion' can in theory be used in this kind of situation, but as stated in the project description this is not desirable. In cases like this we have therefore opted for 50-50 allocation. In the textiles chain this is relevant for PET recycling, for example, where PET bottles are recycled to produce fleece.

⁴ Land Use, Land Use Change and Forestry.



Short-cycle CO₂

In a textiles LCA it is important to decide how short-cycle CO₂⁵ is to be factored into the analysis. This is because biotic raw materials like cotton, wool and linen absorb CO₂ in the production phase, with this CO₂ being released back into the atmosphere in the waste phase. There are then two possible approaches:

1. Include the absorbed CO₂ when it is taken up at the beginning of the chain and also when it is emitted again at the end. This balances out to zero.
2. Ignore short-cycle CO₂ altogether, because the net impact is zero.

In a Cradle-to-Grave⁶ LCA it makes no difference which approach is taken. Although the results for each individual link in the chain will be different, the overall result will be the same. In a Cradle-to-Gate⁷ LCA the different strategies will yield different results, though. If it is opted to include short-cycle CO₂, then in a Cradle-to-Gate LCA this CO₂ is included in the product, but because the waste phase is not included, the later emissions of short-cycle CO₂ are not included, either. If it is opted to ignore short-cycle CO₂, then absorption of such CO₂ in the product is not included, which means that at the 'gate' there will be a difference between the two approaches equal to the amount of CO₂ absorbed⁸.

Ecoinvent is currently working on switching from the principle 'uptake at the start, emission at the end' to ignoring short-cycle CO₂ altogether. In principle we have followed the latter course here, for compatibility with forthcoming Ecoinvent updates.

Land use and LULUCF

Land use is an important theme, but has a somewhat anomalous status compared with the other themes under study. In itself, land use is not really an environmental *impact* but rather an *intervention* leading to impacts, including biodiversity losses, changes to water tables and so on. All these impacts depend very much on the precise location where the land use is taking place and in a lifecycle inventory this is not generally known in any great detail.

Because these impacts are potentially very important, though, land use has here been taken on board as an indicator. Whether or not land use is included is crucial when assessing the merits of recycling renewable materials like paper and cotton, for example. In the present LCA the land use associated with growing biotic raw materials (like cotton) and with minerals extraction have both been included. In this context it should be noted, however, that, kilo for kilo, the land use associated with fossil fuel resources and minerals is generally negligible compared with that associated with biotic raw materials.

⁵ Short-cycle CO₂ is CO₂ that is first absorbed by plants and thereby converted to vegetable matter, and subsequently released again during incineration. A decision needs to be made on how this short-cycle CO₂ is to be dealt with: are both CO₂ uptake and CO₂ emissions to be included (which balances out to zero, because ultimately the same amount is absorbed and released), or is short-cycle CO₂ to be left out of consideration altogether?

⁶ In a Cradle-to-Grave LCA the environmental impact of the entire lifecycle is calculated, i.e. all the way from raw materials through to waste disposal.

⁷ In a Cradle-to-Gate LCA the environmental impact is calculated from raw materials acquisition up to the moment the product leaves the factory gate, thus ignoring the use and waste phases.

⁸ In practice this is particularly problematical with Cradle-to-Gate LCAs in which fossil and biotic products are being compared.



The greenhouse gas emissions associated with land use and, particularly, land use change (LUC) - as in the case of deforestation to create new cropland, for instance - may be very substantial. The precise allocation of concrete LUC to a particular product is tricky, however, because it is scarcely ever feasible to trace a product back to a particular plot of land. Because of these uncertainties LUC and LUC impacts have not been included in our reference analysis. Neither have the sinks⁹ or emissions associated with land use been included.

For certain flows, such as food, this very likely means an underestimate of the aggregate impact, because deforestation and intensive agricultural practices will be involved. Both have an important impact on biodiversity and the carbon balance. In the case of the textiles stream there may also be an underestimate of the overall environmental impact (due to certain impacts not being included), because part of this flow is of biotic origin (cotton, wool, etc.) and because global demand for textiles continues to grow. Compared with food, though, the underestimate is likely to be modest. Owing to the major uncertainties in both the measurement and allocation of these impacts, as stated, this has been left out of consideration. This obviously means that it must likewise be ignored when calculating options for improvement. This means both the reference analysis and the reduction potential are lower in absolute terms. This makes no difference to the feasibility of a relative reduction of 20%. When considering any specific measures to improve performance, though, due care should be taken that these do not lead to any increase in Land Use Change, as this has not been factored into the analysis.

2.3 Impact assessment, environmental themes and weighting method

Once the aim and scope of the LCA have been established and the required data collected, an aggregate inventory result is calculated. This inventory result is a very long list of emissions, raw materials consumed and sometimes other quantities, too. Interpretation of this list is no easy matter. To aid interpretation, a life cycle impact assessment (LCIA) method can be used. The LCIA results in this report have been calculated using the ReCiPe method, which in turn builds on Eco-indicator 99 and CML 2 methods, both in common use.

2.3.1 ReCiPe

The main aim of the ReCiPe method is to convert the long list of inventory results into a limited number of indicator scores. These scores indicate the relative seriousness of each environmental impact category. In ReCiPe, indicators are distinguished at three levels:

1. Eighteen midpoint indicators.
2. Three endpoint indicators.
3. A single score indicator.

The model used in ReCiPe is based on the concept of environmental mechanisms, to be regarded as a series of impacts that together cause a certain level of harm to, say, human health or ecosystems. In the case of climate change, for example, we know that a number of pollutants lead to increased radiative forcing, which means a reduction in the amount of heat radiated from earth back into space. The upshot is that more energy remains on the planet and that global temperatures rise. As a result we can expect

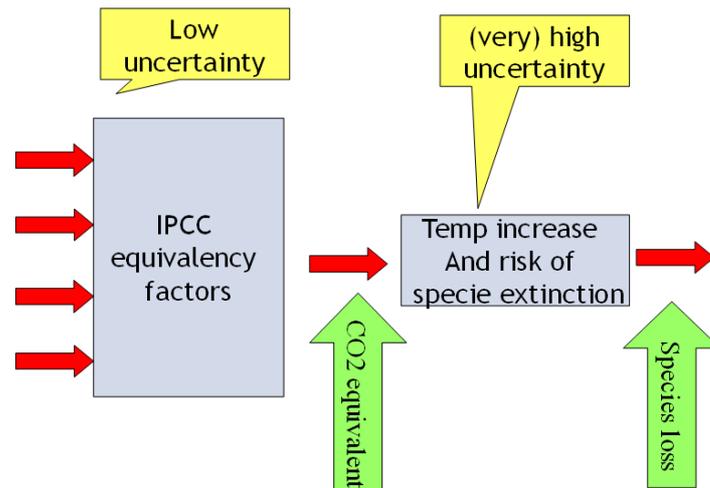
⁹ The sequestration of carbon in soils as a result of natural processes.



changes in the natural environment that is home to biological species, with as a potential consequence a certain fraction of these species becoming extinct.

As this example makes clear, the longer the environmental mechanism that is adopted, the greater will be the uncertainties. While radiative forcing is a physical parameter that is fairly simple to measure in the laboratory, the resultant temperature rise is less straightforward to determine, as there are numerous positive and negative impacts acting in parallel, our understanding of likely changes in the natural environment is incomplete, and so on.

Figure 2 Example of a harmonised midpoint-endpoint model of climate change, coupled to human health and damage to ecosystems
The midpoint indicator is 'CO₂-equivalents', the endpoint indicator 'species loss'



Source: www.lcia-recipe.net.

The clear advantage of only including the first step is thus the relatively low degree of uncertainty.

2.3.2 ReCiPe: combined midpoints and endpoints

In ReCiPe, factors have been calculated for eighteen of these midpoint indicators, as well as for three far more uncertain endpoint indicators. The reason for also calculating endpoint indicators is that the large number of midpoint indicators is very hard to interpret, partly because of the sheer number and partly because their meaning is highly abstract. How is one to compare 'radiative forcing' with 'base saturation', the measure of acidification, for example? The indicators at the endpoint level are intended to facilitate the interpretation process, because there are only three in number and because they are more readily comprehensible.

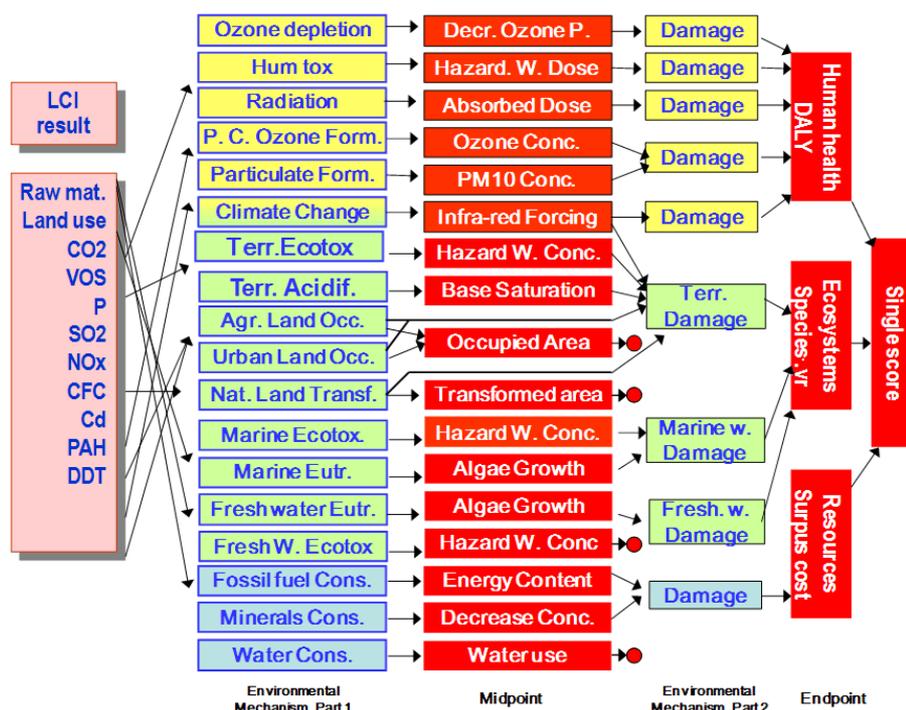
The idea is that each user can choose the level at which they wish to have their results.

- Eighteen relatively robust midpoints that are hard to interpret, though.
- Three easy to understand but more uncertain endpoints:
 - Damage to human health ('years/quality of life lost').
 - Damage to ecosystems ('lost species times years').
 - Damage to resource availability ('surplus cost of extraction').

The user can thus choose between uncertainty in the indicators themselves and uncertainty in correct interpretation thereof.

Figure 3 provides a synopsis of the overall method structure.

Figure 3 Outline structure of the ReCiPe method



Source: www.lcia-recipe.net.

Note that water consumption and marine eutrophication are not included at endpoint level. The theme of climate change (unit: CO₂-equivalents) breaks down into two midpoint categories: one contributing to the endpoint category 'human health' (unit: 'years/quality of life lost'), the other to the endpoint category 'ecosystem damage' (unit: 'lost species times years'). The factors in between the midpoint and endpoint categories are given in Annex C.

Table 2 provides a summary of the environmental themes that have been included in the present reference analysis with their respective units. To determine the aggregate impact, the scores on the various different impact categories need to be weighted. To this end the ReCiPe H/A weighting set has been used, with European normalisation. This weighting set is available as a standard in ReCiPe and assigns a weight of 40% to both human health and ecosystems and a weight of 20% to resource depletion. In this report, when the term 'environmental burden' is employed without any further explanation, this is to be taken to refer to the 'single-score' result calculated according to this weighting set¹⁰. It is on this basis that the reference analysis has been performed for assessing the environmental burden reduction targets.

All the results in this report are expressed in Pt, that is, they have been normalised and weighted.

¹⁰ ReCiPe 2008 method, version 1.02, October 19th 2009, adapted to this analysis by explicitly excluding land use change and the associated CO₂ emissions, normalisation without the contribution of land use change and a PM formation characterisation factor for PM_{2.5} that is 1.577 times higher than that for PM₁₀.



Table 2 Impact categories (midpoint indicators)

Impact category	Unit
Climate change, Human Health	DALY ^(a)
Climate change, Ecosystems	Species. yr
Ozone depletion	DALY
Terrestrial acidification	Species. yr
Freshwater eutrophication	Species. yr
Marine eutrophication ^(b)	
Human toxicity	DALY
Photochemical oxidant formation	DALY
Particulate matter formation	DALY
Terrestrial ecotoxicity	Species.yr
Freshwater ecotoxicity	Species.yr
Marine ecotoxicity	Species.yr
Ionising radiation	DALY
Agricultural land occupation	Species.yr
Urban land occupation	Species.yr
Water depletion ^(b)	
Minerals depletion	\$
Fossil depletion	\$

(a) Disability Adjusted Life Year.

(b) These categories do not count at endpoint level.

2.3.3 Brief explanation of ReCiPe midpoints

Climate change, Human health & Climate change, Ecosystems

Climate change, the reinforced greenhouse effect, triggers a number of environmental mechanisms of influence on the endpoints 'human health' and 'ecosystems'. Because these endpoints are expressed in different units (DALY and species.yr) they are already split at the midpoint level. Carbon dioxide (CO₂) is the best known greenhouse gas.

Ozone layer depletion

Most atmospheric ozone is found at an altitude of around 15-30 kilometres and this part of the atmosphere is therefore known as the ozone layer. This layer absorbs much of the damaging ultraviolet radiation emitted by the sun and since the 1980s there has been a general decline in its thickness. Each year in spring, over half the ozone over the South Pole still disappears for a while. Above our part of the world, the ozone layer has also grown thinner. Here too this reduction is greatest in spring, although by autumn levels are almost back to normal. The ozone layer is depleted by a variety of gases, including chlorofluorocarbons (CFCs). These end up in the ozone layer, where they break down, releasing the chlorine atoms, which in turn destroy the ozone molecules to yield chlorine monoxide and oxygen ($Cl + O_3 \rightarrow ClO + O_2$). The UV radiation then breaks down the chlorine monoxide molecule into two free atoms, after which the chlorine atom goes on to break down another ozone molecule.

Acidification, terrestrial

Acidification of soils (and water) is a consequence of air pollutant emissions by factories, agricultural activities, power stations and vehicles. These acidifying emissions include sulphur dioxide (SO₂), nitrogen oxides (NO_x), ammonia (NH₃) and volatile organic compounds (VOC), which are transported via the atmosphere or the water cycle and end up in soils. This is referred to as acid deposition. By way of foliage and root systems these substances penetrate



trees and other plants, making them more susceptible to disease. Acid deposition also causes damage to lakes and rivers, ultimately harming the wildlife that lives or drinks there, because of elevated acid and aluminium concentrations.

Eutrophication, freshwater

Eutrophication is the term used for elevated nutrient concentrations in water in particular. In biology it is used to refer to the phenomenon of certain species exhibiting strong growth and/or reproduction following addition of a nutrient surplus, generally leading to a sharp decline in species richness, i.e. loss of biodiversity. Eutrophication may occur, for example, in freshwater bodies subject to fertiliser run-off, particularly nitrogen and phosphate deriving from manure, slurry and artificial fertilisers from farming activities. The result is pronounced 'algal bloom', recognisable as dark-coloured water masses with an unpleasant smell. Eutrophication can lead to hypoxia, a deficiency of oxygen in the water.

Human toxicity

The impact category 'human toxicity' covers emissions to air, water and soils that result (ultimately) in damage to human health.

Photochemical oxidant formation

Photochemical oxidant formation, or smog (a combination of the words 'smoke' and 'fog'), is a form of air pollution involving mist polluted by smoke and exhaust fumes, which may in certain periods suddenly increase in severity, with potential consequences for human health. The substances of greatest influence on smog formation are ozone and airborne particulates and, to a lesser extent, nitrogen dioxide and sulphur dioxide.

Particulate matter formation

Particulate matter (PM) refers to airborne particulates with a diameter of less than 10 micrometres. It consists of particles of varying size, origin and chemical composition. When inhaled, PM causes health damage. In people with respiratory disorders and cardiac problems, chronic exposure to airborne particulates aggravates the symptoms, while in children it hampers development of the lung function. The standards for particulate levels are currently exceeded at numerous locations in Europe, particularly along busy roads.

Ecotoxicity, terrestrial, freshwater and marine

The impact category 'ecotoxicity' covers emissions to air, water and soils that result (ultimately) in damage to the ecosystems in soils, freshwater and marine waters.

Ionising radiation

Ionising radiation results from the decay of radioactive atoms like those of uranium-235, krypton-85 and iodine-129. There are two types of ionising radiation: particle-type radiation (alpha radiation, beta radiation, neutrons, protons) and high-energy electromagnetic radiation (X-rays, gamma radiation). Ionising radiation can damage DNA and cause a variety of cancers.



Land use, agricultural and urban

The impact category 'land use' refers to the damage to ecosystems associated with the effects of human land occupation over a certain period of time. Because of insufficient inventory data and uncertainties in these data, in the results presented in this report the ReCiPe category 'land transformation' has been left out of consideration (cf. Section 0).

Depletion, minerals and fossil

Consumption of mineral resources and fossil fuels has been weighted using a factor that increases in magnitude as the resource in question becomes scarcer and their concentration declines. The measure used is the marginal increase in extraction costs (expressed in Dollars per kg).





3 Data

In order to calculate the total environmental impact of textiles consumption in the Netherlands, two types of data are in principle required: on the environmental impact of each potential link in the supply chain (cotton cultivation, PET granulate production, finishing, washing, etc.) and on its magnitude. In this chapter we first consider the LCI data¹¹ and then the data on the scale of each of the flows concerned.

3.1 LCI data

Wherever possible, use has been made of open-source process databases (including the Ecoinvent database) and LCA studies. Most of these are geared to average European or even global production. Because supply chains are situated largely outside the Netherlands (mainly in countries for which data are available in open-source databases), these data are generally sufficiently representative. In addition, data have been retrieved from relevant branches of industry, for example via the stakeholders involved in the Dutch lifecycle-based waste management programme, and from the literature. For processes occurring outside Europe, where necessary the Ecoinvent 'process maps' have been adapted, based on data sources available at CE Delft. Table 3 reviews the sources used for the LCI data in each cell of the matrix.

For the LCI data on fibres, wherever possible use has been made of data from the Ecoinvent database. Where necessary, other literature data have been used, as specified in Table 3. For cotton, these data are based on the US and China, for wool on the US, for jute and kenaf¹² on India, and for the other fibres/granulates on the European situation¹³. For all these data it holds that they provide a good approximation of the fibres available on the Dutch market. The data on processes like bleaching, dyeing, yarn production, processing to fabric and finishing are based on Ecoinvent data and data reported on the Indian website www.thesmarttime.com, which provides the details of a large number of recipes for various different production methods. A figure of 10 litres per kg textile has been assumed for water consumption in batch processes and 3 litres of water per kg textile for continuous processes. For the heating of process water, we have assumed an efficiency of 80%¹⁴ (expert judgement, Anton Luiken) and use of natural gas.

¹¹ LCI data = Life Cycle Inventory data, i.e. a comprehensive review of the inputs and outputs of each link in the chain.

¹² Kenaf is made from the fibres of *Hibiscus cannabinus* and has similar properties to jute.

¹³ In each of these cases the countries in question were chosen because there was reliable data on them in the Ecoinvent database and the national situation was deemed representative for Dutch textiles consumption.

¹⁴ 90% boiler efficiency combined with 90% heat transfer efficiency. Heat losses during the process have been ignored and it is assumed that there is no heat recovery via heat exchangers.



The data on the use phase (for textiles: maintenance in the form of washing, drying, ironing and/or dry cleaning) relate to washing temperatures and washing machine load factors¹⁵ in the Dutch situation and are based largely on data from the organisation Milieu Centraal (with respect to both washing parameters and frequency). The environmental burden due to detergent use has also been included, but not that associated with manufacture of the washing machine or dryer itself. Because it is generally the case for energy-intensive electrical appliances that the vast bulk of the environmental impact (around 90%) is due to this energy consumption, this omission hardly influences the ultimate results. Data on dry cleaning and industrial washing are not presently available, but the size of these flows is negligible compared with the volume of textiles washed at home by consumers.

In the waste phase two flows can be distinguished. A certain fraction of the textiles is separately collected. Some of this is reused as second-hand clothing (most of it abroad¹⁶) and we have here assumed 500 km transport by truck and 7,600 km by ocean-going vessel (from Rotterdam to West Africa). For this second-hand clothing we allocated 70% of the environmental impact to first use in the Netherlands and 30% to the remaining life span¹⁷. The rest of the collected textiles are used as filler or insulation materials¹⁸ or as cleaning rags¹⁹, or end up in municipal waste incinerators.

The remaining discarded textiles are collected along with other household waste and sent to the municipal incinerator, with electricity being generated (efficiency: 20%). Incineration is obviously accompanied by CO₂ emissions and we therefore need to distinguish between 'fossil' CO₂ emissions (e.g. from polyester) and 'biotic' CO₂ emissions (e.g. from cotton)²⁰. In addition, there are product losses in many of the processes along the chain (like cutting losses in the make-up phase). It has been assumed that this waste is processed locally, with 1/3 being reused as fibre and 2/3 as filler/insulation material²¹.

In principle, capital goods (e.g. factory buildings, plant and equipment, infrastructure) are not included in the inventory. In databases like Ecoinvent it is not presently feasible to exclude such goods, however, as they are included in Ecoinvent LCAs as standard practice. In all cases the capital goods were of negligible influence, though, so that their inclusion or exclusion had virtually no impact on the ultimate results of the reference analysis, nor on the conclusions.

¹⁵ On average, 3.4 kg per wash.

¹⁶ Some of this clothing could obviously be reused in the Netherlands. This would probably lead to a reduction in the volume of new clothing sold in the country.

¹⁷ Expert judgement, CE Delft. Based on the life span in years, a smaller fraction might be assigned to Dutch consumption; based on economic value, the fraction is likely to be greater.

¹⁸ Textile waste is often used as a filler or insulation material, particularly in the automotive industry. If this waste were not employed for this purpose, plastics like polyurethane would be used. We have hereby assumed that 1 kg of textile waste replaces 0.8 kg of polyurethane.

¹⁹ If no textile waste were used as cleaning rags, some other material would be used for this purpose. This might be non-woven cloth, but also paper rags. In this case we have assumed that 1 kg of textile waste replaces 0.5 kg of paper towels.

²⁰ Because biotic CO₂ is short-cycle in this case and fossil CO₂ long-cycle. The biotic CO₂ is thus CO₂ that has been absorbed from the atmosphere relatively recently by plants, while the fossil CO₂ is due to the combustion of the carbon in fossil fuels.

²¹ Expert judgement, Anton Luiken.



Table 3 Sources for LCI data

Lifecycle stage	Source
Fibre/granulate	
Cotton	Ecoinvent
Wool	Ecoinvent; Brent & Hietkamp (2003)
Linen	Turunen & van der Werf (2006)
Acryl	Ecoinvent
Organic cotton	Pineau & Gabathuler (2009), IPCC
Tencel	Shen & Patel, 2008
Modal	Shen & Patel, 2008
Bamboo	
Recycled PET	Ecoinvent, CE 2007
PLA	Ecoinvent
PET (= polyester)	Ecoinvent
Nylon/polyamide	Ecoinvent
Polyolefins (PE/PP)	Ecoinvent
Viscose	Ecoinvent; Shen & Patel, 2008
Kenaf	Ecoinvent
Jute	Ecoinvent
Hemp	Ecoinvent
Pre-treatment	
Cotton: scouring, bleaching, singeing and desizing	www.thesmarttime.com
Polyester	www.thesmarttime.com
Yarn production	
Spinning, cotton	Koc & Kaplan
Spinning, bast fibre	Ecoinvent
Spinning, wool	Brent & Hietkamp (2003)
Spinning, extrusion	Ecoinvent
Processing	
Weaving	Ecoinvent
Knitting	Sathaye <i>et al.</i> (2005)
Non-woven	Koc & Kaplan
Dyeing/printing	www.thesmarttime.com
Finishing	Expert judgement, Anton Luiken
Make-up (sewing)	No sources, zero impact
Maintenance	
Washing	Milieu Centraal, 2009
15 degrees	Milieu Centraal, 2009
30 degrees	Milieu Centraal, 2009
40 degrees	Milieu Centraal, 2009
60 degrees	Milieu Centraal, 2009
90 degrees	Milieu Centraal, 2009
Dry cleaning	Unknown, but flow small compared with home washing by consumers
Ironing	Own estimate
Drying	Milieu Centraal, 2008
Industrial washing	Unknown, but flow small compared with home washing by consumers
Waste processing	
Incineration	Ecoinvent
Composting (e.g. PLA)	Giegrich <i>et al.</i> , 2000
Landfill (overseas, after second-hand reuse)	Ecoinvent
Incineration (without power generation;	Ecoinvent



Lifecycle stage	Source
overseas, after second-hand reuse)	
Second-hand clothing	Expert judgement, CE Delft
Cleaning rags	Ecoinvent; expert judgement, CE Delft
Filler and insulation materials	Ecoinvent; expert judgement, CE Delft

3.2 Volume data

To determine the aggregate environmental impact, besides the LCI data we also need data on the size of annual flows. Because there are no reliable data available in the Netherlands on the annual consumption volume of each type of textile²², CE Delft has prepared estimates of its own. In doing so the size of the flows was estimated on the basis of textile waste volumes (using data from Netherlands Statistics, CBS), corrected for the fact that it takes a number of years before textiles are discarded (so that the volume of textiles presently being discarded corresponds to the consumption volume several years ago). We have assumed that on average it is five years before textiles end up as waste and that there has been 10% overall growth over the past five years (CBS data).

According to CBS data, 224 kt of textiles were collected as waste in the Netherlands in 2007 (CBS makes no explicit distinction between personal apparel, work wear, interior textiles and household textiles). Of this figure, 159 kt was collected by municipal refuse agencies along with other domestic waste and burned in municipal incinerators, with the remaining 65 kt being collected separately and subsequently sorted. Of the separately collected textiles, 60% is reused as second-hand clothing and 20% as cleaning rags, with 13% being recycled for a variety of uses, mainly for use as filler or insulation in the automotive industry, and 7% unusable and sent to municipal incinerators. We have assumed that 50% of the reused clothing is ultimately incinerated (without power generation) and that 50% is land filled. The data sources and calculations are as follows²³:

- The volume of separately collected textiles has been taken to be 65 kt. Source: (Internet) CBS, Municipal Waste Disposal Volumes (*Hoeveelheden Gemeentelijke afvalstoffen*), period: 2007, revised data dated 10 December 2009.
- The volume of household residual waste has been taken to be 3,964 kt. Source: (Internet) CBS, Municipal Waste Disposal Volumes [*Hoeveelheden Gemeentelijke afvalstoffen*], period: 2007, revised data dated 10 December 2009.
- The percentage of textiles in residual household waste has been taken as 4.0% (3-year running average calculated in 2007). Source: (Publication) SenterNovem, Composition of Domestic Residual Waste, Results of sorting analyses, 2008, Waste Management Implementation (*Samenstelling van het Huishoudelijk Restafval, Resultaten sorteeranalyses 2008, Uitvoering Afvalbeheer*), p.19.

²² Although Netherlands Statistics (CBS) reports the number of textile articles and the value of the textiles, by fibre type, it does not report textile tonnage. The *number* of winter coats, cotton baby rompers, etc., are thus known, but not how many kilos these comprise.

²³ These figures are based on data reported by SenterNovem and differ somewhat from other data in circulation. The impact on the results of the reference analysis is negligible, though.

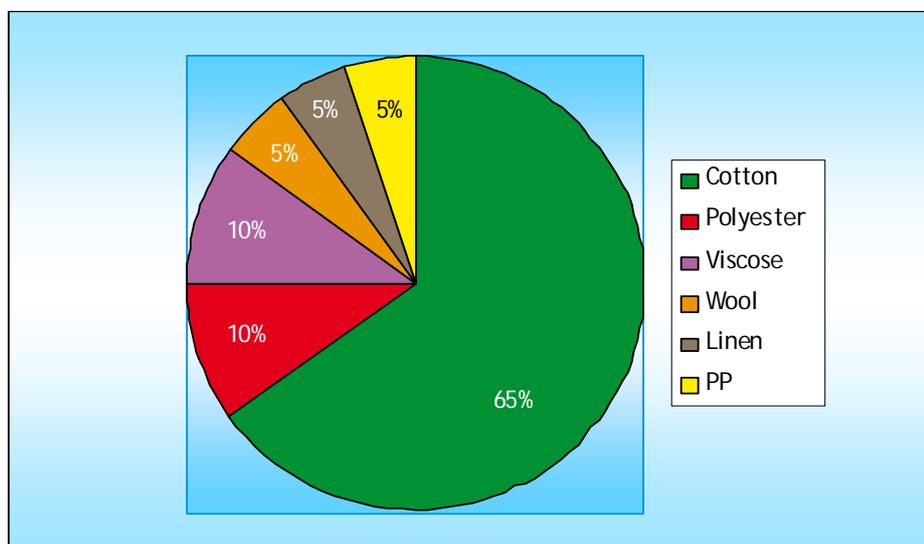
Note that the above final total does not include the textiles included in bulky household (residual) waste. This is because there is insufficient data available on this volume.



- Using the above data, the total volume of textiles in the waste phase was calculated as 224 kt, as follows: volume of textiles in residual waste + volume of separately collected textiles = 65 kt + (4% of 3,964) kt = 65 + 158.56 kt = 224 kt (rounded).
- The destination of separately collected textiles is as follows²⁴:
 - Second-hand clothing circuit: 60%.
 - Cleaning rags: 20%.
 - Other uses, specifically as filler and insulation material: 13%, and waste incineration: 7%.

The composition of the stream is based on Eurostat import and export data (for 2008). In principle, we are again confronted with the problem that much of this data is expressed only in terms of number of articles or value, rather than in kilograms. From an analysis of the data it emerged, however, that the ratio between cotton, man-made fibres, synthetic fibres, wool and so on was reasonably independent of the indicator used (kilograms, pieces, value). This led to a distribution across the fibres as depicted in Figure 4. The majority of throughput consists of cotton, with the rest being made up of smaller flows of polyester, viscose, wool, linen and PP. These figures deviate somewhat from world-average production, as reported for example in the TNO report *'Prioritaire afvalstromen in beeld: textiel'* (TNO, 2009), in which the shares of cotton and wool were far lower and the share of polyester far higher. There are probably two reasons for this. First, the present study is concerned solely with Dutch consumption of clothing (including work wear), interior textiles and household textiles, with flows of carpeting and engineering textiles, for example, being left out of the picture. Second, there may well be differences between the composition of Dutch textiles consumption and global textiles production.

Figure 4 Breakdown of Dutch textile throughput by fibre type



²⁴ Source: Personal communication, Vereniging Herwinning Textiel (Mr Vernooij, board member), 30 September 2009.



In assessing the magnitude of the various flows in each link in the chain, allowance also needs to be made for the fact that there are product losses in some of the links: delivery of a kilo of cotton to private consumers requires more than a kilo of cotton further back up the chain. We have assumed the following product losses: 8% during yarn production, 2% during processing to fabrics and 12% during article make-up (expert judgement, Anton Luiken).

Based on the above data, the tonnages involved in each of the links in the chain have been calculated as reported in Table 4.

Table 4 Annual tonnages per lifecycle stage

	Unit	Quantity
Total, fibres (production phase)	kt	310.6
Cotton	kt	201.9
Wool	kt	5.5
Linen	kt	15.5
Acryl	kt	0
Organic cotton	kt	0
Tencel	kt	0
Bamboo	kt	0
Recycled PET	kt	0
PLA	kt	0
PET (= polyester)	kt	31.1
Nylon /polyamide	kt	0
Polyolefins (PE/PP)	kt	15.5
Viscose	kt	31.1
Kenaf	kt	0
Jute	kt	0
Hemp	kt	0
Total, spinning	kt	279.5
Spinning, cotton	kt	181.7
Spinning, bast fibre	kt	41.9
Spinning, wool	kt	14.0
Spinning, extrusion	kt	41.9
(n.a.)	kt	0
Total, processing	kt	285.7
Weaving	kt	171.4
Knitting	kt	85.7
Non-woven	kt	28.6
(n.a.)	kt	0
Total, colouration	kt	280.0
Dyeing	kt	210.0
Printing	kt	70.0
(n.a.)	kt	0
Total, finishing	kt	280.0
Finishing, cotton	kt	210.0
Finishing, polyester	kt	70.0
Total, make-up (sewing)	kt	280.0
Total, washing	kt	5,416
15 degrees	kt	0
30 degrees	kt	1,408.0
40 degrees	kt	2,003.7
60 degrees	kt	1,570.5
90 degrees	kt	433,2



	Unit	Quantity
Dry cleaning	kt	1
Ironing	kt	1,624.7
Drying	kt	3,815.5
Industrial washing	kt	Unknown, but relatively low compared with home washing/drying
(n.a.)		
Total	kt	224
Incineration	kt	163.5
Composting (e.g. PLA)	kt	0
Landfill (overseas, after second-hand reuse)	kt	19.5
Incineration (without power generation; overseas, after second-hand reuse)	kt	19.5
Collection	kt	65
<i>Second-hand clothing</i>	<i>Portion of collected textiles</i>	<i>39</i>
<i>Cleaning rags</i>	<i>Portion of collected textiles</i>	<i>13</i>
<i>Filler and insulation materials</i>	<i>Portion of collected textiles</i>	<i>8.5</i>
<i>Still to incinerator</i>	<i>Portion of collected textiles</i>	<i>4.5</i>





4 Results

This chapter describes the environmental impacts of, first, the entire textiles stream, then each individual phase in the lifecycle (total volume) and, finally, the individual materials and processes (per unit). Environmental impact is reported under four headings: Climate change²⁵, Fossil depletion, Agricultural land occupation and Other²⁶. The reason for this is that the first three of these dominate the overall picture and to separately report the indicators now amalgamated under 'Other' would render the picture unnecessarily complex.

The tables presenting the impact per kg material or per washing/drying operation include the options incorporated in the reference analysis as well as the alternatives not included therein²⁷.

4.1 Impact of total stream

Figure 5 presents the impact of the aggregate textiles stream, broken down by lifecycle stage. There are two stages that immediately stand out in terms of their impact: raw fibre production and the maintenance phase. Almost half the environmental impact of the fibre/granulate stage (e.g. raw cotton, wool, PET granulate) derives from the area of land required to grow the fibre stock. The consumption phase (washing and drying) scores high on 'climate change' and 'fossil depletion', owing mainly to electrical power consumption. The other links in the chain have a far smaller impact, the bulk of it under the headings 'climate change' and 'fossil depletion', deriving from gas and electricity consumption in these stages. The waste phase has a negative score, because most waste disposal methods mean savings on materials and/or energy in other processes. When textiles are burned in a municipal incinerator, for example, electricity is generated, while collected textile discards can be used as insulation or filler material, or be reused as second-hand clothing (particularly abroad) so that the clothing is used for a longer period of time. Although the waste phase has relatively little impact on the overall picture, there is a considerable spread in the impacts of the various disposal routes, as discussed in Section 4.4.1.

It is now clear which stages of the lifecycle have the greatest environmental impact: cultivation and production of textile fibre stock, and washing and drying in the consumer phase. The question now is therefore what activities are precisely responsible for the impact in the phase concerned. Can one or more elements be identified with an inordinately large impact? And why is this so? In addition, there is the question of what options are available for optimising the waste disposal phase. These issues are considered in the following sections.

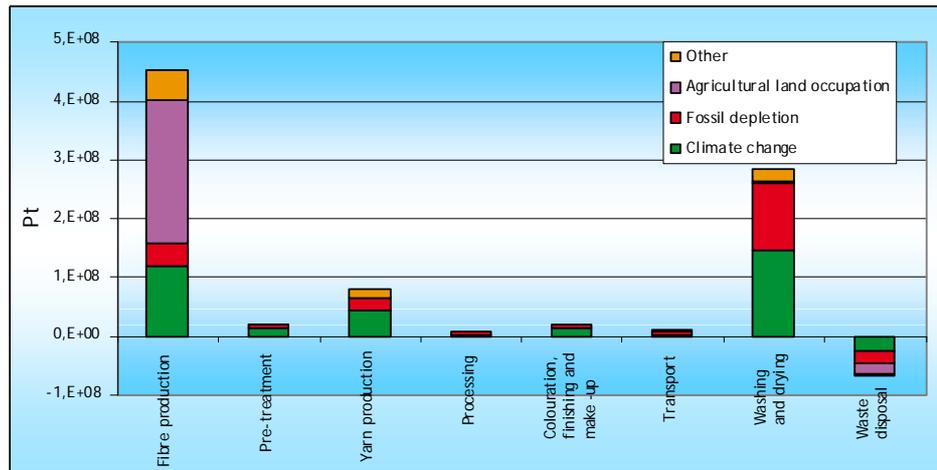
²⁵ The sum of 'Climate change, human health' and 'Climate change, ecosystems'.

²⁶ All the other indicators cited in Table 2.

²⁷ This is because for inclusion in the reference analysis an option must already be in use. With a view to the future, though, it is desirable to look not only at current practice, but also at improvement options that are not currently deployed, but may well be by the year 2015.



Figure 5 Aggregate impact of Dutch textiles consumption (total: 8 E+08 Pt)
 Note that water consumption is not included in the ReCiPe indicators (cf. Chapter 2) and not all pesticides translate to impacts (cf. Section 4.2.1)

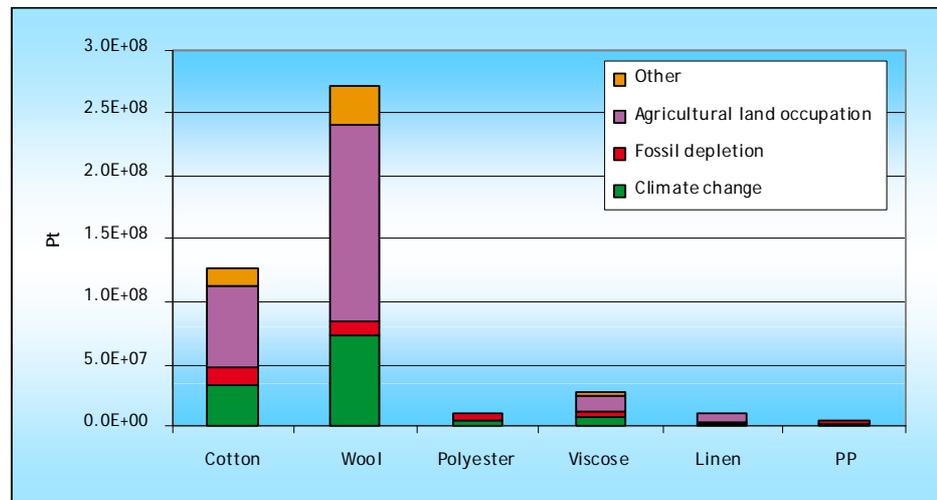


4.2 Fibres

4.2.1 Impacts

Figure 6 gives a breakdown of the impact of the fibre production stage. As can clearly be seen, by far the greatest impact is due to cotton and wool.

Figure 6 Aggregate impact of the fibre production stage



The obvious question now is why cotton and wool have such a large impact: is so much of them being used, are they especially polluting, kilo for kilo, or is it a combination of the two? Table 5 and Figure 7 together answer the question. Table 5 provides a breakdown of Dutch textiles consumption. Cotton, with 65% of total tonnage, is the fibre used most. This is therefore part of the explanation as to why cotton has such a large overall impact. And as Figure 7 shows, cotton scores relatively poorly compared with a number of other fibres. This is due above all to the amount of land and energy used for cotton-growing. It should be noted, though, that the impacts of some of the pesticide use do not show up in this analysis, because for a number of pesticides there



are no impact factors available for emissions to water, soil or air²⁸. The aggregate environmental burden associated with pesticide production can be quantified, however, and has been included in the calculations.

If these impacts were to be taken on board, too, the environmental impact of cotton would be higher than currently calculated. Unfortunately, there is no way of estimating how much greater it would be, because the toxic effects of the various pesticides vary enormously. Organic cotton is often cited as an eco-friendly alternative for conventional cotton. Because the impact of pesticide use cannot be properly factored in, though, it is hard to compare conventional and organic cotton using the ReCiPe method. After all, one of the major differences between the two is precisely pesticide use. In addition, land use knocks on fairly heavily in the ReCiPe method, and organic cotton may in some cases have a slightly lower per-hectare yield than conventional cotton. This would mean factoring in the negatives of organic cotton but not the positives, leading to an unfair comparison. Based on the available data, and with the weighting method employed, it is therefore impossible to draw any conclusions as to how conventional and organic cotton compare in environmental terms.

For wool the situation is different. Although wool accounts for only a minor share of overall consumption (Table 5), its unit environmental impact is very high compared with other fibres (Figure 8). This is due on the one hand to the large amount of land required for sheep-farming and on the other to the considerable emissions of methane these animals cause by belching. It is important in this context to note that the aggregate impact of the fibre production phase is very susceptible to the assumptions made concerning the quantity of wool actually used, because of its very high unit impact. Here, a 5% share in aggregate Dutch textiles consumption has been assumed. If this were 4 or 6%, however, it would make a difference of around 12% in the overall impact of the fibre production phase. In Section 4.6 a more detailed sensitivity analysis is provided.

In the methodology used in this study water consumption is not included²⁹, but depending on the local situation this may well lead to environmental issues. The amount of water required for producing a kilo of fibre depends very much on the fibre concerned. A quantitative analysis of the water requirements of the various fibres and their exact environmental consequences are beyond the scope of the present study, however. As an extension to the results to emerge

²⁸ That is to say, it is unknown what the precise consequences of these emissions are in terms of toxicity, for example. That these emissions have adverse effects is obviously known, but for a number of pesticides these impacts cannot be quantified. For certain pesticides like glyphosate, linuron and diuron, for example, impact factors are available, and for these compounds the impacts have therefore been included. The problem is greatest for cotton, for which numerous different pesticides are used. Over half of these have impact factors listed in ReCiPe. The contribution of these to the aggregate impact of cotton (USA; cf. Figure 7) is around 5% (due mainly to terrestrial ecotoxicity). Three-quarters of that contribution is due to the pesticide cypermethrin, which means that the other (dozens of) pesticides contribute very little. It is therefore impossible to say what the impact of the non-quantified pesticides is, because those impacts may differ widely. When it comes to cultivation of flax, jute and kenaf, the impact factors of most of the pesticides used are known and have been taken on board. In commercial cultivation of hemp there is very little pesticide use, and in N.W. Europe none at all.

²⁹ That is to say, there is no indicator expressing the volume of water used or the potential impact on water-table drawdown. The impacts of pollutant emissions to water (e.g. effluent discharges) are included in the method, though, in the indicators 'eutrophication', 'ecotoxicity, freshwater' and 'ecotoxicity, marine'.



from use of the ReCiPe method, it would be interesting to undertake further study of the impacts of water consumption in the textile production chain.

Table 5 Dutch textiles consumption, by fibre type

Fibre type	%
Cotton	65%
Polyester	10%
Viscose	10%
Wool	5%
Linen	5%
PP	5%

Figure 7 Impacts per kg fibre (excl. wool). NB: water consumption is not included in the ReCiPe method (see Chapter 2) and not all pesticide use translates to impacts (see Section 4.2.1)

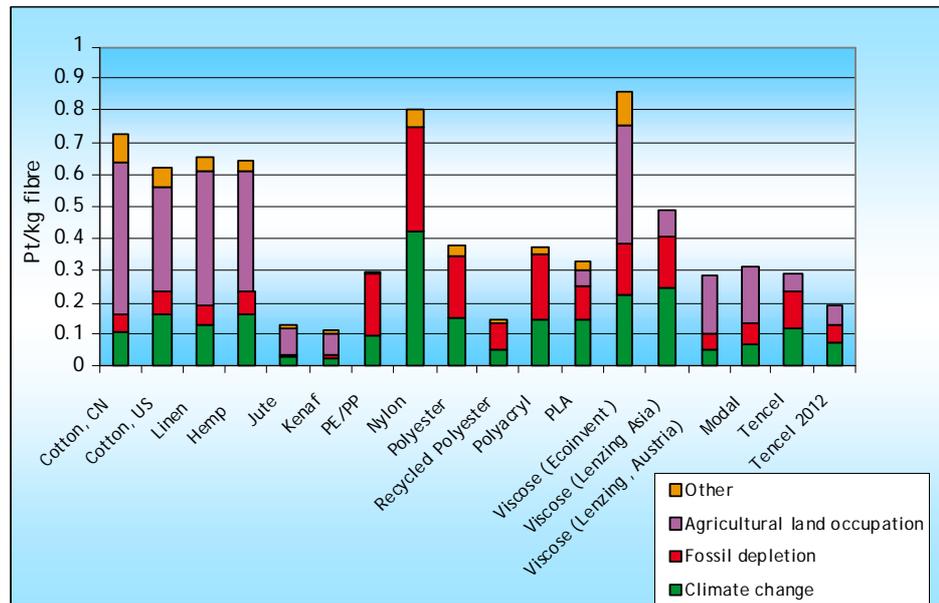
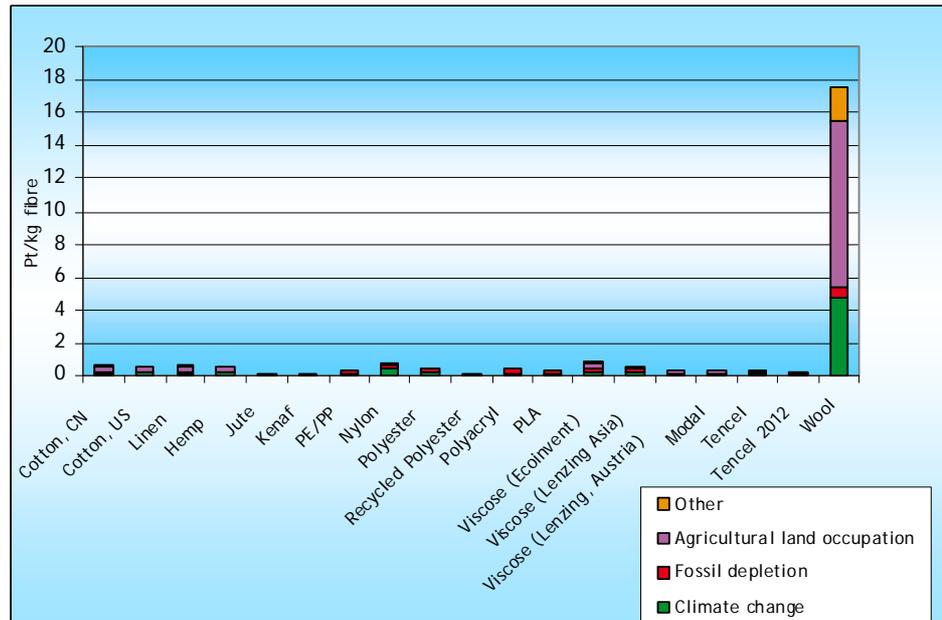


Figure 8 Impact per kg fibre (incl. wool)³⁰



4.2.2 Options for improvement

The most obvious option for improvement would seem to be to engender a move away from fibres with a high impact to alternatives having a lower impact, i.e. from wool to any other fibre, or from cotton to synthetic fibres like (recycled) polyester or to new fibres like PLA, modal, tencel or Austrian-sourced viscose.

Besides a switch from one fibre to another, there is also scope for improvement in the production process, vis-à-vis fibre sourcing, for example, particularly in the case of cotton. It is important to remember at all times that within one and the same fibre type there may also be major differences in environmental impact, due above all to differences in per-hectare yields and process energy consumption. The various kinds of viscose provide a good example here, with the viscose in the Ecoinvent database scoring far worse than viscose from Asia or Austria (Shen & Patel, 2008). In all likelihood there will be similar differences for cotton, too, as yields differ from country to country and, in large nations, from region to region, and the same will hold for process energy consumption, too.

It is therefore very important not only to consider the average values for any particular fibre, but also to never lose sight of the fact that fibre A scoring better than fibre B on average does not automatically mean it is consistently better across all countries and process settings. In a number of cases it will indeed be environmentally beneficial to switch from one fibre to another, but based on averages relatively close together it is impossible to make pronouncements on specific individual cases³¹.

³⁰ Note that because of allocation issues there is uncertainty as to the precise environmental burden to be assigned to wool. To be on the safe side, it is recommended to take a range of 9 to 34 Pt/kg wool. For a more extensive discussion, see Section 4.6.

³¹ A more detailed explanation is provided in Chapter 5.



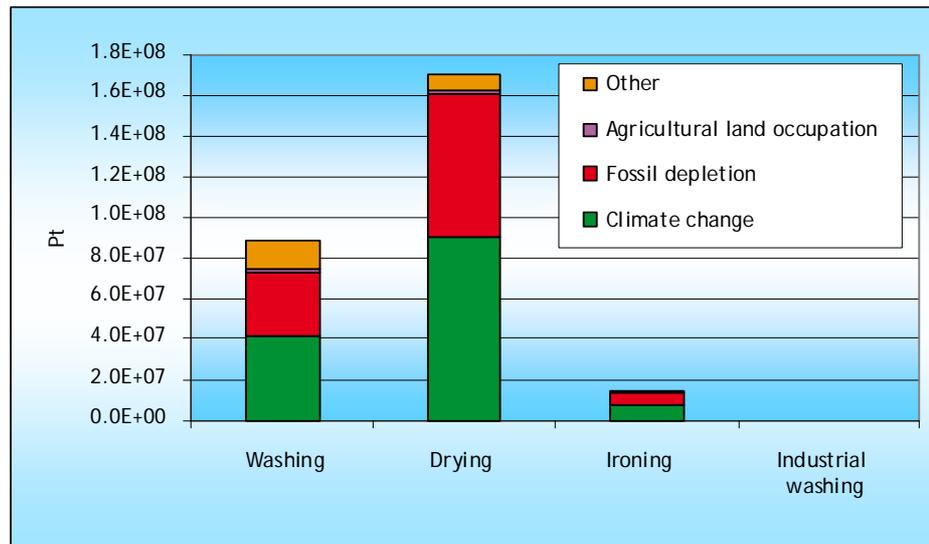
This spread also provides scope for improvement, though: once it becomes clear why the producers scoring better than average differ from the rest, it becomes feasible to apply that knowledge as widely as possible to improve the performance of both 'average' and 'inferior' producers. This obviously holds for all fibres, including wool. With cotton in particular, though, it should be borne in mind that this is an agricultural product and that it is therefore recommended to involve specialists with specific agronomic expertise in this improvement process.

4.3 Use phase

4.3.1 Impacts

For the use phase we assumed 220 washes per year per household (Milieu Centraal, 2009) in an A-label washing machine, and a total of 7.2 million households³². For laundry dryers we assumed an average energy consumption of 384 kWh per unit (a B-label condenser dryer, used in 63% of Dutch households; Milieu Centraal, 2009). The use phase also has a major influence on the overall environmental impact of the textiles chain. The bulk of this is due to the use of laundry dryers in private homes (Figure 9). Home washing has a substantial impact, too. Figure 10 shows the per-kg impacts of textile laundering and drying. As can be clearly seen, a label-B condenser dryer (the type most commonly used in the Netherlands) has by far the greatest impact.

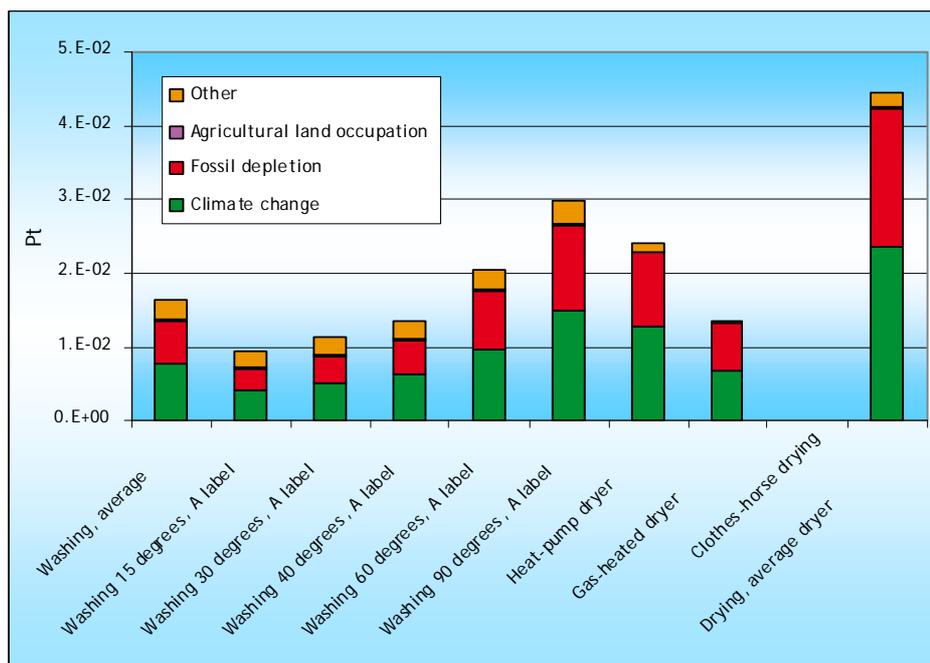
Figure 9 Impacts of use phase, total



³² With respect to temperature we assumed 8% at 90°, 29% at 60°, 37% at 40° and 26% at 30° (Milieu Centraal, 2009).



Figure 10 Impacts of washing and drying, per kg



4.3.2 Options for improvement

Today, the greatest impact in the consumption phase is due to use of 'regular' laundry dryers. There are far more efficient options available, however: gas dryers, heat-pump dryers and clothes horses (i.e. old-fashioned drying racks), leading to respective savings of 70, 45 and 100%. Today, gas dryers and heat-pump dryers are still more expensive to buy than condenser dryers, but that difference is largely recuperated over the appliance's lifetime. The advantage of a clothes horse is that it costs next to nothing and that it has a positive effect on apparel lifetime. At the same time its time and space requirements are slightly higher, though.

With respect to washing, too, there is still plenty of scope for environmental improvement. In the first place it is generally preferable to do the washing at a lower temperature, as this requires less energy to heat the water. Today there are various detergents on the market that give a clean wash at temperatures over 15°C, so that in most cases there is no reason to wash at 60°C or even 90°C. Secondly, there are considerable gains to be achieved by consumers loading their machine full. According to Milieu Centraal, the average household washes 3.4 kg per load, while most washing machines have a capacity of 5 kg. If households were to make better use of that capacity, the impact per kg laundry would be substantially lower.

4.4 Waste disposal

4.4.1 Impacts

Relative to the product chain as a whole, current waste processing activities have only a limited impact. It is still important to look at the waste phase, though, because there are major differences between the impact of the various waste disposal methods. Most textiles waste³³ (approximately 70%) is collected along with general domestic refuse and sent to municipal waste incinerators. Although this is accompanied by power generation, as Figure 11 shows there are various options that score far better than incineration: reuse as second-hand clothing, use as cleaning rags, use as filler/insulation materials, or fibre recycling. With reuse second-hand, the clothing is collected and transported abroad for sale there³⁴. Collected textiles that can no longer be used as clothing are often used as cleaning rags³⁵ or as insulation/filler materials³⁶. At the end of their service life, textiles reused abroad as second-hand clothing are often incinerated (without energy recovery) or land filled. Finally, the figure shows another two options that are not presently used that much, but may with time become interesting. The new fibre PLA can be composted in the waste phase, for example. Because a small amount of methane is released during composting, however, this option does not score not that well. There are also ongoing trials with fibre-level recycling, a form of high-grade recycling in which old textiles are used for the production of new.

All these forms of reuse are only possible if the textiles waste is separately collected, though. At the moment this is the case for around 30% of this waste, but here too there is still probably considerable scope for improvement.

With incineration of polyester in municipal incinerators and fibre recycling of cotton there are both positive and negative effects. Although the former leads to CO₂ emissions, because electricity is also produced there are savings on fossil fuels like gas and coal. And while fibre-level recycling of cotton involves a degree of energy use, it means a certain amount of new cotton production is avoided. The net impact is the difference between the positive and negative effects.

³³ In this context, 'textiles waste' is taken to mean waste in the form of clothing (incl. work wear), household textiles and interior textiles. This does not include textile waste coming under the category 'bulky residual household waste' (e.g. sofa covers).

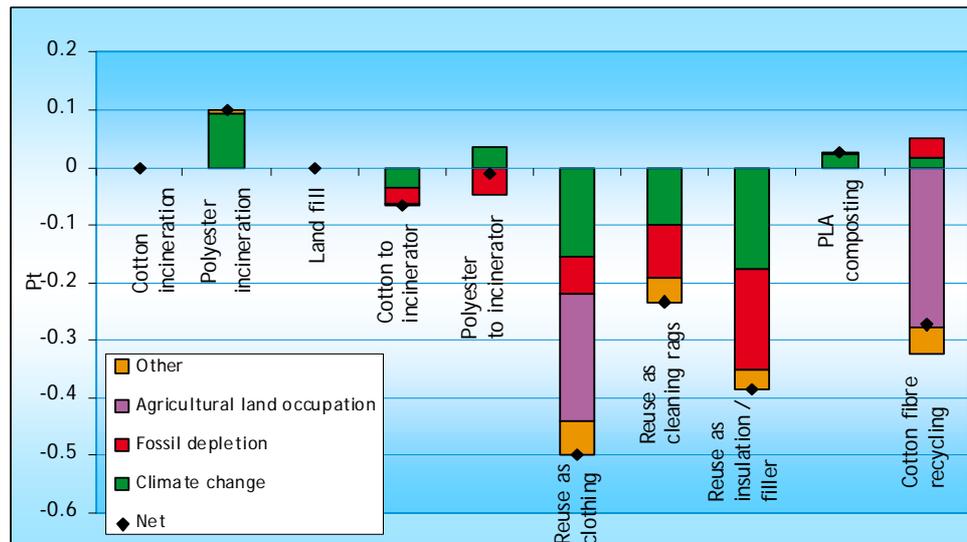
³⁴ These calculations assume 500 km transport by truck and maritime transport of over 7,000 km, i.e. the distance from Rotterdam to West Africa, while 70% of the impact of clothing production (fibres, spinning, etc.) is allocated to the first user, and the other 30% to the following user(s). Naturally, the impacts of maintenance (washing, drying) by Dutch users are allocated to the reference analysis of the impact of the textiles consumption in the Netherlands (but these impacts come under the consumption phase, not under waste disposal). A small fraction of the second-hand clothing is reused in the Netherlands, but this accounts for less than 10% of overall reuse. Overseas reuse is therefore representative for over 90% of aggregate reuse and the discrepancy arising through the present assumption that all second-hand clothing is sent abroad is negligible.

³⁵ If there were no use of textile waste as cleaning rags, some other kind of rag would be required, either non-woven rags or paper towels. In our calculations we have assumed that 1 kg of textile waste replaces 0.5 kg of paper towels.

³⁶ Textiles waste is often used as filler/insulation material, particularly in the automotive industry. If no textiles waste were used for this purpose, plastics like polyurethane would be used. We have assumed that 1 kg of textile waste replaces 0.8 kg of polyurethane.



Figure 11 Impacts of waste disposal per kg textile³⁷ (black diamonds indicate net impact)



4.4.2 Options for improvement

As stated, in order to exploit the options for improvement in the waste disposal phase it is important that textiles are separately collected. This is already the case for a certain volume of textiles waste and the appropriate infrastructure is thus partly in place. The greatest scope for improvement lies in achieving reuse and high-grade recycling rather than sending the waste to incinerators. Although the various recycling methods differ in terms of their impact, they all score significantly better than incineration. For the sake of clarity it should be noted that there is considerable uncertainty about the impacts of the various recycling options. Current estimates are based largely on the expert judgement of CE Delft and a more precise estimate would be required to make a more reliable estimate of the potential.

4.5 Review of impacts

To calculate the environmental burden of various products and determine the effect of changes, it is useful to have a clear and concise synopsis of the respective impacts. Table 6 provides such a synopsis. More extensive reviews are provided in Annex A.

³⁷ In Figure 11 a distinction is made between 'incineration' and 'to incinerator', the difference being that with the former there is no power generation, and with the latter there is.



Table 6 Synopsis of impacts

	Impact (Pt/kg)
Cotton (fibre) (average for US /CN)	0.65
Wool (fibre)	17
Linen (fibre)	0.66
Acryl (fibre)	0.37
Tencel (fibre)	0.29
Recycled PET (fibre)	0.14
PLA (fibre)	0.33
PET (= polyester) (fibre)	0.38
Nylon/polyamide (fibre)	0.80
Polyolefins (PE/PP) (fibre)	0.30
Viscose (fibre)	0.86
Kenaf (fibre)	0.12
Jute (fibre)	0.13
Hemp (fibre)	0.64
Spinning, cotton	0.38
Spinning, wool	0.17
Spinning extrusion	0.10
Weaving	0.04
Knitting	0.01
Non-woven	0.06
Dyeing	0.05
Printing	0.05
Cotton, finishing	0.02
Polyester, finishing	0.01
Washing, 15 degrees	0.01
Washing, 30 degrees	0.01
Washing, 40 degrees	0.01
Washing, 60 degrees	0.02
Washing, 90 degrees	0.03
Drying	0.04
Cotton to incinerator (incineration with power generation)	-0.07
Polyester to incinerator (incineration with power generation)	-0.01
Composting (e.g. PLA)	0.03
Cotton incineration (without power generation)	0
Polyester incineration (without power generation)	0.10
Use as second-hand clothing	-0.52
Reuse as cleaning rags	-0.23
Reuse as filler/insulation	-0.39



4.6 Sensitivity analysis

The results discussed above are, generally speaking, robust. Any (limited) change in the composition of the textile stream would thus lead to only minor changes in the calculation results. The same holds for the use and waste disposal phases in particular: the precise figures would change a little, but the basic conclusions would stay unaltered, with the options for improvement remaining as indicated.

There is one major exception, though: the use of wool, for the contribution of wool to the overall lifecycle impact of the textiles considered is due to the very high per-kilogram impact of wool. This means that minor uncertainties in the volume of wool used may have a major impact on the aggregate environmental impact of Dutch textiles consumption. Thus, if wool consumption proved to account for 6% of the whole rather than 5%, this would mean a 6% higher aggregate lifecycle impact. In the unit impact of wool there are also considerable uncertainties, as per-hectare yields and details of agricultural practices may vary. Per-hectare yields, in particular, have a major influence on the ultimate impact. The data used here³⁸ assume 126 m²/kg wool, equivalent to around 800 m²/sheep. This already makes due allowance for the fact that part of the land use is allocated to meat production (i.e. mutton/lamb: 35%) and part to the wool (65%, in line with Ecoinvent). If the sheep were kept on a smaller area of land, on 80% of the current acreage, for example, the impact per kg wool would be 10% lower³⁹. If the sheep were to be given 20% more space, the impact per kg wool would be 10% higher. In the methodology adopted here, all the land used for sheep-farming is also allocated to sheep-farming. In certain cases this is indeed defensible, viz. when the land on which the sheep are kept could in principle also be used for another purpose (arable farming, for example). However, there are also situations in which this is not the case. Sheep may be used to graze dikes, for example, or for ecological management of heath land. In this kind of situation, only some or perhaps none of the land use should be allocated to sheep-farming, which would reduce the environmental impact of wool substantially. Despite all the uncertainties, though, it may reasonably be assumed that the impact of wool lies within the range of 50-200% of the estimate currently adopted, i.e. between 9 and 34 Pt/kg wool. For the total volume of wool consumed annually in the Netherlands (cf. Table 4) this means an aggregate impact of 49.5 to 187 million Pt.

A major fraction of the impacts associated with wool and cotton are due to land use. Land use is factored into the ReCiPe score via the loss of biodiversity accompanying that land use (cf. Sections 2.2 and 2.3). The actual impact of land use on species diversity depends very much on local circumstances and on the original condition of the land concerned, however. The impacts modelled in ReCiPe are always highly simplified, with use being made of two types of land use: grassland used for grazing (animal husbandry) and land used for arable farming and horticulture. The impact factor taken for arable land is around 1.5 times higher than that for grassland (cf. Annex C.1). The difference may be greater, though: in ReCiPe the difference between highly intensive, monoculturally cropped arable land and extensively grazed organic grassland is

³⁸ Based on the situation in the US, where 80% of sheep-farming is extensive in nature. As far as is known, the data in the Ecoinvent database are the only LCA data on wool that also include sheep methane emissions. In major wool-producing countries like Australia and New-Zealand sheep-farming is also largely extensive, so that the data used are suitably representative.

³⁹ Assuming this has no effect on other sheep-farming inputs like fertiliser use.



a factor 2. With highly extensive husbandry in virtually undeveloped regions, as in Scotland, the difference may be even greater. The factors used are therefore averages and only valid as such, given the diversity of products considered here. In methodological terms, the step from land use (in hectares) to loss of biodiversity is in line with this broader framework. For acidifying, toxic and eutrophying emissions, too, loss of biodiversity has been calculated. These interventions all lead to damage in the realm of 'ecosystem quality' (cf. Section 2.3). The modelling of this 'endpoint' damage thus introduces a certain amount of uncertainty, but this is consistent across the various types of intervention. As long as the same ReCiPe factors are taken for both the reference analysis and the follow-up analyses, this uncertainty can be 'ignored' because in both cases precisely the same the error is introduced.

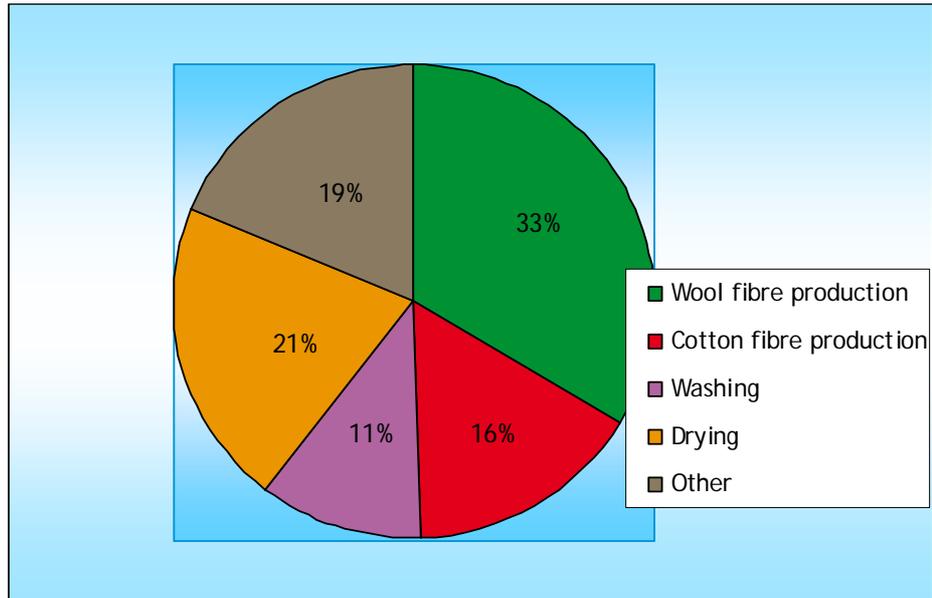
Within these uncertainties the recommendations concerning options for improvement remain valid, but such uncertainties make it hard to assess whether the 20% reduction target will indeed be secured in 2015, or whether the difference lies within the uncertainty margins. For this reason it is important that in calculating the environmental burden in 2015 the same assumptions are as far as possible made as in the present reference analysis. Where it is not feasible to adhere to the same sources and assumptions, it needs to be investigated to what extent this impacts on the ultimate results of the analysis.

4.7 Conclusions

From this chapter it emerges that the greatest impacts are due to the fibres wool and cotton and to home washing and drying by consumers: kilo for kilo, wool has a very high impact, cotton is used in enormous quantities, and home washing and drying in the use phase require considerable amounts of energy. Figure 12 provides a graphic representation of the respective shares in the aggregate impact that can be assigned to wool and cotton production and to washing and drying. Together, these elements account for over 80% of the lifecycle impact of Dutch textiles consumption. The greatest impact is due to wool. Although wool accounts for only a small fraction of the overall textile stream (5%), because of its high unit impact it has a disproportionate influence on the overall impact. It is followed by the impacts of drying (21%), cotton fibre (16%) and washing (11%). All the other links in the chain together are responsible for around 18% of the aggregate impact.



Figure 12 Aggregate impact by lifecycle phase



In addition, it emerges that there is considerable scope for improvement in the waste phase, too. These improvement options are discussed in greater detail in the following chapter, in which we estimate the potential scope for improvement and discuss the practical feasibility of the various options.



5 Savings options

In Chapter 4 a number of specific options for improving the current situation have already been discussed. In addition, certain options were cited that are not specific to any particular phase of the lifecycle, such as energy efficiency, use of greener forms of energy and process optimisation.

In essence, three kinds of savings options can be distinguished:

1. *Volume reduction*. Simply reducing the volume of textiles used would reduce the overall impact of consumption. In practice, though, there is probably little chance of such a move. There may be options to reduce material losses along the supply chain, however.
2. *Process improvements*, with respect to both the cultivation or production of the various fibres and the other links in the chain: for example, a lower impact due to alternative modes of cotton production, improved energy efficiency or use of renewable energy sources in the production process, or by switching from a conventional laundry dryer to a heat-pump dryer or gas dryer.
3. *Shifts between processes/materials*, with two sub options conceivable:
 - a Process/material A has a lower impact than alternative process/material B, with no effect on the other links in the chain. Examples include recycling instead of incineration.
 - b A shift from process/material A to process/material B, but now with an impact on other columns of the matrix. Examples here include use of polycotton rather than pure cotton. Polycotton dries faster than pure cotton, which means less energy consumption for drying in the use phase.

In addition, it is also important to distinguish between options that are *always* worth pursuing and options that are better *on average*.

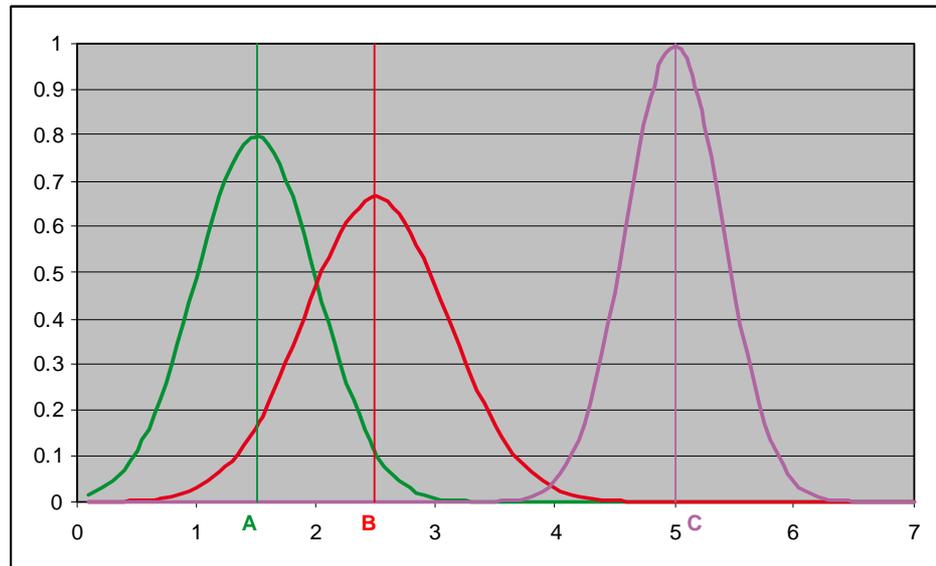
Volume reduction and process improvement are essentially always worth pursuing: the reference situation is clear and there are no doubts as to the improvement option indeed scoring better than the reference.

In the case of shifts between processes or materials, the situation is less cut-and-dried. The values that have been adopted in this study are, of necessity, averages. This suffices for reliable calculation of the overall impact of Dutch textile consumption. For a particular process or material, however, there may be considerable differences in terms of the methodology adopted and thus in terms of environmental impact. In the case of cotton production, for example, there are major inter-country differences with regard to yields, water consumption, fertiliser inputs, energy consumption and energy sources. All these factors influence the ultimate impact of a kilo of cotton fibre. In practice, this means that material A scoring better on average than material B does not automatically mean that material A will *always* score better. A case in point is depicted in Figure 13, which shows the environmental impacts of three hypothetical materials A, B and C, with respective average environmental impacts of 1.5, 2.5 and 5. The impacts are given on the x-axis, the probability of a particular score on the y-axis; the wider the curve, the greater the spread in score. There are also cases in which each material has only a slightly greater or smaller impact than the average. It may therefore well be the case that a particular instance of material B scores better than a



particular instance of material A: the greater the overlap between the respective curves, the greater the probability that this will indeed be the case. In switching from material C to material A, though, it can be said with complete certainty that there will be an improvement: curve C does not overlap with curve A and so the chance of a specific instance of material C scoring better than a specific instance of material A is zero.

Figure 13 Spread of impacts



In order to estimate whether a switch from material B to material A constitutes an improvement, then, it is not enough to know whether material A (polyester, say) scores better on average than material B (cotton, say), but also the size of that difference and how much spread there is within the performance of each of the materials. In drawing up policies, too, this should always be borne in mind. If a policy were to be based entirely on averages, in certain cases there would be a risk of a shift in the wrong direction being encouraged, which is obviously undesirable.

5.1 Savings options

Happily, there are a number of options that are guaranteed to always lead to environmental improvements:

- Energy efficiency:
 - Energy efficiency measures will have their main effect on the impact categories ‘climate change’ and ‘fossil depletion’. A fair amount of the energy consumption associated with textiles occurs outside the Netherlands, in the upstream part of the chain, making it less amenable to influence. There is still certainly scope for improvement here, though: over 20% of lifecycle energy consumption is overseas, often in production centres and processes operating at efficiencies inferior to best available technologies.

- Greening the energy supply:
 - To reduce the environmental impact of textile consumption, (some of) the energy inputs could be replaced by cleaner energy supplies. There are two basic options here: increasing the efficiency of existing power stations, and a fuel shift (from coal to gas) or use of renewable energy (for both electrical power and process heat). A 20% reduction in the environmental impact of energy use upstream in the chain (through improved efficiency and cleaner energy), would reduce the aggregate lifecycle environmental impact by 5% in 2015.
- Process optimisation:
 - In many processes and steps in the supply chain there is a substantial spread in observed impacts. In some cases this is due to external factors (agricultural soil fertility, average temperatures, etc.) about which little can be done. Some of the spread is due to differences in the processes themselves, however, and these can be influenced. One option is to map out the best practices for particular processes and then introduce these elsewhere. This would provide scope for improving the environmental profile of cotton and wool, for example.
 - In certain processes there is room for improvement in the use of auxiliary materials. These materials might be able to be recycled, for example, or replaced by alternative materials having less impact. There may also be scope for switching from batch processes to continuous processes (with lower water requirements, and thus lower energy consumption). Based on the currently available data, it is difficult to estimate the exact extent of the potential here.
- More collection of textiles waste and reuse/recycling:
 - At the moment around 30% of Dutch textiles waste is collected separately and reused as second-hand clothing, cleaning rags or insulation material, for example. In all the cases investigated, recycling scores better than incineration and it is therefore recommended to investigate how the percentage of separately collected textiles waste can be improved. If half the textiles currently sent to the incinerator were to be used as insulation material, lifecycle environmental impacts would be reduced by about 6%. Other forms of reuse are also possible, of course, such as recycling at the fibre level or more reuse in the form of second-hand clothing. Because the data used for the recycling phase are based partly on expert judgement, it is recommended to carry out a follow-up study to obtain more precise data on the various options. This holds particularly for the options of fibre recycling and reuse as cleaning rags.
- More efficient washing:
 - Today, the average household does its laundry at 46°C in a machine that is only part-loaded. It is often perfectly feasible to do the washing at a lower temperature, though, with the machine full. If in 2015 50% of the washing were done at 30°C and 50% at 40°C, and if machines were consistently loaded to 4 kg rather than the present 3.4 kg, the overall impact of the washing phase would fall by 35%, reducing the aggregate impact by around 4%. One thing that would help here would be for new washing machines to be fitted with an indicator showing how full the machine is. Savings associated with growing efficiency of the washing machines in use have not been included here.
- More efficient drying (or none at all!):
 - Around 70% of the laundry washed by consumers at home is immediately thrown into some form of dryer. Home-drying by consumers is responsible for about 20% of the aggregate environmental burden of textile consumption. If driers were to be used 25% less in



2015 than is presently the case, the impact of drying would also drop by 25%, representing around 5% of aggregate lifecycle impact. In recent years, however, the trend has been towards ever greater use of dryers, with a growing number of households owning such an appliance. The various types of dryer differ enormously in their energy consumption, though. Today's condenser dryers consume a vast amount of energy, while new generations of dryers have far lower energy requirements. Compared with a standard dryer, a heat-pump dryer or gas dryer achieves savings of around 45 and 70%, respectively. If in 2015 half of today's laundry dryers were to be replaced by heat-pump models, this would lead to around 25% savings, or about 5% of aggregate lifecycle impact.

In addition, there are a number of options that on average are promising, but need to be examined on a case-by-case basis to assess whether they indeed have a positive effect.

- Shifts between fibre types: substitution of wool by other fibres:
 - The environmental impact of wool is far higher than that of other fibres. To a large extent this is due to the intrinsic difference between an animal product and an arable product: a sheep needs more space and emits more methane than a cotton plant. In the present study the entire environmental impact of sheep-farming has been allocated to the wool and the meat, but there are situations conceivable in which it would be fairer to take a different approach, which would improve the unit environmental performance of wool. It could be argued, for example, that when sheep are used in a conservation context (for grazing heath land or dikes, for example), the land use should not be allocated to the wool. With the available data, no indication can be given of the fraction of Dutch wool consumption to which this would apply. Under the present assumptions, if 20% of the wool used in the Netherlands were to be replaced by other fibres⁴⁰, the aggregate impact of the overall textile stream would fall by around 6%.
- Shifts between fibre types: cotton
 - On average, cotton has a somewhat greater environmental impact than some of the other fibres. In a number of cases it may be environmentally preferable to switch to a different fibre like polyester, viscose, modal or tencel. It is important, though, to assess whether this indeed yields benefits in the particular case concerned. In this context, non-quantifiable pros and cons should also be factored into the equation. For example, cotton cultivation involves the use of many different pesticides, the impact of which scarcely shows up in the calculated environmental burden, if at all⁴¹, because these impacts are not presently quantified in such a way that they can be included in standard LCA impact methodology. Certain types of fibre (organic cotton, for example) may thus be preferable to conventional cotton. If in 2015 20% of cotton were to be replaced by fibres like modal, for example, this would lead to around 3% savings on the aggregate environmental burden due to Dutch textiles consumption.

⁴⁰ Given the huge difference in environmental burden between wool and the other fibres, it is in this respect hardly relevant which fibre is used as a replacement.

⁴¹ This is because for many pesticides there are no impact factors available for emissions to water, soil and air. In other words, it is unknown what the exact effects of such emissions are in terms of toxicity, among other things. If the environmental impacts of the pesticides could be factored in, too, the overall impact of cotton would be higher than is currently the case.



- Demand reduction through longer product lifetimes⁴²:
 - By extending textile lifetimes, a lower volume would be required annually, thereby reducing the aggregate environmental impact. In the Netherlands, when it comes to increasing product lifetimes the main scope for improvement is with textiles for which lifetime is in practice governed by technical lifetime (overalls, towels and bedding at institutions and suchlike), rather than those whose lifetime is determined by fashion⁴³. Extending lifetimes is obviously only effective if the benefits outweigh the drawbacks: to increase lifetimes may require an extra processing step, but as long as this has less impact than the reduction in impact due to a longer lifetime, this is no problem.
- Shift to faster-drying fibres:
 - Some fibres dry faster than others. Polyester dries faster than cotton, for example, which means less energy is needed for drying. In practice polyester-cotton mixes are already often used that combine the comfortable properties of cotton with far faster drying than in the case of pure cotton. Based on the available data, it is hard to estimate the exact savings potential here.

Table 7 summarises the savings potential in 2015, based on the options discussed above. In the longer term, there will be even greater scope for improvement, for it will be a while before all the dryers currently in use are replaced by more efficient models. Similarly, energy efficiency and cleaner energy production methods take time to realise. Some of the potential, summarised in Table 7, can probably already be achieved by 2015, but beyond that date there still remains scope for further savings.

Table 7 Synopsis of savings potential in 2015

Option	Potential
Energy efficiency/cleaner energy supply	5%
Processing of textile waste	6%
More efficient washing	4%
More efficient drying	5% + 5%
Alternative fibre types	6% (wool) + 3% (cotton → modal)
Total	34%

5.2 Technology or behaviour

As stated, Table 7 summarises the scope for improvement via the various available options. What is immediately striking is that with around half this potential the key to success lies with consumers, for it is they who decide whether they are prepared to bring in their textiles waste for separate processing, at what temperature they do their washing, how full they load their machine, whether they hang up their washing to dry or throw it in the dryer, and what kind of dryer they buy when their present appliance fails. That consumers hold the key does not mean that government or industry hold no influence, however. The government can, for example, set requirements on

⁴² The reference here is explicitly to increased lifetimes in the Netherlands. Increasing overall lifetime by collecting discarded clothing in the Netherlands and reusing it abroad is described under the heading 'More collection of textiles waste and reuse/recycling'.

⁴³ Although second-hand shops may also provide some scope for extending the lifetime of designer clothing.



the laundry dryers and washing machines on the market (via the Ecodesign directive, say). On top of this, the interests of government and consumers to a certain extent run parallel: the government seeks to achieve a 20% reduction in environmental impact by 2015, while consumers are always keen to lower their energy bill. Those bills are not the only issue of relevance on the consumer side, though. Things like ease of use and habit also play a part, and the same holds for social influences and practical considerations (a detached house with a garden has more space to hang out the washing than a flat).

The bottom line is that the inefficiency of consumer washing and drying behaviour has a major influence on the environmental impact of the textiles chain. With this sort of behaviour, psychologists often distinguish between habitual behaviour and investment behaviour. Habitual behaviour is behaviour displayed without much further thought: the whites are washed at 60°C, the coloureds at 40°C and the fines at 30°C, because this is how the actor involved has always done it. To change habitual behaviour it is first necessary to create an awareness of that behaviour, so the user takes a moment to consider what he or she is doing, rather than keeping to their routine without no further thought to the matter. It is not easy to transform habitual behaviour into conscious behaviour, but nor it is impossible. From health psychology much is already known about influencing habitual behaviour and there are a number of theories that can be employed to gain a better understanding of this kind of behaviour and its amenability to influence. Certain companies have also already been active in this area. Some time ago, for instance, Procter & Gamble ran a campaign (called 'Tikkie Terug', or 'One setting lower') encouraging consumers to do their washing at a lower temperature.

Besides habitual behaviour investment behaviour is also important, in this case purchase of washing machines and dryers. In contrast to habitual behaviour, investment behaviour is conscious: it relates to fairly large and expensive appliances with a long service life and consumers generally devote some thought to such decisions, weighing up all the various pros and cons. However, this is not to say that consumers automatically include all relevant aspects in their deliberations. In the first place, consumers do not all consider the same issues important. For some consumers purchase price is the top priority, for other the make of the appliance, and so on. Second, there is not always information available in a form consumers find easy to work with. For most consumers it is very hard to assess the lifetime energy costs of an appliance and whether a slightly higher purchase price will be adequately recuperated. By emphasising certain aspects (like the costs of energy consumption during appliance usage) and by providing information on these in a form consumers can relate to, these aspects will be given greater attention and therefore greater weight in purchasing decisions.

Besides the options for which there is a key role for consumers, there are also options where industry and/or government has the greatest part to play. Most important in this respect are greening of the energy supply, reuse and recycling of textiles waste and improvements with respect to the types of fibres used. To some extent these can build on initiatives already being developed.

There is also a need for new initiatives, though, and the above options provide leverage for steering these. To properly weigh up the various options there is a need to look beyond just the environmental aspects, as economics and social aspects are also important and on top of this certain options are easier than others to implement. As Table 7 shows, the total potential for savings in 2015 is over 30%.



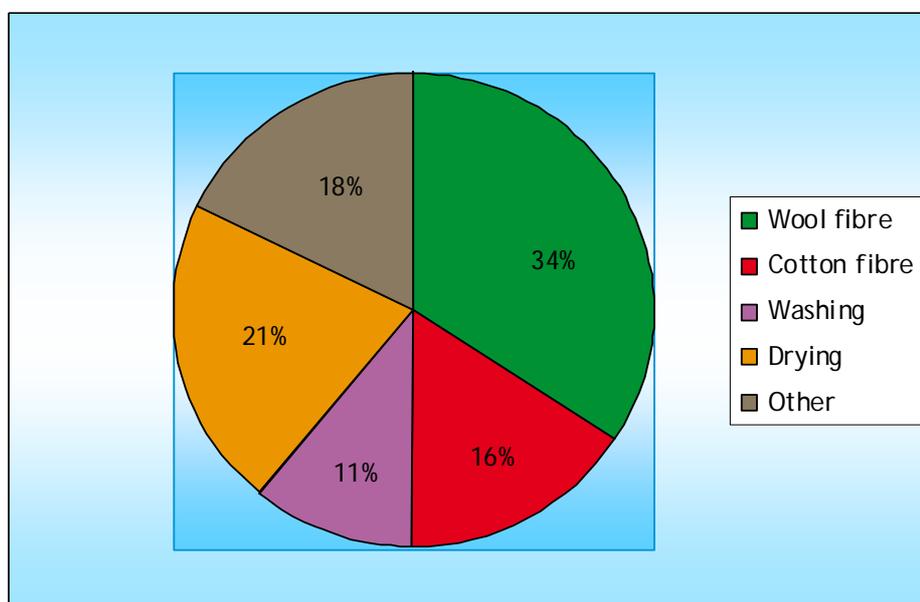
6 Conclusions & recommendations

6.1 Conclusions

This report has described the environmental impact of Dutch textiles consumption, covering all stages of the lifecycle, from procurement of the raw materials (cotton cultivation, petroleum extraction) used to produce the fibres, via a whole range of processing steps through to the use phase, in which the textiles are washed and dried, and ultimately to the waste disposal phase.

From a consideration of the lifecycle environmental impact of the entire textile stream, it emerges that a very large part of that impact is due to wool fibre, cotton fibre, washing and drying (Figure 14). Although wool is used in relatively minor quantities, kilo for kilo it has a very high impact, because a lot of land is required to graze the sheep and because they belch out a considerable amount of methane. In this context it should be noted, though, that there is substantial uncertainty regarding the precise impact of wool. Cotton is used in large quantities (2/3 of the textiles stream consists of cotton) and has a slightly greater unit environmental impact than most other fibres. The impact of cotton is due mainly to the amount of land required for growing the crop. Washing and drying are also responsible for a sizeable portion of the lifecycle environmental impact of textiles, due largely to the electrical power consumption involved, which leads to high scores on the themes of 'climate change' and 'fossil depletion'.

Figure 14 Breakdown of environmental impacts of the textile chain



There is considerable scope for reducing the environmental impact of textiles consumption. The greatest potential lies in the realm of energy efficiency and/or cleaner energy in the upstream part of product chains, a shift from wool and cotton to alternative fibres, more efficient washing and drying, and, finally, more recycling in the waste phase. Together, these options provide savings potential of over 30%.

In fleshing out these options for improvement it is important, though, to distinguish between those that always lead to gains and those that do so only on average. Energy efficiency and use of cleaner energy systems are examples of options that are consistently recommendable, because they will always lead to reduced environmental impact. A shift from cotton to other types of fibre is on average beneficial, but this is not to say this is always so. The precise environmental impact of a kilo of cotton hinges on the specific amount of land use, fertiliser inputs, and so on. Given the major variation in cultivation practices, there will be similar variation in environmental impact, so that it will depend on the specific circumstances whether a particular change will indeed lead to improvements. However, these variations also provide insight into the options for improvement within a given fibre type and improving the environmental profile of natural fibres is therefore certainly also an option. With regard to agriculturally related issues, though, it is recommended to consult agronomists before consideration is given to introducing any major changes.

6.2 Recommendations

For much of the scope for improvement, the key to success lies with consumers: improving the efficiency of washing and drying and boosting the volume of textiles that are separately collected will only succeed if consumers indeed take such action. To encourage these efforts the government can act as a facilitator, though, not only by enabling separate textiles collection but also by bringing influence to bear on washing and drying behaviour. In this respect, it is not only habitual behaviour (use of washing machines and dryers without much thought being given to the matter) that is amenable to influence, but also investment behaviour (purchase of new appliances). While this is not straightforward, it is by no means impossible. From a range of perspectives (health psychology, marketing, etc.) there is already a wealth of knowledge and experience vis-à-vis influencing this kind of behaviour. To exploit the potential for savings it is therefore recommended to make full use of this kind of knowledge and apply it in concrete campaigns and policy interventions.

Another portion of the savings potential can be realised by the government working alongside industry. Although this is already happening in numerous areas, the results of this study certainly provide several lines of thought for new initiatives.

The findings and conclusions of this study are generally robust. Even under slightly changed assumptions, wool, cotton, washing and drying would still account for the greatest impacts. The options for improvement are also fairly insensitive to changes in assumptions. One issue that needs considering is the use of wool. Wool has a very high unit impact, which means any minor uncertainties in the amount of wool consumed may still have a fairly major effect on the aggregate environmental impact of Dutch textiles consumption. When quantitatively reviewing the situation in 2015 it is therefore important to use the same sources as now for the overall size of the stream, for otherwise there will be no way of knowing for sure whether a 20% reduction



has indeed been achieved, or whether the results are within the uncertainty margins.

In addition, it is recommended to carry out further study on the environmental burden associated with wool, as it emerges from the reference analysis that wool is responsible for a substantial share of the aggregate environmental burden of Dutch textiles consumption, even though it accounts for only a small fraction in volume terms. It would also be very useful to improve understanding of the environmental impacts of pesticide use, particularly in cotton cultivation. At the moment there are no characterisation factors available for many pesticides, which means the environmental burden cannot be quantified and cannot therefore be factored into the quantitative results.





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Annex A Impacts (endpoint)

A.1 Lifecycle impacts of aggregate Dutch textiles stream

Table 8 reports the sum total of environmental impacts of the Dutch textiles stream, broken down by lifecycle phase and impact category.



Table 8 Lifecycle impacts of entire Dutch textiles stream

Impact category	Unit	Fibre consumption (Dutch, annual)	Pre-treatment (Dutch consumption, annual)	Yarn production (Dutch consumption, annual)	Processing (Dutch consumption, annual)	Colouration & finishing (Dutch consumption, annual)	Transport	Washing & drying (Netherlands, annual)	Waste disposal
Total	Pt	4.5E+08	2.0E+07	8.1E+07	9.0E+06	1.9E+07	1.1E+07	2.9E+08	-6.9E+07
Climate change, Human Health	Pt	7.3E+07	7.8E+06	2.6E+07	2.9E+06	8.0E+06	2.8E+06	8.9E+07	-1.6E+07
Climate change, Ecosystems	Pt	4.8E+07	5.1E+06	1.7E+07	1.9E+06	5.2E+06	1.8E+06	5.9E+07	-1.0E+07
Ozone depletion	Pt	4.9E+03	9.9E+02	7.2E+02	2.4E+02	3.4E+02	7.0E+02	6.6E+03	-1.9E+03
Terrestrial acidification	Pt	7.2E+05	1.1E+04	9.9E+04	5.6E+03	2.7E+03	1.8E+04	7.1E+04	-7.0E+04
Freshwater eutrophication	Pt	1.9E+05	4.5E+03	1.6E+03	1.6E+02	1.8E+02	1.5E+02	3.3E+04	-1.9E+04
Marine eutrophication	Pt	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Human toxicity	Pt	2.3E+06	3.8E+05	1.2E+06	8.8E+04	4.5E+04	6.0E+04	1.0E+07	-4.7E+05
Photochemical oxidant formation	Pt	4.0E+03	3.0E+02	2.6E+03	1.9E+02	1.6E+02	9.0E+02	3.9E+03	-1.3E+03
Particulate matter formation	Pt	4.4E+07	1.3E+06	1.3E+07	7.3E+05	3.4E+05	2.2E+06	1.1E+07	-6.2E+06
Terrestrial ecotoxicity	Pt	6.0E+05	6.3E+03	1.5E+04	2.5E+03	2.4E+03	3.2E+03	6.0E+05	-5.9E+04
Freshwater ecotoxicity	Pt	2.3E+04	3.4E+02	6.2E+02	6.6E+01	2.4E+02	6.0E+01	3.9E+04	-2.1E+03
Marine ecotoxicity	Pt	1.0E+01	8.8E-01	2.3E+00	2.8E-01	1.6E-01	5.0E-01	2.5E+01	-2.3E-01
Ionising radiation	Pt	7.1E+04	1.9E+04	3.1E+04	1.9E+04	3.2E+03	3.9E+03	1.7E+05	-2.4E+04
Agricultural land occupation	Pt	2.4E+08	8.2E+04	9.1E+05	3.6E+04	1.7E+04	8.9E+03	2.0E+06	-1.6E+07
Urban land occupation	Pt	1.9E+06	6.9E+04	3.3E+05	1.9E+04	8.4E+03	3.8E+04	6.6E+05	-1.2E+05
Metal depletion	Pt	4.1E+04	6.8E+03	8.8E+03	1.1E+03	1.5E+03	1.6E+03	6.4E+04	-9.3E+03
Fossil depletion	Pt	3.9E+07	5.2E+06	2.3E+07	3.4E+06	5.3E+06	3.9E+06	1.1E+08	-2.0E+07

A.2 Impact per lifecycle phase

Table 9 reports the environmental impacts associated with the fibres required for annual Dutch textiles consumption.

Table 10 reports the impacts of the use phase (specifically: washing and drying).

In both tables the impacts have been broken down by lifecycle phase and impact category.



Table 9 Impacts of fibre phase

Impact category	Unit	Total	Cotton fibre, ginned, at farm/CN S	Polyethylene terephthalate, granulate, amorphous, at plant/RER S	Viscose fibre, at plant/GLO S	Shrink-proofed wool	Flax sliver	Polypropylene, granulate, at plant/RER U
Total	Pt	4.49E+08	1.26E+08	1.03E+07	2.68E+07	2.72E+08	1.02E+07	4.16E+06
Climate change, Human Health	Pt	7.27E+07	1.97E+07	2.37E+06	4.19E+06	4.44E+07	1.22E+06	8.06E+05
Climate change, Ecosystems	Pt	4.76E+07	1.29E+07	1.55E+06	2.74E+06	2.90E+07	8.02E+05	5.28E+05
Ozone depletion	Pt	4.94E+03	2.12E+03	2.14E+02	5.18E+02	1.98E+03	1.14E+02	1.28E-01
Terrestrial acidification	Pt	7.22E+05	1.66E+05	3.64E+03	1.94E+04	5.24E+05	7.27E+03	1.11E+03
Freshwater eutrophication	Pt	1.92E+05	8.61E+04	3.24E+02	1.66E+03	9.87E+04	4.97E+03	1.35E+02
Marine eutrophication	Pt	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Human toxicity	Pt	2.34E+06	8.77E+05	8.00E+04	5.22E+05	7.69E+05	8.59E+04	2.87E+03
Photochemical oxidant formation	Pt	4.02E+03	1.57E+03	1.86E+02	4.68E+02	1.61E+03	9.86E+01	8.71E+01
Particulate matter formation	Pt	4.35E+07	1.15E+07	4.87E+05	2.41E+06	2.84E+07	5.70E+05	1.33E+05
Terrestrial ecotoxicity	Pt	5.99E+05	2.20E+05	2.00E+03	2.13E+04	3.32E+05	2.34E+04	3.52E+02
Freshwater ecotoxicity	Pt	2.35E+04	5.72E+03	7.10E+01	2.21E+02	1.74E+04	5.45E+01	4.74E+01
Marine ecotoxicity	Pt	1.04E+01	3.23E+00	3.24E-01	7.82E-01	5.89E+00	1.68E-01	2.05E-02
Ionising radiation	Pt	7.15E+04	3.05E+04	5.33E+03	1.88E+04	1.38E+04	3.04E+03	1.65E+00
Agricultural land occupation	Pt	2.41E+08	6.61E+07	3.26E+04	1.16E+07	1.57E+08	6.56E+06	1.65E+02
Urban land occupation	Pt	1.94E+06	2.19E+05	1.60E+04	3.57E+05	1.34E+06	7.74E+03	7.38E+01
Metal depletion	Pt	4.06E+04	1.97E+04	3.13E+03	4.66E+03	1.21E+04	1.08E+03	1.26E+01
Fossil depletion	Pt	3.86E+07	1.42E+07	5.73E+06	4.98E+06	1.02E+07	8.66E+05	2.69E+06

Table 10 Impacts of use phase

Impact category	Unit	Total	Washing 30 degrees, A label	Washing 40 degrees, A label	Washing 60 degrees, A label	Washing 90 degrees, A label	Condenser dryer (B label); average Dutch dryer	Ironing
Total	Pt	2.73E+08	15964839	27152347	31995023	12979798	1.70E+08	14936930
Climate change Human Health	Pt	84211300	4218665	7426601	9260046	3887865	54623121	4795003
Climate change Ecosystems	Pt	55177091	2764096	4865983	6067329	2547404	35790471	3141809
Ozone depletion	Pt	6409.159	411.2588	686.3027	782.1168	310.4337	3878.573	340.4743
Terrestrial acidification	Pt	69344.363	5504.441	8841.638	9366.886	3528.771	38704.97	3397.654
Freshwater eutrophication	Pt	33165.375	8241.208	11758.61	9290.491	2591.694	1179.805	103.5672
Marine eutrophication	Pt	0	0	0	0	0	0	0
Human toxicity	Pt	10054637	2232241	3207403	2588228	742806.4	1180344	103614.6
Photochemical oxidant formation	Pt	3769.5827	252.3853	417.7513	469.0133	184.2759	2248.754	197.4032
Particulate matter formation	Pt	10438567	781170.3	1267280	1369341	523550	5972905	524321.8
Terrestrial ecotoxicity	Pt	598945.65	134424.9	193011.9	155424	44482.38	65824.28	5778.279
Freshwater ecotoxicity	Pt	39263.301	10104.25	14387.51	11296.97	3124.268	322.0294	28.26884
Marine ecotoxicity	Pt	25.303245	5.593172	8.038871	6.492514	1.86539	3.045916	0.267381
Ionising radiation	Pt	168479.42	11338.72	18749.7	21012.47	8245.537	100326	8806.96
Agricultural land occupation	Pt	1999579.7	272565.6	407794	367743.3	120102.8	764282.7	67091.33
Urban land occupation	Pt	643739.36	58193.87	91604.3	93040.33	33901.92	337382.4	29616.57
Metal depletion	Pt	62163.691	5448.828	8616.663	8838.126	3246.27	33107.51	2906.29
Fossil depletion	Pt	1.10E+08	5462176	9629205	12032810	5058453	71242580	6253915

A.3 Unit impacts

Table 11 provides a synopsis of the environmental impacts of the 'fibres/ granulate' phase of the lifecycle, and that phase only, i.e. the impacts of growing 1 kg cotton, for example.

Table 12 summarises the impacts of spinning, weaving, knitting, colouration and finishing per kg material.

Table 13 reviews the impacts of the use phase, per kilogram and per washing or drying operation.

Table 14 reviews the impacts of waste disposal per kg material.



Table 11 Impacts of unit fibre production

Impact category	Unit	Cotton fibre, at farm/US S	Cotton fibre, ginned, at farm/CN S	Cotton, organic	Flax sliver	Sliver (hemp)	Jute fibre, irrigated system, at farm/IN S	Kenaf fibre, at farm/IN S	LDPE resin E	Nylon 6 E	PET (amorphous) E
Total	Pt	7.26E-01	6.24E-01	6.60E-01	6.55E-01	6.43E-01	1.27E-01	1.15E-01	2.98E-01	8.00E-01	3.77E-01
Climate change, Human Health	Pt	6.57E-02	9.76E-02	7.39E-03	7.90E-02	9.97E-02	1.68E-02	1.57E-02	5.81E-02	2.55E-01	9.07E-02
Climate change, Ecosystems	Pt	4.30E-02	6.39E-02	4.84E-03	5.17E-02	6.53E-02	1.10E-02	1.03E-02	3.80E-02	1.67E-01	5.94E-02
Ozone depletion	Pt	8.82E-06	1.05E-05	0.00E+00	7.33E-06	1.05E-05	9.95E-07	1.30E-06	0.00E+00	0.00E+00	0.00E+00
Terrestrial acidification	Pt	3.67E-04	8.24E-04	2.54E-04	4.69E-04	2.23E-04	1.54E-04	1.40E-04	9.50E-05	3.65E-04	1.89E-04
Freshwater eutrophication	Pt	8.83E-04	4.26E-04	0.00E+00	3.21E-04	4.51E-04	6.55E-05	5.44E-05	0.00E+00	0.00E+00	0.00E+00
Marine eutrophication	Pt	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Human toxicity	Pt	2.98E-03	4.34E-03	0.00E+00	5.54E-03	5.68E-03	2.88E-04	1.31E-04	3.78E-05	1.57E-04	8.48E-05
Photochemical oxidant formation	Pt	8.79E-06	7.77E-06	1.02E-05	6.36E-06	7.31E-06	5.63E-07	1.25E-06	3.63E-06	1.55E-05	7.34E-06
Particulate matter formation	Pt	3.50E-02	5.69E-02	2.29E-02	3.68E-02	2.61E-02	9.00E-03	9.37E-03	1.30E-02	5.34E-02	2.85E-02
Terrestrial ecotoxicity	Pt	4.67E-02	1.09E-03	0.00E+00	1.51E-03	7.07E-05	2.28E-04	1.98E-04	1.34E-07	5.98E-06	1.02E-05
Freshwater ecotoxicity	Pt	1.61E-04	2.84E-05	0.00E+00	3.52E-06	1.97E-06	1.78E-05	1.53E-05	1.21E-09	2.36E-07	1.19E-08
Marine ecotoxicity	Pt	4.02E-08	1.60E-08	0.00E+00	1.08E-08	1.03E-08	4.09E-09	3.61E-09	7.83E-12	1.27E-09	1.08E-09
Ionising radiation	Pt	5.72E-05	1.51E-04	0.00E+00	1.96E-04	2.32E-04	8.10E-06	7.46E-06	0.00E+00	0.00E+00	0.00E+00
Agricultural land occupation	Pt	4.77E-01	3.27E-01	6.24E-01	4.23E-01	3.76E-01	8.35E-02	7.16E-02	0.00E+00	0.00E+00	0.00E+00
Urban land occupation	Pt	1.01E-03	1.08E-03	0.00E+00	5.00E-04	6.75E-04	5.75E-05	8.37E-05	0.00E+00	0.00E+00	0.00E+00
Metal depletion	Pt	9.80E-05	9.75E-05	0.00E+00	6.98E-05	9.02E-05	7.66E-06	9.72E-06	4.72E-07	9.05E-07	1.58E-07
Fossil depletion	Pt	5.27E-02	7.01E-02	0.00E+00	5.59E-02	6.84E-02	6.42E-03	7.47E-03	1.89E-01	3.24E-01	1.98E-01

Table 1 (continued)

Impact category	Unit	Recycled PET	Polyacryl	Poly lactide, granulate, at plant/GLO S	Viscose fibre, at plant/GLO S	Lenzing viscose, Asia ⁴⁴	Lenzing viscose, Austria	Lenzing, modal	Tencel, Austria	Tencel, Austria 2012	Shrink-proofed wool
Total	Pt	1.42E-01	3.69E-01	3.25E-01	8.63E-01	4.92E-01	2.81E-01	3.13E-01	2.92E-01	1.87E-01	1.76E+01
Climate change, Human Health	Pt	3.43E-02	8.58E-02	8.71E-02	1.35E-01	1.50E-01	3.33E-02	4.16E-02	7.21E-02	4.44E-02	2.87E+00
Climate change, Ecosystems	Pt	2.25E-02	5.62E-02	5.70E-02	8.82E-02	9.81E-02	2.18E-02	2.72E-02	4.72E-02	2.91E-02	1.87E+00
Ozone depletion	Pt	3.01E-06	2.08E-08	1.56E-05	1.66E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28E-04
Terrestrial acidification	Pt	4.79E-05	1.45E-04	1.63E-04	6.25E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.38E-02
Freshwater eutrophication	Pt	4.01E-06	5.34E-06	1.12E-04	5.33E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.37E-03
Marine eutrophication	Pt	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Human toxicity	Pt	1.03E-03	3.67E-04	2.32E-03	1.68E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.96E-02
Photochemical oxidant formation	Pt	2.51E-06	9.99E-06	6.59E-06	1.51E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.04E-04
Particulate matter formation	Pt	6.50E-03	1.55E-02	1.75E-02	7.76E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.83E+00
Terrestrial ecotoxicity	Pt	2.96E-05	4.11E-06	2.31E-03	6.85E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.14E-02
Freshwater ecotoxicity	Pt	8.85E-07	5.72E-07	1.51E-05	7.11E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.12E-03
Marine ecotoxicity	Pt	4.11E-09	1.12E-09	1.18E-08	2.51E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.80E-07
Ionising radiation	Pt	7.47E-05	3.76E-07	3.14E-04	6.04E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.93E-04
Agricultural land occupation	Pt	4.64E-04	1.43E-04	4.63E-02	3.72E-01	8.47E-02	1.77E-01	1.80E-01	6.16E-02	5.64E-02	1.01E+01
Urban land occupation	Pt	2.24E-04	1.05E-05	2.10E-03	1.15E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.65E-02
Metal depletion	Pt	3.83E-05	3.89E-06	7.50E-05	1.50E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.78E-04
Fossil depletion	Pt	7.66E-02	2.11E-01	1.10E-01	1.60E-01	1.60E-01	4.90E-02	6.45E-02	1.11E-01	5.68E-02	6.60E-01

⁴⁴ In the case of Lenzing viscose Asia, Lenzing viscose Austria, Lenzing modal, Tencel Austria and Tencel Austria 2012, a score could be calculated for only three of the impact categories. With the other fibres, however, these were the categories that emerged as having the greatest influence. To check how great the approximate difference is, for viscose the total impact was calculated as well as the impact under the impact categories 'Climate change', 'Agricultural land occupation' and 'Fossil depletion'. This indicated that the discrepancy was only minor and that the impact categories 'Climate change', 'Agricultural land occupation' and 'Fossil depletion' provide a robust picture of the aggregate impact.

Table 12 Impacts of unit manufacture

Impact category	Unit	Wool, spinning	Polyester, spinning	Cotton, spinning	Knitting	Non-woven, make-up	Weaving, bast fibre/IN S	Cotton, singeing & desizing	Cotton, scouring & bleaching - pre-treatment
Total	Pt	1.67E-01	1.00E-01	3.79E-01	1.34E-02	6.27E-02	3.55E-02	1.04E-02	8.48E-02
Climate change, Human Health	Pt	4.96E-02	3.11E-02	1.22E-01	4.43E-03	2.01E-02	1.13E-02	3.66E-03	3.31E-02
Climate change, Ecosystems	Pt	3.25E-02	2.04E-02	7.98E-02	2.90E-03	1.32E-02	7.38E-03	2.40E-03	2.17E-02
Ozone depletion	Pt	1.25E-05	2.94E-06	1.34E-06	2.03E-07	1.43E-06	1.07E-06	7.85E-07	4.08E-06
Terrestrial acidification	Pt	5.32E-05	5.85E-05	0.00051	9.41E-06	1.43E-05	2.55E-05	8.62E-06	4.68E-05
Freshwater eutrophication	Pt	6.77E-07	1.89E-06	7.50E-06	3.58E-07	4.35E-07	6.88E-07	4.57E-06	1.76E-05
Marine eutrophication	Pt	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Human toxicity	Pt	1.12E-03	1.19E-03	5.73E-03	2.31E-04	4.35E-04	3.27E-04	1.55E-04	1.71E-03
Photochemical oxidant formation	Pt	1.91E-06	1.82E-06	1.30E-05	2.45E-07	8.28E-07	8.32E-07	2.01E-07	1.26E-06
Particulate matter formation	Pt	6.83E-03	7.65E-03	6.73E-02	1.18E-03	2.20E-03	3.28E-03	9.20E-04	5.43E-03
Terrestrial ecotoxicity	Pt	4.73E-05	3.46E-05	5.13E-05	3.54E-06	2.42E-05	8.74E-06	3.46E-06	2.73E-05
Freshwater ecotoxicity	Pt	3.36E-07	9.23E-07	2.92E-06	1.62E-07	1.19E-07	2.81E-07	2.32E-07	1.46E-06
Marine ecotoxicity	Pt	3.76E-09	3.66E-09	1.06E-08	6.13E-10	1.12E-09	1.12E-09	5.76E-10	3.75E-09
Ionising radiation	Pt	1.65E-05	2.45E-04	2.98E-05	1.35E-05	3.70E-05	1.00E-04	8.08E-06	8.44E-05
Agricultural land occupation	Pt	6.83E-05	4.42E-03	3.40E-03	7.16E-05	2.82E-04	1.30E-04	4.48E-05	3.56E-04
Urban land occupation	Pt	7.67E-05	0.000305	0.001703	2.59E-05	0.000124	7.74E-05	5.60E-05	0.000285
Metal depletion	Pt	5.06E-06	2.19E-05	4.09E-05	1.93E-06	1.22E-05	3.54E-06	3.72E-06	2.95E-05
Fossil depletion	Pt	0.076688	0.034957	0.098731	0.004554	0.026246	0.01295	0.003099	0.021973

(Table 12, continued)

Impact category	Unit	Carrier dyeing + reduction cleaning	Disperse dyeing + reduction cleaning	Printing, colouration	Cotton, finishing	Polyester, finishing
Total	Pt	5.27E-02	5.05E-02	5.16E-02	1.67E-02	1.39E-02
Climate change, Human Health	Pt	2.31E-02	2.46E-02	2.38E-02	5.05E-03	3.34E-03
Climate change, Ecosystems	Pt	1.51E-02	1.61E-02	1.56E-02	3.31E-03	2.19E-03
Ozone depletion	Pt	8.82E-07	7.34E-07	8.08E-07	4.20E-07	4.20E-07
Terrestrial acidification	Pt	6.84E-06	4.95E-06	5.89E-06	3.79E-06	3.79E-06
Freshwater eutrophication	Pt	4.52E-07	3.14E-07	3.83E-07	2.60E-07	2.60E-07
Marine eutrophication	Pt	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Human toxicity	Pt	1.16E-04	9.17E-05	1.04E-04	5.84E-05	5.84E-05
Photochemical oxidant formation	Pt	4.13E-07	2.94E-07	3.54E-07	2.32E-07	2.32E-07
Particulate matter formation	Pt	8.64E-04	6.30E-04	7.47E-04	4.76E-04	4.76E-04
Terrestrial ecotoxicity	Pt	6.44E-06	6.76E-06	6.60E-06	2.08E-06	2.08E-06
Freshwater ecotoxicity	Pt	6.81E-07	9.15E-07	7.98E-07	7.61E-08	7.61E-08
Marine ecotoxicity	Pt	4.12E-10	3.44E-10	3.78E-10	1.95E-10	1.95E-10
Ionising radiation	Pt	8.28E-06	7.97E-06	8.13E-06	3.18E-06	3.18E-06
Agricultural land occupation	Pt	4.48E-05	3.68E-05	4.08E-05	2.17E-05	2.17E-05
Urban land occupation	Pt	2.17E-05	1.93E-05	2.05E-05	9.52E-06	9.52E-06
Metal depletion	Pt	3.94E-06	3.28E-06	3.61E-06	1.88E-06	1.88E-06
Fossil depletion	Pt	0.013316	0.009073	0.011195	0.007787	0.007787

Table 13 Impacts per unit in use phase

Impact category	Unit	Washing, average Dutch washing machine (current) and temp. spread	Washing 15 degrees, A label	Washing 30 degrees, A label	Washing 40 degrees, A label	Washing 60 degrees, A label	Washing 90 degrees, A label	Washing 60 degrees, C label; full load
Total	Pt	0.016267	0.009495	0.011338	0.013551	0.020372	0.02996	0.020942
Climate change, Human Health	Pt	0.004578	0.002404	0.002996	0.003706	0.005896	0.008974	0.006285
Climate change, Ecosystems	Pt	0.003	0.001575	0.001963	0.002428	0.003863	0.00588	0.004118
Ozone depletion	Pt	4.04E-07	2.50E-07	2.92E-07	3.43E-07	4.98E-07	7.17E-07	5.00E-07
Terrestrial acidification	Pt	5.03E-06	3.49E-06	3.91E-06	4.41E-06	5.96E-06	8.15E-06	5.67E-06
Freshwater eutrophication	Pt	5.89E-06	5.84E-06	5.85E-06	5.87E-06	5.92E-06	5.98E-06	4.07E-06
Marine eutrophication	Pt	0	0	0	0	0	0	0
Human toxicity	Pt	0.00162	0.001573	0.001585	0.001601	0.001648	0.001715	0.00117
Photochemical oxidant formation	Pt	2.44E-07	1.55E-07	1.79E-07	2.08E-07	2.99E-07	4.25E-07	2.97E-07
Particulate matter formation	Pt	0.000728	0.00049	0.000555	0.000632	0.000872	0.001208	0.000842
Terrestrial ecotoxicity	Pt	9.74E-05	9.48E-05	9.55E-05	9.63E-05	9.90E-05	0.000103	7.00E-05
Freshwater ecotoxicity	Pt	7.19E-06	7.17E-06	7.18E-06	7.18E-06	7.19E-06	7.21E-06	4.90E-06
Marine ecotoxicity	Pt	4.06E-09	3.94E-09	3.97E-09	4.01E-09	4.13E-09	4.31E-09	2.94E-09
Ionising radiation	Pt	1.10E-05	6.97E-06	8.05E-06	9.36E-06	1.34E-05	1.90E-05	1.33E-05
Agricultural land occupation	Pt	0.000216	0.000185	0.000194	0.000204	0.000234	0.000277	0.000191
Urban land occupation	Pt	5.11E-05	3.77E-05	4.13E-05	4.57E-05	5.92E-05	7.83E-05	5.43E-05
Metal depletion	Pt	4.83E-06	3.51E-06	3.87E-06	4.30E-06	5.63E-06	7.49E-06	5.21E-06
Fossil depletion	Pt	0.005943	0.003107	0.003879	0.004806	0.007662	0.011676	0.008178

(Table 13, continued)

Impact category	Unit	Heat-pump dryer (A label)	Gas-heated dryer	Drying, clothes horse	Condenser dryer (B label); average Dutch dryer	Condenser dryer (C label)	Condenser dryer (D label)	Ventilation dryer (B label)	Ventilation dryer (C label)	Ventilation dryer (D label)
Total	Pt	0.024179	0.013613	0	0.044596	0.050865	0.057134	0.041014	0.046567	0.052119
Climate change, Human Health	Pt	0.007762	0.003963	0	0.014316	0.016329	0.018341	0.013166	0.014949	0.016731
Climate change, Ecosystems	Pt	0.005086	0.002597	0	0.00938	0.010699	0.012017	0.008627	0.009795	0.010963
Ozone depletion	Pt	5.51E-07	8.88E-07	0.00E+00	1.02E-06	1.16E-06	1.30E-06	9.35E-07	1.06E-06	1.19E-06
Terrestrial acidification	Pt	5.50E-06	1.47E-06	0.00E+00	1.01E-05	1.16E-05	1.30E-05	9.33E-06	1.06E-05	1.19E-05
Freshwater eutrophication	Pt	1.68E-07	4.16E-08	0.00E+00	3.09E-07	3.53E-07	3.96E-07	2.84E-07	3.23E-07	3.61E-07
Marine eutrophication	Pt	0	0	0	0	0	0	0	0	0
Human toxicity	Pt	0.000168	2.48E-05	0	0.000309	0.000353	0.000396	0.000285	0.000323	0.000362
Photochemical oxidant formation	Pt	3.20E-07	9.76E-08	0.00E+00	5.89E-07	6.72E-07	7.55E-07	5.42E-07	6.15E-07	6.89E-07
Particulate matter formation	Pt	0.000849	0.000194	0	0.001565	0.001785	0.002006	0.00144	0.001635	0.001829
Terrestrial ecotoxicity	Pt	9.35E-06	1.65E-06	0.00E+00	1.73E-05	1.97E-05	2.21E-05	1.59E-05	1.80E-05	2.02E-05
Freshwater ecotoxicity	Pt	4.58E-08	8.78E-09	0.00E+00	8.44E-08	9.63E-08	1.08E-07	7.76E-08	8.81E-08	9.86E-08
Marine ecotoxicity	Pt	4.33E-10	1.14E-10	0.00E+00	7.98E-10	9.11E-10	1.02E-09	7.34E-10	8.34E-10	9.33E-10
Ionising radiation	Pt	1.43E-05	1.72E-06	0.00E+00	2.63E-05	3.00E-05	3.37E-05	2.42E-05	2.75E-05	3.07E-05
Agricultural land occupation	Pt	0.000109	1.29E-05	0	0.0002	0.000228	0.000257	0.000184	0.000209	0.000234
Urban land occupation	Pt	4.79E-05	7.37E-06	0.00E+00	8.84E-05	0.000101	1.13E-04	8.13E-05	9.23E-05	0.000103
Metal depletion	Pt	4.70E-06	6.99E-07	0.00E+00	8.68E-06	9.90E-06	1.11E-05	7.98E-06	9.06E-06	1.01E-05
Fossil depletion	Pt	0.010123	0.006808	0	0.018672	0.021297	0.023921	0.017172	0.019497	0.021821

Table 14 Impacts of unit waste disposal

Impact category	Unit	Cotton incinerated, no power generation	PET incinerated, no power generation	Cotton to incinerator, with power generation	PET to incinerator, with power generation	Reuse as second-hand clothing	Use of textile waste as cleaning rags	Use of textile waste as insulation/filling	PLA, composting	Cotton, recycling
Total	Pt	0	0.098147	-0.06677	-0.00981	-0.52454	-0.23448	-0.38587	0.025159	-0.2732
Climate change, Human Health	Pt	0	0.056351	-0.0226	0.021694	-0.09897	-0.06088	-0.10552	0.013048	0.00985
Climate change, Ecosystems	Pt	0	0.036923	-0.01481	0.014216	-0.06477	-0.03989	-0.06913	0.008542	0.006469
Ozone depletion	Pt	0	9.10E-08	-9.67E-06	-2.37E-06	-5.86E-06	-7.97E-07	-8.16E-07	1.69E-07	-2.46E-06
Terrestrial acidification	Pt	0	4.75E-06	-2.87E-05	-1.98E-05	-0.00079	-0.00041	-0.0002	-1.13E-06	-0.00037
Freshwater eutrophication	Pt	0	1.34E-07	-1.93E-06	-6.15E-07	-0.00019	-1.98E-06	-4.13E-05	3.18E-08	-0.00046
Marine eutrophication	Pt	0	0	0	0	0	0	0	0	0
Human toxicity	Pt	0	0.003541	-0.00097	0.002792	-0.00315	-0.00118	-0.00294	5.42E-05	-0.00125
Photochemical oxidant formation	Pt	0	4.89E-07	-1.11E-06	-9.37E-07	-5.57E-06	-1.43E-05	-9.39E-06	6.45E-08	-3.31E-06
Particulate matter formation	Pt	0	0.000736	-0.00328	-0.00305	-0.05358	-0.04053	-0.03116	9.64E-05	-0.02553
Terrestrial ecotoxicity	Pt	0	1.27E-05	-1.04E-05	-2.90E-05	-0.0006	-7.41E-06	-0.00018	3.09E-06	-0.01666
Freshwater ecotoxicity	Pt	0	1.66E-05	-3.69E-07	1.64E-05	-2.09E-05	-8.33E-08	-1.80E-05	1.37E-08	-6.60E-05
Marine ecotoxicity	Pt	0	4.69E-08	-1.41E-09	4.50E-08	-4.56E-09	-6.08E-10	-1.05E-08	1.39E-10	-1.63E-08
Ionising radiation	Pt	0	5.55E-07	-8.16E-05	-6.31E-05	-0.00013	0	-5.28E-05	4.53E-06	3.87E-05
Agricultural land occupation	Pt	0	2.99E-06	0	-0.00048	-0.23381	0	-0.00042	2.25E-05	-0.28067
Urban land occupation	Pt	0	9.26E-06	0	-0.0002	-0.00218	0	-0.00015	1.42E-05	-0.00035
Metal depletion	Pt	0	7.42E-07	-1.88E-05	-2.03E-05	-5.41E-05	0	-3.40E-05	1.47E-06	-3.17E-05
Fossil depletion	Pt	0	0.000548	-0.02495	-0.04465	-0.06628	-0.09156	-0.17603	0.003374	0.035837



Annex B Impacts (midpoint)

In the previous annex the impacts of Dutch textiles consumption were reviewed at endpoint level. In certain cases, though, it is useful to also have information on impacts at the midpoint level. For completeness' sake, in this annex we therefore also list the midpoint impacts. These scores have not been normalised or weighted.

Table 15 reviews the environmental impacts of the 'fibres/granulate' phase of the lifecycle, and that phase only, i.e. the impacts of growing 1 kg cotton, for example.

Table 16 summarises the impacts of spinning, weaving, knitting, colouration and finishing per kg material.

Table 17 reviews the impacts in the consumption phase, per kilogram and per washing or drying operation.

Table 18 summarises the impacts of waste disposal per kg material.



Table 15 Impacts of unit fibre production (midpoint)

Impact category	Unit	Cotton (US)	Cotton (CN)	Organic cotton	Flax	Hemp	Jute	Kenaf	LDPE	Nylon	PET	Recycled PET
Climate change	kg CO ₂ eq.	2.369891	3.520801	0.26677	2.849057	3.59566	0.603501	0.565609	2.095146	9.198058	3.270074	1.236634
Ozone depletion	kg CFC-11 eq.	1.70E-07	2.03E-07	0	1.42E-07	1.98E-07	1.90E-08	2.50E-08	1.28E-11	6.63E-11	1.84E-11	5.84E-08
Terrestrial acidification	kg SO ₂ eq.	0.027599	0.062086	0.019152	0.035338	0.016756	0.011596	0.010574	0.00715	0.027449	0.014192	0.003605
Freshwater eutrophication	kg P eq.	0.008673	0.004187	0	0.003152	0.004426	0.000644	0.000534	0	0	0	3.93E-05
Marine eutrophication	kg N eq.	3.42E-02	9.37E-02	0.056083	1.83E-01	1.70E-01	1.67E-02	1.27E-02	0.000491	0.005762	0.000952	2.65E-04
Human toxicity	kg 1,4-DB eq.	0.214631	0.313465	0	0.399852	0.409632	0.020766	0.00943	2.73E-03	0.011333	0.006122	7.42E-02
Photochemical oxidant formation	kg NMVOC	0.011387	0.010062	0.0132	0.008236	0.009466	7.29E-04	1.62E-03	0.004702	0.02003	0.009508	3.25E-03
Particulate matter formation	kg PM ₁₀ eq.	0.006616	0.011007	0.00444	0.007078	0.005013	0.001765	0.001788	0.002533	0.010378	0.005536	0.00132
Terrestrial ecotoxicity	kg 1,4-DB eq.	0.160083	0.003744	0	0.005199	0.000243	0.000784	0.000678	4.60E-07	2.05E-05	3.50E-05	0.000102
Freshwater ecotoxicity	kg 1,4-DB eq.	2.71E-01	4.76E-02	0.00E+00	5.90E-03	3.31E-03	2.99E-02	2.57E-02	2.03E-06	3.96E-04	2.00E-05	1.48E-03
Marine ecotoxicity	kg 1,4-DB eq.	0.021919	0.008718	0	0.005902	0.005594	0.002229	0.00197	4.28E-06	0.000694	0.000591	0.002243
Ionising radiation	kg U235 eq.	0.176185	0.464592	0	0.604206	7.15E-01	0.024928	0.022975	0.00E+00	0.00E+00	0.00E+00	2.30E-01
Agricultural land occupation	m ² a	11.34494	7.79E+00	14.81482	1.00E+01	8.94E+00	1.98E+00	1.70E+00	0.00E+00	0.00E+00	0.00E+00	1.81E-02
Urban land occupation	m ² a	2.29E-02	2.45E-02	0	1.13E-02	1.53E-02	1.30E-03	1.89E-03	0.00E+00	0.00E+00	0.00E+00	5.06E-03
Metal depletion	kg Fe eq.	0.20336	0.20232	0	0.145071	0.187248	1.59E-02	2.02E-02	0.000979	0.001879	0.000328	0.07951
Fossil depletion	kg oil eq.	0.486849	0.646642	0	0.515583	0.631146	0.059221	0.068892	1.74615	2.991676	1.833518	0.706666

(Table 15, continued)

Impact category	Unit	Polyacryl	PLA	Viscose	Lenzing viscose, Asia ⁴⁵	Lenzing viscose, Austria	Lenzing modal	Tencel, Austria	Tencel, Austria 2012	Wool
Climate change	kg CO ₂ eq.	3.096306	3.140319	4.856816	5.4	1.2	1.5	2.6	1.6	102.7404
Ozone depletion	kg CFC-11 eq.	7.67E-10	3.01E-07	3.21E-07	0	0	0	0	0	2.51E-06
Terrestrial acidification	kg SO ₂ eq.	0.010947	0.012302	0.047047	0	0	0	0	0	2.547046
Freshwater eutrophication	kg P eq.	5.25E-05	0.001096	0.000524	0	0	0	0	0	0.062554
Marine eutrophication	kg N eq.	2.27E-03	4.64E-02	5.57E-03	0	0	0	0	0	2.472436
Human toxicity	kg 1,4-DB eq.	0.026485	0.16719	1.211538	0	0	0	0	0	3.576924
Photochemical oxidant formation	kg NMVOC	1.29E-02	0.008539	1.95E-02	0	0	0	0	0	0.134776
Particulate matter formation	kg PM ₁₀ eq.	0.003231	0.00333	0.014385	0	0	0	0	0	0.357168
Terrestrial ecotoxicity	kg 1,4-DB eq.	1.41E-05	0.007938	0.002355	0	0	0	0	0	0.073528
Freshwater ecotoxicity	kg 1,4-DB eq.	9.61E-04	2.54E-02	1.19E-02	0	0	0	0	0	1.881333
Marine ecotoxicity	kg 1,4-DB eq.	0.000608	0.00642	0.013714	0	0	0	0	0	0.207128
Ionising radiation	kg U235 eq.	1.16E-03	0.965545	1.858828	0	0	0	0	0	2.748366
Agricultural land occupation	m ² a	5.56E-03	1.11E+00	1.45E+01	3.3	6.9	7	2.4	2.2	277.7308
Urban land occupation	m ² a	2.38E-04	4.74E-02	2.59E-01	0	0	0	0	0	1.96E+00
Metal depletion	kg Fe eq.	8.07E-03	0.155793	0.310827	0	0	0	0	0	1.615502
Fossil depletion	kg oil eq.	1.948481	1.013318	1.478282	1.475314	0.452112	0.594884	1.023201	0.523498	6.085413

⁴⁵ In the case of Lenzing viscose Asia, Lenzing viscose Austria, Lenzing modal, Tencel Austria and Tencel Austria 2012, a score could be calculated for only three of the impact categories. With the other fibres, however, these were the categories that emerged as having the greatest influence. To check how great the approximate difference is, for viscose the total impact was calculated as well as the impact under the impact categories 'Climate change', 'Agricultural land occupation' and 'Fossil depletion'. This indicated that the discrepancy was only minor and that the impact categories 'Climate change', 'Agricultural land occupation' and 'Fossil depletion' provide a robust picture of the aggregate impact.

Table 16 Impacts of unit manufacture (midpoint)

Impact category	Unit	Wool, spinning	Polyester, spinning	Cotton, spinning	Knitting	Non-woven, article make-up	Weaving, bast fibre/ IN S	Cotton, singeing & desizing
Climate change	kg CO ₂ eq.	1.79E+00	1.12E+00	4.39E+00	1.60E-01	7.26E-01	4.06E-01	1.32E-01
Ozone depletion	kg CFC-11 eq.	2.37E-07	5.90E-08	2.55E-08	4.06E-09	2.81E-08	2.17E-08	1.35E-08
Terrestrial acidification	kg SO ₂ eq.	4.00E-03	4.40E-03	3.83E-02	7.08E-04	1.07E-03	1.92E-03	6.49E-04
Freshwater eutrophication	kg P eq.	6.65E-06	1.85E-05	7.37E-05	3.52E-06	4.27E-06	6.76E-06	4.49E-05
Marine eutrophication	kg N eq.	2.12E-04	2.98E-04	1.80E-03	3.49E-05	1.34E-04	1.21E-04	3.68E-05
Human toxicity	kg 1,4-DB eq.	8.09E-02	8.59E-02	0.413617	1.67E-02	3.14E-02	0.023614	1.12E-02
Photochemical oxidant formation	kg NMVOC	2.47E-03	2.35E-03	1.68E-02	3.17E-04	1.07E-03	1.08E-03	2.61E-04
Particulate matter formation	kg PM ₁₀ eq.	1.24E-03	1.40E-03	1.20E-02	2.14E-04	4.08E-04	6.05E-04	1.90E-04
Terrestrial ecotoxicity	kg 1,4-DB eq.	1.62E-04	1.19E-04	1.76E-04	1.22E-05	8.34E-05	3.00E-05	1.19E-05
Freshwater ecotoxicity	kg 1,4-DB eq.	5.64E-04	1.55E-03	4.89E-03	2.72E-04	1.99E-04	4.72E-04	3.90E-04
Marine ecotoxicity	kg 1,4-DB eq.	2.05E-03	1.99E-03	5.77E-03	3.34E-04	6.12E-04	6.09E-04	3.14E-04
Ionising radiation	kg U235- q.	5.07E-02	7.53E-01	9.17E-02	4.17E-02	1.14E-01	3.08E-01	2.49E-02
Agricultural land occupation	m ² a	2.65E-03	1.72E-01	1.32E-01	2.79E-03	1.10E-02	5.06E-03	1.74E-03
Urban land occupation	m ² a	1.74E-03	6.90E-03	3.85E-02	5.87E-04	2.81E-03	1.75E-03	1.27E-03
Metal depletion	kg Fe eq.	1.05E-02	0.045528	0.085016	4.00E-03	0.025337	0.007348	7.73E-03
Fossil depletion	kg oil eq.	0.706569	0.322549	0.911816	0.042047	0.241906	0.119515	0.02858

(Table 16, continued)

Impact category	Unit	Cotton, scouring & bleaching - pre-treatment	Carrier dyeing + reduction cleaning	Disperse dyeing + reduction cleaning	Printing/ colouration	Finishing, cotton	Finishing, polyester
Climate change	kg CO ₂ eq.	1.20E+00	8.34E-01	8.86E-01	8.60E-01	1.82E-01	1.20E-01
Ozone depletion	kg CFC-11 eq.	7.35E-08	1.59E-08	1.36E-08	1.47E-08	7.30E-09	7.30E-09
Terrestrial acidification	kg SO ₂ eq.	3.52E-03	5.15E-04	3.72E-04	4.43E-04	2.86E-04	2.86E-04
Freshwater eutrophication	kg P eq.	1.73E-04	4.44E-06	3.08E-06	3.76E-06	2.56E-06	2.56E-06
Marine eutrophication	kg N eq.	5.67E-04	3.86E-05	2.66E-05	3.26E-05	2.24E-05	2.24E-05
Human toxicity	kg 1,4-DB eq.	1.23E-01	8.34E-03	6.62E-03	7.48E-03	4.21E-03	4.21E-03
Photochemical oxidant formation	kg NMVOC	1.63E-03	5.34E-04	3.81E-04	4.58E-04	3.00E-04	3.00E-04
Particulate matter formation	kg PM ₁₀ eq.	1.09E-03	1.75E-04	1.26E-04	1.51E-04	9.77E-05	9.77E-05
Terrestrial ecotoxicity	kg 1,4-DB eq.	9.36E-05	2.22E-05	2.33E-05	2.27E-05	7.14E-06	7.14E-06
Freshwater ecotoxicity	kg 1,4-DB eq.	2.44E-03	1.14E-03	1.54E-03	1.34E-03	1.28E-04	1.28E-04
Marine ecotoxicity	kg 1,4-DB eq.	2.04E-03	2.24E-04	1.88E-04	2.06E-04	1.07E-04	1.07E-04
Ionising radiation	kg U235 eq.	2.60E-01	2.55E-02	2.46E-02	2.50E-02	9.78E-03	9.78E-03
Agricultural land occupation	m ² a	1.39E-02	1.74E-03	1.43E-03	1.59E-03	8.42E-04	8.42E-04
Urban land occupation	m ² a	6.45E-03	4.92E-04	4.36E-04	4.64E-04	2.15E-04	2.15E-04
Metal depletion	kg Fe eq.	0.061197	8.18E-03	6.80E-03	7.49E-03	3.90E-03	3.90E-03
Fossil depletion	kg oil eq.	0.202671	0.122837	0.083691	0.103264	0.071832	0.071832

Table 17 Unit impacts in use phase (midpoint)

Impact category	Unit	Washing, average Dutch washing machine (current) and temp. spread	Washing 15 degrees, A label	Washing 30 degrees, A label	Washing 40 degrees, A label	Washing 60 degrees, A label	Washing 90 degrees, A label	Washing 60 degrees, C label; full load
Climate change	kg CO ₂ eq.	0.165776	0.087359	0.108709	0.134328	0.213322	0.32434	0.22715
Ozone depletion	kg CFC-11 eq.	7.90E-09	4.87E-09	5.69E-09	6.68E-09	9.74E-09	1.40E-08	9.81E-09
Terrestrial acidification	kg SO ₂ eq.	0.000379	0.000263	0.000294	0.000332	0.000449	0.000613	0.000427
Freshwater eutrophication	kg P eq.	5.78E-05	5.74E-05	5.75E-05	5.76E-05	5.81E-05	5.87E-05	4.00E-05
Marine eutrophication	kg N eq.	1.14E-03	1.13E-03	1.13E-03	1.14E-03	1.15E-03	1.17E-03	7.98E-04
Human toxicity	kg 1,4-DB eq.	1.17E-01	1.13E-01	1.14E-01	1.15E-01	1.19E-01	1.24E-01	8.44E-02
Photochemical oxidant formation	kg NMVOC	3.16E-04	2.01E-04	2.32E-04	2.70E-04	3.87E-04	5.51E-04	3.84E-04
Particulate matter formation	kg PM ₁₀ eq.	0.000144	0.0001	0.000112	0.000127	0.000171	0.000233	0.000162
Terrestrial ecotoxicity	kg 1,4-DB eq.	0.000334	0.000325	0.000328	0.000331	0.00034	0.000353	0.00024
Freshwater ecotoxicity	kg 1,4-DB eq.	1.21E-02	1.20E-02	1.20E-02	1.21E-02	1.21E-02	1.21E-02	8.24E-03
Marine ecotoxicity	kg 1,4-DB eq.	0.002217	0.002151	0.002169	0.002191	0.002257	0.002351	0.001604
Ionising radiation	kg U235 eq.	3.37E-02	2.14E-02	2.48E-02	2.88E-02	4.12E-02	0.058596	4.09E-02
Agricultural land occupation	m ² a	7.01E-03	5.82E-03	6.14E-03	6.53E-03	7.72E-03	9.40E-03	6.49E-03
Urban land occupation	m ² a	1.16E-03	8.52E-04	9.35E-04	1.03E-03	1.34E-03	1.77E-03	1.23E-03
Metal depletion	kg Fe eq.	1.00E-02	7.29E-03	8.03E-03	8.93E-03	1.17E-02	1.56E-02	1.08E-02
Fossil depletion	kg oil eq.	0.054786	0.028653	0.035768	0.044306	0.070631	0.107629	0.075387

(Table 17, continued)

Impact category	Unit	Heat-pump dryer (A label)	Gas-heated dryer	Drying, clothes horse	Condenser dryer (B label); average Dutch dryer	Condenser dryer (C label)	Condenser dryer (D label)	Ventilation dryer (B label)	Ventilation dryer (C label)	Ventilation dryer (D label)
Climate change	kg CO ₂ eq.	0.279986	0.142949	0	0.516418	0.589007	0.661596	0.474939	0.539232	0.603525
Ozone depletion	kg CFC-11 eq.	1.08E-08	1.69E-08	0	2.00E-08	2.28E-08	2.56E-08	1.84E-08	2.09E-08	2.34E-08
Terrestrial acidification	kg SO ₂ eq.	0.000414	0.000111	0	0.000763	0.000871	0.000978	0.000702	0.000797	0.000892
Freshwater eutrophication	kg P eq.	1.65E-06	4.08E-07	0	3.04E-06	3.46E-06	3.89E-06	2.79E-06	3.17E-06	3.55E-06
Marine eutrophication	kg N eq.	5.16E-05	1.10E-05	0.00E+00	9.52E-05	1.09E-04	1.22E-04	8.76E-05	9.94E-05	1.11E-04
Human toxicity	kg 1,4-DB eq.	1.21E-02	1.79E-03	0.00E+00	2.23E-02	2.54E-02	2.86E-02	2.05E-02	2.33E-02	2.61E-02
Photochemical oxidant formation	kg NMVOC	4.14E-04	1.26E-04	0.00E+00	7.63E-04	8.70E-04	9.78E-04	7.02E-04	7.97E-04	8.92E-04
Particulate matter formation	kg PM ₁₀ eq.	0.000157	3.69E-05	0	0.00029	0.000331	0.000372	0.000267	0.000303	0.000339
Terrestrial ecotoxicity	kg 1,4-DB eq.	3.22E-05	5.68E-06	0	5.93E-05	6.77E-05	7.60E-05	5.46E-05	6.20E-05	6.94E-05
Freshwater ecotoxicity	kg 1,4-DB eq.	7.68E-05	1.47E-05	0.00E+00	1.42E-04	1.62E-04	1.81E-04	1.30E-04	1.48E-04	1.65E-04
Marine ecotoxicity	kg 1,4-DB eq.	0.000236	6.23E-05	0	0.000435	0.000497	0.000558	0.0004	0.000455	0.000509
Ionising radiation	kg U235 eq.	4.39E-02	5.30E-03	0.00E+00	8.10E-02	9.23E-02	1.04E-01	7.45E-02	8.45E-02	9.46E-02
Agricultural land occupation	m ² a	4.23E-03	5.02E-04	0.00E+00	7.80E-03	8.90E-03	1.00E-02	7.18E-03	8.15E-03	9.12E-03
Urban land occupation	m ² a	1.08E-03	1.67E-04	0.00E+00	2.00E-03	2.28E-03	2.56E-03	1.84E-03	2.09E-03	2.34E-03
Metal depletion	kg Fe eq.	9.77E-03	1.45E-03	0.00E+00	1.80E-02	0.020559	2.31E-02	1.66E-02	1.88E-02	0.021066
Fossil depletion	kg oil eq.	0.093307	0.062684	0	0.172099	0.196289	0.22048	0.158276	0.179702	0.201127

Table 18 Impacts of unit waste disposal (midpoint)

Impact category	Unit	Cotton incinerated, no power generation	PET incinerated, no power generation	Cotton to incinerator, with power generation	PET to incinerator, with power generation
Climate change	kg CO ₂ eq.	0	2.032646	-0.81531	0.782504
Ozone depletion	kg CFC-11 eq.	0	1.73E-09	-1.78E-07	-4.67E-08
Terrestrial acidification	kg SO ₂ eq.	0	0.000357	-0.00216	-0.00149
Freshwater eutrophication	kg P eq.	0	1.32E-06	-1.89E-05	-6.03E-06
Marine eutrophication	kg N eq.	0	3.94E-04	-1.49E-04	1.63E-04
Human toxicity	kg 1,4-DB eq.	0	2.56E-01	-7.01E-02	2.02E-01
Photochemical oxidant formation	kg NMVOC	0	6.34E-04	-1.44E-03	-1.21E-03
Particulate matter formation	kg PM ₁₀ eq.	0	0.000142	-0.00064	-0.00056
Terrestrial ecotoxicity	kg 1,4-DB eq.	0	4.38E-05	-3.59E-05	-9.98E-05
Freshwater ecotoxicity	kg 1,4-DB eq.	0	2.78E-02	-6.20E-04	2.74E-02
Marine ecotoxicity	kg 1,4-DB eq.	0	0.025591	-0.00077	0.024537
Ionising radiation	kg U235 eq.	0	1.71E-03	-2.51E-01	-1.94E-01
Agricultural land occupation	M ² a	0	1.14E-04	0.00E+00	-1.88E-02
Urban land occupation	M ² a	0	2.09E-04	0.00E+00	-4.63E-03
Metal depletion	kg Fe eq.	0	1.54E-03	-0.03897	-0.0421
Fossil depletion	kg oil eq.	0	0.005053	-0.23038	-0.41156

(Table 18, continued)

Impact category	Unit	Reuse as second-hand clothing	Use of textile waste as cleaning rags	Use of textile waste as insulation/filler	PLA, composting	Cotton, recycling
Climate change	kg CO ₂ eq.	-3.42285	-2.19603	-3.80613	0.470887	0.354722
Ozone depletion	kg CFC-11 eq.	-1.04E-07	-1.22E-08	-7.83E-08	3.33E-09	-4.59E-08
Terrestrial acidification	kg SO ₂ eq.	-0.05672	-0.03116	-0.01482	-8.48E-05	-0.02816
Freshwater eutrophication	kg P eq.	-0.00172	-1.94E-05	-0.00041	3.13E-07	-0.00449
Marine eutrophication	kg N eq.	-5.49E-02	-1.34E-03	-9.44E-03	-1.51E-06	-4.44E-02
Human toxicity	kg 1,4-DB eq.	-0.21532	-0.08543	-0.21218	3.91E-03	-0.09
Photochemical oxidant formation	kg NMVOC	-0.00682	-1.85E-02	-1.22E-02	8.36E-05	-0.00428
Particulate matter formation	kg PM ₁₀ eq.	-0.00976	-0.00787	-0.0073	1.62E-05	-0.00494
Terrestrial ecotoxicity	kg 1,4-DB eq.	-0.0019	-2.55E-05	-0.00061	1.06E-05	-0.05709
Freshwater ecotoxicity	kg 1,4-DB eq.	-3.33E-02	-1.40E-04	-3.03E-02	2.30E-05	-1.11E-01
Marine ecotoxicity	kg 1,4-DB eq.	-0.00215	-0.00033	-0.00573	7.57E-05	-0.00887
Ionising radiation	kg U235 eq.	-0.39125	0.00E+00	-0.16269	1.39E-02	0.119073
Agricultural land occupation	m ² a	-6.00E+00	0.00E+00	-1.62E-02	8.78E-04	-6.66E+00
Urban land occupation	m ² a	-4.83E-02	0.00E+00	-3.41E-03	3.20E-04	-8.02E-03
Metal depletion	Kg Fe eq.	-0.10435	0	-0.07052	3.05E-03	-0.06577
Fossil depletion	Kg oil eq.	-0.58631	-0.84662	-1.62359	0.031094	0.329842



Annex C ReCiPe factors

ReCiPe has both midpoint and endpoint characterisation factors. In this study we have worked with endpoint characterisation, to obtain an unambiguous final score. The 'conversion' scheme from midpoint to endpoint indicators is given in Table 19. The complete list of characterisation factors used in ReCiPe 1.02 (nearly 6,000 lines) is available separately.

Table 19 Midpoint-to-endpoint conversion factors

	Endpoint unit	Midpoint unit	Factor	Unit
Climate change, Human Health	DALY	kg CO ₂ eq.	1.40E-06	DALY/kg CO ₂ eq.
Climate change, Ecosystems	Species.yr	kg CO ₂ eq.	7.93E-09	Species*yr/kg CO ₂ eq.
Ozone depletion	DALY	kg CFC-11 eq.	2.61E-03	DALY/kg CFC11 eq.
Terrestrial acidification	Species.yr	kg SO ₂ eq.	5.80E-09	Species*yr/kg SO ₂ eq.
Freshwater eutrophication	Species.yr	kg P eq.	4.45E-08	Species*yr/kg P eq.
Human toxicity	DALY	kg 1,4-DB eq.	6.99E-07	DALY/kg 1,4DB eq.
Photochemical oxidant formation	DALY	kg NMVOC	3.90E-08	DALY/kg NMVOC
Particulate matter formation	DALY	kg PM ₁₀ eq.	2.60E-04	DALY/kg PM ₁₀ eq.
Terrestrial ecotoxicity	Species.yr	kg 1,4-DB eq.	1.27E-07	Species*yr/kg 1,4DB eq.
Freshwater ecotoxicity	Species.yr	kg 1,4-DB eq.	2.60E-10	Species*yr/kg 1,4DB eq.
Marine ecotoxicity	Species.yr	kg 1,4-DB eq.	8.00E-13	Species*yr/kg 1,4DB eq.
Ionising radiation	DALY	kg U235 eq.	various	DALY/kBq substance
Agricultural land occupation	Species.yr	M ² a	various	Per type of land use
<i>Arable (this study)</i>	Species.yr	M ² a	1.84E-08	Species*yr/m ² a
<i>Grassland (this study)</i>	Species.yr	M ² a	1.27E-08	Species*yr/m ² a
Urban land occupation	Species.yr	M ² a	1.93E-08	Species*yr/m ² a
Metal depletion	\$	kg Fe eq.	0.0714	Dollar/kg Fe eq.
Fossil depletion	\$	kg oil eq.	16.0845	Dollar/kg oil eq.

Ultimate summation to yield ReCiPe 'points' proceeds via normalisation of the endpoint scores and subsequent weighting (as explained in Section 2.3).

Table 20 Normalisation and weighting factors: Europe - ReCiPe H/A, without land transformation

	Normalisation	Weighting
Human health	49.5/DALY	400
Ecosystems	5726/species.yr	400
Resources	3.37E-05/\$	400

All the results in this report are expressed in Pt, i.e. they have been normalised and weighted.

