

EDIPTEX – Environmental assessment of textiles

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Foreword

The report is the result of the project "Textilenhedsprocedatabase – som grundlag for miljøvurdering af tekstilprodukter – UMIPTEX" (textile unit process database - a basis for environmental assessment of textile products - EDIPTEX).

The project is funded by the Council for Recycling and Cleaner Technology and has been carried out by the Danish Technological Institute (Textile) in close cooperation with IPU (institute for product development), the Institute for the Water Environment (now DHI Water & Environment), the Federation of Danish Textile & Clothing (a sector organisation) and a number of enterprises.

Translation from Danish to English is co-financed together with United Kingdom, Department for Environment, Food and Rural Affairs (Defra)".

Special thanks go to the enterprises mentioned below as they have been directly involved in collecting data and have contributed with valuable data about chemicals used, energy consumption and waste. Without their contributions and commitment, it would not have been possible to carry out the EDIPTEX project.

egetæpper a/s
J. Mørup Stof ApS
Kemotextil A/S
Sunds Velour A/S
A/S S. Thygesen
Nordisk Tekstil Produktion A/S
Kansas Wenaas A/S
Sødahl Design A/S

The project should be regarded as a development project within the Danish EPA's framework programme on development and implementation of cleaner technology in the textile and clothing industry and was carried out 1998-2002.

A steering group with the following members was involved in the project:

Anette Christiansen	Danish Environmental Protection Agency
Ulla Ringbæk	Danish Environmental Protection Agency
Aage K. Feddersen	Federation of Danish Textile & Clothing
Dennis Pedersen	General Workers' Union in Denmark,
Environment	
Dorte Harning	Danish Working Environment Authority
Anne Mette Zacahariassen	Knowledge Centre for Smart Textiles
Søren Ellebæk Laursen	Danish Technological Institute, Textile
John Hansen	Danish Technological Institute, Textile
Hans Henrik Knudsen	Institute for Product Development (IPU)
Henrik Wenzel	Institute for Product Development (IPU)
Henrik Fred Larsen	DHI Water & Environment, now IPU

This project is a follow-up on the pre-project "Textilhedsprocesdatabase – som grundlag for miljøvurdering og miljøforbedring af tekstilprodukter" (textile unit process database - a basis for environmental assessment and improvement of textile products). During the pre-project, proposals were made for a process structure for a database of significant processes in the lifecycle of selected textile products in the EDIP unit process database.

Summary and conclusions

The EDIPTTEX project has three main deliverables. These are

1. Modelling of the lifecycle of six textile products and calculation of the connected environmental impact
2. Obtaining almost 500 textile unit processes following the EDIP unit process data format
3. Calculation of equivalency factors for a number of chemicals

For each of the deliverables extensive documentation material exists, which is published in this report.

Lifecycle assessment of six textile products

In the EDIPTTEX project, a number of lifecycle assessments (environmental assessments) were carried out on textile products. But an extensive and detailed lifecycle assessment case is not particularly information friendly - only to other lifecycle assessment experts and consultants.

The Programme for Cleaner Products etc. has therefore supported a dissemination project "Information on EDIPTTEX". In this dissemination project the six EDIPTTEX environmental assessments were transformed into six leaflets which, on only four pages each and in a professional layout, outline the environmental profile of the six products.

The six environmental assessments include:

- A T-shirt of 100% cotton /1/
- A jogging suit of nylon microfibres with a cotton lining /2/
- A work jacket of 65 per cent polyester and 35 per cent cotton /3/
- A blouse of viscose, nylon and elastane /4/
- A tablecloth of cotton /5/
- A floor covering of nylon and polypropylene /6/

The present report informs in detail about methods and principles used in the environmental assessments of the six selected EDIPTTEX textile products.

Textile unit processes

The major part of the lifecycle is common for many textile products, e.g. energy production, production of raw materials (e.g. cultivation and harvesting cotton), certain production processes (such as dyeing polyester), washing and ironing in the use phase and incineration during disposal. Such basic data have been established during the EDIPTTEX project.

The EDIPTTEX project has been based upon the nationally and internationally recognised environmental assessment method EDIP - "Environmental Design of Industrial Products".

The project has obtained environmental data for several hundred processes "from cradle to grave" in the lifecycle of textiles.

EDIPTTEX environmental data and a PC tool provide the possibility for combining the lifecycle of a textile product from cradle to grave, process by process, on the computer screen through a modelling, and letting the computers calculate the equivalency impacts.

EDIPTTEX environmental data and the environmental assessments, which can be modelled on the basis of these data, thus represent a unique tool in connection with e.g. preparing and documenting lifecycle assessments and environmental declarations for goods.

In connection with the project "Information on EDIPTTEX" a leaflet has been prepared "EDIP environmental data for textiles - a survey" /7/, which gives an overview of the environmental data, so that others can use the data during environmental assessment of textiles.

All data are now also available in the PC tool GaBi EDIP - the successor of the EDIP PC tool.

Equivalency factors

For a number of commonly occurring emissions (discharges) and for emissions which have been assessed in previous projects within EDIP, equivalency factors had already been established.

But for a number emissions, no equivalency factors had been calculated. If these emissions were to be included in the calculations of the contribution of a product on the impact categories regarding toxicity, equivalency factors for the substances would have to be calculated, and they would have to be included in the PC tool.

In the EDIPTTEX case scenarios, equivalency factors for ecotoxicity and human toxicity for approx. 50 textile specific chemicals are used. Within the EDIPTTEX project, equivalency factors for ecotoxicity and human toxicity have been calculated for approx. 35 different substances, which are part of the very often composite chemicals. Further, approx. 20 substances are assessed as unproblematic regarding ecotoxicity and human toxicity in discharges via wastewater treatment plants.

Fate factors for the technosphere for the substances have also been calculated, i.e. spraying with pesticides on farmland and discharge to wastewater treatment plant.

Fate factors for pesticides have been calculated, i.e. distribution factors regarding where the substances end up after spraying.

Similarly non-pesticides fate factors have been calculated for discharge to wastewater treatment plant, i.e. whether the substances end up in sludge, water or air after wastewater treatment.

Using fate factors for the technosphere, takes into account that wastewater discharges from Danish textile factories are treated in wastewater treatment plants prior to discharge to the environment. For example, readily biodegradable substances will by and large disappear in the wastewater

treatment plant and as such will not directly have an impact on the environment.

The EDIP database included equivalency factors on human toxicity for approx. 100 substances and on ecotoxicity for approx. 70 substances. This is an important increase in equivalency factors.

All equivalency factors are now also available in the PC tool GaBi EDIP - the successor of the EDIP PC tool.

Sammenfatning og konklusioner

UMIPTEX-projektet har tre hovedleverancer. De er

1. Modellering af livsforløbet for seks tekstilprodukter og beregning af miljøbelastningerne forbundet hermed
2. Tilvejebringelse af knapt 500 tekstilenhedsprocesser som følger UMIP-enhedsproces dataformatet
3. Udregning af effektfaktorer på en lang række kemikalier

For hver af leverancerne foreligger et omfattende dokumentationsmateriale, som er afrapporteret i nærværende rapport.

Livscyklusvurderinger af seks tekstilprodukter

Der er i UMIPTEX udført en række LCA'er (miljøvurderinger) på tekstilprodukter. Men en omfattende og detaljeret LCA-case er ikke særlig formidlingsvenlig – kun til andre LCA-eksperter og -konsulenter.

Program for renere produkter m.v. har derfor givet støtte til et formidlingsprojekt "Formidling af UMIPTEX". I forbindelse med dette formidlingsprojekt er de seks UMIPTEX miljøvurderinger omarbejdet til seks pjecer, som hver på kun fire A4-sider og i professionelt lay-out, fortæller miljøhistorierne om de seks tekstilprodukter.

De seks miljøvurderinger omfatter:

- En T-shirt af 100% bomuld /1/
- En træningsdragt af nylon mikrofibre med bomuldsfor /2/
- En arbejdsjakke af 65% polyester og 35% bomuld /3/
- En bluse af viskose, nylon og elasthan /4/
- En dug af bomuld /5/
- Et gulvtæppe af nylon og polypropylen /6/

I nærværende rapport er redegjort i detaljer for metoder og principper anvendt i miljøvurderingerne af de 6 udvalgte UMIPTEX tekstilprodukter.

Tekstil enhedsprocesser

Størstedelen af livsforløbet for tekstilprodukter er fælles for mange produkttyper, f.eks. energifremstilling, råvarefremstilling (f.eks. dyrkning og høst af bomuld), visse produktionsprocesser (som farvning af polyester), vask- og strygning i brugsfasen og forbrænding under bortskaffelsen. Det er et sådant et datagrundlag, der er blevet etableret i UMIPTEX-projektet.

UMIPTEX -projektet har været baseret på den både nationalt og internationalt anerkendte miljøvurderingsmetode UMIP - "Udvikling af Miljøvenlige Industri Produkter".

Projektet har tilvejebragt miljødata for flere hundrede processer fra "vugge til grav" i tekstilers livscyklus.

UMIPTEX miljødata, og et tilhørende PC-værktøj, giver mulighed for at sammensætte et tekstilprodukts livscyklus fra vugge til grav, proces for proces, på computerskærmen, ved en såkaldt modellering, og lade computerne regne på miljøeffekterne.

UMIPTEX miljødata og de miljøvurderinger, der kan modelleres ud fra disse, udgør således et enestående værktøj i forbindelse med f.eks. udarbejdelse og dokumentation af livscyklusanalyser og miljøvaredeklarationer.

I forbindelse med projektet "Formidling af UMIPTEX" er der også udarbejdet en folder "UMIP miljødata for tekstiler – et overblik" /7/ der giver et overblik over miljødataene, så andre har mulighed for at tage afsæt i dataene ved miljøvurdering af tekstiler.

Alle data er nu også tilgængelige i PC-værktøjet GaBi-UMIP - afløseren for UMIP-PC-værktøjet.

Effektfaktorer

For en række af normalt forekommende emissioner (udledning) samt for emissioner, som er blevet vurderet i forbindelse med tidligere projekter i UMIP-regi var der allerede effektfaktorer.

Men for en lang række af emissioner var der imidlertid ikke beregnet effektfaktorer. Hvis disse emissioner skulle kunne indgå i beregningerne af et produkts bidrag til effektkategorierne vedrørende giftvirkninger, skulle der beregnes effektfaktorer for stofferne, og disse skulle indtastes i PC-værktøjet.

I UMIPTEX case scenarierne anvendes ialt effektfaktorer for øko- og humantox for ca. 50 tekstilspecifikke kemikalier. I UMIPTEX-projektet er der derfor beregnet effektfaktorer for øko- og humantoksicitet for ca. 35 forskellige stoffer, der indgår i de ofte sammensatte kemikalier. Endvidere er ca. 20 stoffer vurderet at være uproblematisk hvad angår øko- og humantox ved afledning via renseanlæg.

For stofferne er der desuden beregnet skæbnefaktorer for tekno sfæren, dvs. sprøjtning med pesticider på landbrugsjord og afledning til renseanlæg.

For pesticiderne er beregnet skæbnefaktorer, dvs. fordelingsfaktorer på hvor stofferne ender efter sprøjtning.

På samme måde er der for ikke-pesticider beregnet skæbnefaktorer ved afledning til renseanlæg, dvs. om stofferne ender i slam, vand eller luft efter behandlingen i renseanlægget.

Ved at anvende skæbnefaktorer for tekno sfæren tages der f.eks. højde for, at spildevandsudledninger fra danske tekstilvirksomheder behandles i renseanlæg inden udledning til miljøet. F.eks. vil let nedbrydelige stoffer stort set forsvinde i renseanlægget og hermed ikke direkte belaste miljøet.

UMIP-databasen indeholdt effektfaktorer på humantoksicitet for ca. 100

stoffer og for økotoksicitet ca. 70 stoffer. Der er således tale om en væsentlig forøgelse af effektfaktorer.

Alle effektfaktorer er nu også tilgængelige i PC-værktøjet GaBi-UMIP - afløseren for UMIP-PC-værktøjet.

1 Introduction

In their daily work, enterprises meet environment requirements at many levels. This could be in connection with preparation and documentation of environmental approvals; purchasers' and end-users' demand for environmental documentation; certification in accordance with environmental management standards; or documentation for approved ecolabels.

The message in both the Danish EPA's report on product-oriented environmental efforts (Danish EPA, 1998) and "Industri og miljø" (industry and environment, published by the Confederation of Danish Industries, 1997) is that there is a need to be able to environmentally assess the products using a recognised assessment method and a data basis that makes such environmental assessment possible.

The EDIP method is a nationally as well as internationally recognised assessment method, developed under the five-year programme Environmental Design of Industrial Products. A PC calculation tool and a database support the methodological basis. The EDIP database contains approx. 250 unit processes that form the data basis for modelling a product's lifecycle and the associated environmental impacts during the entire lifecycle – from cradle to grave. Unfortunately, the EDIP database did not initially contain data specifically about textile production processes.

An EDIP database supplemented by data for significant parts of the lifecycle of textile products will be of great value for enterprises wishing to use the environment actively in dialogue with their customers, suppliers and other important stakeholders.

However, as a basic requirement for the environmental information given about a product is that the information be objective, well-documented and live up to the international consensus about lifecycle assessment – i.e. cradle to grave considerations – it takes a long time to establish such a database.

The main part of the lifecycle is common for many textile products, e.g. energy generation, transport processes, production of raw materials, certain production processes, washing and ironing in the use phase and incineration during disposal.

Therefore, sector-specific environment data in the EDIP database may help the enterprise.

Such basic data have been established during the EDIPTEX project.

All data are now also available in the PC tool GaBi-EDIP – the successor of the EDIP PC tool.

1.1 Background for the project

At sector seminars in 1996 and 1997, enterprises in the textile sector expressed great interest in being able to apply the EDIP method in their environmental work. However, at that time the EDIP method's calculation

tool and the associated unit process database did not contain data for processes in the lifecycle of textile products.

1.2 Objective of the project

The overall objective of the project was to collect data for significant processes during the lifecycle of textiles. The project also had to demonstrate the usefulness of the EDIP method when preparing lifecycle assessments for six selected textile products.

1.3 Project organisation

The project group members were: Søren Ellebæk Laursen and John Hansen, Danish Technological Institute (Textile); Hans Henrik Knudsen, Institute for Product Development (IPU) at the Technical University of Denmark; and Henrik Fred Larsen, DHI Water & Environment (now at the Institute for Product Development).

Moreover, the following people participated in the project: Henrik Wenzel, Marianne Wessnæs, Stig Irving Olsen, Rasmus Friche and Lene Gottrup, all from the Institute for Product Development; and Frans Møller Christensen, Danish Toxicology Centre. During the reporting phase, Christine Molin from the Institute for Product Development participated in the work on preparing and editing the report. Niels Frees, Institute for Product Development contributed with quality assurance of the chapters that specifically deal with unit processes.

The steering group and, in particular, the EDIPTEX enterprises have participated significantly in the creation of the project results.

1.4. Report composition

Chapters 1-5 of the report deal with data collection and preparation of unit processes, supplemented by background papers in the annexes on management of chemicals in EDIPTEX (including calculation of equivalency factors) and data on cotton cultivation, spinning and buttons/zippers. Background knowledge about other materials and processes in connection with textile production was already available at the participating institutions, and it has been reported and described in a number of projects carried out for the Danish EPA over the years.

Chapter 6 introduces the data basis for the six environmental assessments. The six textile case stories are in annexes and can be read separately.

2 Choice of products for EDIPTTEX

In order to establish a representative and useful number of textile unit processes, six products were selected and followed through their entire lifecycle.

As can be seen in the process tree in figure 2.1, the production phase from yarn spinning to making-up is a very complex phase in the lifecycle of textiles. In this process, all end products will go through several unit processes. One example is that both fibres and fabric are dyed, and so are made-up garments. The production phase is also the phase where the Danish textiles sector is active, and the database must therefore be very differentiated and detailed for this phase.

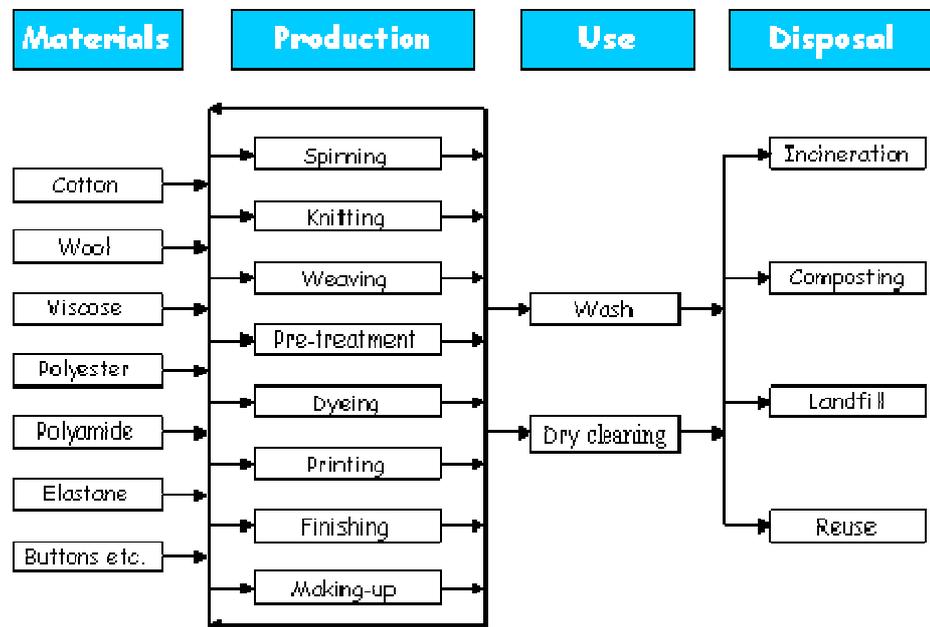


Figure 2.1 Basic process tree for many types of textile product

For each EDIPTTEX product, bills of materials have been prepared, listing the sub-products used, and a process tree from cradle to grave has been made for each EDIPTTEX product. The six EDIPTTEX products form the mainstay of the database and can form the basis for further work by the part of the textiles sector that sells finished goods to retailers.

Table 2.1 Overview of EDIPTTEX products

No.	EDIPTTEX product
1	A T-shirt of 100 % cotton
2	A jogging suit of nylon microfibrres with cotton lining
3	A work jacket of 65 per cent polyester and 35 per cent cotton
4	A blouse of viscose, nylon and elastane
5	A tablecloth of cotton
6	A floor covering of nylon and polypropylene

For each sub-product in the six EDIPTTEX products, bills of materials and process trees have also been made - and these form the basis for the actual data collection and for the further work at the individual enterprises producing the sub-products (or carrying out part of the production, such as a knitting mills, dye houses, etc.).

Details of the individual EDIPTTEX products can be found in the six case stories in annexes 1-6.

2.1 Criteria for selection of EDIPTTEX products

As the majority of Danish retail trade within textiles involves imported goods and the majority of the Danish textile production is exported, it has not been a criterion for all sub-products of an EDIPTTEX product to be produced in Denmark. The Danish textiles sector has the production facilities as well as the expertise to produce all sub-products. Therefore, in situations where sub-products of an EDIPTTEX product are not currently being produced in Denmark, we have applied production and emission data from existing Danish production facilities that could have produced similar sub-products.

The overall criteria for selecting the six EDIPTTEX products that constitute the mainstay of the EDIPTTEX database were:

- Together, the products must represent relevant types of fibre in Danish textile production.
- The lifecycles of the products must include environmentally important refining processes in Danish textile production.
- The products must be significant for Danish textile processing enterprises - and the enterprises showing interest in the project and participating in the data collection will have great influence on the choice of products.

It must be possible to illustrate the usefulness of the database through a number of relevant and up-to-date cleaner technology-scenarios - e.g. organic versus conventional cotton and dry cleaning versus washing.

The following literature references were also included in the selection of the EDIPTTEX products:

- Statistics Denmark's commodity statistics for the textile industry in 1997. Unfortunately, the statistics are not very detailed as regards fibre types. The category "Blouses (including shirts), knitwear; of synthetic fibres for men/boys" is a typical example. The categories are often very general; for example, there is only one overall category for clothes for infants ("Garments and accessories").
- "Profil af den danske tøjindustri" (publication from the Federation of Danish Textile and Clothing about the Danish clothing industry, November 1992) contains a statement of significant product categories. It also uses overall product names such as "children's clothing" and "dresses".
- The updated product and enterprise archive of the Federation of Danish Textile and Clothing (www.textile.dk). This archive is based on the member enterprises' own information about their business area (fibre

types, products/semi-finished goods), but it contains no figures for amounts or revenue.

The steering group of the project has evaluated the selection of products, and the selection was presented at an information meeting for the textiles sector arranged by the Federation of Danish Textile and Clothing in Herning.

Comments from the steering group and the enterprises led to the selection of the six EDIPTEx products described in table 2.1.

Acrylic

The enterprises show very little interest in products made of acrylic, which is described as a marginal product on the way out. Therefore, the EDIPTEx project did not include products containing acrylic. However, the most recent available data for production of acrylic fibres were entered in the database so that others who do wish to work with acrylic products have the possibility of benefiting from the data.

2.2 An EDIPTEx sister project on wool len furniture fabrics

Only producers of floor coverings, rugs and blankets state an interest in wool. No producers of garments made of wool or blends thereof have showed an interest in participating in the project, and several important links in the production chain for wool for garments are missing in the Danish group of enterprises.

However, a large part of the lifecycle of wool products is covered by the project "Livscyklus i salg, design og produktudvikling" (lifecycle in sales, design and product development – only available in Danish) carried out by the textiles enterprise Gabriel A/S in cooperation with COWI and Dansk Kvalitetsrådgivning.

The project dealt with woollen furniture fabrics and it was based on the EDIP method.

On the basis of this, wool products have not been included in this project.

2.3 Bills of materials for the products

On the basis of the product choices, "bills of materials" were prepared. A bill of materials lists the intermediate products and processes of which the end product is composed during production, use and disposal. The bills of materials together gave an overview of the intermediate products and processes for which unit processes in the EDIPTEx database needed to be established.

The bills of materials were reviewed in cooperation with relevant enterprises so that each intermediate product was related to up-to-date and current processes. Each enterprise was allocated one or more reference products for which data was collected in cooperation with the project participants.

2.4 Textile enterprises in EDIPTEx

The enterprises that participated in EDIPTEx are listed in table 2.2.

The enterprises contributed in various ways. Some contributed with comments on product models and processes - others were directly involved in collection of data and contributed with valuable data on e.g. chemicals being used, energy consumption and waste.

Tabel 2.2 Overview of EDIPTEx enterprises.

EDIPTEx enterprises	Enterprise type/products
Windfeld-Hansens Bomuldsspinderi	Spinning mill/yarn dye house (various yarns, including organic)
Trevira Neckelmann	Yarn dye house (polyester yarns, particularly for textiles for vehicles)
Sunds Velour	Knitting mill/dye house (knitted fabrics for garments, velour)
S. Thygesen	Knitting mill (knitted fabrics for clothing)
J.Mørup Stof	Knitting mill (fabrics for clothing, velour, including organic textiles)
Sunesens Tekstilforædling	Dye house
Nordisk Tekstilforædling – Nortex	Dye house
Kemotextil	Dye house
Nordisk Tekstil Produktion	Making-up/dye house/textile printing house (furnishing fabrics, especially bed linen, woven fabrics, including organic products)
Södahl Design	Making-up/textile printing house/dressmaking factory (many products, primarily furnishing fabrics, including organic textiles)
Egetæpper	Producer of floor coverings and rugs, including dye house
Dan-Floor	Producer of floor coverings and rugs (incl. dye house, Foamtex)
Grenå Dampvæveri	Weaving and dyeing of woven articles in continuous dyeing range
Kay Borck A/S	Making-up of work clothes
Novotex	Producer of various garments
Tytex	Producer of medical and technical textile products (cutting, special knitting, finishing)

3 Unit processes - the building blocks of the product system

The environmental impacts of a product occur in the processes that make up the lifecycle. The entire lifecycle of the product is also called the product system. The phases of the lifecycle: materials, production, transport, use and disposal each consist of a number of processes that could also be called the building blocks of the product system.

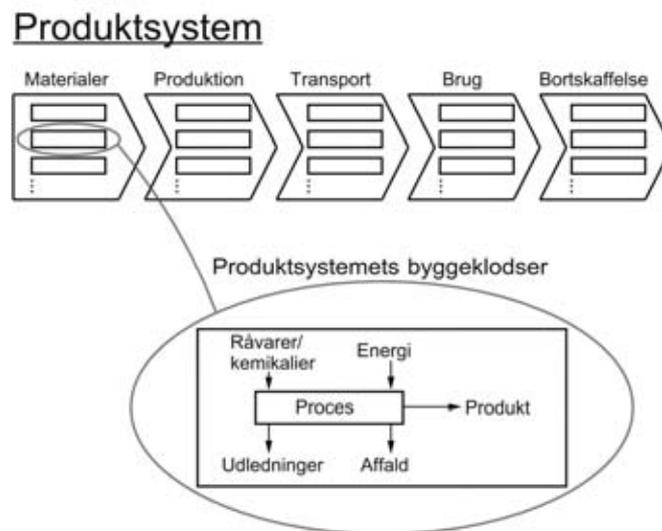


Figure 3.1. The product system and its building blocks (processes) – for translation of Danish terms see glossary in annex 11

When the building block is quantified, it is called a unit process. This means that data is processed and related to a specific volume of the product from the process in question. This makes the data scalable and thus generally applicable in various contexts of environmental assessment.

Produktsystemets byggekloids, kvantificeret

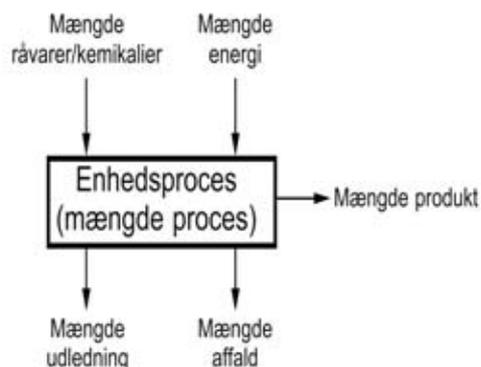


Figure 3.2 building block is related to a specific volume and is designated "unit process" – for translation of Danish terms see glossary in annex 11

3.1 Brief description of the EDIP assessment method

A specific procedure is followed when a product is environmentally assessed. Internationally¹, it has been agreed that an environmental assessment must follow the steps briefly described below.

Objective

In this step, the purpose of the environmental assessment is described, as well as the recipient(s) and the decisions it is intended to support.

Delimitation

In this step, the product to be assessed is described, the product's performance is stated, and the amount included in the assessment is defined. In order to ensure that the same performance is assessed every time, the performance is defined in relation to the volume and quality of the performance. This is called **the functional unit**. Crucial for the results of the environmental assessment is that the functional unit is defined correctly and precisely. This step also includes parameters like time, geography and technology. For example, it should be determined whether modern or older production methods are used, where the product is sold, etc.

Statement

In this step, data from all the processes of the product's lifecycle are collected and processed, i.e. from cradle to grave. These data will be used to calculate consumption and discharges from all processes of the product's lifecycle. The EDIP method applies a bill of materials as the structure for the product, and materials content and production processes are specified in detail.

Data is processed and stored for the **unit processes**. The data format in the EDIP database for unit processes contains three categories of information:

- description of the process
- statement of the interchange with the environment (input and output), and
- a description of the data information.

The EDIP unit process database contains a possibility for correcting or establishing new data descriptions when necessary. Collecting and processing data can be a very time-consuming task.

The assessment

When the statement is complete, it must be assessed. The first step of the assessment is a translation of data to the environmental impacts expected from the individual discharges and emissions. This translation is called **characterisation**, and **environmental impact potentials** are worked out.

Environmental impacts, resource consumption and impacts on occupational health and safety are assessed in the EDIP method. What is the resource consumption? How big are the environmental impacts? In order to be able to interpret resource consumption and expected environmental impacts, it is necessary to bring them on to a common scale and use the same comparison reference. This is called **normalisation**.

¹ ISO 14040 series

During normalisation, the size of the expected environmental impacts and resource consumption are expressed in a unit it is easy to relate to; i.e. fractions of the annual impact from an average person. It is expressed in the unit **person-equivalents** (PE), e.g. for an average person's impact in Denmark in 1990 and is written PE_{DK90} and for the world PE_{W90} .

The EDIP PC tool supports this procedure, and the results can be shown as easy-to-read diagrams. Subsequently, uncertainty and sensitivity analyses of the results of the assessment are carried out.

The assessment also allows for interpretation of the results of the normalisation, i.e. for making mutual comparisons. This is called **weighting**. How serious are the expected environmental impacts or the demand on resources, and what is worse; contributions to the greenhouse effect or to acidification? Which impact types are global and which are regional, and what is important?

The mutual degree of importance of the environmental impacts is shown in a set of weighting factors that reflect the possible consequences of the environmental impacts in relation to each other. The weighting can be based on purely environmental parameters as critical threshold values and on more attitudinal parameters like politically set reduction goals for emissions, such as CO₂ emissions.

The EDIP method is based on the existing goals for reduction of various types of environmental impacts expressed as the unit $PE_{MWDK2000}$. This stands for person-equivalent for target or accepted emissions in 2000 globally, regionally as well as locally.

The weighting procedure is also carried out in the EDIP PC tool, and the results are illustrated in easy-to-read diagrams, just as for normalisation.

Interpretation

Further interpretation also includes an assessment of whether the results adequately meet the objective of the environmental assessment.

4 Strategy for collection of data

The enterprises were asked to enter the relevant data for each process or production system in an Excel spreadsheet. Moreover, the enterprises were asked to state any inadequacies in the data and briefly describe the reason, as well as the assumptions applied for data collection and calculations.

The data collection was carried out in accordance with a checklist form in the following structure:

- 1. General information**
- 2. Input**
- 3. Output**

1. General information includes process description:

- Where does the process begin and end?
- Which technology is used?
- Name and volume of reference product
- Validity period for data.

2. Input includes:

- Raw materials, components and auxiliary materials
- Transport
- Energy consumption.

3. Output includes:

- Coproducts (any material leaving the process with the reference product, and for which there is a positive financial value for the enterprise (opposite of waste))
- Emissions into air
- Discharges into water
- Discharges to soil
- Waste
- Transport of the reference product.

5 Structure of the EDIPTEx database

The overall structure of the database follows the structure of the EDIP unit process database. The structure can be illustrated using the process tree below for the four lifecycle phases at level I: Materials, Production, Use and Disposal; and level II for the processes of the different phases.

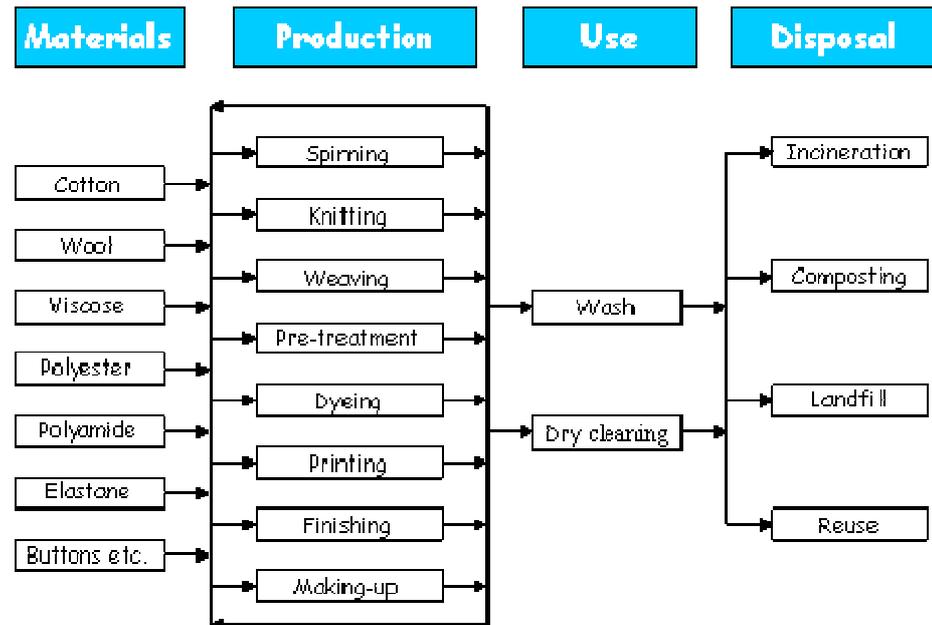


Figure 5.1 Structure and levels in the EDIPTEx database

For each category at level II, there may be further details at levels III, IV, V and so on.

The processes cover production of *materials* cotton, viscose, polyester, polyamide (type PA 6.6), polypropylene and acrylic. In total, these six fibre types cover more than 90 per cent of the EU market for garment textiles. The six fibres are also dominant for many other product groups. Data for elastane were not available, but a process has been established for elastane where data for polyurethane flexible foam are used (elastane consists of 85 per cent polyurethane). Data for standard components like zippers and buttons, i.e. metals and plastic materials, are well supported by existing data in the EDIP database.

The production phase, from yarn manufacturing to making-up, is the phase of the textiles' the lifecycle where the Danish textiles sector is active, and the database is therefore very differentiated and detailed for this phase. Unit processes established in the project's database are verified and representative for the sector. Sixteen enterprises from all links in the production chain have been involved. There have been one or two representative enterprises from each of the areas spinning, weaving, knitting, dyeing, printing, finishing and making-up. No direct measurements of e.g. energy consumption or wastewater analyses have been made for the project. It has been possible to

document energy consumption sufficiently by calculating energy consumption for heating and drying and by taking readings of the individual machines' energy consumption on their rating plates. The composition of the wastewater has been documented by consulting the lists of ingredients used in combination with the available knowledge on the fate of the individual chemicals in production and wastewater treatment plants. Verification of these data was carried out by means of energy and mass balances for the enterprise's total energy consumption as well as existing wastewater analyses.

The unit processes established in the database for the *use phase* are standard maintenance processes where resource consumption and environmental impacts have been calculated and verified by the Danish Technological Institute, Textile.

Examples of environmental assessments prepared on the basis of the project's database have identified the lifetime of the textiles as a crucial factor for the environmental assessment. The Danish Technological Institute, Textile has defined realistic lifetimes for the products on the basis of the centre's extensive knowledge on textiles, fabrics and materials, and in cooperation with the participating enterprises.

Disposal data in the project's database have been calculated in accordance with the current practice for lifecycle assessment.

Emissions during incineration have been calculated on the basis of the chemical composition of the fibres.

As the textiles sector uses a large number of different chemicals in production - both single chemicals and composite products - many assumptions have been made during the course of the project. From the beginning of the project, it was decided not to include the production of any of the chemicals in EDIPTEX. Moreover, occupational health and safety has not been included.

Data for human toxicity and ecotoxicity for a total of 50 different chemicals have been included. To the extent necessary, the names of the chemicals have been made anonymous and appear under general names. It is very difficult, if not impossible, to obtain sufficient information for a lifecycle assessment from chemicals suppliers and producers. The project has assessed chemicals at a theoretical level in accordance with the methods recognised in the EDIP method.

A more detailed account of the principles for assessments of chemicals can be found in annex 7: "Management of chemicals in EDIPTEX".

6 The EDIPTEX case stories

The six case stories (environmental assessments - lifecycle assessments) vary a lot in scope. They can be divided into two main groups - with variations within these two main groups. The two main groups are:

- Group I: Products 1, 2 and 3 in table 2.1, i.e. the T-shirt, the jogging suit and the work jacket.
- Group II: Products 4, 5 and 6 in table 2.1, i.e. the blouse, the tablecloth and the floor covering.

The division into groups I and II relates to the scope of the collection of data as well as the quality of data.

As previously mentioned, the case stories are placed separately in annexes 1-6 and structured so that they can be read individually.

6.1 The T-shirt, the jogging suit and the work jacket - case group I

For group I, it was possible to collect (and process) data for all significant processes. The data are of such quality that these three products have been selected to illustrate how far it is possible to take lifecycle assessment for textiles and to illustrate all relevant aspects of the EDIP method.

6.1.1 Case for T-shirt

Within group I, the case for the T-shirt is special as regards the relevant aspects of the EDIP method. It was possible to make assessments of human toxicity and ecotoxicity for all types of chemicals used and to calculate the equivalency factors that are central to the EDIP method (please refer to annex 7: "Management of chemicals in EDIPTEX" for a more detailed description of this very complicated subject).

Moreover, this case applied an almost complete set of data for the unit process "cotton cultivation and harvest". Annex 8 describes in detail the extensive work on this central process. The project group does not know of more thorough and comprehensive work in this area.

For the T-shirt, a lot of work was put into describing what is called "source identification" in EDIP jargon. It is often necessary to study the large information volumes included in the results of a lifecycle assessment in order to achieve the best possible benefit of the assessment. A process is composed of a number of factors that all contribute to the environmental impact categories. By carrying out source identification, the reasons for the individual contributions can be found.

This knowledge makes the assessment more useful for the producer, as the producer can change factors with undesired environmental impacts already in the development phase.

The case story presents an overview of the most important contributions to the following categories:

- Primary energy
- Resource consumption
- Toxicological environmental impacts
- Environmental impacts related to energy
- Environmental impacts related to waste

A number of what-if simulations or scenarios were prepared for the T-shirt.

The environmental profile for a given product can be affected by the choices made by the producer and by the consumer. In order to elucidate the consequences of possible changes in the product's lifecycle, a number of scenarios have been prepared that focus on the producer and consumer respectively.

By changing one or more of the reference conditions, it is possible to form a picture of the scope of the consequences based on the choices made by the producer and the consumer, and subsequently assess the results of the choices.

9 and 10 different producer and consumer scenarios respectively were prepared for the T-shirt. An example of a producer scenario is "Choice of raw materials - organic cotton", and a consumer scenario could be "Reduced washing temperature from 60 °C to 40 °C".

6.1.2 Case for jogging suit

The jogging suit case is very similar in scope to the T-shirt case, and "source identification" was also carried out here. However, there are "only" seven and four different producer and consumer scenarios respectively.

By contrast, the jogging suit is much more complicated than a T-shirt, which is a simple single-layer product.

The jogging suit consists of top and trousers - outer fabric (nylon) and a lining (cotton) - and the top includes a polyester zipper (both tape and chain). This case illustrates that with the EDIPTEX database and the EDIP PC tool it is possible to work with very complex products.

The quality of data for production of nylon fibres is not as good as that of the data for cotton in the T-shirt case. Data for nylon originates from the series of lifecycle assessment cases (v. Boustead) the fibre industry conducted and published in the 1990s. These lifecycle assessments contain a lot of quality data on energy consumption and emissions into air and water. However, it is not always possible to check/calculate how emissions data have been obtained. Moreover, industry states many emissions in groups like "aldehydes", and it is not possible to calculate the essential equivalency factors for such groups. However, there is currently no better data than those of the industry, so the unit process for nylon in the EDIPTEX database represents the knowledge currently available. Therefore, in terms of lifecycle assessment quality, cases that include nylon, like the jogging suit (and the blouse), are not fully comparable with cases where only cotton is included.

6.1.3 Case for work jacket

The work jacket consists of 65 per cent polyester and 35 per cent cotton, including zipper and brass buttons. The same applies to data for polyester fibres as to nylon (see the jogging suit case). Source identification has not been prepared for the work jacket. The project group considered that this aspect of lifecycle assessment and EDIP is sufficiently covered for the T-shirt and the jogging suit. Five and three producer and consumer scenarios respectively were prepared - including the scenarios "Household wash vs. industrial wash" and "Dry cleaning vs. industrial wash".

6.2 The blouse, the tablecloth and the floor covering - case group II

For group II, it was not possible to complete all sub-processes. Although only 1-2 sub-processes for each product have considerable lack of data, these processes are deemed potentially significant for the overall lifecycle assessment. The group II case stories are therefore of an entirely different character than those of group I. The group II cases illustrate that it is possible to tell an interesting and exciting "environment story" based on lifecycle assessment (and EDIP) even though it has not been possible to analyse all aspects of lifecycle assessment data. This situation will arise very often in lifecycle assessment work. However, there is a significant difference in this EDIPTEX connection; it is possible to draw on results from the three lifecycle assessments from case group I (and this has been done), which improves the quality of the case stories.

6.2.1 Case for blouse

The blouse is composed of 70 per cent viscose, 25 per cent nylon and 5 per cent elastane.

The same applies to viscose fibres as for nylon (see the jogging suit case). Data for elastane were not available, but a process has been established for elastane where data for polyurethane flexible foam are used (elastane consists of 85 per cent polyurethane). It is uncertain how "correct" this assumption is.

These aspects of data quality mean that the primary focus for this case is on primary energy and environmental impacts. However, a statement of toxicological environmental impacts has also been made (there is quite a lot of data on impacts of other chemicals used) - and the significance of the lack of data for the statement is discussed.

6.2.2 Case for tablecloth

The tablecloth is made of 100 per cent cotton. The tablecloth is printed with pigments and has been finished to make it easier to maintain.

Chemical emissions to the air while drying after pigment printing have been difficult to manage. Furthermore, it has not been possible to obtain data to enable calculation of equivalency factors for an important finishing chemical.

As for the blouse, this case primarily focused on primary energy and environmental impacts. The same applies for toxicological environmental impacts - including discussion of the importance of lack of data.

6.2.3 Case for floor covering

The floor covering consists of pile (the surface) of 100 per cent nylon, a primary backing material of 100 per cent polypropylene (to which the pile is stitched), and the actual backside of latex foam.

The same applies for data for polypropylene as for nylon (see jogging suit case).

It has not been possible to collect data for the production of the primary backing material of polypropylene fibres. At an overall level, this process corresponds to the process "weaving" for the jogging suit and work jacket cases. Therefore, the floor covering model is based of data for weaving, which seems to be a reasonable assumption.

Emissions of chemicals into the air during production of the floor covering have turned out to be difficult to handle, and have thus not been included in the model. However, energy consumption during the processes has been included.

As for the blouse and the tablecloth, this case primarily focused on primary energy and environmental impacts. The same applies for toxicological environmental impacts - including discussion of the importance of lack of data.

7 Literature

EDIPTEX publications

- /1/ *Miljøvurdering af en T-shirt af 100% bomuld (environmental assessment of a T-shirt of 100 % cotton).*
Søren Ellebæk Laursen from Danish Technological Institute, Textile, Hans Henrik Knudsen from Institute for Product Development, the Technical University of Denmark, Inge Fisker from Valør & Tinge, 2004.
- /2/ *Miljøvurdering af en træningsdragt af nylon mikrofibre og bomuld (environmental assessment of a jogging suit of nylon and cotton).*
Søren Ellebæk Laursen from Danish Technological Institute, Textile, Hans Henrik Knudsen from Institute for Product Development, the Technical University of Denmark, Inge Fisker from Valør & Tinge, 2004.
- /3/ *Miljøvurdering af en arbejdsjakke af 65% polyester og 35% bomuld (environmental assessment of a work jacket of 65 per cent polyester and 35 per cent cotton).*
Søren Ellebæk Laursen from Danish Technological Institute, Textile, Hans Henrik Knudsen from Institute for Product Development, the Technical University of Denmark, Inge Fisker from Valør & Tinge, 2004.
- /4/ *Miljøvurdering af en bluse af viskose, nylon og elasthan (environmental assessment of a blouse made of viscose, nylon and elastane).*
Søren Ellebæk Laursen from Danish Technological Institute, Textile, Hans Henrik Knudsen from Institute for Product Development, the Technical University of Denmark, Inge Fisker from Valør & Tinge, 2004.
- /5/ *Miljøvurdering af en bordduk af bomuld (environmental assessment of a tablecloth of cotton).*
Hans Henrik Knudsen from Institute for Product Development, the Technical University of Denmark, Søren Ellebæk Laursen from Danish Technological Institute, Textile, Inge Fisker from Valør & Tinge, 2004.
- /6/ *Miljøvurdering af et gulvtæppe af nylon og polypropylen (environmental assessment of a floor covering of nylon and polypropylene).*
Hans Henrik Knudsen from Institute for Product Development, the Technical University of Denmark, Søren Ellebæk Laursen from Danish Technological Institute, Textile, Inge Fisker from Valør & Tinge, 2004.
- /7/ *UMIP miljødata for tekstiler – et overblik (EDIP environmental data for textiles - an overview).*
Søren Ellebæk Laursen from Danish Technological Institute, Textile, Hans Henrik Knudsen from Institute for Product Development, the Technical University of Denmark, Inge Fisker from Valør & Tinge, 2004.

EDIP publications and tools as well as the ISO 14040 series

EDIP unit process database (manual and presentation disc).
Niels Frees and Morten Als Pedersen, Danish EPA, 1996.

User manual for EDIP PC tool (beta version)
Morten Als Pedersen, Danish EPA 1998.

Miljøvurdering af Produkter, UMIP (environmental assessment of products, EDIP) Wenzel, H., Hauschild, M. & Rasmussen, E. Danish EPA and Confederation of Danish Industries, 1996.

Baggrund for miljøvurdering af produkter (background for environmental assessment of products) Hauschild, ed.: Danish EPA & Confederation of Danish Industries 1996.

Livscyklusvurderinger – en kommenteret oversættelse af ISO 14040 til 14043 (lifecycle assessments - a comment translation of ISO 14040 to 14043) *DS handbook 126*. Danish Standards Association, 2001.

A number of books and articles have been published on environmental assessments of products. This is a list of some of them.

In Danish:

Håndbog i miljøvurdering af produkter – en enkel metode (handbook in environmental assessment of products - a simple method).
Pommer K., Bech P., Wenzel, H., Caspersen N. & Olsen S.I. Danish EPA, Environment News no. 58, 2001

In English:

An introduction to life-cycle thinking and management
Remmen A. Environment News no. 68, Danish EPA 2002

Manual of product-oriented environmental work.
Schmidt K., Christensen F. M., Juul L., Øllgaard H., Nielsen C. B. Danish EPA,

Environment News no. 53, 2000.

Product families – short cuts to environmental knowledge
Lenau T, Frees N, Olsen SI, Willum O, Molin C and Wenzel H. Danish EPA 2001

Product Lifecycle Check., - guide. 1st draft
Wenzel H., Caspersen N., Schmidt A. & Hauschild M. Institute for Product Development, Technical University of Denmark, 2000.

Environmental Assessment of Products, volume 1: Methodology, tools and case studies in product development
Wenzel H, Hauschild M & Alting L. Kluwer Academic Publishers, ISBN 0-412-80800-5 (hardbound), ISBN 0-7923-7859-8 (paperback).

Environmental Assessment of Products, volume 2: Scientific background
Hauschild M & Wenzel H. (eds). (Chapman & Hall) Kluwer Academic
Publishers, ISBN 0412 80810

On the Internet

Danish Environmental Protection Agency www.mst.dk
Danish Ministry of Environment and Energy's Centre for Information
www.mem.dk/butik/
Danish EPA's lifecycle assessment website www.mst.dk/produkt/
Nordic Council, nrpost@ft.dk
European Commission on Integrated Product Policy:
<http://europa.eu.int/comm/environment/ipp/home.htm>

Annex 1: A T-shirt of 100 % cotton

The T-shirt - summary and conclusions

In this section, the sub-conclusions from the individual scenarios will be summarised in an assessment of producers' and consumers' choices and their consequences.

The main scenario shows that the most significant contributions to the environmental impact potentials related to chemicals originate from cotton cultivation. Resource consumption and the contributions to the environmental impact potentials related to energy, as well as waste categories mainly originate from generation of electricity for the large consumption of electrical energy in the use phase.

At an overall level, the scenarios indicate that the consumer holds the best possibilities for influencing the product's overall environmental profile. This is due to the dominant use phase. The individual consumer's consumption patterns and environmental awareness are therefore crucial, i.e. awareness of ecolabelling of products in combination with good habits like:

- minimal use of washing powder
- no use of fabric softeners
- no tumbler drying
- no ironing
- disposal to incineration plant.

The producer is primarily able to affect the T-shirt's environmental profile through choice of materials. This is clear in the scenarios where organic cotton has been used. By living up to European and Scandinavian ecolabelling criteria and obtaining labelling approval, the producer can signal to the conscious consumer that the product in question has been produced in an environmentally sound manner. Moreover, there are a number of production-related improvements that only the producer can influence. This could be choices related to:

- organic materials
- choice of softening process
- no treatment to improve colour fastness
- non-toxic reactive dyes.

Introduction

Lifecycle assessment is a method for identification and evaluation of environmental impact potentials of a product or a service from cradle to grave. This method enables the user to make an environmental assessment and focus on the most important environmental impacts.

Lifecycle assessment is an iterative process. The first definition of purpose and delimitations often need to be revised during work with lifecycle

assessment. The amount of data available sets limits, and consequently the limits of the system are changed.

The method used in this case for assessment of products is "Environmental Design of Industrial Products" (EDIP) and the associated database and PC tool.

In the EDIPTEX project, sector-specific data have been prepared for the textiles sector in connection with the existing EDIP database. The reports contain environmental assessments for the following textile products:

- T-shirt
- Jogging suit
- Work jacket
- Floor covering
- Tablecloth
- Blouse.

These environmental assessments are intended to illustrate the scope for application of the EDIPTEX database by using the PC modelling tool and, at a more general level, application of the EDIP method.

Method

The six case stories vary a lot in scope. They can be divided into two main groups - with variations within these two main groups. The two main groups are:

- Group I: The T-shirt, the jogging suit and the work jacket.
- Group II: The floor covering, the tablecloth and the blouse.

The division into groups I and II relates to the scope of the collection of data as well as the quality of data.

For group I, it was possible to collect (and process) data for all significant processes. The data are of such quality that these three products have been selected to illustrate how far it is possible to take lifecycle assessment for textiles and to illustrate all relevant aspects of the EDIP method.

Each of the three group I cases contains:

- Definition of functional unit and reference product
- Modelling of main scenario
- Preparation of producer and consumer references
- Simulation of environmental impacts caused by choices made by producer and consumer respectively.

Work with these cases has been divided into phases as illustrated in figure 1.1.

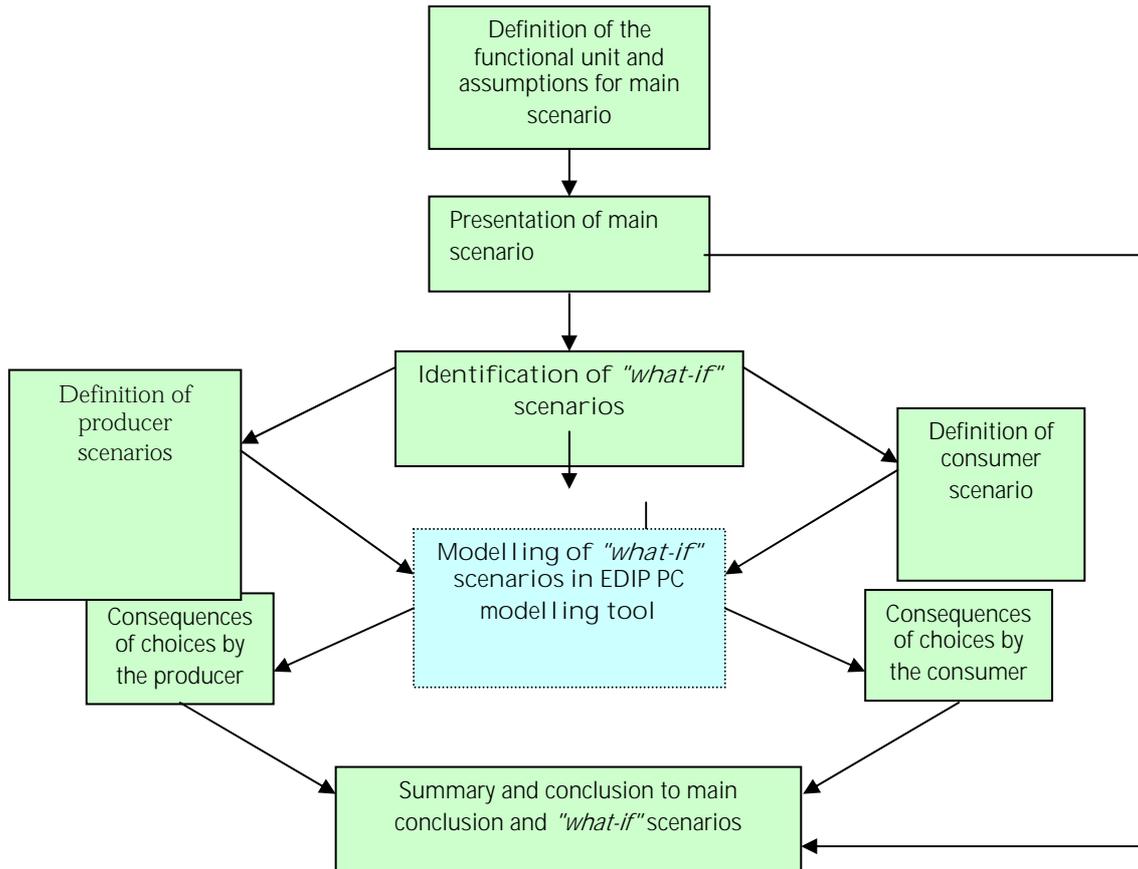


Figure 1.1 EDIPTEX case group I flow diagram

For group II, it was not possible to complete all sub-processes. Although only 1-2 sub-processes for each product have considerable lack of data, these processes are deemed potentially significant for the overall lifecycle assessment. The group II case stories are therefore of an entirely different character than those of group I. The group II cases illustrate that it is possible to tell an interesting and exciting "environment story" based on lifecycle assessment (and EDIP) even though it has not been possible to analyse all aspects of lifecycle assessment data. This situation will arise very often in lifecycle assessment work. However, there is a significant difference in this EDIPTEX connection; it is possible to draw on results from the three lifecycle assessments from case group I (and this has been done), which improves the quality of the case stories.

Comments to the method

Product references

The "what-if" simulations were carried out to elucidate the consequences of possible changes in the product's lifecycle. A special product reference has been defined for the producer scenarios in some of the case stories. The producer only has limited influence on the use phase. In order to take this into account, a product reference has been prepared for the producer scenarios where only a limited part of the impacts from the use phase has been included in relation to the product reference from the main scenario. This was done in order to give producers a clearer picture of the influence of the production

phase on the product's environmental profile in the "what-if" producer scenarios.

Data

With regard to data, it should be noted that the validity of the data in the database varies, depending on the processes considered. A global process like cultivation and harvest of cotton is subject to considerable uncertainty. This is because cotton is produced in countries with very different levels of development. For example, production varies a lot between South America and the US because of large differences in the use of pesticides, crop yields, etc.

This difference has not been taken directly into account in the EDIPTTEX database, but a representative level for the data has been defined. Therefore, the data are very general and not necessarily representative for all lifecycle assessments. Other processes are more exact, such as extraction of crude oil for nylon. This process is well documented, both as regards industrial accidents and as regards resource consumption.

Production data primarily come from Danish enterprises. The number of enterprises involved represents limitations in this connection. For example, only one reactive dye and one acid dye have been studied thoroughly. These two substances represent the entire group of dyes, despite the major differences that may occur.

A large proportion of the environmental impacts come from the consumption of electrical energy. The data used in the database originate from the EDIP database, and the reference year is 1990. It is important to note that this lifecycle assessment was carried out using the 1990 data in all processes that consume electrical energy.

The T-shirt

Product description: The T-shirt is made of pure cotton. The assessment does not include multicoloured patterns or prints on the product. Data for a black reactive dye are used, and this is assessed to be a worst-case assumption.

Functional unit

The performance assessed can be described as a "functional unit", comprising a qualitative and a quantitative description, including the product's lifetime. The qualitative description is to define the quality level for the performance, so that products can be compared at a somewhat uniform quality level. The quantitative description is to determine the size and duration of the performance.

In this project, the functional unit is defined as:

"50 days' use of T-shirt over the course of one year"

Assumptions in connection with the lifecycle assessment:

The calculations are carried out for "1 T-shirt", this needs to be converted in relation to lifetime, and the calculations need to be converted to "per year". It is assumed that the T-shirt can be washed 50 times before it is discarded.

It is assumed that the consumer wears the T-shirt 50 days per year.
It is assumed that the T-shirt is used 1 day and is then washed.

Estimated lifetime

If the T-shirt is washed after each use, 50 days' use of the T-shirt means that 1 T-shirt is completely used up in one year - or more likely - that a person has 5 T-shirts that together last 5 years.

Considerations in relation to the use phase

It is assumed that 50 days correspond to the number of days a consumer wears a T-shirt over the course of 1 year. Some consumers have an entirely different consumption of T-shirts. Some people wear a T-shirt every day (often men), while other people do not own a single T-shirt (e.g. women in the age of 60-80).

Reference product and main scenario

The reference product is a product that meets the criteria of one functional unit. Here, we have chosen a T-shirt in coloured cotton. The following assumptions apply to the assessment and are thus included in the modelling of the main scenario.

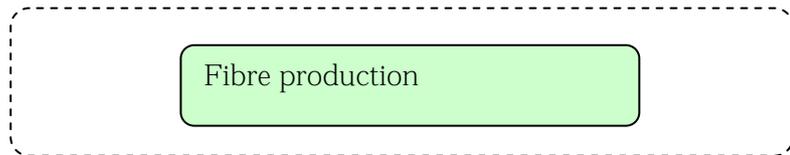
- 100 per cent cotton.
- Dye: reactive dye.
- Washing 60°C.
- Tumbler drying.
- Ironing not necessary, but it is assumed that many people do it.
- Lifetime: 50 washes.
- Weight: Three different qualities of T-shirt have been weighed: 178 g ("thin" quality), 223 g and 292 g (heavy quality). For this environmental assessment, the assumption is that the T-shirt weighs 250 g.

A more detailed description of the processes, calculations of volumes, waste, etc. can be found in the section "Background data".

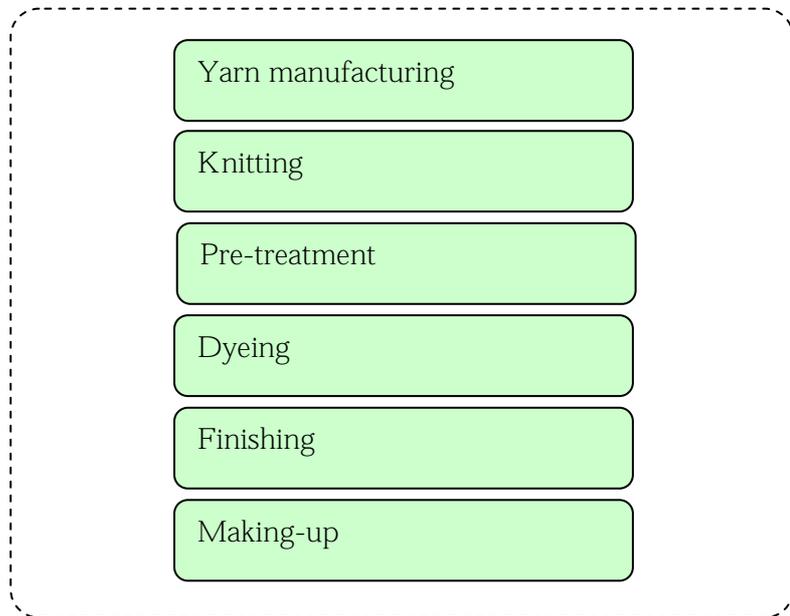
Product system

In the following, all phases of the T-shirt's lifecycle will be described from extraction of raw materials through production to the making-up of the finished T-shirt.

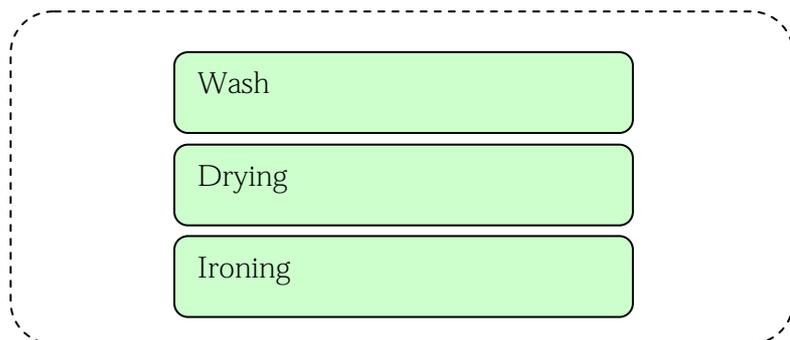
Materials phase



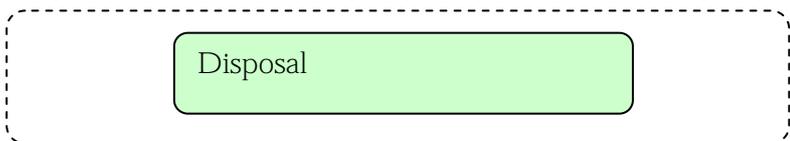
Production phase



Use phase



Disposal phase



Transport phase

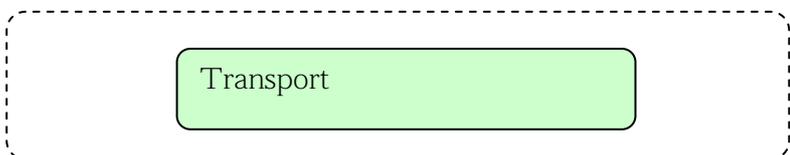


Figure 1.2 Lifecycle, flow and phases

Manufacture of raw materials

The T-shirt consists solely of cotton. Cotton is cultivated in many countries under different geographical and climatic conditions. Cultivation often entails a large consumption of artificial fertilizer, large water consumption and a large consumption of pesticides against insect attacks, diseases, worms and weeds. The extent of this depends largely on local conditions. The consumption of

pesticides entails an important environmental problem for both human health and nature.

Irrigation and use of artificial fertilizer impact groundwater and surface water resources quantitatively as well as qualitatively. Before picking, it is common to use defoliating agents so that picking can be done mechanically.

Organic cotton

It is normally not permitted to use pesticides and artificial fertilizer in cultivation of organic cotton. Thus, it is only permitted to use a very limited selection of plant protection agents, and only when there is an acute danger for the crop. Organic production of cotton constitutes less than 1 per cent of total cotton production, but organic production is increasing and is expected to increase further due to increased demand.

Production of the T-shirt

Production is divided into several processes: yarn manufacturing, knitting, pre-treatment, dyeing, finishing and making-up.

Yarn manufacturing

From when the cotton is harvested to the manufacture of the yarn can begin, the fibres need to be separated from the remaining plant material. One of the largest environmental risks in this process is inhalation of cotton dust. In just a few years, staff can develop the disease Byssinosis (commonly called "Brown Lung") which may be fatal. It is important that machines be closed in so that dust development is minimal.

Knitting

Dust development during knitting - both in general and for cotton - is minimal compared to yarn manufacturing. However, mineral knitting oils are often used in connection with knitting, and they are persistent substances. The oils are washed out in subsequent processes where the cotton yarns or the cotton products go through several treatments with water and chemicals, and the oils finally end up in the wastewater from the wet processor/dyer.

Pre-treatment

Raw cotton contains some cotton wax that needs to be removed before it is possible to dye the cotton. This is done in a scouring process at high pH and high temperatures. Remains of pesticides from cotton cultivation, mainly defoliation agents used in connection with the harvest, are washed out in this process and end up in the wastewater.

If the end product is to have a light colour, the cotton is bleached. If the pre-treater/dyer uses chlorine compounds, AOX compounds (adsorbable organic halogens) will be formed and subsequently discharged, and these are harmful to the environment. It is possible to bleach using hydrogen peroxide that does not cause discharges of AOX.

Washing and bleaching with hydrogen peroxide, which is normal in Denmark, has been used as the basis for the environmental assessment of the T-shirt. Moreover, the environmental assessment includes limited discharges of pesticides (0.005 g defoliation agent per kg cotton).

Dyeing

Dyes for dyeing textiles are chemically often based on azo groups and may contain heavy metals. Some dyes containing azo groups may release carcinogenic substances of the type arylamines. However, the textile sector and producers of dyes have been aware of the arylamine issue for many years. The major dye producers and modern European dye houses have thus fully phased out these dyes, but they may still be found in goods imported to Europe. The number of dyes containing heavy metals is being reduced year by year, but dye houses that choose not to use dyes containing heavy metals still have to accept they cannot dye in some specific nuances.

A dye from the group of reactive dyes without heavy metals and without arylamine problems has been selected for this environmental assessment.

Finishing

For a cotton T-shirt, finishing will normally consist of the application of a sewing improvement agent (softening) for the subsequent making-up stage. However, many cotton textiles are given specific functional properties in finishing by means of chemicals. For example, some of the well-known properties are non-iron and fire retardant. Auxiliary chemicals in these productions often have many extremely undesirable environmental properties, both for the environment and for occupational health and safety.

For the environmental assessment of the T-shirt, a non-problematic softener has been selected.

Making-up

In the actual making-up process, there may be great differences in the environmental impacts for the different textile products. This is because the waste from the cutting-to-size process for the final product varies from 6-25 per cent. However, this waste is not necessarily the same as resources lost, because some of the waste products are reused - but often for products of a lower quality. The waste may also be sent to waste incineration with energy recovery, and in reality, the energy content is recovered as electricity for production and should thus be set off against energy consumption by the production equipment. For a T-shirt, "waste" is minimal in making-up - approx. 6 per cent.

Distribution

The T-shirt is packed in polyester bags and then on a wood pallet. Finally, it is distributed to retail suppliers throughout Denmark.

Use phase

The consumption of washing agents and fabric softeners and the consequential discharge of detergents and nutrient salts lead to possible local and regional impacts in the aquatic environment.

Transport

The mode of transport when the T-shirt is transported from the shop to the buyer's home is also important in connection with the overall environmental profile of the product. Options like driving a car, using public transport or a bike make a significant difference in this part of the product's lifecycle.

The disposal phase

Textiles may not be landfilled. On final disposal, they must be incinerated so that the energy content is recovered and replaces non-renewable energy sources like oil and natural gas. In some situations, the used T-shirt will be

reused in a third-world country. In such situations, it is not possible to recover energy by incineration in Denmark.

Main scenario - results

The results of the main scenario are presented according to processes. The negative contributions that occur in some processes are due to estimated reuse potentials, resource consumption and contribution to environmental impact potentials. In the processes in question, the contributions can be allocated to other products and thus appear as negative contributions in the T-shirt's environmental profile.

The values in the five figures are not immediately comparable, as the unit is not the same for the five categories. The consumption of primary energy is calculated in mega-joules (MJ), while the resource consumption is shown in the unit "person-reserves". Person-reserves take into account the supply horizon of the individual resources, calculated on the basis of the reserves available in the world in 1990. It should be noted that the data used here are more than ten years old, and therefore, new knowledge about the world's resources may have become available. The environmental impact potentials are presented as "milli-person equivalents" and are directly comparable. Milli-person equivalents are calculated as the direct impact for the year 2000. The weighting factors are based on global (w) or Danish (DK) discharges in the year 2000.

Consumption of primary energy

Figure 1.3 shows that the processes in the use phase represent the majority of the consumption of primary energy. The consumption of primary energy reflects the processes that require a lot of electrical energy or heating air or water. Fibre production consumes a lot of energy due to driving vehicles in the fields and production of artificial fertilizer and pesticides. The production of cotton fibres and the processing into yarns represent the largest contributions during production of the T-shirt. In the use phase, the electricity consumption for washing and, in particular, tumbler drying cause the impacts. When the T-shirt is incinerated in an incineration plant, some energy is recovered and this is credited in the energy accounts.

Resource consumption

The T-shirt consumes a relatively large amount of fossil fuels because of the energy-intensive processes in its lifecycle - see figure 1.4. Because of the large electricity consumption, the resource consumption is high in the use phase. Fossil fuels for generation of electricity and heating are the primary cause of this. In the processes that use Danish electricity, as in the use phase, consumption of coal is highest. In the disposal phase, some resources are credited because energy is recovered that would otherwise have come from burning fossil fuels.

Environmental impact potentials

Figures 1.5 and 1.7 show that the contributions to the toxicological environmental impact potentials are dominant. Particularly ecotoxicity and persistence toxicity are very high, primarily because of the pesticides that are spread on the cotton fields during the cultivation process. The data used to determine the pesticide volumes per hectare are based on a worst-case assumption. For further information, please see annex 8: Memo on data for cotton cultivation and harvest. Therefore, the focus in this phase is to reduce pesticide consumption during cultivation of cotton.

In the production phase, the environmental profile indicates that primarily the finishing process contributes on a large scale. The reason for this is the softening process after dyeing. This process is the focal point of the production phase.

In the use phase, primarily washing agents result in potential persistent toxicity. It has been assumed that no users add fabric softener when washing, and therefore the figures probably do not tally with the actual conditions in private Danish households.

The contributions to the waste categories mainly originate from electricity generation.

Results from modelling and calculation of the main scenario

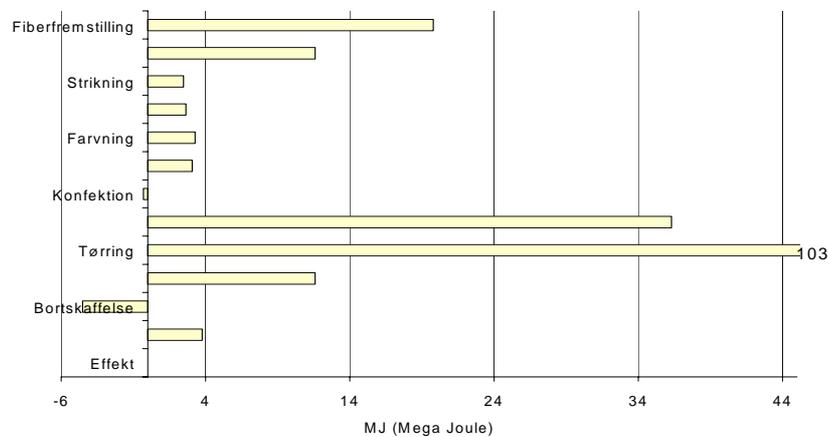


Figure 1.3 Consumption of primary energy per functional unit – for translation of Danish terms see glossary in annex 11

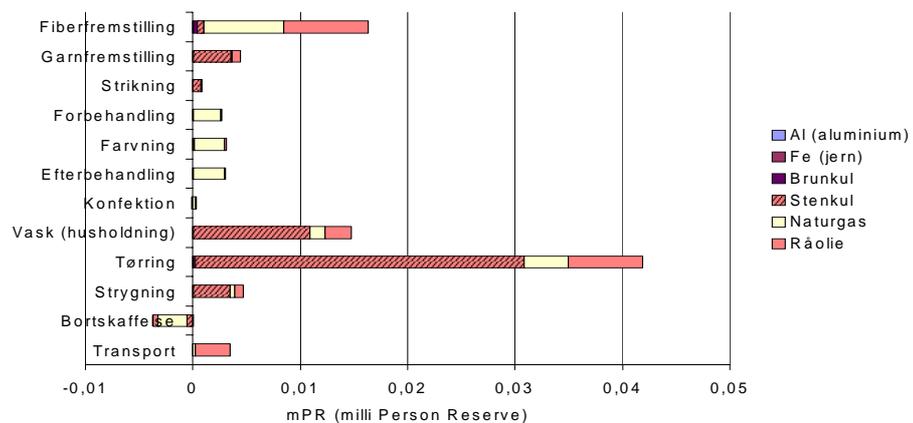


Figure 1.4 Resource consumption per functional unit – for translation of Danish terms see glossary in annex 11

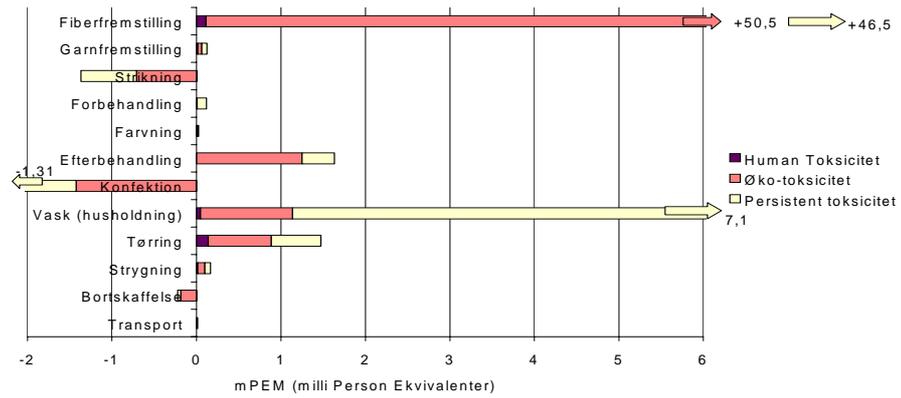


Figure 1.5 Toxicological environmental impact potentials per functional unit – for translation of Danish terms see glossary in annex 11

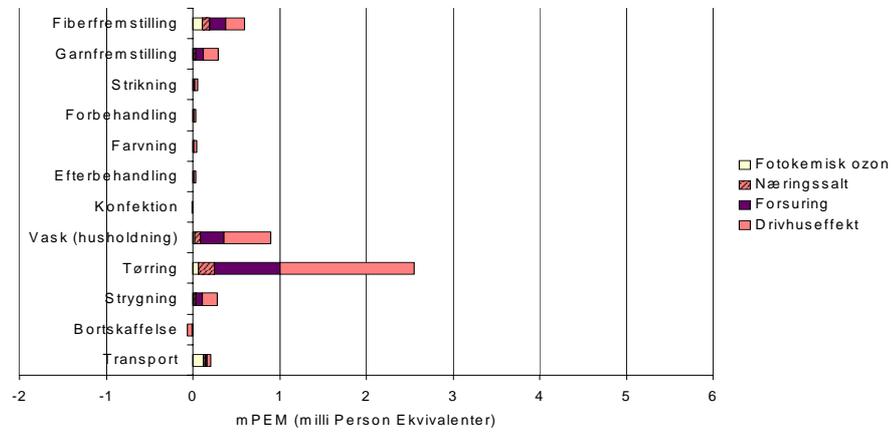


Figure 1.6 Environmental impacts related to energy per functional unit – for translation of Danish terms see glossary in annex 11

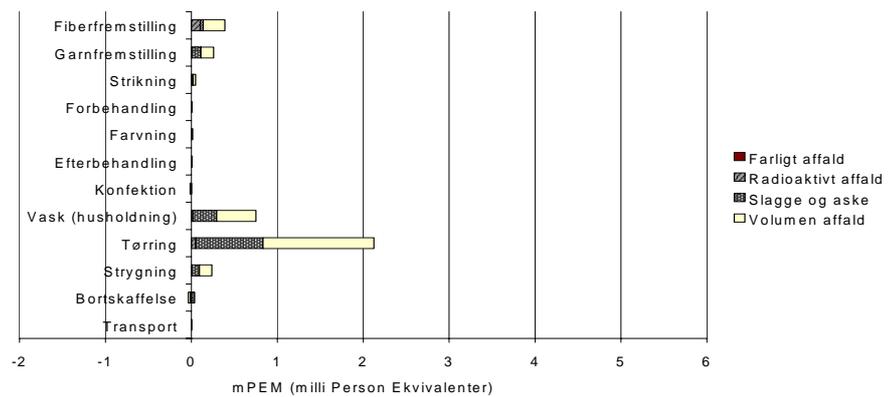


Figure 1.7 Environmental impacts, waste per functional unit – for translation of Danish terms see glossary in annex 11

Source identification

It is often necessary to study the large information volumes included in the results of a lifecycle assessment in order to achieve the best possible benefit of the assessment. A process is composed of a number of factors that all contribute to the impact categories. By carrying out source identification, the reasons for the individual contributions can be found.

This knowledge makes the assessment more useful for the producer, as the producer can change factors with undesired environmental impacts already in the development phase.

Below is an overview of the most significant contributions to the categories:

- Primary energy
- Resource consumption
- Toxicological environmental impacts
- Environmental impacts related to energy
- Waste.

Primary energy

The breakdown of consumption of primary energy over the processes during the lifecycle of the T-shirt is shown in figure 1.3.

The calculation of the consumption of primary energy does not include prints or multicoloured patterns on the T-shirt.

Table 1.1 Source identification of the most energy-intensive processes in the T-shirt's lifecycle

	Consumption of primary energy/MJ
Materials phase	10 % of total primary energy consumption
Fibre production	Approx. 70 % of this phase's contribution originates from transport of the fibres, while production of N artificial fertilizer and pesticides comprises 13 % of this phase's energy consumption.
Production phase	12 % of total primary energy consumption
Yarn manufacturing	Approx. 55 % of the production phase's consumption of primary energy originates from electricity consumption during yarn manufacturing.
Knitting	The consumption in this process originates from the consumption of Danish electricity corresponding to 10 % of this phase's total consumption.
Pre-treatment	The consumption of primary energy in this process originates primarily from burning natural gas, approx. 12 %.
Dyeing	The consumption of primary energy in this process originates primarily from burning natural gas, approx. 12 %.
Finishing	The consumption of primary energy in this process originates primarily from burning natural gas, approx. 12 %.
Making-up	Credit of energy from reuse of cut-off textiles, approx. 1 %.
Use phase	78 % of total primary energy consumption
Washing (households)	24 % of this phase's consumption originates from electricity consumption for heating water in the washing machine.
Tumbler drying	68 % of this phase's consumption is due to consumption of Danish electricity for tumbler dryers.
Ironing	8 % of this phase's consumption originates from the consumption of Danish electricity.
Disposal phase	-2 % of total primary energy consumption
Incineration	Credit of the energy recovered by incineration of the T-shirt.

Transport phase	2 % of total primary energy consumption
Transport	Consumption of fossil fuels for petrol and diesel for various vehicles.

Description of the most significant observations

The primary contribution originates from transport of cotton fibres. This contribution represents 70 per cent of the total consumption of primary energy in fibre production. 13 per cent originates from production of artificial fertilizer and pesticides.

Spreading fertilizer and pesticides is not included in the model for the T-shirt.

Electricity consumption for drying the T-shirt in a tumbler dryer represents the largest contribution in the entire lifecycle and is thus an important focal point. The consumption of primary energy for the washing machine also represents an important part of total consumption.

Resource consumption

The distribution of resource consumption in the processes in the T-shirt's lifecycle is shown in figure 1.4.

Table 1.2 Source identification of the most resource-intensive processes in the lifecycle of the T-shirt

	Crude oil	Natural gas	Hard coal
<i>Materials phase</i>	36% of total consumption	38% of total consumption	1% of total consumption
Fibre production	Primarily from production of artificial fertilizer and pesticides, and transport of fibres	Primarily from production of artificial fertilizer and pesticides, and transport of fibres	Primarily from production of artificial fertilizer and pesticides
<i>Production phase</i>	6% of total consumption	43% of total consumption	9% of total consumption
Yarn manufacturing	56 %, primarily for electricity generation for spinning the yarn	1 %, primarily for electricity generation for spinning the yarn	80 % of this phase's total coal consumption due to electricity consumption
Knitting	6 %, primarily due to electricity consumption	No importance	16 % of this phase's total coal consumption due to electricity consumption
Pre-treatment	8 %, primarily due to electricity consumption	30%, primarily due to electricity consumption	1 % of this phase's total coal consumption due to electricity consumption
Dyeing	14 %, primarily for heating water	33%, primarily for heating water	4 % of this phase's total coal consumption due to electricity consumption
Finishing	9 %, primarily from electrical energy used for drying	34%, primarily from electrical energy used for drying	1 % of this phase's total coal consumption due to electricity consumption
Making-up	7 % of this phase's total crude oil consumption due to reuse of textile in another product	2 % of this phase's total natural gas consumption due to reuse of textile in another product	-2 % of this phase's total coal consumption due to reuse of textile in another product
<i>Use phase</i>	46% of total consumption	32% of total consumption	91% of total consumption
Washing (households)	24 % of this phase's contribution, primarily from consumption of Danish electricity	24 % of this phase's contribution, primarily from consumption of Danish electricity	24 % of this phase's contribution, primarily from consumption of Danish electricity
Drying	68 % of this phase's contribution, primarily from electricity consumption from tumbler drying	68 % of this phase's contribution, primarily from electricity consumption from tumbler drying	68 % of this phase's contribution, primarily from electricity consumption from tumbler drying
Ironing	8 %, primarily from consumption of Danish electricity	8 %, primarily from consumption of Danish electricity	8 %, primarily from consumption of Danish electricity
<i>Disposal phase</i>	-2 % of total crude oil consumption can be credited	-14 % of total natural gas consumption can be credited	-1 % of total coal consumption can be credited
Incineration	Incineration of the T-shirt recovers energy in the form of heat, and this replaces burning natural gas	Incineration of the T-shirt recovers energy in the form of heat, and this replaces burning natural gas	Incineration of the T-shirt recovers energy in the form of heat
Transport phase	15% of total consumption	1% of total consumption	No importance
Transport	Consumption of petrol and diesel	Consumption of petrol and diesel	

The consumption of Fe, Al and lignite is very limited. This resource consumption has not been included here.

The consumption of crude oil and natural gas is most important. Hard coal is burned in the generation of Danish electricity.

Description of the most significant observations

In the fibre production process, primarily the production of pesticides and artificial fertilizer are energy-intensive, and thus represents most of the consumption of crude oil and natural gas. The assumption here is that European electricity is used, and therefore there is no large consumption of coal.

Energy-intensive processes like heating water for dyeing and air for drying represent the main part of resource consumption in this phase. The dyeing and finishing processes are equally as energy-intensive. For finishing, this is primarily due to the drying process.

The use phase is the most resource-intensive phase in the T-shirt's lifecycle. Electricity consumption represents most of the resource consumption. Washing in a washing machine in a normal household requires energy for heating the washing water. Tumbler drying requires a lot of energy. Danish electricity is primarily based on burning coal, while space and water heating are often based on burning natural gas and oil.

Energy is generated when the T-shirt is incinerated, and this replaces fossil fuels. However, resources for the operation of the plant are consumed at the same time.

The main contributions in this phase are small. They originate from consumption of crude oil for production of diesel and petrol. In this case, we have assumed that the T-shirt is transported to the private household by car, but that other goods are bought at the same time.

Toxicological environmental impacts

Toxicological environmental impacts, analysed by the T-shirt's lifecycle phases are shown in figure 1.5.

Table 1.3 Source identification for individual toxicity categories

	Human toxicity	Ecotoxicity	Persistent toxicity
<i>Materials phase</i>	Approx. 30 % of the total impact potential originates from this phase	98 % of the total impact potential originates from this phase	Approx. 90 % of the total impact potential originates from this phase
Fiber production	Primarily from pesticides, emissions into the air.	Approx. 90 % of this phase's contribution originates from pesticides in cotton cultivation	Approx. 90 % of this phase's contribution originates from pesticides in cotton cultivation
Production phase	5 % of the total impact potential can be attributed to this phase	In total, a negative contribution due to reuse potential for knitting and making-up	In total, a negative contribution due to reuse potential for knitting and making-up
Yarn manufacturing	Approx. 75 % of this phase's contribution is due to electricity consumption when spinning the yarn	Approx. 4 % of this phase's positive contribution is due to electricity consumption	Approx. 10 % of this phase's positive contribution to the impact potential is due to electricity consumption when spinning the yarn
Knitting	Credit of impact potential due to reuse	Credit of impact potential due to reuse options in this process	Credit of impact potential due to reuse options in this process

	options in this process		
Pre-treatment	Approx. 5 % of this phase's positive contribution is due to electricity consumption	No significant contribution	20 % of this phase's positive contribution originates from the washing agent used before the yarn is dyed
Dyeing	Approx. 8 % of this phase's positive contribution is due to electricity consumption	Dyeing represents 1 % of this phase's total positive contribution originating from the use of reactive dyes.	2 % of this phase's positive contribution to the toxicity potential is due to the use of reactive dyes and electricity
Finishing	Approx. 5 % of this phase's positive contribution is due to electricity consumption	This process contributes with the largest ecotoxicity potential. 95 % of this phase's positive contribution is due to the softening process.	Approx. 65 % of this phase's positive contribution to the toxicity potential is due to the use of fabric softener.
Making-up	Credit of impact potential due to recycling options in this process	Credit of impact potentials due to recycling options in this process	Credit of impact potentials due to recycling options in this process
<i>Use phase</i>	Approx. 60 % of total contribution	Approx. 4 % of total contribution	Approx. 15 % of total contribution
Washing	Approx. 25 % of this phase's impact potential originates from the washing agent	Approx. 55 % of this phase's impact potential originates from the washing agent	92 % of this phase's impact potential originates from the washing agent
Tumbler drying	Approx. 68 % of this phase's contribution is due to consumption of Danish electricity	Approx. 40 % of this phase's impact potential is due to electricity consumption for tumbler drying	Approx. 7 % of this phase's contribution is due to electricity consumption for tumbler drying
Ironing	Approx. 7 % of this phase's contribution is due to electricity consumption for ironing	Approx. 5 % of this phase's contribution is due to electricity consumption for ironing	Approx. 1 % of this phase's contribution is due to electricity consumption for ironing
<i>Disposal phase</i>	Negative contribution due to recovery of energy	Negative contribution due to recovery of energy	Negative contribution due to recovery of energy
Incineration			
Transport phase	4 % of total impact potential	No significant contribution	No significant contribution
Transport	From burning fossil fuels		

Description of the most significant observations

In the production phase, knitting and making-up are assumed to contribute with a reuse potential that can be credited to fibre production. This means that the production phase has a net negative contribution to ecotoxicity and persistent toxicity impact potentials. In the table, the positive contribution from the production phase has only been calculated and used as a total value. The contribution from the actual phase is calculated on the basis of the total potential, i.e. including the negative contribution.

The most significant factors in this calculation are the ecotoxicity and the persistent toxicity from cotton cultivation. The high impact potentials are due to the use of pesticides: herbicides, insecticides, fungicides, growth regulators and defoliation agents.

Detergents in washing agents result in contributions primarily to human toxicity and persistent toxicity. Moreover, there is a small contribution to ecotoxicity (primarily from alcohol ethoxylate). However, it is important to mention that the contributions from this phase are small compared to the contributions from fibre production.

Electricity generation also contributes to the toxicity categories. Mining operations release some undesired substances to the environment, such as strontium. The same applies for the drying process.

Environmental impacts related to energy

The potential environmental impacts related to energy from the T-shirt's lifecycle phases are distributed as shown in figure 1.6.

Table 1.4 Source identification for environmental impact potentials related to energy

	Greenhouse effect	Acidification	Nutrient loading	Photochemical ozone formation
<i>Materials phase</i>	8 % of total contribution	14 % of total contribution	20 % of total contribution	32 % of total consumption
Fiber production	Originating primarily from burning fossil fuels and energy for production of N artificial fertilizer	Originating primarily from burning fossil fuels and energy for production of N artificial fertilizer	Originating from burning fossil fuels and energy for production of N artificial fertilizer	Originating from burning fossil fuels
<i>Production phase</i>	10 % of total contribution	8 % of total contribution	8 % of total contribution	7 % of total contribution
Yarn manufacturing	60 % of this phase's contribution originates from electricity consumption in this process	78 % of this phase's contribution originates from electricity consumption in this process	71 % of this phase's contribution originates from	The main part, approx. 36 %, of this phase's contribution originates from unburnt fuels in connection with transport
Knitting	12 % of this phase's contribution is due to electricity consumption	14 % of this phase's contribution is due to electricity consumption	11 % of this phase's contribution is due to electricity consumption	Not significant
Pre-treatment	8 % of this phase's contribution is due to electricity consumption	3 % of this phase's contribution is due to electricity consumption	7 % of this phase's contribution is due to electricity consumption	16 % of this phase's contribution is due to unburnt fuel in connection with transport
Dyeing	11 % of this phase's contribution is due to electricity consumption	6 % of this phase's contribution is due to electricity consumption	10 % of this phase's contribution is due to electricity consumption	20 % of this phase's contribution is due to unburnt fuel in connection with transport
Finishing	9 % of this phase's contribution is due to electricity consumption	4 % of this phase's contribution is due to electricity consumption	8 % of this phase's contribution is due to electricity consumption	18 % of this phase's contribution is due to unburnt fuel in connection with transport
Making-up	Credit of minimal contribution due to assessed reuse potential	-4 % credit of contribution due to assessed reuse potential	-6 % credit of contribution due to assessed reuse potential	10 % due to incomplete burning fossil fuels
<i>Use phase</i>	82 % of total contribution	78 % of total contribution	68 % of total contribution	26 % of total contribution
Washing (households)	24 % of this phase's impact contribution originates from electricity consumption for heating water in the washing machine	24 %, see greenhouse effect for explanation	24 %, see greenhouse effect for explanation	24 %, see greenhouse effect for explanation
Tumbler drying	68 % of this phase's impact potential is due to consumption of electricity for tumbler dryers	68 % of this phase's impact potential is due to consumption of electricity for tumbler dryers	68 % of this phase's impact potential is due to consumption of electricity for tumbler dryers	68 % due to incomplete burning in connection with transport
Ironing	8 % of this phase's impact potential is due to the consumption of electricity for irons	8 % of this phase's impact potential is due to the consumption of electricity for irons	8 % of this phase's impact potential is due to the consumption of electricity for irons	8 % due to incomplete burning in connection with electricity generation

<i>Disposal phase</i>	Credit of impact potentials due to exploitation of energy from incineration, approx. -2 % of total	Credit of impact potentials due to exploitation of energy from incineration, approx. -1 % of total	Credit of impact potentials due to exploitation of energy from incineration, approx. -1 % of total	Approx. 1 % of this phase's total contribution originates from incineration of the T-shirt
Incineration				
Transport phase	2 % of total contribution	2 % of total contribution	4 % of total contribution	34 % of total contribution
Transport	Transport with diesel and petrol driven vehicles	Burning fossil fuels	Burning fossil fuels	Burning fossil fuels

Description of the most significant observations

Incomplete burning contributes to photochemical ozone formation, while burning fossil fuels generally contributes to all categories.

Burning fossil fuels for transport of the cotton fibres and electricity consumption in production of artificial fertilizer and pesticides are the main causes of the environmental impact contributions from this phase.

In this phase, electricity consumption again represents the main part of the impact potentials. Especially the yarn manufacturing process is energy-intensive.

The phase when the T-shirt is consumed is the absolute main contributor to the environmental impact potentials related to energy. This is caused by electricity for tumble dryers, irons and heating water for washing machines. Energy consumption from production of washing agents has not been included. If this had been included, the contribution from this phase would have been even larger. This result indicates that the consumer has considerable influence on the T-shirt's overall environmental profile.

Waste

The waste category is most important in fibre production, yarn manufacturing and in the use phase processes, see figure 1.7. "Waste for landfilling" is actually a non-terminated interchange - it has not yet been possible to calculate these emissions satisfactorily, as the degree and effect of emissions from landfill are not sufficiently known for a model to be set up.

Table 1.5. Identification of the processes with the largest contributions to the four waste categories

	Bulky waste	Slag and ash	Radioactive waste
<i>Materials phase</i>	11% of total	2% of total	54% of total
Fiber production	Small contributions from many processes	Small contributions from many sub-processes	From European electricity generation
Production phase	8% of total	10% of total	3% of total
Yarn manufacturing	82 % of this phase's contribution originates from this process. Primarily from electricity generation	80 % of this phase's contribution originates from this process. Primarily from incineration of waste cotton	93 % of the positive contribution to this phase's radioactive waste due to imports of Swedish electricity generated at nuclear power stations
Knitting	16 % of this phase's contribution originates from this process, primarily from electricity generation	15 % of this phase's contribution originates from this process, primarily from incineration of waste cotton	Negative contribution to this phase's total volume of radioactive waste due to reuse and credit of European electricity from fibre production
Pre-treatment	1 % of this phase's contribution originates from this process, primarily from electricity	1 % of this phase's contribution originates from this process, primarily from electricity generation	2 % of the positive contribution to this phase's radioactive waste due to imports of Swedish electricity

	generation		generated at nuclear power stations
Dyeing	5 % of this phase's contribution originates from this process, primarily from electricity generation	3 % of this phase's contribution originates from this process, primarily from electricity generation	3 % of the positive contribution to this phase's radioactive waste due to imports of Swedish electricity generated at nuclear power stations
Finishing	1 % of this phase's contribution originates from this process, primarily from electricity generation	2 % of this phase's contribution originates from this process, primarily from electricity generation	2 % of the positive contribution to this phase's radioactive waste due to imports of Swedish electricity generated at nuclear power stations
Making-up	-5 % of this phase's contribution, credited due to reuse potential	-1 % of this phase's contribution, credited due to reuse potential	Negative contribution to this phase's total volume of radioactive waste due to reuse and credit of European electricity from fibre production
<i>Use phase</i>	82 % of total, primarily from electricity generation.	86 % of total, primarily from electricity generation.	40 % of total, primarily from electricity generation.
Washing (households)	24 % of this phase's contribution	24% of this phase's contribution	24% of this phase's contribution
Tumbler drying	68% of this phase's contribution	68% of this phase's contribution	68% of this phase's contribution
Ironing	8% of this phase's contribution	8% of this phase's contribution	8% of this phase's contribution
<i>Disposal phase</i>	-2% of total	2% of total	2% of total
Incineration	Credit of waste volume	Waste from the incineration plant	Waste from the incineration plant
Transport phase	No significant contribution	No significant contribution	No significant contribution
Transport			

Description of the most significant observations

The contributions to these impact categories are limited seen over the entire lifecycle of the T-shirt. The category "hazardous waste" is not commented on in the source identification, as the contributions were deemed so small that they do not influence the environmental profile of the T-shirt.

There is no primary source for the contributions in fibre production, except radioactive waste from the use of European electricity, where some electricity is generated at nuclear power stations.

This phase is the most significant in the waste statement. The large consumption of electricity for washing and drying results in higher contributions for the "bulky waste" and "slag and ash" categories. The radioactive contribution from use of Danish electricity is due to trading with Sweden, from/to which Denmark imports and exports electricity. Sweden generates some electricity at nuclear power stations.

When the T-shirt is incinerated, some bulky waste is converted to slag and ash. This is the reason for the negative contribution to this category.

What-if simulations

The environmental profile for a given product - in this case a T-shirt - can be affected by the choices made by the producer and by the consumer. In order to elucidate the consequences of possible changes in the product's lifecycle, a

number of scenarios have been prepared that focus on the producer and consumer respectively.

By changing one or more of the reference conditions, it is possible to form a picture of the scope of the consequences based on the choices made by the producer and the consumer. Subsequently, the influence of the two groups on the final results can be assessed.

In the following, the scenarios will be assessed in relation to the producer reference and the consumer reference. The latter is identical to that in the main scenario.

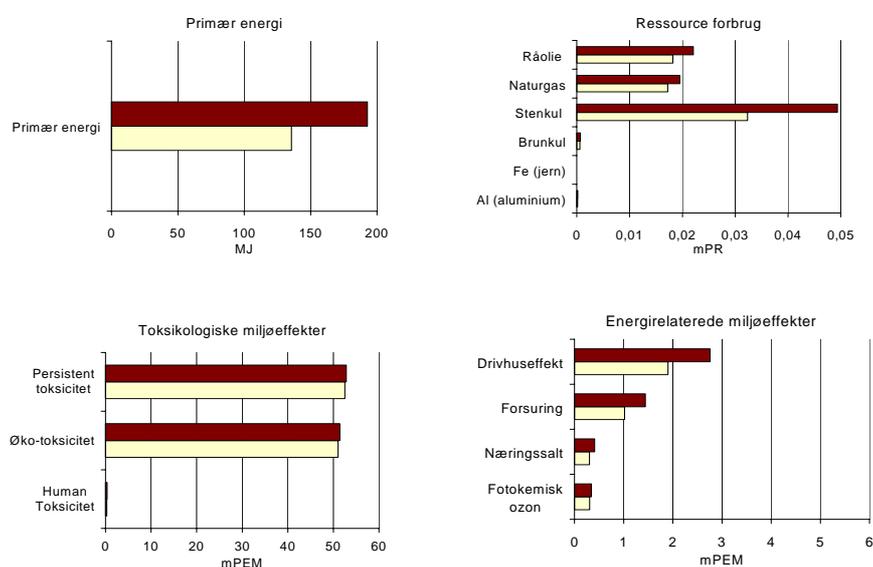
Consequences of choices by the producer

The producer influences all processes from extraction of raw materials until the finished product leaves the distribution phase. To some extent, the producer can affect the processes in the use phase. However, it is not possible for the producer to affect all consumers of the product equally. In order to take this into account, a product reference has been prepared for the producer scenarios where only a limited part of the impacts from the use phase has been included.

For example, washing after use as defined in the functional unit, no use of fabric softener when washing in private households, and tumbler drying after every second wash. It is assumed that the T-shirt is drip-dried the remaining times.

The producer reference has been prepared in order to give producers a clearer picture of the influence of the production phase on the product's overall environmental profile in relation to an average use phase.

In connection with the use of a T-shirt, the following averages are assumed: Washing after every time the T-shirt has been used for 1 day, as described in the functional unit, no use of fabric softener when washing in private households. The T-shirt is tumbler dried 50 per cent of washes. The remaining times it is assumed that the T-shirt is drip-dried on a clothesline. It is assumed that the T-shirt is ironed 10 per cent of the times it is washed.



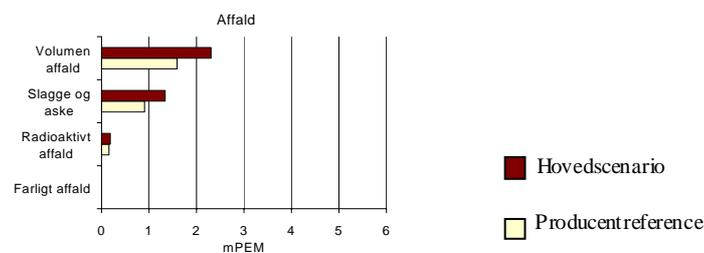


Figure 1.8 The main scenario compared with the producer reference – for translation of Danish terms see glossary in annex 11

Figure 1.8 shows that the producer reference scenario has a 30 per cent lower consumption of primary energy per functional unit than the main scenario. This is due to lower consumption of electrical energy in the use phase. For the same reason, the environmental impacts related to energy are reduced by 10-30 per cent.

The resource consumption is 20-30 per cent lower in the producer reference due to the reduced impacts in the use phase. The environmental impacts related to chemicals are only reduced by just less than 1 per cent, which is because the most significant contributions to these impact categories originate from the cotton fibre production which is equal in the two scenarios.

In the following, the results of the scenarios are presented as summarised contributions over the entire lifecycle and compared with the producer reference scenario.

Scenarios – Producer

Choice of raw materials

Scenario 1: Choice of raw materials - organic cotton

Scenario 2: Choice of raw materials - halved cotton waste

Production phase

Scenario 3: Choice of chemicals - choice of reactive dyes

Scenario 4: Choice of chemicals - choice of fabric softener - 100% of fabric softener washed out in the use phase

Scenario 5: Choice of chemicals - use of fastness improver

The use phase

Scenario 6: Use phase - extended textile lifetime

Scenario 7: Use phase - colour staining

Influence of the consumer

Scenario 8: Influence of the consumer - no tumbler drying

Scenario 9: Influence of the consumer - non-iron T-shirt

Scenario 1: Choice of raw materials - organic cotton

The toxicological environmental impacts are the environmental impact potentials with the highest weight in the life of the T-shirt. This has been ascertained as primarily due to use of pesticides during cultivation of the cotton.

In order to assess the significance of the chemicals used in conventional cotton cultivation, the material is changed to organic cotton. Here the use of pesticides and artificial fertilizer disappears. A further benefit is that the transport required to spread these substances on the field also disappears. However, it should be added that organic farming does utilise mechanical weed control and requires transport to spread organic manure. Transport is not, however, included in either the main or the producer reference scenarios. Less transport reduces consumption of fossil fuels and is therefore also part of the energy-related environmental impacts. The element of pesticides washed out during bleaching in pre-treatment of organic production also disappears.

For conventional cotton cultivation about 18 g pesticides are used per kg cotton. The main scenario applies an estimated average from cotton cultivation in the US and South America. The impacts of pesticides on the environment have been assessed and the factors have been included in the database. Pesticide residues can cause toxic impacts in humans during further processing of the cotton fibres. These residues are assumed to be washed out of the cotton during wet treatment.

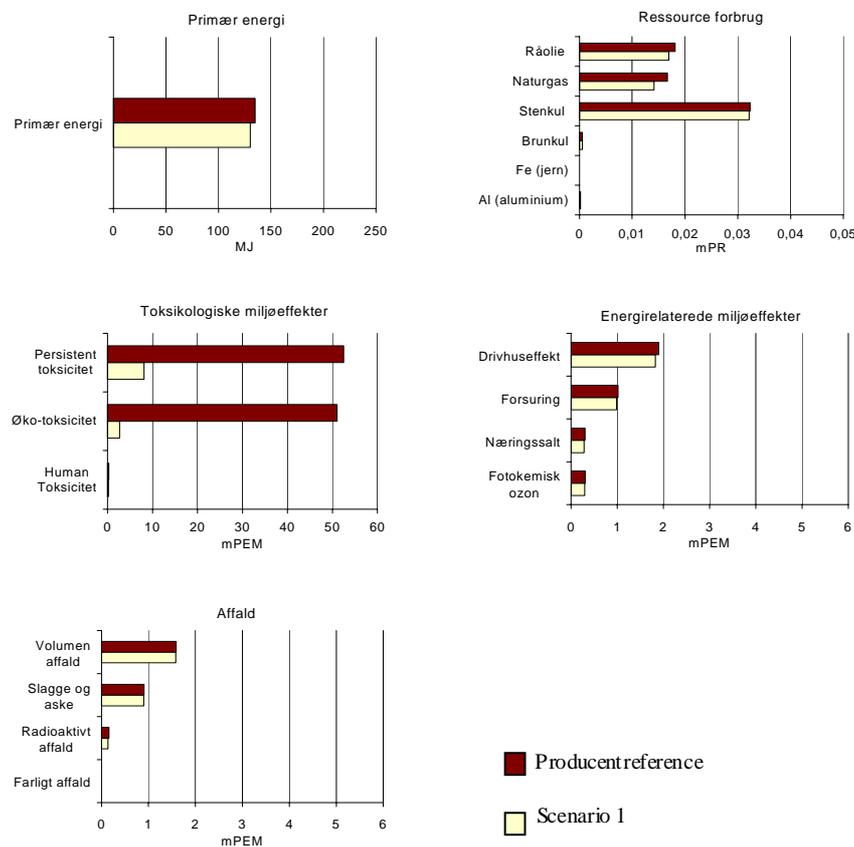


Figure 1.9 Result of scenario 1 - significant impact on chemical-related environmental impacts – for translation of Danish terms see glossary in annex 11

Consumption of primary energy does not change significantly, only by about 4 per cent over the total life of the T-shirt. This is because most of the energy consumption arises from processes in the production and use phases and these do not change in this scenario.

As shown in figure 1.9, the toxicological environmental impacts are reduced considerably using organically cultivated cotton. Persistent toxicity is reduced

by 85 per cent, while ecotoxicity is reduced by 95 per cent compared with the reference scenario.

The energy-related environmental impacts, the greenhouse effect, nutrient loading, and photochemical ozone formation are reduced by 5-10 per cent. The reason is that there is no longer a contribution to these potentials from production of artificial fertilizer and pesticides. The same applies for the waste categories.

Conclusion to scenario 1 - organic cotton is recommended

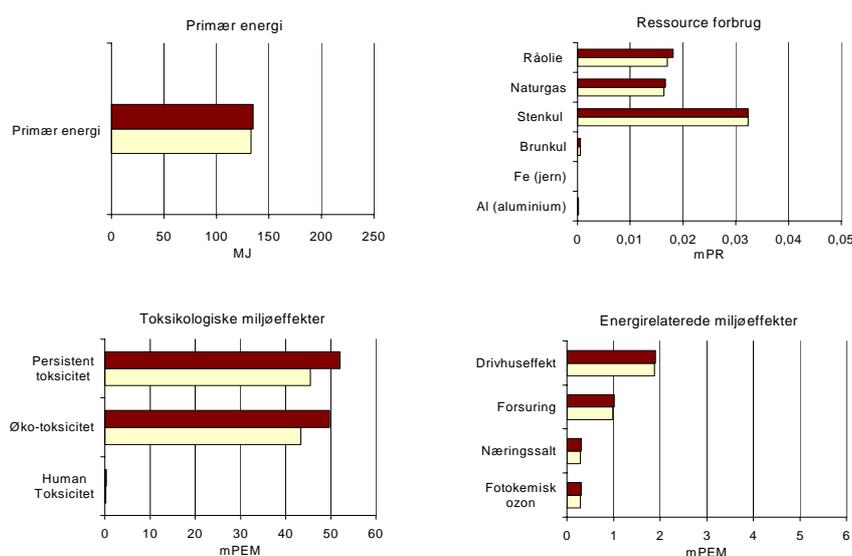
It can be concluded that the producer has great possibilities to influence the overall environmental profile of the textile, especially the toxicological impact potentials. Use of organic cotton rather than conventionally cultivated cotton to the greatest possible extent can clearly be recommended. It should also be considered that many of the agents used during cultivation of cotton are harmful to human health. Incorrect or careless use could mean that suppliers expose themselves and their employees to health hazards. Pesticide residues washed out in several pre-treatment processes are yet another reason to avoid conventionally cultivated cotton.

Scenario 2: Choice of raw materials - halved cotton waste

Yarn production from cotton creates a lot of waste. During manufacture of carded cotton there is about 15 per cent waste. For combed cotton there is about 30 per cent waste (15 per cent from combing alone).

During manufacture of combed cotton, it is possible to use the fibre waste for lower quality yarn. In the producer reference it is assumed that the fibre waste is not recirculated, i.e. 30 per cent waste. Not much information is available to estimate the proportion of recyclable waste, but the potential does exist.

In this scenario waste is estimated as reduced to 15 per cent. The T-shirt is assumed to weigh the same as in the reference scenario.



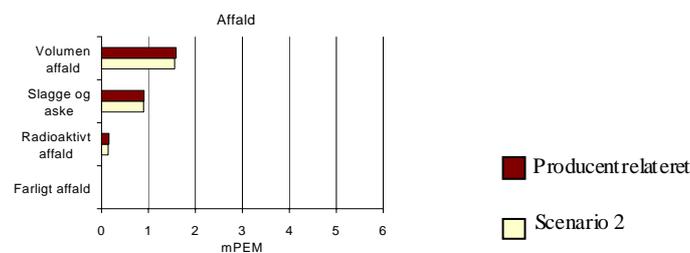


Figure 1.10 Result of scenario 2 - halved waste – for translation of Danish terms see glossary in annex 11

The reduction is because smaller quantities of cotton fibre are produced for manufacture of a single T-shirt. Because of the lower level of waste, less cotton is incinerated at incineration plants and therefore less energy is recovered in the yarn-manufacturing phase. The result of reduced waste is a reduction in total consumption of primary energy of 2 per cent compared with the producer reference. There is a corresponding reduction in consumption of crude oil (7 per cent) and natural gas (5 per cent), as well as in greenhouse gases (2 per cent).

The waste categories show a limited reduction in the volume of bulky waste and slag and ash of between 1 and 3 per cent. This reduction is also due to less consumption of fossil fuels. The change in the scenario does not affect the use of electricity in the production and use phases, which are the primary sources of the types of impact mentioned.

The toxicological environmental impact potentials in manufacture of fibres are reduced by 15 per cent because of the smaller quantity of cotton cultivated per T-shirt.

Conclusion to scenario 2 - reducing waste can be recommended

It can be concluded that the reduction in the toxicological environmental impact potentials is an important reason to focus on less waste in the production processes.

Of course this is not unambiguous, but depends partly on the state of the regional and local environment at the production location, availability of treatment plant and its effectiveness for primary pesticide residues. Minimising waste in all processes, not only waste of primary materials but also of auxiliary chemicals, energy etc. can often improve the environmental profile of the product and establish a basis for a more profitable production.

Scenario 3: Choice of raw materials - choice of reactive dyes

Dyes in the dyeing process add to the toxicological environmental impact potentials, although to a considerably smaller extent than pesticides and artificial fertilizer from cultivating conventional cotton. The database only includes equivalency factors for a single reactive dye "Reactive black 5", and the producer reference uses the dyes "Reactive dye 2 and 3", all allocated the same equivalency factors. Note that the limited knowledge on large parts of the dye range means that this assumption should not be regarded as representative for the whole group of dyes.

It is assumed that 85 per cent of the dye dose adsorbs to the textile, the rest is discharged with wastewater to a treatment plant. Of the amount of reactive dye discharged to the treatment plant, 90 per cent is discharged to the water

and 10 per cent to soil, as the reactive dye adsorbs poorly in the sludge. The dyes primarily add to chronic ecotoxicity which affects the column for persistent toxicity. The producer reference is based on these assumptions.

The toxicological equivalency factors for the dyes are set as zero in this scenario to enable an assessment of the effect of the dyes on the total profile.

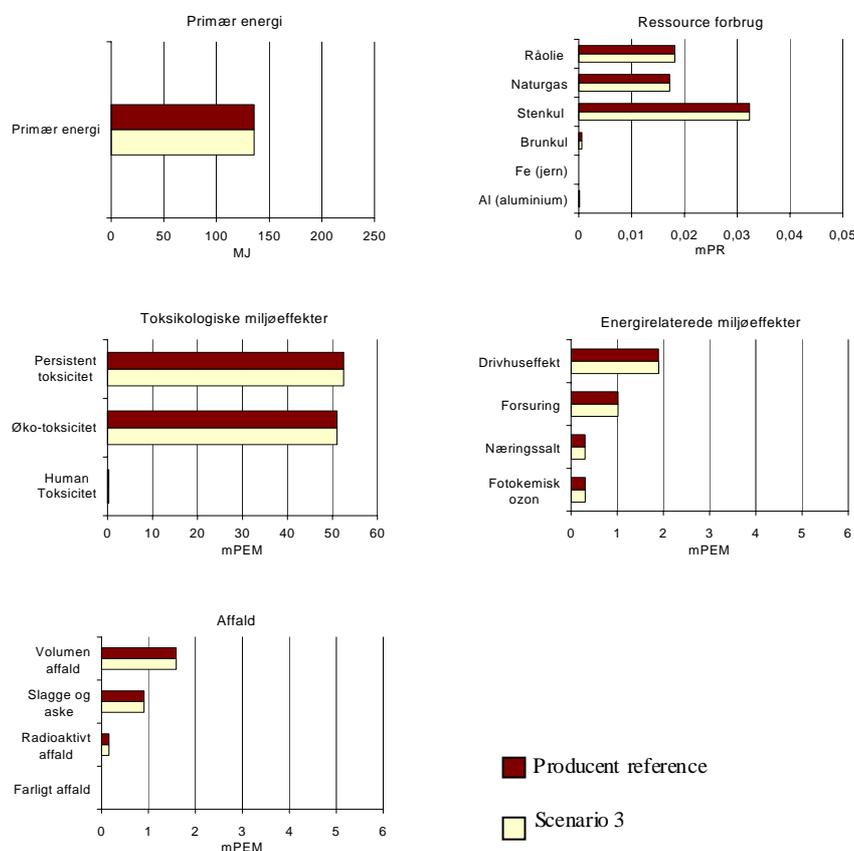


Figure 1.11 Result of scenario 3 - no significant consequences – for translation of Danish terms see glossary in annex 11

Figure 1.11 shows that there are no appreciable changes between the producer reference and scenario 3. The result shows that the dyes only have a minimal impact on the toxicity potentials compared with pesticides and artificial fertilizer.

Overall the toxicity potentials are reduced by less than 0.1 per cent. Note that only one reactive dye forms the basis for the contribution in the producer reference. In the dyeing process alone persistent toxicity is reduced by 60 per cent by removing the equivalency factors, while the ecotoxicity potential is slightly increased. The remaining contribution in the dyeing process comes primarily from consumption of electricity to heat the water.

Conclusion to scenario 3 - choice of reactive dyes, gather more knowledge

Therefore, it can be concluded that production should focus on acquiring knowledge on the dyes used and their impact and degradability in the environment. The factors in this tool can be used as standards of reference and can thereby form the basis for choosing more environmentally friendly reactive dyes. The consequences of the choice are limited, however, compared with the contributions to the toxicological environmental impact potentials

from conventional cultivation of cotton. The producer should focus environmental efforts on reducing energy consumption, reducing consumption of pesticides during cultivation of cotton, minimising waste etc., rather than looking for new reactive dyes.

Scenario 4: Choice of raw materials - choice of fabric softener

This scenario illustrates the effect of choice of fabric softener as well as the significance of any washing out of the fabric softener in the use phase. The producer reference includes the most commonly used fabric softener in the model for the lifecycle of the T-shirt. This chemical is the most toxic of the two fabric softeners in the EDIP-TEX database. It is assumed that 85 per cent of the added amounts adsorbs to the textile and is not washed out in the use phase.

Attempts have been made to clarify the effects of washing out fabric softener in the use phase on the overall environmental profile.

- Therefore it is assumed that 100 per cent of the fabric softener is washed out in the use phase. This is illustrated in the figure below.

The producer is able to use fabric softeners of any toxicity.

- Therefore it is assumed that a less toxic chemical is used. Just as in the producer reference, it is assumed that 85 per cent of the substance added remains on the textile, and that none of the substance is washed out during the use phase.

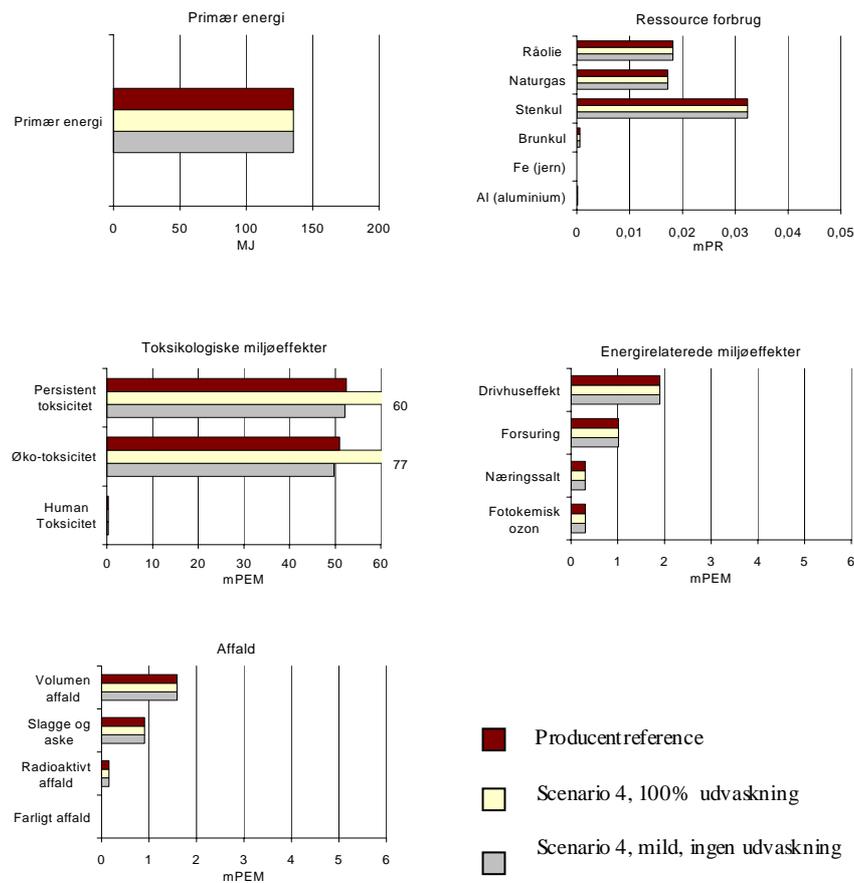


Figure 1.12 Result of scenario 4 – for translation of Danish terms see glossary in annex 11

The producer has several possibilities to change the softening process, which can be carried out using different techniques.

- Addition of fabric softener in a wet treatment process.
- Fabric softener can be sprayed on the woven or knitted textile through nozzles.
- Lengths of textile can be led through a bath containing fabric softener where the softener is exhausted or absorbed by the material.
- Mechanical softening of the textile lengths where the fibres are softened through repeated mechanical treatment.

Data for the manufacture of fabric softeners is not included, and therefore only the toxicological environmental impact potentials are changed as a result of the assumptions of this scenario.

Figure 1.12 shows that the greatest influence comes from the assumption of washing out in the use phase. Here, the contribution increases by 15 per cent for persistent toxicity and 50 per cent for ecotoxicity in the toxicological environmental impact potentials. The choice of a less toxic fabric softener has no great immediate impact because of the higher contribution to these categories from cotton cultivation.

Conclusion to scenario 4 - washing out in the use phase is very significant

It can be concluded that washing out during the use phase is most important for the overall result. This is particularly due to the assumption that 100 per cent of the amount of fabric softener added is discharged via the treatment plant to water and soil throughout the lifecycle of the T-shirt.

Choosing a less toxic fabric softener reduces the total contribution to the toxicological environmental impacts by about 2 per cent. The reduction may seem insignificant, but it has a great influence on the environmental profile of the product in the production phase. Legislation on ecolabelling indicates the substances that should be phased out, and those which should be avoided completely from an environmental perspective. This could be a guide for environmental work at the individual enterprise.

Scenario 5: Choice of raw materials - use of fastness improver

In order to achieve a better quality cotton T-shirt, the textile can be treated with fastness improvers in the same bath as the fabric softener. The fastness improver means that the coloured textile has a better wash fastness, i.e. the risk of staining other textiles is reduced and the product can resist more washes without changing its colour.

This scenario assumes that fastness improvers are used and 85 per cent adsorbs to the textile.

In order to illustrate the significance of this process, scenario 5 includes the rough assumption to allocate the fastness improver the same toxicity factors as the fabric softener in the producer reference, as no equivalency factors have been prepared specifically for fastness improver. It has not been possible to identify the chemical structure of the fastness improver, other than, like the fabric softener mentioned above, it may be a cation-active substance. It is assumed that 85 per cent of the amounts added adsorbs to the textile, while the rest is led through a treatment plant and discharged into the environment.

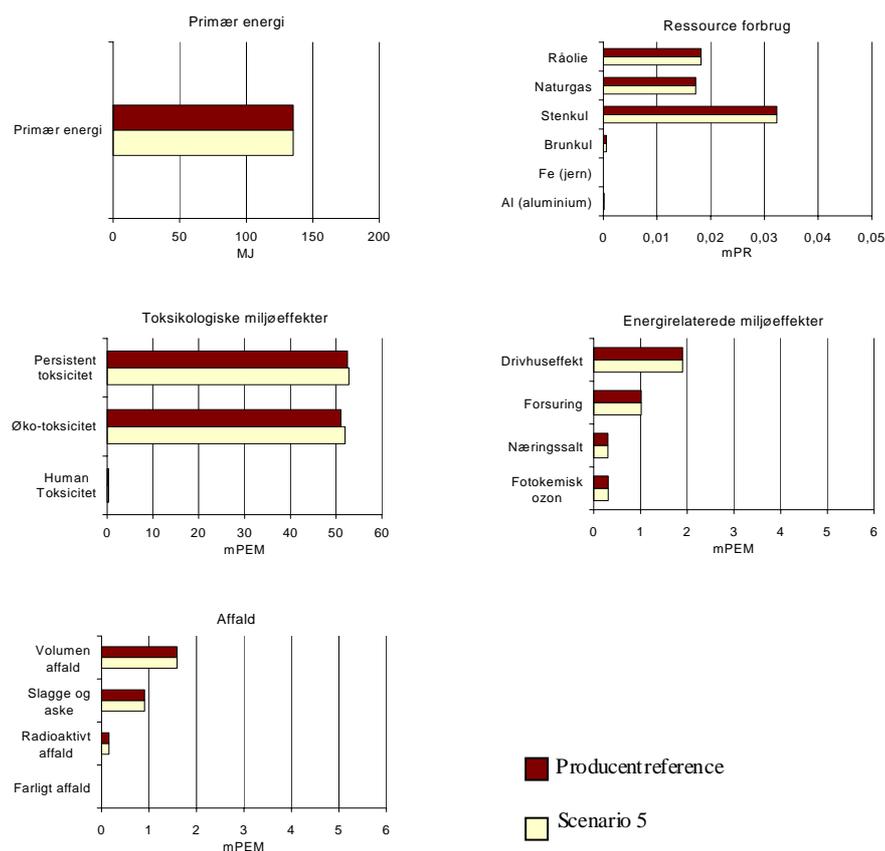


Figure 1.13 Result of scenario 5 - small changes in toxicological environmental impacts – for translation of Danish terms see glossary in annex 11

The results figure shows that there are only minimal changes over the whole lifecycle. Compared with the producer reference, the contribution to ecotoxicity increases by almost 2 per cent, while the contribution to persistent toxicity increases by almost 1 per cent. As in scenario 4, the contributions are overshadowed by the large environmental impact potentials from fibre manufacture. If the T-shirt were manufactured from organic cotton, the contribution from the fastness improver would seem more significant.

Conclusion to scenario 5 - less impact, no real picture

The conclusion to scenario 5 is that use of fastness improvers does not change the environmental profile of the T-shirt significantly. However, it should be noted that energy consumption in manufacture of the chemical has not been included in the calculations and therefore use of fastness improvers in industry will influence resource consumption and energy-related environmental impact potentials which are not illustrated here. For the production phase alone, the contribution from finishing to the toxicological environmental impact potentials is considerable, and therefore there should be focus on minimal use of these auxiliary chemicals.

Scenario 6: Influence of product quality - reduced lifetime

Product quality influences the lifetime of the product. Colour fastness, durability of the fibre and stitching are examples of areas on which the durability and quality of the product can be judged. In relation to lifecycle assessments, the quality of the product will be important for the manufacture

and disposal phases, as these are extended/reduced in order to meet the functional unit.

Scenario 6 is based on halving the lifetime of the T-shirt compared with the producer reference. The assumption results in doubling fibre manufacture, production, disposal and transport as two T-shirts are now required to meet the functional unit.

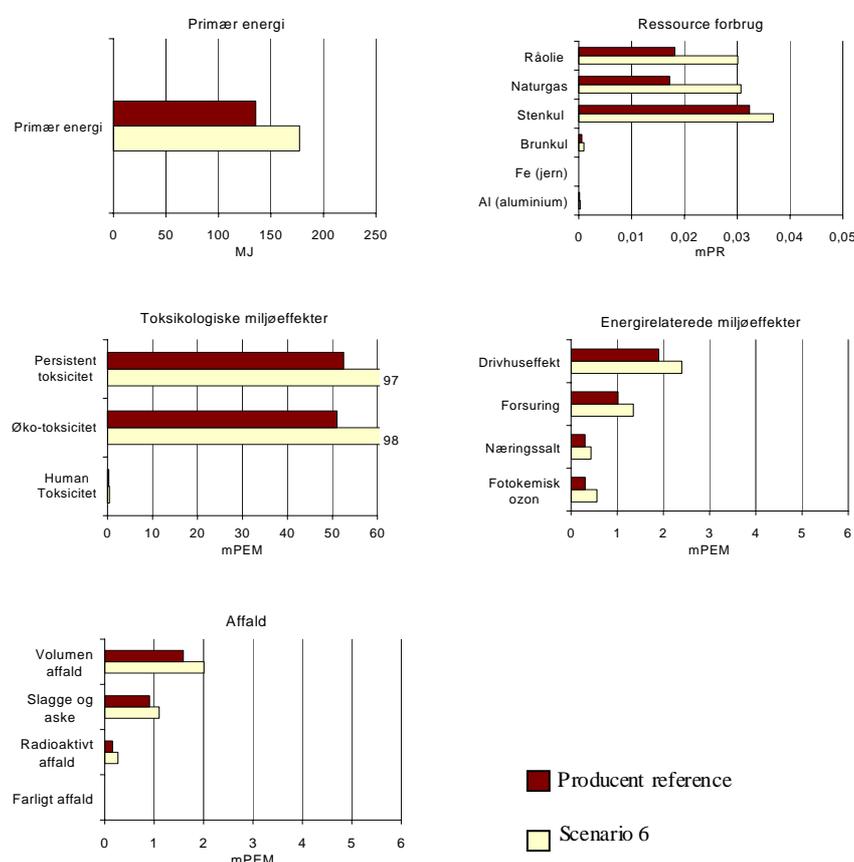


Figure 1.14 Result of scenario 6 - increase in all categories – for translation of Danish terms see glossary in annex 11

Results figure 1.14 shows that, over the whole lifecycle, lifetime is important. The consumption of primary energy increases by approx. 30 %. Resource consumption is increased correspondingly, crude oil by 66 per cent, natural gas by 76 per cent, and coal by 11 per cent. This is due to increased consumption of electricity for production of the extra T-shirt. The contribution to the energy-related environmental impacts as a consequence of this increases by about 26 - 86 per cent.

The waste categories increase by about 30 per cent for the same reasons.

Similarly, the toxicological environmental impact potentials are increased by 40 per cent, and again the determining factor in this context is the increased production of cotton.

Conclusion to scenario 6 - the lifetime of the T-shirt is significant for the overall environmental profile

The conclusion to this scenario is that the quality of the T-shirt is an important focus point for the producer, as it is decisive for the overall

environmental profile, in particular with regard to consumption of primary energy and thus fossil fuels and the energy-related environmental impacts.

The toxicological environmental impacts also increase considerably with double the consumption of cotton per functional unit. One possibility to improve the environmental profile, despite reduced lifetime is organised reuse of the material.

The lifetime of the textile is not only determined by the producer, the consumer also has a great influence on this parameter. Consequences related to the consumer patterns are described in scenarios 10 - 18.

Scenario 7: Influence of product quality - colour staining

The quality of the dyeing, colour fastness, is important for the quality consumers perceive in the product. This scenario illustrates the impacts on the overall environmental profile of the T-shirt if an entire machine wash becomes unusable because the colour comes out of the T-shirt once in its lifetime. It is assumed that the wash weighs 5 kg, the material is cotton, and that all the clothes become unusable because of staining.

18 cotton T-shirts are ruined because of discolouring. The simulation is carried out by assuming that the wash is composed of 20 cotton T-shirts, each weighing 250 g.

Therefore 20 T-shirts corresponding to the reference must be produced, transported and disposed of. The use phase of the spoiled textiles is not included in the calculations.

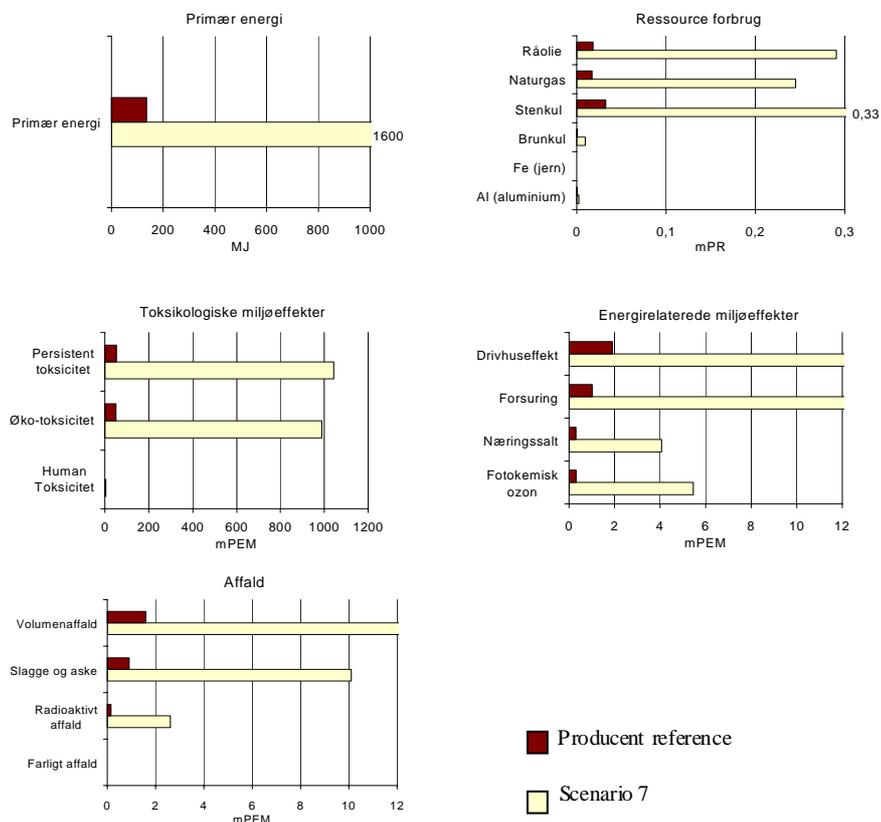


Figure 1.15 Result of scenario 7 - significant changes – for translation of Danish terms see glossary in annex 11

The graphs show that production of the 18 T-shirts causes an increase in consumption of primary energy of 1200 per cent. The same trend is apparent for the remaining environmental impact categories.

Conclusion to scenario 7 - the significance of the use phase is reduced by discolouration

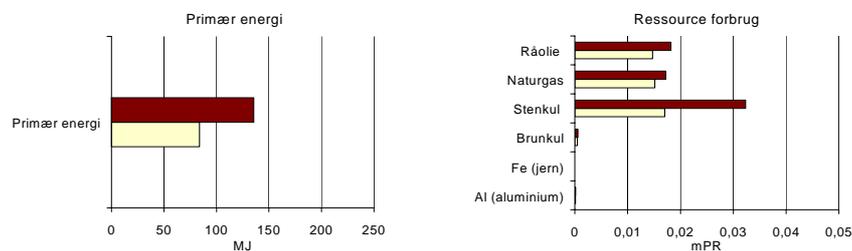
The scenario indicates that the use phase of the individual T-shirts, otherwise dominant for the majority of the impact categories, is now overshadowed by production of the textile (T-shirts), corresponding to 4.5 kg in total. Therefore it is important for the producer to manufacture textile clothing with high colour fastness or at least inform customers of the risk of colour staining during washing, so that the consumer can take precautions and wash the textile separately at first.

Scenario 8: Influence of the use phase - no tumbler drying

Reduction of the dominance of the use phase - quick-drying textiles. The use phase has a great influence on the overall environmental profile of the T-shirt. Therefore, it is desirable that the producer improve the properties of the product to reduce the environmental impacts in this phase. As can be seen in the producer reference, electricity consumption has most significance, more specifically in the drying process. The producer reference assumes that the T-shirt is dried in a tumbler dryer for half of the washes.

This scenario assumes that the T-shirt is always hung up to dry on a clothesline and drip-dried. Emissions into the air from this process have not been included. The model simulates the change by setting the drying process at zero.

The possibilities for the producer to influence the drying method chosen by the consumer could include processing, weaving, or knitting the textile so that the textile retains less water after centrifuging in the washing machine. This will reduce the need for drying and more consumers will probably drip-dry the product.



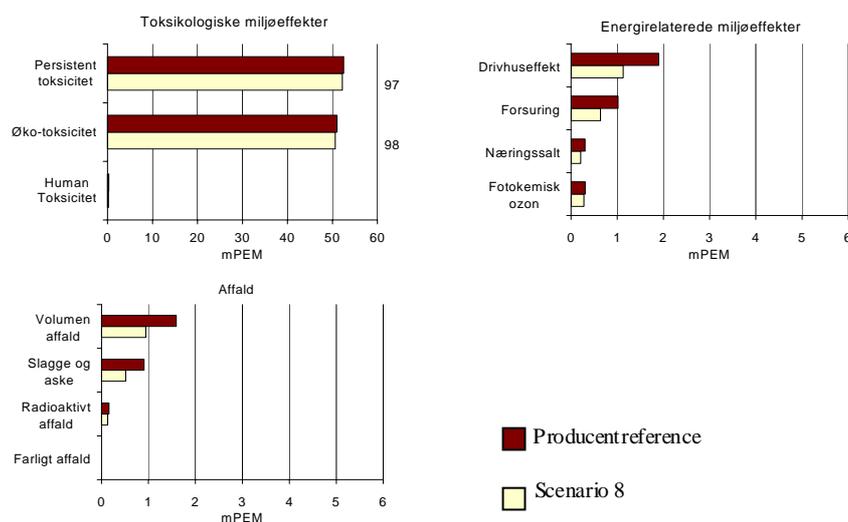


Figure 1.16 Result of scenario 8 - large changes – for translation of Danish terms see glossary in annex 11

Figure 1.16 shows that drying in a tumbler dryer has a great influence on the overall consumption of primary energy, and this is reduced by almost 40 per cent. Consumption of resources is also reduced, consumption of crude oil by approx. 20 per cent, natural gas by approx. 15 per cent, and coal by about 50 per cent.

Eliminating drying in a tumbler dryer results in significantly less consumption of Danish electricity. Danish electricity is primarily produced at coal-fired power plants, and therefore consumption of coal is reduced more than crude oil and natural gas. The energy-related environmental impacts are correspondingly reduced.

The toxicological environmental impact potentials are reduced by just less than 1 per cent, which indicates that electricity consumption does not contribute significantly to this impact category.

Conclusion to scenario 8 - reducing drying needs has a positive impact on the environmental profile

It can be concluded that drying in a tumbler dryer during the use phase has a great influence on the overall environmental profile. It would therefore be an advantage if the producer processed the textile so that water is easier to centrifuge out of the T-shirt. It is necessary to consider the impact of any extra pre-treatment process in relation to savings in the use phase. Another knitting method or surface treatment will require energy, consumption of resources and add to the environmental impacts.

Scenario 9: Influence of the use phase - non-iron T-shirt

This scenario illustrates the significance of ironing in the use phase. The producer reference assumes that the T-shirt is ironed after every 10 washes, i.e. 5 times per lifetime. Assuming that the T-shirt is never ironed illustrates the impact of this process on the overall statement for the product. The model sets the "ironing" process in the use phase at zero.

The producer can influence the need to iron the T-shirt by pre-treating the textile so that it does not require ironing after washing. Here, it is important to

study the process chosen for smoothing the fibre and compare it with the impact of ironing on the environment. This will avoid substituting the ironing process with something more harmful to the environment than electricity consumption during ironing. This is auxiliary chemicals, electricity consumption to operate the process or similar. Another consideration is that, even though the producer treats the textile so that it no longer creases, there will still be users of the T-shirt who iron it. Therefore the scenario is not considered as an indication of the significance of ironing as a process.

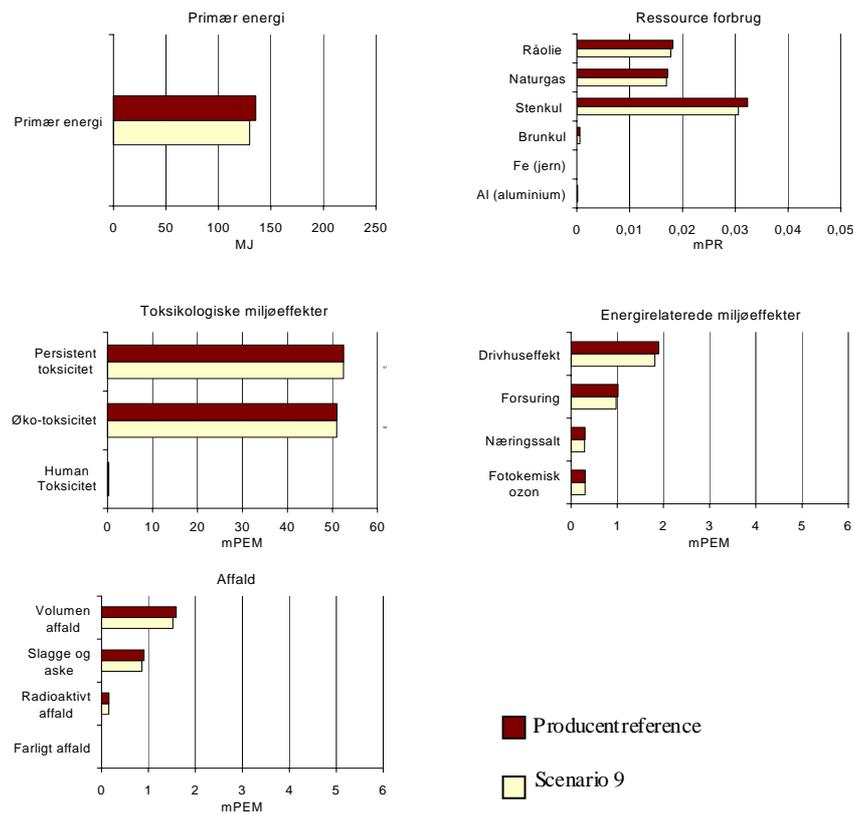


Figure 1.17 Result of scenario 9 – for translation of Danish terms see glossary in annex 11

Figure 1.17 shows that eliminating ironing results in less electricity consumption. The environmental impacts affected by this are consumption of primary energy and thus fossil fuels, contributions to environmental impacts related to energy and waste categories. The total consumption of primary energy is reduced by 5 per cent. The contributions to the environmental impacts related to energy are also reduced by about 5 per cent.

The toxicological environmental impacts are reduced by less than 0.1 per cent and therefore assumed as unchanged.

Conclusion to scenario 9 - ironing has an impact on the overall environmental profile

It can be concluded that all processes consuming electricity, which can be minimised or replaced, have a positive influence on the environmental profile of the product. The producer reference assumes that the T-shirt is ironed after 10 per cent of washes. This is realistic for a normal T-shirt, but for other types of cotton clothing, where the ironing requirement is 100 per cent,

minimised need for ironing will have a greater impact. Again, any new process will have to be assessed for environmental impacts in order to determine its contribution to the environmental impact potentials. The producer has an indirect possibility to make the consumption pattern more environmentally friendly by removing general annoyance factors such as creased textiles.

Consequences of choices by the consumer

The consumer reference is based on the main scenario for the lifecycle of 1 T-shirt. The assumptions for the model are described in the Background Data section at the end of this annex.

The consumer is primarily able to influence the use phase and parts of the transport phase. The other phases can primarily be influenced by the producer. Secondly, the consumer is able to choose producer selectively through, e.g. ecolabel schemes, which can ensure an environmentally correct choice.

The use phase includes washes with prewash and at 60°C, 100 per cent drying, and 100 per cent ironing. Transport home by car from the shop is included, and the impact is spread over 6 kg goods per T-shirt.

Scenarios - consumer

Scenario 10: Choice of wash - halving wash frequency

Scenario 11: Choice of wash - reduced washing temperature from 60 °C to 40 °C and no prewash

Scenario 12: Choice of wash - use of fabric softener

Ironing and drying

Scenario 13: No use of tumbler dryer

Scenario 14: No ironing

Transport home

Scenario 15: Transport home - car with shopping

Optimised use phase

Scenario 16: Half the number of washes, no drying in tumbler dryer and 10 per cent ironing

- incl. lifetime

Scenario 17: Half the number of washes, no drying in tumbler dryer and 10 per cent ironing and twice as long lifetime

- the green consumer's T-shirt

Scenario 18: Half the number of washes, no drying in tumbler dryer and 10 per cent ironing, produced in organic cotton.

Scenario 10: Choice of wash - halving wash frequency

In the functional unit the T-shirt is deemed to be washed after use for 1 day with a lifetime corresponding to 50 washes. The consumer can influence this parameter. This involves consumer habits and consumption patterns. This scenario is to show how much consumer habits influence the overall environmental profile. The following assumes that the T-shirt is washed after being used twice, i.e. half as many washes in private households, resulting in half as many dryings in a tumbler dryer and ironing compared to the

consumer-reference scenario. The changes are expected to influence environmental impacts related to energy, resource consumption, as well as toxicological impact types, where use of washing agent has an impact.

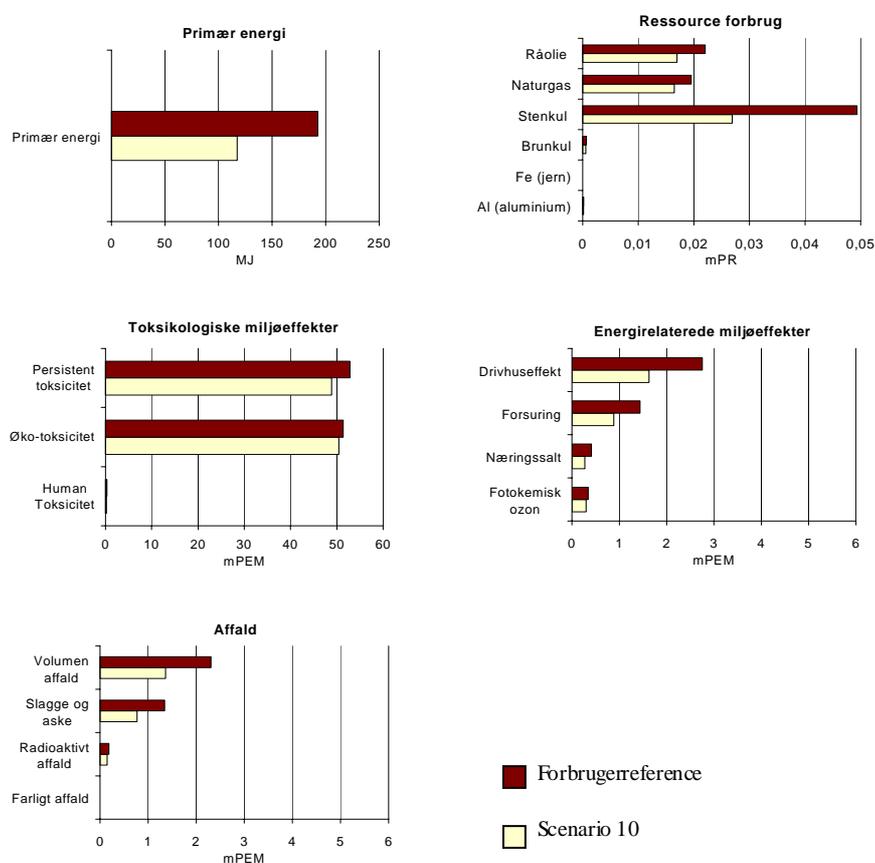


Figure 1.18 Result of scenario 10 - great consumer influence – for translation of Danish terms see glossary in annex 11

Consumption of primary energy is reduced by 40 per cent as a result of lower electricity consumption, primarily for drying. With regard to resources, consumption of fossil fuels is also reduced. The largest reduction is consumption of coal (about 50 per cent), as shown in figure 1.18. Furthermore the environmental impacts related to energy are reduced by 30 - 40 per cent because of the 50 per cent reduction in use of electricity. As a result of the lower number of washes and consequent lower use of washing agent, there is a slight reduction in the toxicological environmental impacts.

Conclusion to scenario 10

The conclusion to this scenario is that the consumer has a large influence on the overall environmental profile of the T-shirt. A lower number of washes saves the environment from a number of impacts and also increases the lifetime of the T-shirt, provided the assumption that the number of washes wears out the T-shirt is correct. The increased lifetime is not taken into account. This would mean a reduction in the environmental impacts in the manufacturing and production phase.

Scenario 11: Choice of wash - lower wash temperature and no prewash

An important parameter in the use phase is the temperature of the water in the washing process and the choice of programme with or without prewash. The effectiveness of modern washing machines can mean that temperature and prewash do not affect the quality of the wash.

In this scenario the household wash in the use phase is done at 40 °C and without a prewash. It is assumed that the wash programme does not affect the quality of the wash, i.e. the wash process is identical for the two wash programmes being compared.

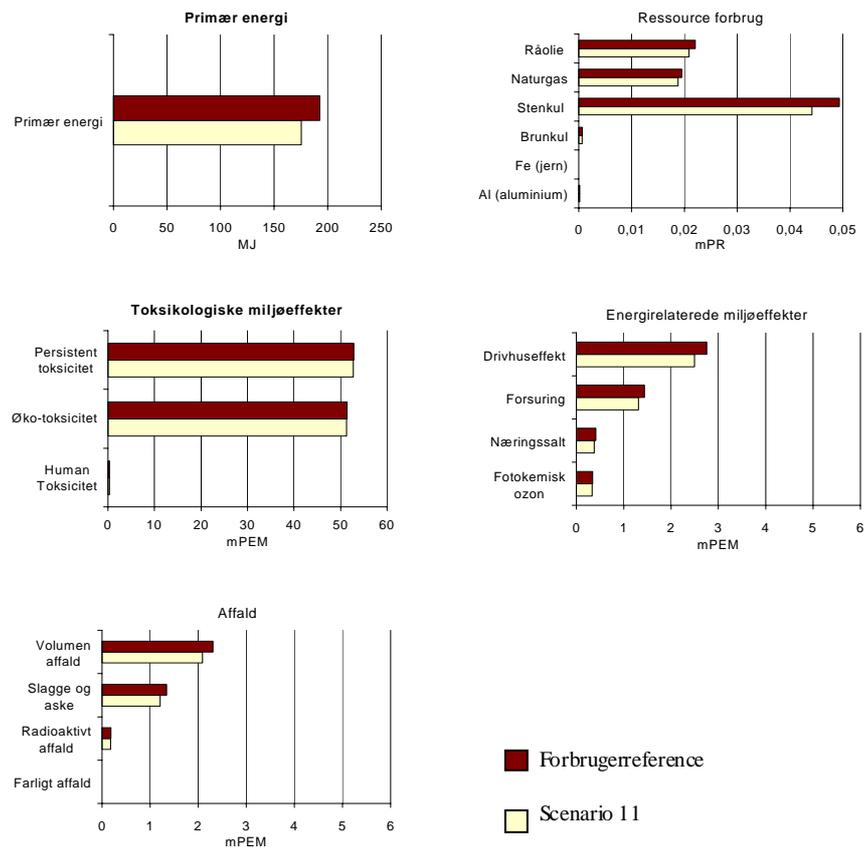


Figure 1.19 Result of scenario 11 – for translation of Danish terms see glossary in annex 11

Figure 1.19 shows a moderate influence on the overall environmental profile compared with the reference scenario. The lower consumption of primary energy is due to lower energy consumption to heat water and for the extra prewash. The same applies for resource consumption, waste and environmental impacts related to energy. The profile is unchanged for chemical-related environmental impacts.

Conclusion to scenario 11

There is no great reduction in the overall environmental profile from reducing wash temperature and skipping the prewash. However, it can be concluded that the consumer can influence the environmental profile through choice of wash procedure. And from a larger perspective the consumer can save the environment from considerable impacts by thinking about how washing is done.

Scenario 12: Choice of wash - use of fabric softener

Fabric softener is primarily used in the production phase, which uses large amounts after dyeing to achieve the quality required for further processing. Moreover, fabric softener is used in many homes as part of an ordinary machine wash.

Consumer surveys show that 60 per cent of the Danish population use fabric softener (Madsen, 1995). Fabric softeners in households are not the same as those used by industry, so it is not possible to compare the two processes directly. This scenario has been prepared in order to demonstrate the use of fabric softeners in the home.

It is assumed that 3 g of active substance are used per wash. This dosage is different from product to product, but is based on an average. Therefore it is also assumed that the consumer uses the recommended dose. The database does not include production of the fabric softener, packaging or transport home. Therefore the only difference is that the toxicological environmental impacts are increased.

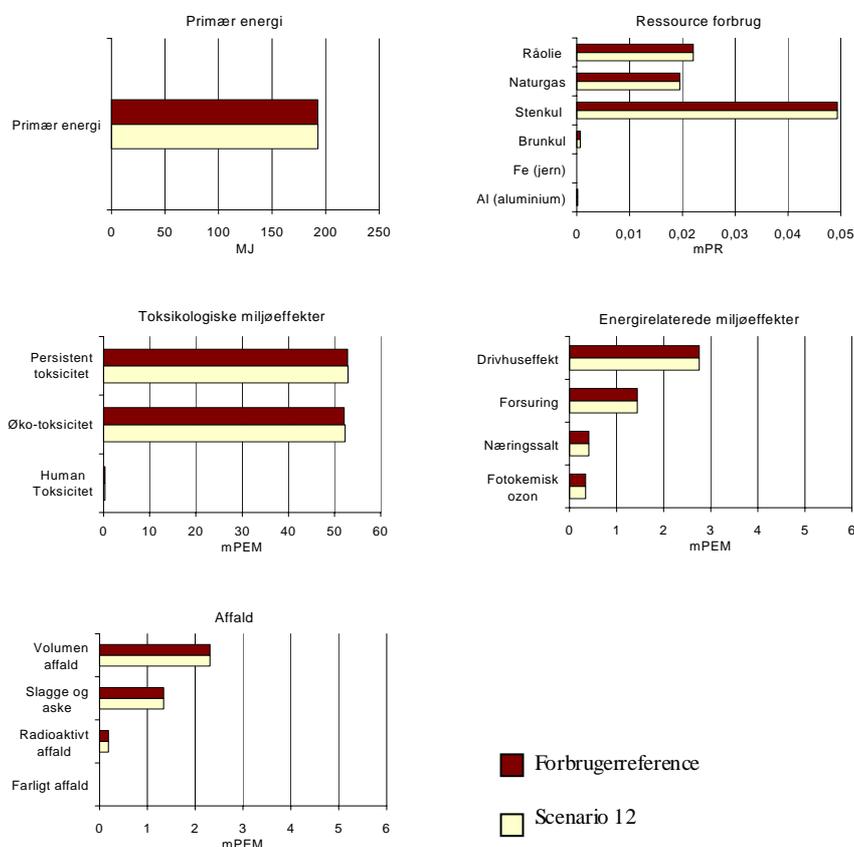


Figure 1.20 Result of scenario 12 – for translation of Danish terms see glossary in annex 11

The largest increase is for ecotoxicity, which is increased by about 0.4 per cent. There is almost no change in persistent toxicity at only 0.1 per cent. Human toxicity is unchanged compared with the consumer reference scenario.

Conclusion to scenario 12

The conclusion to this scenario is that fabric softeners used in household washes affect the overall environmental profile of a T-shirt when toxicological environmental impacts are looked at in isolation. The impact is greatest if the material is organic. Furthermore, if overdoses are applied there will be greater consequences for the environmental profile and thus even greater toxicological environmental impacts. This scenario can also give a signal to the producer to improve the product so that it is not necessary to use softener.

Scenario 13: No tumbler drying

Drying in the home can primarily use two methods. Drip drying on a clothesline or use of tumbler dryer. Often simple factors such as space, time, and economics determine the method used. The clothesline requires more space and can be time demanding in some seasons (if clothes dry outdoors), but it is more or less cost free. Tumbler drying does not require much space and has a constant and short drying time, but it requires electricity consumption.

This scenario ignores any wear on the T-shirt from using a tumbler dryer. The reference scenario is based on the T-shirt being tumbler dried after washing. In this scenario drying in a tumbler dryer is excluded. The scenario is to show the consequences of choosing to tumbler dry on the overall environmental profile.

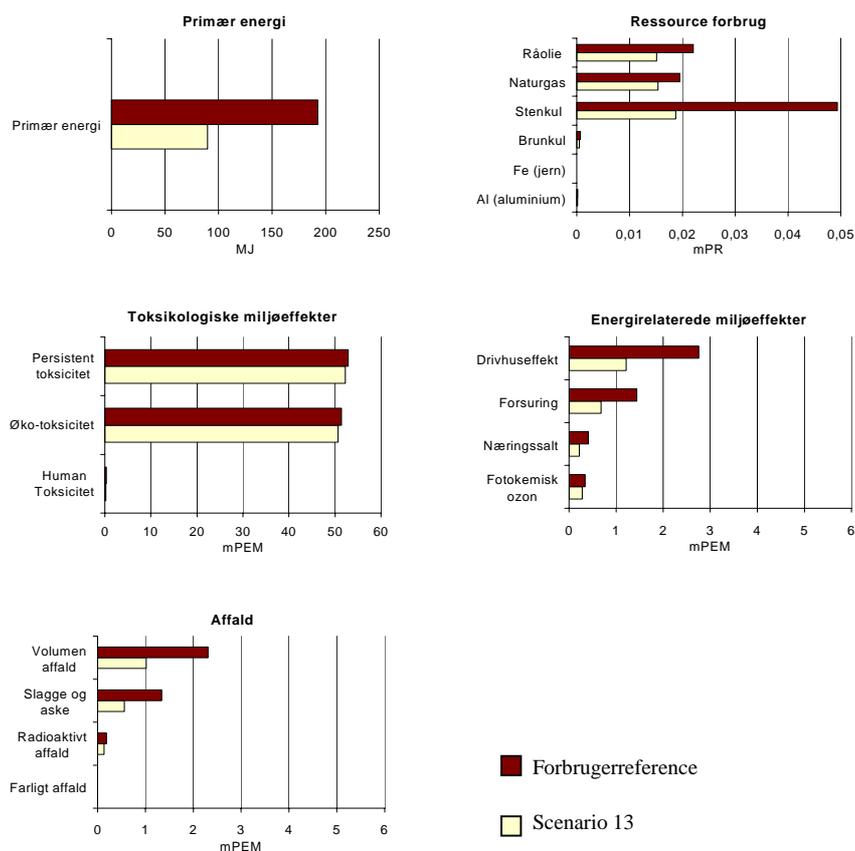


Figure 1.21 Result of scenario 13 – for translation of Danish terms see glossary in annex 11

Consumption of primary energy is reduced by 50 per cent as a result of lower electricity consumption. With regard to resources, consumption of fossil fuels is also reduced. The greatest reduction, as shown in figure 1.21, is

consumption of coal, by approx. 60 per cent. Furthermore most of the impact potentials in the environmental impacts related to energy are reduced by 40-50 per cent because of lower consumption of electricity. There are only slight changes in the toxicological environmental impacts.

Conclusion to scenario 13

The conclusion to this scenario is that, just as in scenario 10, the consumer's consumption patterns have a great influence on the overall environmental profile of the T-shirt. Drying in a tumbler dryer is very detrimental to the environmental profile, reductions of up to 40-60 per cent can be achieved in a number of impacts by not drying in a tumbler dryer.

Large electricity consumption results in high consumption of resources and gives many environmental impacts related to energy. By not tumbler drying it is also possible that the lifetime of the product will increase as tumbler drying wears the product. No account is taken of extended lifetime in this case. Extended lifetime will mean a reduction in the environmental impacts in the manufacturing and production phases.

Scenario 14: No ironing

Ironing is the final step in the use phase before use. It is hard to say exactly how often a T-shirt is ironed as this depends on the individual consumption pattern. In order to get an impression of the significance of the process for the overall profile, this scenario assumes that the product is not ironed after washing and drying. This is a considerable reduction compared with the reference scenario, which assumes ironing after each wash and drying.

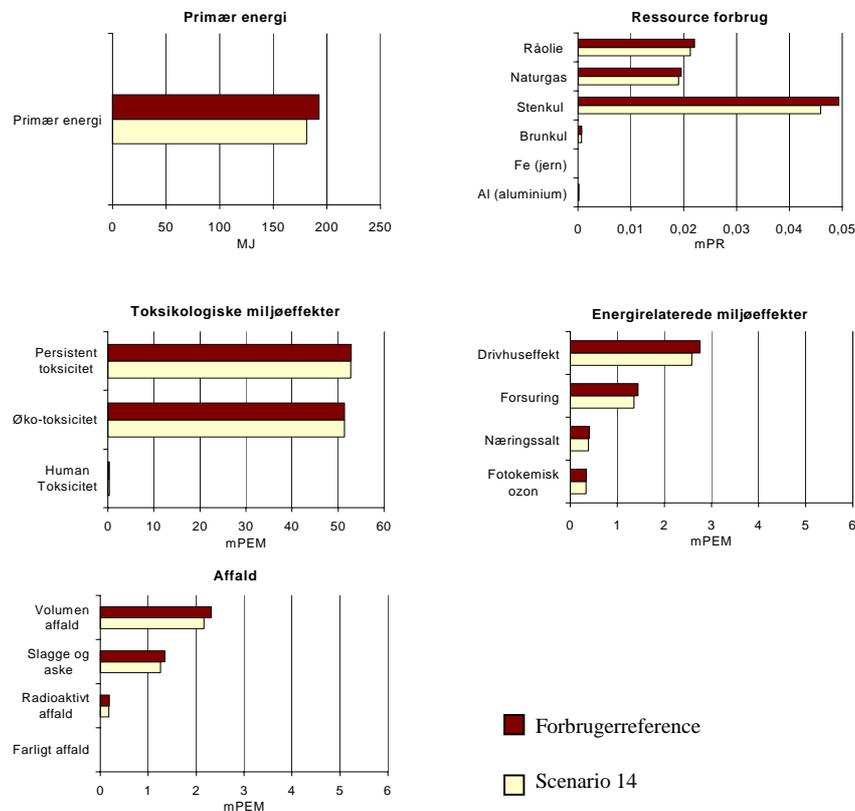


Figure 1.22 Result of scenario 14 - minimal consequences – for translation of Danish terms see glossary in annex 11

Figure 1.22 shows that ironing only has a slight impact on the environmental profile. There is a slight reduction of 2-6 per cent in primary energy, resources, and in almost all impact categories corresponding to the energy consumption in ironing. Only the toxicological environmental impacts are unchanged compared with the reference scenario.

Conclusion to scenario 14

Whether or not the T-shirt is ironed has no great impact on the overall environmental profile. There are other, more important processes in the use phase with greater influence, as shown in some of the other scenarios. The reduction achieved by reducing ironing frequency could be seen in another light, if at first the contributions to the overall profile from the other processes are reduced. Then the impacts of leaving out the ironing process will comprise a greater proportion.

Scenario 15: Transport home - car with shopping

Transport in the use phase can vary from a trip on a bike, to public transport to transport in a private motorised vehicle. Moreover, transport from the shop to the home can be with or without other shopping. It is assumed that transport is in a petrol-powered car. If transport is with other products, the trip must be divided between these. The reference scenario assumes total shopping of 6 kg, of which the T-shirt comprises 250 g. The distance driven is estimated at 10 km with petrol consumption of 12 km per litre. In order to simplify the influence of transport to the home on the environmental profile, this scenario does not allocate the impacts to other products in transport home. I.e. the entire petrol consumption for transport home from the shop is allocated to the T-shirt.

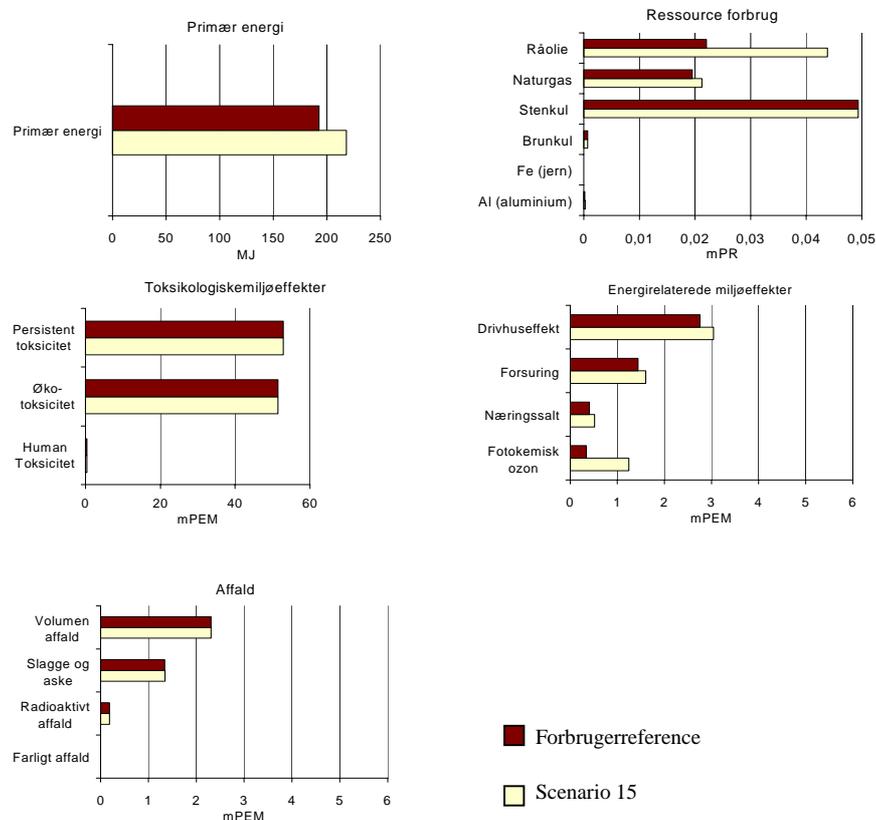


Figure 1.23 Result of scenario 15 – for translation of Danish terms see glossary in annex 11

The change in mode of transport home, as shown in figure 1.23, means an increase in consumption of primary energy corresponding to approx. 12 per cent. This is due to extra consumption of crude oil of about 50 per cent to produce the petrol (see the figure). Combustion of petrol by the engine means that there is a slight increase in the environmental impacts related to energy. The largest increase is photochemical ozone, which increases by 65 per cent.

Conclusion to scenario 15

This scenario shows that the consumer can influence consumption of crude oil and the resulting impact potential considerably in the choice of transport means and planning shopping. Shopping for one item alone is very detrimental to the overall environmental profile. By coordinating shopping, the consumer can reduce total transport use.

Optimised use phase scenarios

The three following scenarios attempt to illustrate the various optimised use phases. Scenarios 16-18 are set up at three levels of optimisation. Scenario 16 contains optimised washing processes, scenario 17 involves lifetime, and finally scenario 18 shows the consequence of including organic cotton.

Scenario 16: Optimised use phase - half the number of washes, no tumbler drying, 10 per cent ironing

By combining the previous scenarios, a consumption pattern is modelled including a T-shirt which is washed 25 times, dried without using a tumbler dryer and ironed 10 per cent of the time.

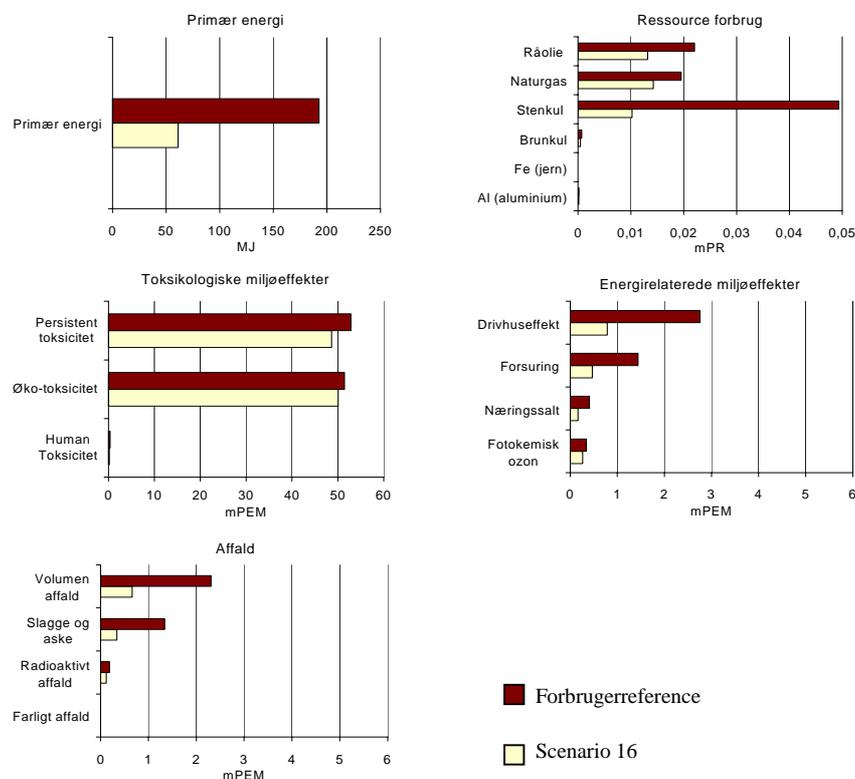


Figure 1.24 Result of scenario 16 – for translation of Danish terms see glossary in annex 11

As for scenarios 10 and 13, the large reduction in consumption of primary energy is because the tumbler dryer is not used in the use phase. Compared with the reference scenario the reduction in primary energy is 70 per cent. This large energy reduction leads to a corresponding drop in resource consumption, primarily comprising coal to generate Danish electricity. The environmental impacts related to energy and the waste categories are therefore also reduced because of lower energy consumption. There is no significant reduction in toxicological impacts.

Conclusion to scenario 16

The first optimised use phase scenario shows that the consumer can relatively easily influence the lifecycle profile of a T-shirt by washing less frequently and not using a tumbler dryer. Scenario 14 showed that ironing had more or less no influence on the environmental profile, but by combining less ironing with less use of the tumbler dryer and less washes, an overall larger environmental benefit can be achieved.

Scenario 17: Optimised use phase - half the number of washes, no drying in a tumbler dryer, 10 per cent ironing and double lifetime

This scenario is a further development of scenario 16.

It is assumed that halving the number of washes and better product quality gives a longer product life of 2 years. In relation to the functional unit and the reference scenario, this means that in 1 year, half a T-shirt is worn out. This means that for each year only half the amount of material is required and only half a T-shirt needs to be produced, transported and disposed of. On the assumption of extended lifetime, the result is as in figure 1.25.

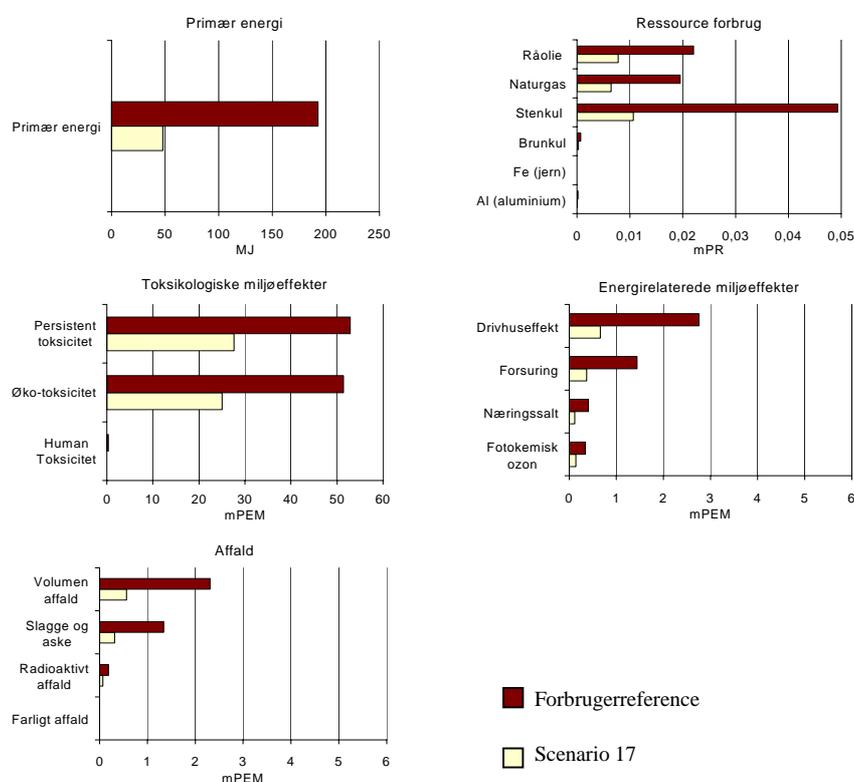


Figure 1.25 Result of scenario 17 – for translation of Danish terms see glossary in annex 11

There is a considerable reduction in consumption of primary energy of about 75 per cent, and similar reductions in consumption of resources and environmental impacts related to energy. The reduction is primarily because a tumbler dryer is not used and there are fewer washes in the use phase. Because materials, production, transport and disposal of a T-shirt are spread over 2 years, the phases' contributions are reduced by 50 per cent. This halving also means a 50 per cent reduction in the toxicological environmental impacts. This is primarily because the toxicological environmental impacts come from the material phase, where many pesticides are used in cotton cultivation.

Conclusion to scenario 17

This scenario shows that by combining product improvements and consumption patterns, significant environmental benefits can be achieved. In this scenario all impacts and parameters are reduced by at least 50 per cent compared with the reference scenario.

Scenario 18: Optimised use phase - half the number of washes, no drying in a tumbler dryer, 10 per cent ironing, double lifetime and produced in organic cotton

This scenario is identical to the previous scenario 17, with the addition that material made of organic cotton is used.

An environmentally correct consumption pattern, combined with use of organic materials in the materials phase. The green T-shirt.

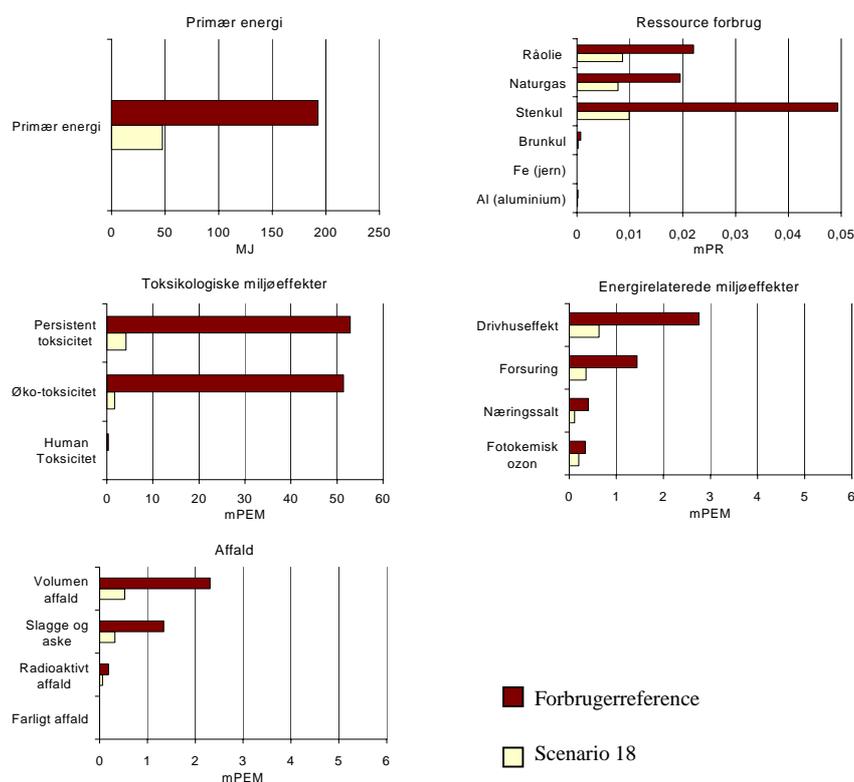


Figure 1.26 Result of scenario 18 – for translation of Danish terms see glossary in annex 11

Figure 1.26 shows the environmental profile for the green T-shirt. The picture is more or less the same as in scenario 17 for primary energy, resources and the environmental impacts related to energy. For toxicological

environmental impacts, a total reduction of 93-97 per cent is achieved. This is primarily due to use of organic cotton and extended lifetime. Today, large amounts of pesticides are used in conventional cotton production in order to ensure large yields. Scenario 1 shows the consequences of using organic cotton in isolation.

Conclusion to scenario 18

Scenario 18 shows the result of taking the right environmental decisions throughout the whole lifecycle. There is at least a 70 per cent reduction in all categories compared with the reference scenario. The conclusion is that the consumer has the greatest influence on the environmental profile of a T-shirt – first by choosing an organic product and then considering the environment in the use phase by washing as little as possible, drip drying and not ironing. The producer can help here by manufacturing non-iron textiles with lower drying requirements (scenario 8) and mechanical softening after dyeing.

Considerations regarding disposal

There is no scenario dealing with the disposal process because the T-shirt is expected to be disposed of with household refuse in Denmark. It is assumed that old T-shirts are relatively rarely sent to recycling stations or the Third World, as old cotton T-shirts are often used as dusters or similar before being thrown away. If the T-shirt is sent to the Third World, it will probably be very worn before being disposed of at a landfill or burnt. Both processes recover no energy and the total contribution to the lifecycle of the T-shirt therefore changes. Only the consumer can influence this choice and thus influence the total consumption of primary energy.

Background data

System structure in the EDIPTEx database for the T-shirt

	Ref. no.: EDIPTEx database
1 T-shirt (cotton)	(TX0-02)
1 materials phase: 0.4 kg cotton fibre (incl. cultivation and harvest)	(TX6-1-04) (TX1-01-1)
1 production phase: 0.2727 kg bleach H ₂ O ₂ (knitted cotton) 0.28 kg yarn manufacture (cotton yarn) 0.275 kg T-shirt knitting 0.2727 reactive dyeing (3%) of cotton goods 0.27 kg drying final fixing + set of m ² weight 0.27 kg softening cotton textile 1.773 m ² fabric inspection + rolling onto cardboard roll 1 cutting and stitching 1 packing	(TX6-2-11) (TX24-1-03) (TX21-1) (TX22-1-02) (TX25-01-01) (TX27-3-06) (TX6-2-16) (TX27-3-08-06) (TX28-1-02) (TX28-2-03-02)
1 use phase: 12.5 kg household wash, 60 °C, with prewash 12.5 kg tumbler drying cotton (vented), cupboard dry 150 min. Ironing cotton or other cellulose	(TX33-1-202) (TX33-3-01) (TX33-3-01)
1 disposal phase: 0.25 kg waste incineration of cotton	(TX6-4-02) (TX41-1-01)
1 transport phase: 0.07 kg petrol combusted in petrol engine 800 kg km container ship 2-t. 28000DWT, terminated 66.8 kg km lorry > 16 t diesel out-of-town, terminated 66.8 kg km lorry > 16 t diesel urban traffic, terminated 66.8 kg km lorry > 16 t diesel motorway, terminated	(TX6-5-02) (E32751) (O3715T98) (O32694T98) (O32695T98) (O32693T98)

Details of the T-shirt model in the EDIPTEx database

Assumptions:

- 100 per cent cotton
- Dye: reactive dye
- Washing 40°C, possibly 60°C
- Tumbler drying
- Ironing not necessary (but done by many)
- Lifetime: 50 washes.
- Weight: Three different qualities of T-shirt have been weighed: 178 g ("thin" quality), 223 g and 292 g (heavy quality). For this environmental assessment, the assumption is that the T-shirt weighs 250 g.

Functional unit

The calculations are for "1 T-shirt".

This needs to be converted in relation to lifetime, and the calculations need to be converted to "per year".

It is assumed that the T-shirt can be washed 50 times before it is discarded. It is assumed that the consumer wears the T-shirt 50 days per year.

It is assumed that the T-shirt is used for 1 day and is then washed. Any need for a sweatshirt over the T-shirt to keep warm on some days has not been included.

If the T-shirt is washed after each use, 50 days' use of the T-shirt means that 1 T-shirt is completely used up in one year - or more likely - that a person has 5 T-shirts that together last 5 years.

The functional unit for a T-shirt is therefore:
"50 days' use of T-shirts washed each time after use".

It is assumed that 50 days correspond to the number of days a consumer wears a T-shirt over the course of 1 year. Some consumers have an entirely different consumption of T-shirts. Some people wear a T-shirt every day (often men), while other people do not own a single T-shirt (e.g. women in the age of 60-80).

For the reference scenario this corresponds to 1 T-shirt being completely worn out (in that it is assumed that the T-shirt is washed after use for 1 day).

Note: There are also calculations of the significance of the consumer using the T-shirt twice before each wash, even though this means that the consumer must compromise quality requirements for cleanliness. This calculation has another functional unit than the above and therefore there are reservations regarding comparisons.

Disposal:

It is assumed that the T-shirt is sold in Denmark and disposed of through waste incineration. 0.25 kg cotton.

Household wash:

It is assumed that the T-shirt can be washed 50 times in its lifetime. This means that $0.25 \text{ kg} * 50 = 12.5 \text{ kg}$ cotton must be washed in the lifetime of the T-shirt.

Drying:

It is assumed that the T-shirt is dried in a tumbler dryer. 12.5 kg cotton.

Ironing:

It is not necessary to iron a T-shirt. Many do so anyway. Ironing is therefore included as a "case". The calculations assume it takes 3 minutes to iron a T-shirt (1 minute each side and 1 minute to heat up the iron). If the T-shirt is ironed after each wash, this is $3 \text{ minutes} * 50 = 150 \text{ minutes}$.

Packing the T-shirt:

It is assumed that the T-shirt is packed in a thin plastic bag. It is assumed the bag weighs 10g.

Laying out, cutting and sewing the T-shirt:

There is no company data for a T-shirt. A new process has been set up: Laying out, cutting and sewing the T-shirt. TX28-1-02. The process is calculated "per T-shirt". It is assumed that energy consumption is the same as for a tablecloth (for which there is company data).

According to Laursen et al. 1997, waste is 6-25 per cent. For a T-shirt it is assumed that waste is 6 per cent as a T-shirt is one of the simplest garments for cutting and sewing. This means $0.25 \text{ kg} / (1-0.06) = 0.266 \text{ kg}$ textile must

be used. It is assumed that the waste is discarded (incinerated at a waste incineration plant).

Fabric - inspection and rolling onto a cardboard roll

There is no company data for knitted fabric for a T-shirt. It is assumed that data is the same as for woven fabric for a tablecloth. Therefore process no. TX27-3-08-06 is used. Amount: see previous process: 0.266 kg approved textile after the fabric inspection.

Fabric inspection uses 1.015 kg textile per kg approved textile after the fabric inspection. Therefore 0.270 kg textile must be produced (dried and fixed).

Drying, final fixing and setting square-metre weight:

As mentioned above, 0.270 kg textile must be used per T-shirt. This corresponds to 1.8 m² textile (dried and fixed) per T-shirt weighing 150 g per m².

As there is waste in drying and final fixing, 1010 g dyed fabric per kg dried fabric are used. This means 1.01 * 0.270 kg = 0.2727 kg reactive-dyed textile must be used.

Reactive dyeing (3%) cotton goods:

0.2727 kg is used by this process per T-shirt. There is no waste of textile in this process.

Bleaching with H₂O₂ (knitted cotton):

0.2727 kg is used by this process per T-shirt.

There is waste in the process, and therefore 1010 g knitted textile must be used per kg bleached textile. Therefore 0.275 kg knitted textile must be used per T-shirt.

Knitting:

0.275 kg textile must be knitted per T-shirt.

1.015 kg yarn is used per kg circular-knitted textile. Therefore 0.280 kg yarn is used per T-shirt.

Yarn manufacturing:

0.280 kg yarn must be used per T-shirt. 1.43 kg cotton fibre is used per kg cotton yarn. Therefore 0.40 kg cotton yarn is used for one T-shirt.

Cotton fibre:

0.40 kg cotton fibre is used for one T-shirt.

Transport:

All transport distances are estimated. See table below.

Transport	Quantity for one T-shirt	Kg km
Transport of cotton	0.40 kg transported 2000 km by ship	800 kg km by ship
Transport of yarn	0.28 kg transported 200 km by lorry	56 kg km by lorry
Transport of knitted fabric	0.275 kg transported 200 km by lorry	55 kg km by lorry
Transport of dyed fabric	0.27 kg transported 100 km by lorry	27 kg km by lorry
Transport from factory to shop, lorry	0.25 kg transported 200 km by lorry	50 kg by lorry
Transport of discarded T-shirt (with household refuse)	0.25 kg transported 50 km by lorry	12,5 kg by lorry

Lorry, total: 200 kg km (assumed 33 per cent urban, 33 per cent out-of-town, 33 per cent motorway).

Consumer transport: It is assumed that the consumer drives in town by car to buy 1 T-shirt and 2 kg other goods. It is assumed the consumer drives 10 km and the car goes 12 km per litre. This means 0.83 l petrol is used (= 0.61 kg petrol, as petrol weighs 0.73 kg per litre). Of this, $0.61 * 0.25/2.25$ is allocated to the T-shirt, i.e. 0.07 kg petrol.

I.e. total transport:

Process no. in EDIPTEX database	Name of process	Transport need
O32715T98	Container ship, 2-t, 28000 DWT, TERMINATED	800 kg km by ship
O32695T98	Lastbil >16t, diesel urban traffic TERMINATED	66,8 kg km by lorry
O32694T98	Lastbil >16t diesel out of town landev.TERMINATED	66,8 kg km by lorry
O32693T98	Lastbil, >16t diesel motorway.TERMINATED	66,8 kg km by lorry
E32751	Petrol consumed in petrol engine	0,07 kg petrol

Annex 2: Jogging suit of nylon and cotton

The jogging suit - summary and conclusions

The main scenario for the jogging suit shows that the most significant focus areas are toxicological environmental impacts and resource consumption. The contribution to the toxicological environmental impact potentials originates from fertilizer and insecticides for cotton in fibre production and from production of the artificial fertilizer used. The resource consumption and the contributions to the environmental impact potentials related to energy mainly originate from nylon production and washing and drying of the jogging suit during its use phase.

At an overall level, the scenarios indicate that there are good possibilities for influencing the environmental profile of the jogging suit for both the producer and the consumer.

The producer's options primarily lie in its choice of materials and chemicals. The former is made clear in the scenarios where organic cotton has been used. By living up to European and Scandinavian ecolabelling criteria and obtaining labelling approval, the producer can signal to the conscious consumer that the product in question has been produced in an environmentally sound manner. Moreover, there are a number of production-related improvements that only the producer can influence. This could be choices related to:

- use of organic materials
- development of hard-wearing materials
- choice of softener
- choice of fastness improver
- choice of knitting oil
- use of non-toxic dyes.

The individual consumer's consumption patterns and environmental awareness are also crucial for the jogging suit's environmental profile. Knowledge and choice of ecolabelled products may encourage the producer to produce environment-friendly products as described in brief above. In the use phase, good environmentally friendly habits allow the consumer to affect the overall profile. As the use phase is very dominant, this is an extremely important area.

- choice of the product that has been produced in the most environmentally friendly manner
- most environmentally friendly washing (40/60/90)
- minimal use of washing agent
- no use of fabric softeners
- no tumbler drying.

Thus, the conclusion is that focus should be on the fibre production phase, the production phase and the use phase.

Introduction

Lifecycle assessment is a method for identification and evaluation of environmental impact potentials of a product or a service from cradle to grave. This method enables the user to make an environmental assessment and focus on the most important environmental impacts.

Lifecycle assessment is an iterative process. The first definition of purpose and delimitations often need to be revised during work with lifecycle assessment. The amount of data available sets limits, and consequently the limits of the system are changed.

The method used in this case for assessment of products is "Environmental Design of Industrial Products" (EDIP) and the associated database and PC tool.

In the EDIPTEX project, sector-specific data have been prepared for the textiles sector in connection with the existing EDIP database. The reports contain environmental assessments for the following textile products:

- T-shirt
- Jogging suit
- Work jacket
- Floor covering
- Tablecloth
- Blouse.

These environmental assessments are intended to illustrate the scope for application of the EDIPTEX database by using the PC modelling tool and, at a more general level, application of the EDIP method.

Method

The six case stories vary a lot in scope. They can be divided into two main groups - with variations within these two main groups. The two main groups are:

- Group I: The T-shirt, the jogging suit and the work jacket.
- Group II: The floor covering, the tablecloth and the blouse.

The division into groups I and II relates to the scope of the collection of data as well as the quality of data.

For group I, it was possible to collect (and process) data for all significant processes. The data are of such quality that these three products have been selected to illustrate how far it is possible to take lifecycle assessment for textiles and to illustrate all relevant aspects of the EDIP method.

Each of the three group I cases contains:

- Definition of functional unit and reference product
- Modelling of main scenario

- Preparation of producer and consumer references
- Simulation of environmental impacts caused by choices made by producer and consumer respectively.

Work with these cases has been divided into phases as illustrated in figure 2.1.

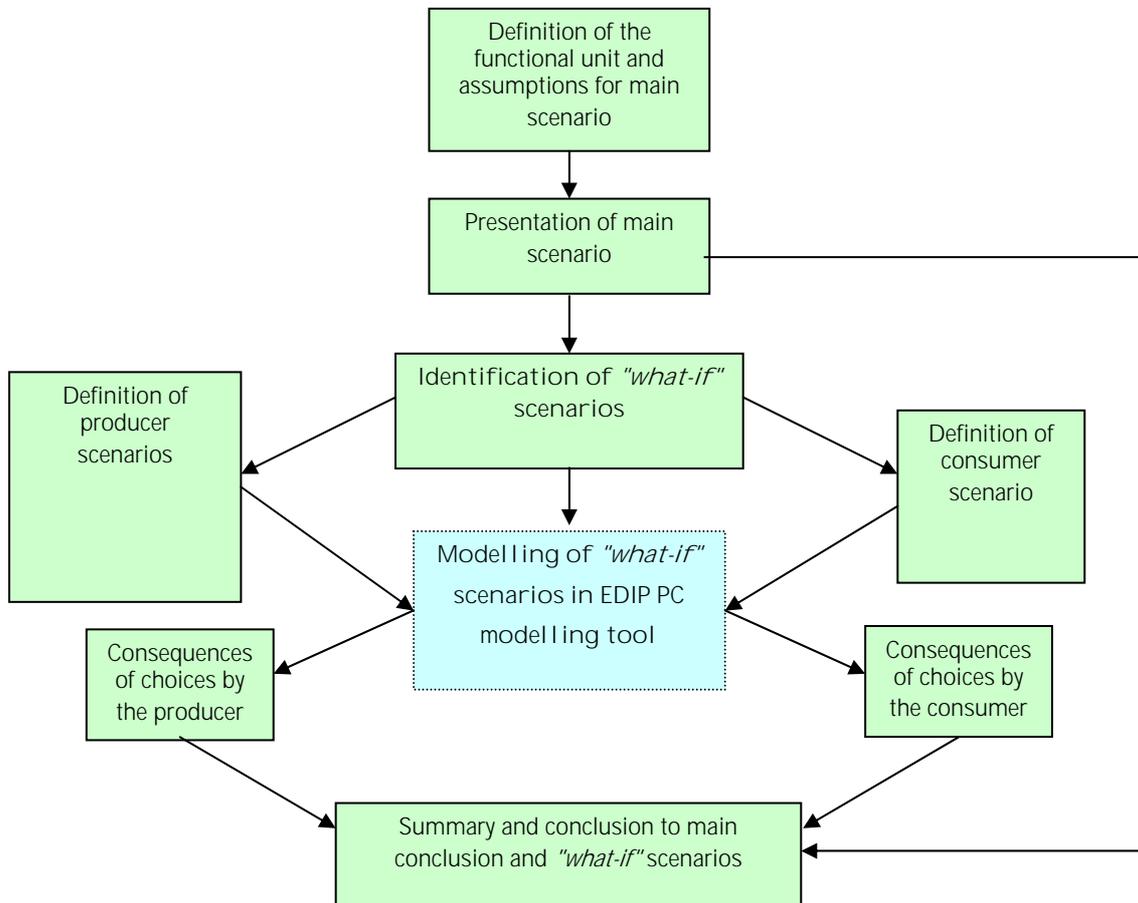


Figure 2.1 EDIPTEX case group I flow diagram

For group II, it was not possible to complete all sub-processes. Although only 1-2 sub-processes for each product have considerable lack of data, these processes are deemed potentially significant for the overall lifecycle assessment. The group II case stories are therefore of an entirely different character than those of group I.

The group II cases illustrate that it is possible to tell an interesting and exciting "environment story" based on lifecycle assessment (and EDIP) even though it has not been possible to analyse all aspects of lifecycle assessment data. This situation will arise very often in lifecycle assessment work. However, there is a significant difference in this EDIPTEX connection; it is possible to draw on results from the three lifecycle assessments from case group I (and this has been done), which improves the quality of the case stories.

Comments to the method

Product references

The "what-if" simulations were carried out to elucidate the consequences of possible changes in the product's lifecycle. A special product reference has been defined for the producer scenarios in some of the case stories. The producer only has limited influence on the use phase. In order to take this into account, a product reference has been prepared for the producer scenarios where only a limited part of the impacts from the use phase has been included in relation to the product reference from the main scenario. This was done in order to give producers a clearer picture of the influence of the production phase on the product's environmental profile in the "what-if" producer scenarios.

Data

With regard to data, it should be noted that the validity of the data in the database varies, depending on the processes considered. A global process like cultivation and harvest of cotton is subject to considerable uncertainty. This is because cotton is produced in countries with very different levels of development. For example, production varies a lot between South America and the US because of large differences in the use of pesticides, crop yields, etc.

This difference has not been taken directly into account in the EDIPTTEX database, but a representative level for the data has been defined. Therefore, the data are very general and not necessarily representative for all lifecycle assessments. Other processes are more exact, such as extraction of crude oil for nylon. This process is well documented, both as regards industrial accidents and as regards resource consumption.

Production data primarily come from Danish enterprises. The number of enterprises involved represents limitations in this connection. For example, only one reactive dye and one acid dye have been studied thoroughly. These two substances represent the entire group of dyes, despite the major differences that may occur.

A large proportion of the environmental impacts come from the consumption of electrical energy. The data currently used in the database originate from the EDIP database, and the reference year is 1990. This area is being studied in order to update this part of the database. It is important to note that this lifecycle assessment was carried out using the 1990 data in all processes that consume electrical energy.

The jogging suit

Product description: two-piece jogging suit; trousers and top with outer covering of nylon and lining of uncoloured cotton. Elastic in trouser waist and legs and cuffs in top are not included.

Functional unit

The performance assessed can be described as a "functional unit", comprising a qualitative and a quantitative description, including the product's lifetime.

The qualitative description is to define the quality level for the performance, so that products can be compared at a somewhat uniform quality level. The quantitative description is to determine the size and duration of the performance.

In this project, the functional unit is defined as:

"24 days' use of jogging suit over the course of one year"

Reference product and main scenario

The jogging suit consists of two layers of textile; an outer shell of nylon (also called microfibre) and a lining of uncoloured cotton. Moreover, this assessment includes a zipper in the top. It is assumed that cotton and nylon represent equal parts of the jogging suit as regards weight. Elastic in trouser waist and legs and cuffs has been disregarded due to lack of data for materials and production processes. These assumptions are included in the discussion.

If the jogging suit is washed after each use, 24 days use of the jogging suit means that 1 jogging suit is completely used up in one year. The use of jogging suits varies a lot from consumer to consumer.

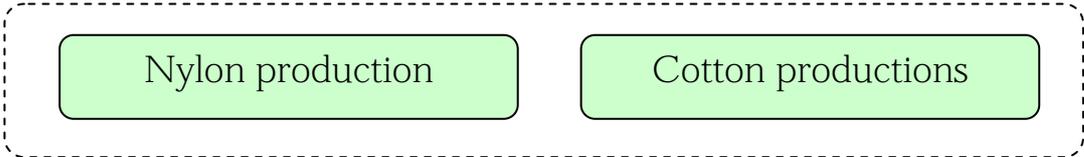
The reference product is assumed to meet the following criteria:

- Outer shell of woven nylon
- Nylon dyeing: acid dyes
- Lining of knitted cotton
- Cotton lining assumed to have been pre-washed, softened and bleached after knitting
- Two-piece; top and trousers
- Top includes zipper of polyester (both tape and teeth), approx. 60 cm long - zipper weights approx. 6 g, i.e. 0.1 g per cm.
- No print on the jogging suit
- Wash at 40°C
- Tumbler drying
- Ironing not necessary
- Weight: top weighs 406 g, of which 6 g is the zipper; trousers weigh 300 g. The lining weighs 50 per cent of the total weight, i.e. top: 200 g cotton, 200 g nylon. Trousers: 150 g cotton, 150 g nylon. Total: 350 g nylon and 350 g cotton. Total weight: 706 g.

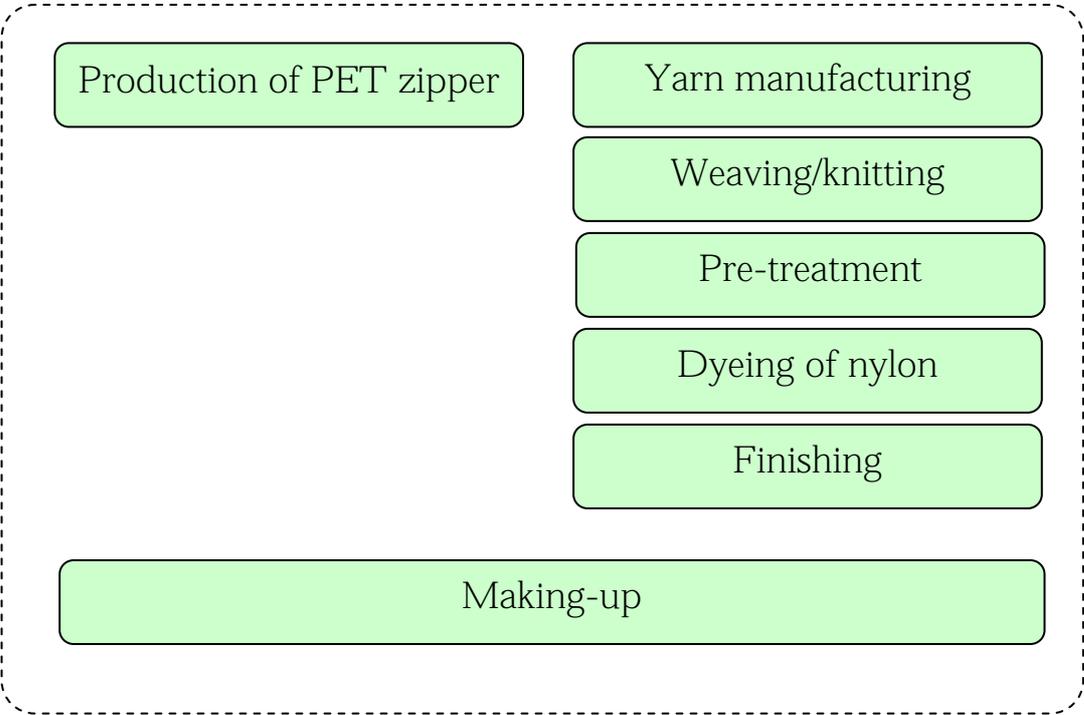
A more detailed description of the processes, calculations of volumes, waste, etc. can be found in the section "Background data" at the end of this annex.

Product system

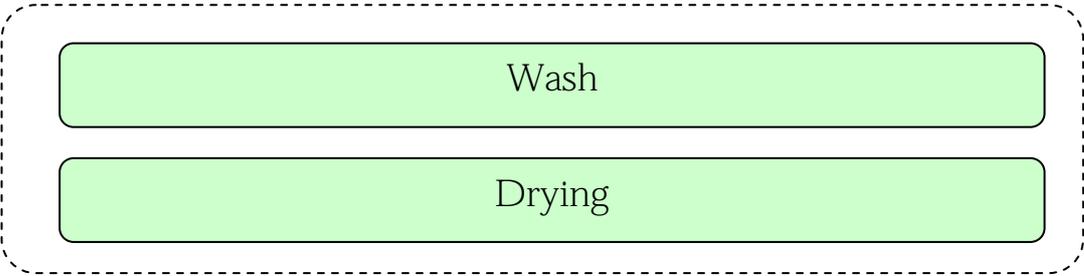
Materials phase



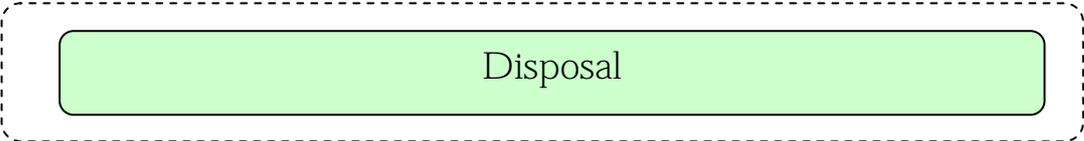
Production phase



Use phase



Disposal phase



Transport phase

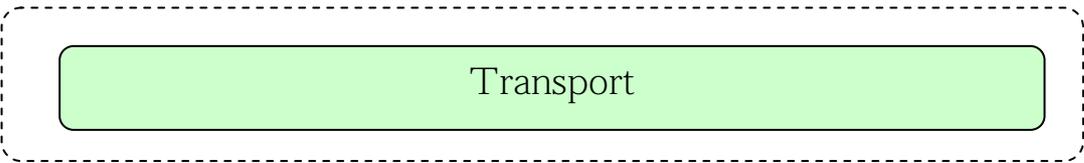


Figure 2.2 Lifecycle, flow and phases

Figure 2.2 describes the lifecycle of the jogging suit. From extraction of raw materials through production to the making-up of the finished jogging suit, the product has two parallel lifecycles due to the two layers of textile, cotton and microfibre.

The product's lifecycle phases from extraction of raw materials to disposal are described in the following.

Manufacture of raw materials

As mentioned, there are two main materials in the jogging suit assessed:

- Cotton
- Nylon (microfibre)

In the following, the lifecycle is described in more detail.

Cotton manufacture

Cotton is cultivated in many countries under different geographical and climatic conditions. Cultivation often entails a large consumption of artificial fertilizer, large water consumption and a large consumption of pesticides against insect attacks, diseases, worms and weeds. The extent of this depends largely on local conditions. The consumption of pesticides entails an important environmental problem for both human health and nature.

Irrigation and use of artificial fertilizer impact groundwater and surface water resources quantitatively as well as qualitatively. Before picking, it is common to use defoliating agents so that picking can be done mechanically.

Organic cotton

It is normally not permitted to use pesticides and artificial fertilizer in cultivation of organic cotton. Thus, it is only permitted to use a very limited selection of plant protection agents, and only when there is an acute danger for the crop. Organic production of cotton constitutes less than 1 per cent of total cotton production, but organic production is increasing and is expected to increase further due to increased demand.

Production of synthetic fibres

Nylon is produced on the basis of crude oil and natural gas that are converted to plastic through a number of chemical processes. The raw material is a limited resource, and production may lead to impacts on humans and the environment at local, regional and global levels. During processing of the materials into fibres, lubricants are usually added in the form of spindle oil and antistatic agents. Bactericides and fungicides may be added.

Production of the jogging suit

Production is divided into several sub-processes: yarn manufacturing, dyeing, finishing, making-up and distribution. Both cotton and nylon go through all these processes, although yarn manufacturing, dyeing and finishing are not the same for the two types of textile.

Yarn manufacturing

The cotton fibres are carded, combed and spun into yarns at a spinning mill. Before the cotton can be spun into yarn, the fibres need to be separated from the remaining plant material. One of the largest environmental risks in this process is inhalation of cotton dust. In just a few years, staff can develop the fatal disease Byssinosis (commonly called "Brown Lung"). It is therefore

important that machines be closed in so that dust development is minimal. This also applies for the actual spinning process where the fibres are spun into yarns.

Nylon yarns are produced by extruding the heated nylon granulates into endless yarns; called filament yarns. Then the yarns are split into very thin fibres called microfibrils. During the processing into yarn and microfibre, lubricants in the form of spindle oil and antistatic agents are usually added.

Manufacture of fabric

The cotton yarns are knitted on a circular knitting machine for fabric.

The nylon microfibrils are woven into fabric, without the use of sizing agents. These are agents that make the yarn stronger. Microfibrils give a light and strong textile with a silky, soft feel.

Pre-treatment

The cotton contains dirt and cotton wax that needs to be washed away in order to get a nice and uniform product. Remains of pesticides from cotton cultivation, mainly defoliation agents used in connection with the harvest, are also washed out in this process and end up in the wastewater.

The natural colour of the cotton fibres is removed by bleaching them. If chlorine bleaching is carried out, AOX compounds (adsorbable organic halogens) will be formed and subsequently discharged. They are harmful to the environment. It is also possible to bleach using hydrogen peroxide that does not cause discharges of AOX compounds.

Washing and bleaching with hydrogen peroxide, which is normal in Denmark, has been used as the basis for the environmental assessment of the jogging suit. Moreover, the environmental assessment includes limited discharges of pesticides (0.005 g defoliation agent per kg cotton).

Dyeing

The cotton lining is not dyed. The nylon microfibre textile is dyed with acid dyes. After dyeing, the nylon fabric is treated with fastness improvers. This ensures a good and lasting colour fastness and reduces colour loss when the textile is washed.

Dyes for dyeing textiles are chemically often based on azo groups and may contain heavy metals. Some dyes containing azo groups may release carcinogenic substances of the type arylamines.

A dye from the group of acid dyes without heavy metals and without arylamine problems has been selected for this environmental assessment. The nylon microfibre textile is dyed in a jigger dyeing machine. It has not been possible to collect enough data to carry out an environmental assessment of the fastness improver. Therefore, the properties of this chemical cannot be included in this environmental assessment.

Finishing

For cotton textiles, finishing will normally consist of treatment with a sewability improvement agent (softening) to facilitate the subsequent making-up stage.

The dyed nylon fabric is finished with two types of chemical. The objective is for the surface to become wind-proof as well as water-repellent and dirt-repellent. The chemicals also help improve sewability for the subsequent making-up process.

Chemicals are used to give many textiles specific functional properties in finishing, such as non-iron, water-repellent and fire-retardant. Auxiliary chemicals in these productions often have many extremely adverse properties, both for the environment and for occupational health and safety. Finishing with a fabric softener has been used as the basis for the environmental assessment of the jogging suit.

Making-up

In the making-up stage, there is waste from the cutting-to-size process for the final product. For the jogging suit, waste of 10 per cent is assumed.

Some of the waste products are reused for products of a lower quality, but the main part is sent to waste incineration with heat and energy recovery, which is set off against energy consumption by the production equipment.

Occupational health and safety

The supplier is obliged to reduce the amount of monotonous repetitive work and dust nuisance at work. Cotton dust may cause lung damage, for example.

Distribution

The jogging suit is packed in polyester bags and then on a wood pallet. Finally, it is distributed to retail suppliers.

Use phase

In this environmental assessment of the jogging suit, the main scenario is that it is washed at 40°C without prewash and then tumbler dried.

Disposal phase

Textiles may not be landfilled. On final disposal, they must be incinerated so that the energy content is recovered and replaces non-renewable energy sources like oil and natural gas. In some situations, the used jogging suit will be reused in a third-world country. In such situations, it is not possible to recover energy by incineration in Denmark.

Transport phase

In the environmental assessment of the jogging suit, transport scenarios are included to and from the different processing links in the production chain, and finally from the sewing factory to Danish retailers.

Main scenario - results

The results of the main scenario are presented according to processes. The negative contributions that occur in some processes are due to estimated reuse potentials, resource consumption and contribution to environmental impact potentials. In the processes in question, the contributions can be allocated to other products and thus appear as negative contributions in the jogging suit's environmental profile.

The values in the five figures are not immediately comparable, as the unit is not the same for the five categories. The consumption of primary energy is

calculated in mega-joules (MJ), while the resource consumption is shown in the unit "person-reserves". Person-reserves take into account the supply horizon of the individual resources, calculated on the basis of the reserves available in the world in 1990. It should be noted that the data used here are more than ten years old, and therefore, new knowledge about the world's resources may have become available. The environmental impact potentials are presented as "milli-person equivalents" and are directly comparable. Milli-person equivalents are calculated as the direct impact for the year 2000. The weighting factors are based on global (w) or Danish (DK) discharges in the year 2000.

Consumption of primary energy

Figure 2.3 shows that the processes in the use phase represent the majority of the consumption of primary energy. The consumption of primary energy reflects the processes that require a lot of electrical energy or heating air or water. Fibre production consumes a lot of energy due to driving vehicles in the fields and production of artificial fertilizer and pesticides. In the use phase, particularly electricity consumption for washing and tumbler drying cause the impacts.

Resource consumption

The jogging suit consumes a relatively large amount of fossil fuels, partly because of the energy-intensive processes in its lifecycle, and partly because of the production of nylon for the outer shell - see figure 2.4. Nylon is produced from crude oil. As it is assumed that the jogging suit will be used in Denmark, electricity consumption is primarily based on burning coal at coal-fired power plants. In the disposal phase, some resources are credited because energy is recovered that would otherwise have come from burning fossil fuels.

Environmental impact potentials

Environmental impact potentials related to chemicals

Of the three environmental impact categories, those related to chemicals are dominant (see figure 2.5). This is due to the use of pesticides in cotton cultivation, softening of cotton fibres in connection with wet treatment, and use of knitting oil when processing the textiles. The nylon is dyed and surface-treated. Both processes contribute to environmental impact potentials related to chemicals.

In the use phase, primarily detergents in washing agents result in potential persistent toxicity. It is assumed that consumers do not add fabric softeners when washing, and therefore the impact potential probably does not tally completely with the actual conditions in Denmark.

Environmental impact potentials related to energy

The environmental impact potentials related to energy - illustrated in figure 2.6 - are caused by burning fossil fuels in the situations mentioned above.

Waste

The contributions to the waste categories mainly originate from electricity generation.

The conclusion of the lifecycle statement is that the product is resource-intensive primarily because of the large consumption of electrical energy in the use phase.

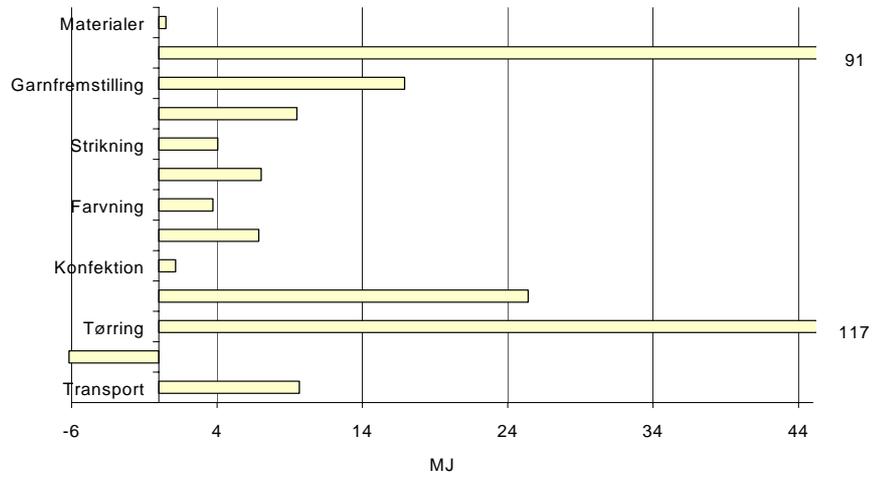


Figure 2.3 Result of main scenario: consumption of primary energy per functional unit – for translation of Danish terms see glossary in annex 11

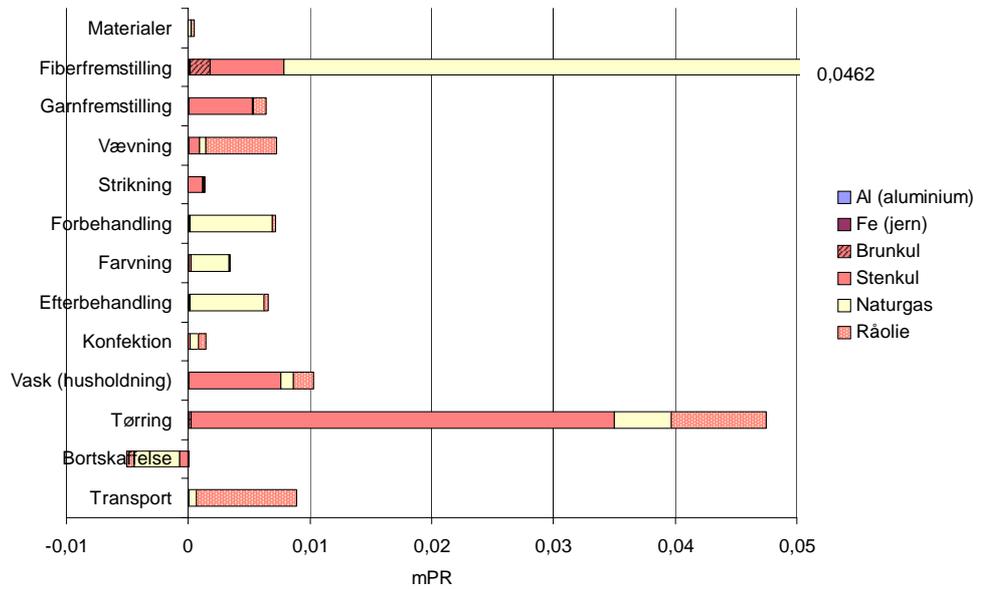


Figure 2.4 Result of main scenario; resource consumption per functional unit – for translation of Danish terms see glossary in annex 11

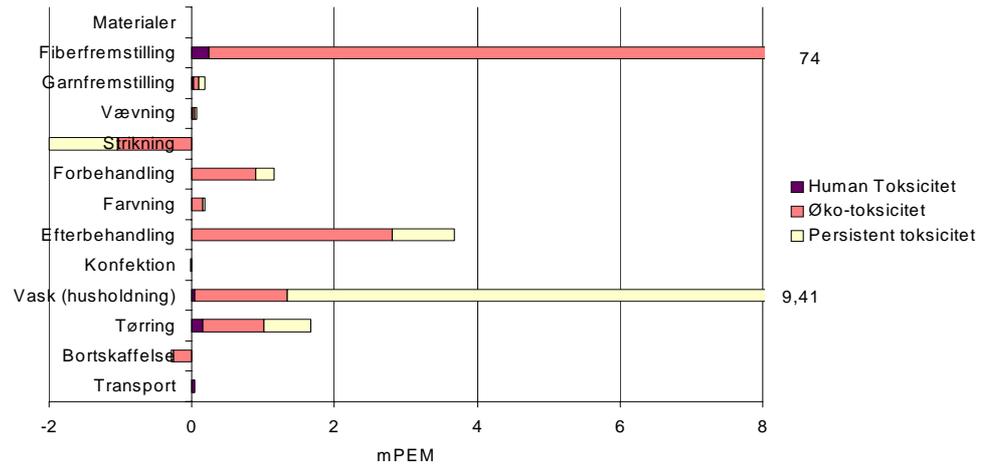


Figure 2.5 Result of main scenario; toxicological environmental impact potentials per functional unit – for translation of Danish terms see glossary in annex 11

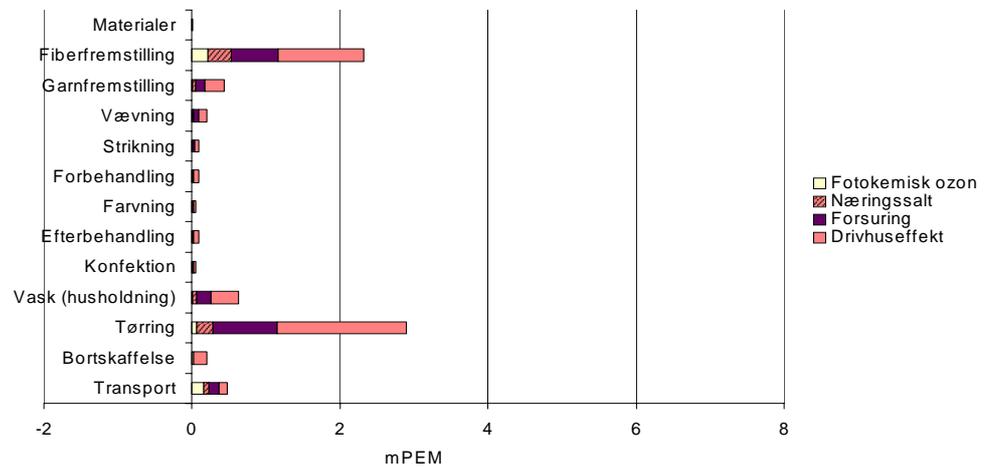


Figure 2.6 Result of main scenario; environmental impact potentials related to energy per functional unit – for translation of Danish terms see glossary in annex 11

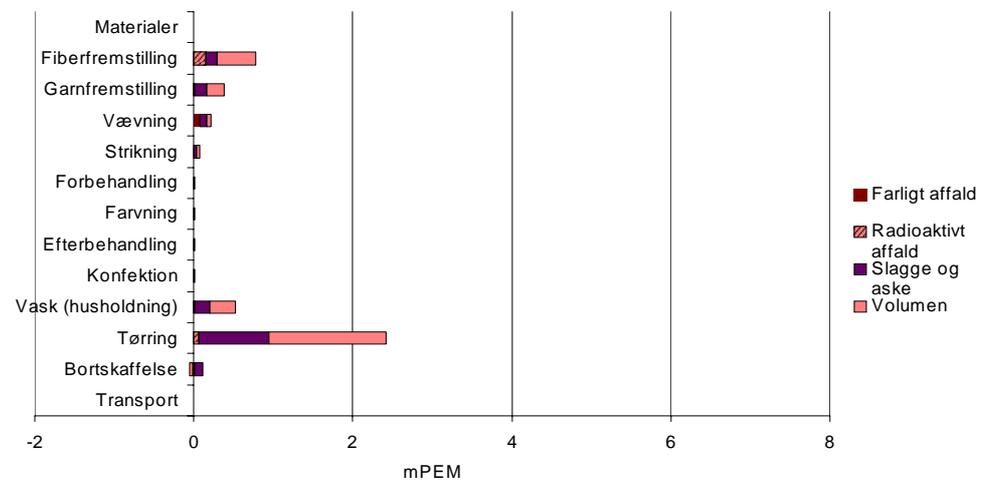


Figure 2.7 Result of main scenario; environmental impact potentials related to waste per functional unit – for translation of Danish terms see glossary in annex 11

Source identification

It is often necessary to study the large information volumes included in the results of a lifecycle assessment in order to achieve the best possible benefit of the assessment. Below is an overview of the most significant contributions to the categories:

- Primary energy
- Resource consumption.

The following three categories have the same unit, and are directly comparable:

- Toxicological environmental impacts
- Environmental impacts related to energy
- Environmental impacts related to waste.

The calculation of the consumption of primary energy does not include production of elastic or sewing of casings etc. for the jogging suit. There are no data for the materials the elastic is made of.

Primary energy

The consumption of primary energy in the jogging suit's lifecycle phases is distributed as shown in figure 2.3 of the main scenario; consumption of primary energy per functional unit.

Table 2.1 Source identification, primary energy analysed by lifecycle phases

	Consumption of primary energy/MJ
<i>Materials phase</i>	32 % of total primary energy consumption
Materials	No significant contributions from the production of the zipper.
Fiber production	Almost 100 % of this phase's contribution originates from fibre production. Primary consumption of electrical energy for production of nylon fibres approx. 70 %, while production of cotton fibres represents the remaining 30 %. This primarily originates from cotton cultivation, including transport with tractors etc.
<i>Production phase</i>	17 % of total primary energy consumption
Yarn manufacturing	Just less than 35 % of the production phase's consumption of primary energy originates from electricity consumption during yarn manufacturing for cotton lining.
Weaving	Approx. 20 % of the phase's primary energy consumption originates from the electricity consumption during weaving of nylon filament yarn for the jogging suit's outer shell.
Knitting	Consumption originates from the manufacture of cotton lining. Primarily from consumption of Danish electricity, corresponding to approx. 8 % of the phase's consumption from knitting cotton lining.
Pre-treatment	The consumption of primary energy in this process originates primarily from consumption of Danish electricity, approx. 14 %. Pre-treatment of cotton requires more energy than pre-treatment of nylon.
Dyeing	The consumption of primary energy in this process originates primarily from consumption of electricity in the process and natural gas to heat the process water, approx. 8 %. Only the microfibre is dyed.
Finishing	The consumption of primary energy in this process originates primarily from burning natural gas and consumption of Danish electricity, approx. 13 %, primarily from the cotton lining.
Making-up	Approx. 2 % of the phase's consumption of primary energy originates from this process. Primarily from production of

	plastic bags for packaging the jogging suit.
<i>Use phase</i>	50 % of total primary energy consumption
Washing (households)	18 % of this phase's consumption originates from electricity consumption for heating water in the washing machine
Tumbler drying	82 % of this phase's consumption is due to consumption of Danish electricity for tumbler dryers
<i>Disposal phase</i>	-2 % of total primary energy consumption
Incineration	Credit of the energy recovered by incineration of the jogging suit.
<i>Transport phase</i>	3 % of total primary energy consumption
Transport	Consumption of fossil fuels for petrol and diesel for various vehicles.

Fibre production

The primary contribution originates from the production of nylon for the jogging suit's outer shell; raw materials and electricity for the processes. As regards the cotton lining, the most significant contribution originates from driving vehicles in the fields in connection with cultivation and harvest of cotton fibres. A small part originates from production of artificial fertilizer and pesticides. In the model for production of the cotton lining for the jogging suit, transport for spreading fertilizer and pesticides is not included.

Production phase

There are no data for electricity consumption during finishing of the microfibre. Finishing the cotton thus appears to contribute more in this process, but this is not necessarily the case in reality.

Drying

Electricity consumption for drying the jogging suit in a tumbler dryer represents the largest contribution in the entire lifecycle and is thus an important focal point. The consumption of primary energy for the washing machine also represents an important part of total consumption.

Resource consumption

The distribution of resource consumption in the processes in the jogging suit's lifecycle is shown in figure 2.4.

Table 2.2 Source identification of the most resource-intensive processes in the lifecycle of the jogging suit

	Crude oil	Natural gas	Hard coal
<i>Materials phase</i>	50 % of total consumption	70% of total consumption	11 % of total consumption
Materials	1 % originates from extraction of oil for the plastic zipper	1 % originates from extraction of oil for the plastic zipper, residual product	No significant consumption
Fibre production	99 % of this phase's consumption of crude oil primarily originates from production of artificial fertilizer and pesticides, and transport of fibres	99 %, primarily from production of artificial fertilizer and pesticides, and transport of fibres	100 %, primarily from production of artificial fertilizer and pesticides
<i>Production phase</i>	16 % of total consumption	26 % of total consumption	14 % of total consumption
Yarn manufacturing	12 %, primarily for electricity generation for spinning the yarn	No significant consumption	66 %, primarily due to electricity consumption
Knitting	2 %, primarily due to electricity consumption	No significant consumption	15 %, primarily due to electricity consumption
Weaving	70 %, primarily due to electricity consumption	3%, primarily due to electricity consumption	11 %, primarily due to electricity consumption
Pre-treatment	3 %, primarily due to electricity consumption	40 %, primarily due to electricity consumption	2 %, primarily due to electricity consumption
Dying	2 %, primært til opvarmning af	18 %, primarily for heating	3 %, primarily due to

	vand primarily for heating water	water	electricity consumption
Finishing	3 %, primarily from electrical energy used for drying	35 %, primarily from electrical energy used for drying the textiles	1 %, primarily due to electricity consumption
Making-up	8 % of this phase's total crude oil consumption due to reuse of textile in another product	4 % of this phase's total natural gas consumption due to reuse of textile in another product	1 % of this phase's total coal consumption due to reuse of textile in another product
Use phase	19 % of total consumption	8 % of total consumption	76 % of total consumption
Washing (households)	18 % of this phase's contribution, primarily from consumption of Danish electricity	18 % of this phase's contribution, primarily from consumption of Danish electricity	18 % of this phase's contribution, primarily from consumption of Danish electricity
Drying	82 % of this phase's contribution primarily originates from electricity consumption from tumbler drying	82 % of this phase's contribution primarily originates from electricity consumption from tumbler drying	82 % of the phase's contribution, primarily from electricity consumption from tumbler drying
Disposal phase	1 % of total crude oil consumption can be credited	5 % of the total natural gas consumption can be credited	1 % of total coal consumption can be credited
Incineration	Incineration of the jogging suit recovers energy in the form of heat, and this replaces burning natural gas	Incineration of the jogging suit recovers energy in the form of heat, and this replaces burning natural gas	Incineration of the jogging suit recovers energy in the form of heat
Transport phase	16 % of total consumption	1 % of total consumption	No importance
Transport	Consumption of petrol and diesel	Consumption of petrol and diesel	

The consumption of Fe, Al and lignite is very limited. This resource consumption has not been included here. The consumption of natural gas and coal is most important for the environmental profile of the jogging suit. Hard coal is burned in the generation of Danish electricity. Natural gas is primarily used during production of pesticides and artificial fertilizer, and for heating dye baths, while crude oil is used as a raw material for the zipper, but primarily as fuel for various vehicles.

Materials phase

In the fibre production process, primarily the production of pesticides and artificial fertilizer are energy-intensive, and thus represents most of the consumption of crude oil and natural gas. The assumption here is that European electricity is used, and therefore there is no large consumption of coal.

Production phase

Energy-intensive processes like heating water for dyeing and air for drying represent the main part of resource consumption in this phase. The dyeing and finishing processes are equally as energy-intensive. For finishing, this is primarily due to the drying process.

Use phase

The use phase is the most resource-intensive phase in the jogging suit's lifecycle. Electricity consumption represents most of the resource consumption. Washing in a washing machine in a normal household requires energy for heating the washing water. Tumbler drying requires a lot of electrical energy. Danish electricity is primarily based on burning coal, while space and water heating are often based on burning natural gas and oil.

Disposal phase

Energy is generated when the jogging suit is incinerated, and this replaces fossil fuels. However, resources for the operation of the plant are consumed at the same time.

Transport phase

The main contributions in this phase are small. They originate from consumption of crude oil for production of diesel and petrol. In this case, we have assumed that the jogging suit is transported to the private household by car, but that other goods are bought at the same time.

Toxicological environmental impacts

The background for the statement of the environmental impacts related to chemicals is not complete. The EDIPTEX database does not contain data for the chemicals used for surface treatment of the microfibre (nylon). The data basis is also limited for the acid dyes, and therefore, the environmental impacts related to chemicals will seem less than they actually are in the dyeing process.

Environmental impact potentials, toxicity, divided into the lifecycle phases of the jogging suit can be seen in figure 2.5 of the main scenario.

Table 2.3 Source identification for individual toxicity categories

	Human toxicity	Ecotoxicity	Persistent toxicity
Material phase	Approx. 45 % of the total impact potential originates from this phase	Approx. 98 % of the total impact potential originates from this phase	Approx. 87 % of the total impact potential originates from this phase
Fiber production	Primarily from pesticides, emissions into the air.	100 % of this phase's contribution originates from pesticides in cotton cultivation	Approx. 90 % of this phase's contribution originates from pesticides in cotton cultivation
Production phase	Just under 10 % of the total impact potential can be attributed to this phase	The negative contributions from knitting and making-up due to the reuse potential reduce this phase's total contribution to 0.1 %.	In total, a negative contribution due to reuse potential for knitting and making-up
Yarn manufacturing	Approx. 50 % of this phase's contribution is due to electricity consumption for spinning cotton yarn	Approx. 6 % of this phase's positive contribution is due to electricity consumption	Approx. 10 % of this phase's positive contribution to the impact potential is due to electricity consumption when spinning the yarn
Weaving	27%	2%	
Knitting	6%	Credit of impact potentials due to recycling options in this process	Credit of impact potentials due to recycling options in this process
Pre-treatment	Approx. 6 % of this phase's contribution is due to electricity consumption	78 % of this phase's total positive contribution originating from	20 % of this phase's positive contribution originates from the washing agent used before the yarn is dyed
Dyeing	Approx. 4 % of this phase's contribution is due to electricity consumption	Dyeing represents 13 % of this phase's total positive contribution originating from the use of acid dyes.	2 % of this phase's positive contribution to the toxicity potential is due to the use of reactive dyes and electricity
Finishing	Approx. 4 % of this phase's contribution is due to electricity consumption	This process contributes with the largest ecotoxicity potential, 1 % of the phase's positive contribution in this phase is due to the softening process.	Approx. 65 % of this phase's positive contribution to the toxicity potential is due to the use of fabric softener.
Making-up	Credit of impact potentials due to recycling options in this process	Credit of impact potentials due to recycling options in this process	Credit of impact potentials due to recycling options in this process

Use phase	Approx. 37 % of total contribution	Approx. 3 % of total contribution	Approx. 15 % of total contribution
Washing	Approx. 82 % of this phase's impact potential originates from the washing agent	Approx. 60 % of this phase's impact potential originates from the washing agent	92 % of this phase's impact potential originates from detergents in the washing agent
Tumbler drying	Approx. 18 % of this phase's contribution is due to use of Danish electricity	Approx. 40 % of this phase's impact potential is due to electricity consumption for tumbler dryers	Approx. 7 % of this phase's contribution is due to electricity consumption for tumbler dryers
Disposal phase	Negative contribution due to recovery of energy	Negative contribution due to recovery of energy	Negative contribution due to recovery of energy
Incineration			
Transport phase	8 % of total impact potential	No significant contribution	No significant contribution
Transport	From burning fossil fuels		

In the production phase, knitting and making-up are assumed to contribute with a reuse potential that can be credited to fibre production. This means that the production phase has a net negative contribution to ecotoxicity and persistent toxicity impact potentials. In the table, the positive contribution from the production phase has only been calculated and used as a total value. The contribution from the actual phase is calculated on the basis of the total potential, i.e. including the negative contribution.

Materials phase

The most significant factors in this calculation are the ecotoxicity and the persistent toxicity from cotton cultivation. The high impact potentials are due to the use of pesticides: herbicides, insecticides, fungicides, growth regulators and defoliation agents.

Production phase

Pre-treatment of the nylon textile does not require the same amount of auxiliary chemicals, and therefore, pre-treatment should be regarded as two separate and different processes.

Use phase

Detergents in washing agents result in contributions primarily to human toxicity and persistent toxicity. Moreover, there is a small contribution to ecotoxicity (primarily from alcohol ethoxylate). However, it is important to mention that the contributions from this phase are small compared to the contributions from fibre production.

Electricity generation also contributes to the toxicity categories. Mining operations release some undesired substances to the environment, such as strontium.

Environmental impacts related to energy

The potential environmental impacts related to energy from the jogging suit's lifecycle phases are distributed as shown in figure 2.6 of the main scenario, toxicological environmental impact potentials per functional unit.

Table 2.4 Source identification for environmental impact potentials related to energy

	Greenhouse effect	Acidification	Nutrient loading	Photochemical ozone formation
Materials phase	28 % of total contribution	30 % of total contribution	44 % of total contribution	41 % of total contribution
Materials	No significant contribution	No significant contribution	No significant contribution	3 per cent originates from extraction of crude oil for the zipper
Fibre production	100 %, originating primarily from burning fossil fuels and energy for production of N artificial fertilizer	100 %, originating primarily from burning fossil fuels and energy for production of N artificial fertilizer	100 %, originating from burning fossil fuels and energy for production of N artificial fertilizer	97 %, originating from burning fossil fuels
Production phase	15 % of total contribution	12 % af det samlede bidrag of total contribution	10 % of total contribution	11 % of total contribution
Yarn manufacturing	41 % of this phase's contribution originates from electricity consumption in this process	51 % of this phase's contribution originates from electricity consumption in this process	47 % of this phase's contribution originates from electricity consumption in this process	The main part, approx. 20 %, of this phase's contribution originates from unburnt fuels in connection with transport
Knitting	9 % of this phase's contribution is due to electricity consumption	10 % of this phase's contribution is due to electricity consumption	9 % of this phase's contribution is due to electricity consumption	Not significant
Weaving	19 % of this phase's contribution is due to electricity consumption	24 % of this phase's contribution is due to electricity consumption	19 % of this phase's contribution is due to electricity consumption	20 %
Pre-treatment	10 % of this phase's contribution is due to electricity consumption	5 % of this phase's contribution is due to electricity consumption	8 % of this phase's contribution is due to electricity consumption	16 % of this phase's contribution is due to incompletely burnt fuel in connection with transport
Dying	6 % of this phase's contribution is due to electricity consumption	3 % of this phase's contribution is due to electricity consumption	6 % of this phase's contribution is due to electricity consumption	8 % of this phase's contribution, due to incompletely burnt fuel in connection with transport
Finishing	10 % of this phase's contribution is due to electricity consumption	4 % of this phase's contribution is due to electricity consumption	8 % of this phase's contribution is due to electricity consumption	16 % of this phase's contribution is due to unburnt fuel in connection with transport
Making-up	5 %	3 %	3 %	20 % due to incomplete burning fossil fuels
Use phase	50 % of total contribution	51 % of total contribution	36 % of total contribution	16 % of total contribution
Washing (households)	18 % of this phase's impact contribution originates from electricity consumption for heating water in the washing machine	18 % of this phase's impact contribution originates from electricity consumption for heating water in the washing machine	18 % of this phase's impact contribution originates from electricity consumption for heating water in the washing machine	18 % of this phase's impact contribution originates from electricity consumption for heating water in the washing machine
Tumbler drying	82 % of this phase's impact potential is due to the consumption of electricity for tumbler dryers	82 % of this phase's impact potential is due to the consumption of electricity for tumbler dryers	82 % of this phase's impact potential is due to the consumption of electricity for tumbler dryers	82 % due to incomplete burning in connection with transport
Disposal phase	4 % of total	No significant contribution or credit	No significant contribution or credit	Approx. 3 % of this phase's total contribution originates from incineration of the jogging suit

Incineration				
Transport phase	3 % of total contribution	7 % of total contribution	1 % of total contribution	29 % of total contribution
Transport	Transport with diesel and petrol driven vehicles	Burning fossil fuels	Burning fossil fuels	Burning fossil fuels

Incomplete burning contributes to photochemical ozone formation, while burning fossil fuels generally contributes to all categories.

Materials phase

Burning fossil fuels for transport of the cotton fibres and electricity consumption in production of artificial fertilizer and pesticides are the main causes of the environmental impact contributions from this phase.

Production phase

In this phase, electricity consumption again represents the main part of the impact potentials. Especially the yarn manufacturing process is energy-intensive.

Use phase

The phase when the jogging suit is consumed is the absolute main contributor to the environmental impact potentials related to energy. This is caused by electricity for tumbler dryers and heating water for washing machines. Energy consumption from production of washing agents has not been included. If this had been included, the contribution from this phase would have been even larger. This result indicates that the consumer has considerable influence on the jogging suit's overall environmental profile.

What-if simulations

The environmental profile for a given product - in this case a jogging suit - can be affected by the choices made by the producer and by the consumer. In order to elucidate the consequences of possible changes in the product's lifecycle, a number of scenarios have been prepared that focus on the producer and consumer respectively.

By changing one or more of the reference conditions, it is possible to form a picture of the scope of the consequences based on the choices made. These changes are illustrated graphically by means of lifecycle statements within five categories, as described in the following section. The following scenarios have been prepared taking into account the producer's and the consumer's influence on the environmental profile of the product.

Consequences of choices by the producer

The producer influences all processes from extraction of raw materials until the finished product leaves the distribution phase. To some extent, the producer can affect the processes in the use phase. However, it is not possible for the producer to affect all consumers of the product equally. In order to take this into account, a product reference has been prepared for the producer scenarios where only a limited part of the impacts from the use phase has been included.

The revised use phase contains: washing after use as defined in the functional unit. No use of fabric softener when washing in private households, and tumbler drying after 50 per cent of washes. It is assumed that the jogging suit is drip-dried the remaining times.

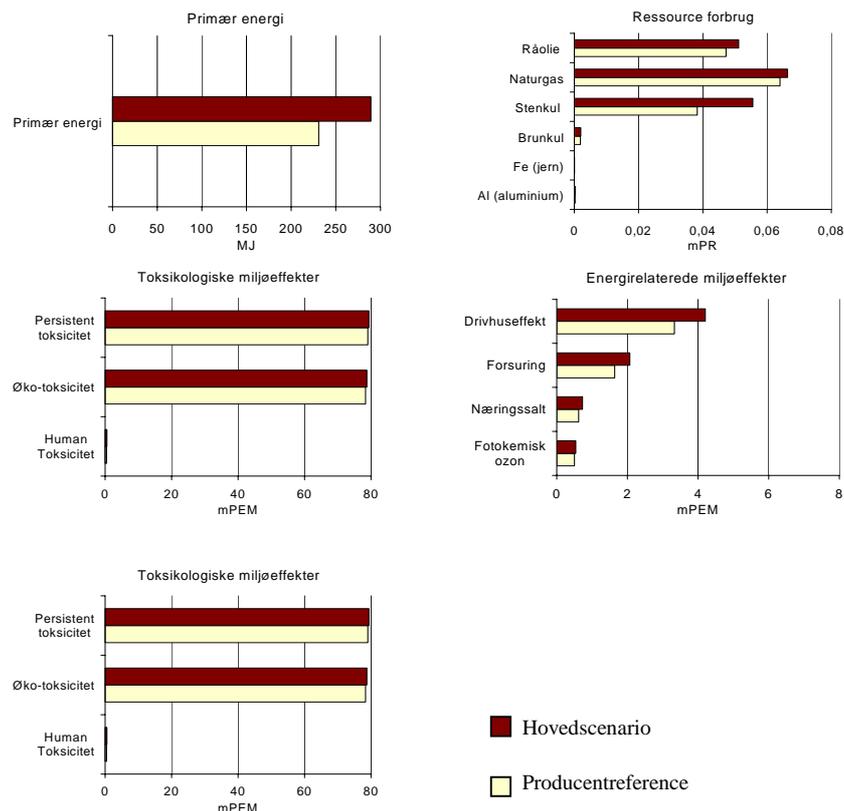


Figure 2.8 The producer reference in relation to the main scenario – for translation of Danish terms see glossary in annex 11

Figure 2.8 shows that the producer reference scenario has a 20 per cent lower consumption of primary energy per functional unit than the main scenario. This is due to lower consumption of electricity in the use phase, due to the reduced tumbler drying. For the same reason, the consumption of fossil fuels and the environmental impacts related to energy are reduced, both categories by between 10 and 30 per cent, the main part for coal.

The toxicological environmental impacts are only reduced by a few per cent, as cotton cultivation and use of softeners and dyes in the production of the jogging suit outweigh the contributions from coal-fired power plants.

In the following, the results of the producer-related scenarios are presented as summarised contributions over the entire lifecycle and compared with the producer reference scenario.

Scenarios - producer

Raw materials phase

Scenario 1: Choice of raw materials - Organic cotton lining

Production phase

Scenario 2: Choice of chemicals - dyes for cotton lining

Scenario 3: Choice of chemicals - choice of acid dyes

Scenario 4: Choice of chemicals - choice of dyes, 10 per cent dyeing

Scenario 5: Choice of chemicals - choice of fabric softener

Scenario 6: Choice of chemicals - use of fastness improver

Scenario 7: Choice of chemicals - use of extra knitting oil

Use phase

Scenario 8: Influence on product quality - 20 per cent colour loss

Scenario 9: Influence on product quality - colour staining

Scenario 10: Influence on product quality - reduced lifetime

Scenario 11: Influence on use phase - no tumbler drying

Scenario 1: Choice of raw materials - organic cotton

The toxicological environmental impacts are the environmental impact potentials with the highest weight in the life of the jogging suit. The contributions to this category have been ascertained as primarily due to use of pesticides and spreading artificial fertilizer during cotton cultivation.

For conventional cotton cultivation about 18 g pesticides are used per kg cotton in the worst case. The main scenario applies an estimated average of the pesticide volumes from cotton cultivation in the US and South America. The impact of pesticides on the environment has been assessed, and the factors have been included in the database. Pesticide residues can cause toxic impacts in humans during processing of the cotton fibres, as the oil used in this process is used for cooking in some countries. In this way, the pesticide residues end up in food and thus in people. The residues are assumed to be washed out of the cotton during wet treatment.

In order to assess the significance of the chemicals used in conventional cotton cultivation, the material is changed to organic cotton. In this way, the use of pesticides and artificial fertilizer is avoided and wash-out of pesticides during cotton fibre processing is also eliminated. In production of organic cotton fibres, no chemicals are used for bleaching in pre-treatment, and this leads to another reduction of the toxicological environmental impact potentials. A further benefit is that the transport required to spread these substances on the field also disappears. This transport is not, however, included in either the main or the producer reference scenarios, due to the large differences between the cotton-producing countries. In some countries, vehicles only drive in the fields a few times per cultivation round. In other countries, typically South American countries, it is common to drive more in the fields to secure the crop yield. Less transport reduces consumption of fossil fuels and is therefore also part of the environmental impacts related to energy.

Consumption of primary energy does not change significantly because of the changed choice of raw materials. This is because most of the energy consumption arises from processes in the production and use phases and these do not change in this scenario. In total, energy consumption falls by 2-3 per cent for the changed choice of raw materials.

The toxicological environmental impacts are significantly reduced using organically cultivated cotton. Persistent toxicity is reduced by about 80-85 per cent, while ecotoxicity is reduced by up to 95 per cent compared with the reference scenario.

The environmental impacts related to energy, greenhouse effect, nutrient loading, and photochemical ozone formation are reduced by a small percentage, approx. 2-5 per cent. The reason is that there is no longer a contribution to these potentials from production of artificial fertilizer and pesticides. The same applies for the waste categories.

Conclusion to scenario 1 - organic cotton is recommended

It can be concluded that the producer has great possibilities to influence the overall environmental profile of the textile, especially the toxicological environmental impact potentials. Use of organic cotton rather than conventionally cultivated cotton to the greatest possible extent can clearly be recommended. It should also be considered that many of the agents used during cultivation of cotton are harmful to human health. Incorrect or careless use could mean that suppliers expose themselves and their employees to health hazards. Pesticide residues washed out in several pre-treatment processes are yet another reason to avoid conventionally cultivated cotton.

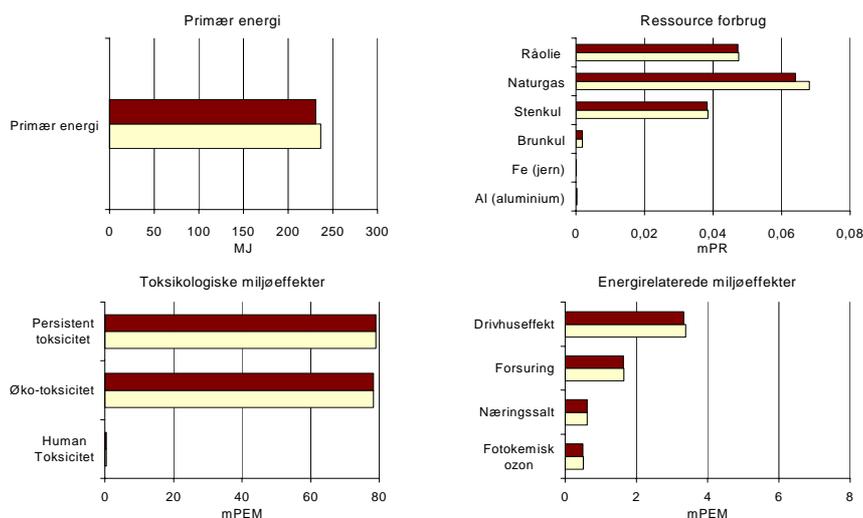
Scenario 2: Choice of chemicals - dyed cotton lining

The toxicological environmental impacts are the environmental impact potentials with the highest weight in the life of the jogging suit. The contributions to this category primarily originate from pesticides used in cotton cultivation, dyeing of textiles, and use of fabric softeners in the production and use phases.

In the reference scenario, it is assumed that the lining is not dyed. This scenario illustrates the environmental importance of dyeing the cotton lining.

The number of environmental equivalency factors for reactive dyes is limited in the EDIPTEX database. It is therefore important that the results of this scenario be regarded as a guide. There may be other equally common dyes that contribute more, or less, to the toxicological environmental impacts than those included here.

Cotton is dyed with reactive dyes. The model assumes that the cotton is dyed with 3 per cent dye, that 85 per cent of the dye dose is adsorbed to the textile, and that the remainder is discharged via treatment plants into water and soil. It is also assumed that the dyes are not washed out in the use phase.



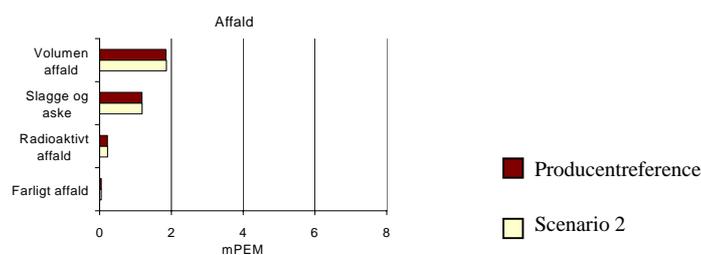


Figure 2.9 Result of scenario 2 – for translation of Danish terms see glossary in annex 11

The figure shows that the total impact is limited. The consumption of primary energy increases 2 per cent, as is the case for the environmental impacts related to energy. As regards resources, consumption of natural gas increases the most, by about 6 per cent. Natural gas is used to heat water etc. in the dyeing process.

Overall, the contributions to human toxicity increase by 0.5 per cent, while both persistent toxicity and ecotoxicity increase by less than 0.1 per cent if the lining is dyed. If only the contributions to toxicological environmental impacts from the dyeing process are considered, there is an increase of 130 per cent in human toxicity, 11 per cent in ecotoxicity and 50 per cent in persistent toxicity. Thus, dyeing the cotton lining of the jogging suit influences the product's environmental profile related to production greatly.

Conclusion to scenario 2 - impact on energy consumption and toxicological environmental impacts

Dyeing cotton has a toxicological impact on the environment. In this scenario, the assumption is that no dye is washed out during the use phase. In practice, this means that the washing out that does occur is disregarded. The production, distribution, storage and use of the dye have an undesired environmental impact on the product's environmental profile. These data are not available in the database, and therefore the impact of a cotton dye is larger than indicated by the results of this scenario.

In total, energy consumption increases by approx. 3 per cent when the cotton lining is dyed. This is a considerable increase, when we take into account that this is a single process in the production phase. It can be concluded that dyeing the lining should be avoided.

Scenario 3: Choice of chemicals - choice of acid dyes

The microfibre is dyed with acid dyes after the textile has been woven. Dyes add to the toxicological environmental impact potentials, although to a smaller extent than pesticides and artificial fertilizer from cultivating cotton. The database only includes equivalency factors for a single acid dye, and in the producer reference, the dyes are all allocated the same equivalency factors. Note that the limited knowledge on large parts of the dye range means that these models should not be regarded as representative for the whole group of dyes, but rather be seen as guides.

It is also assumed in the producer reference that 85 per cent of the dye dose adsorbs to the textile, the rest is discharged with wastewater to a treatment plant, where 13 per cent is discharged into water and 87 per cent into the soil. The dyes primarily contribute to ecotoxicity.

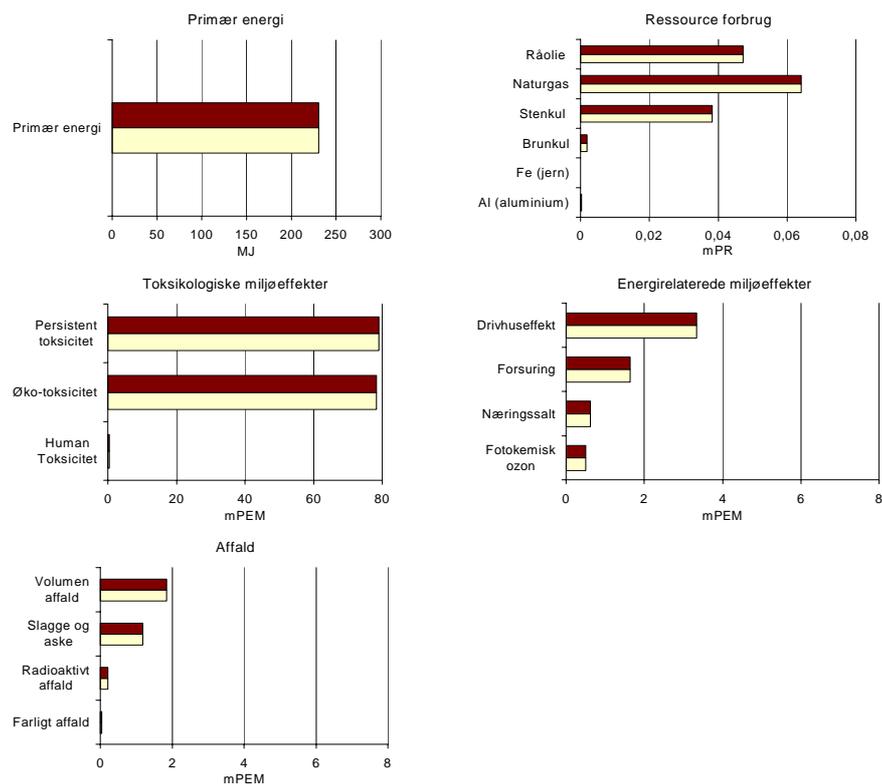


Figure 2.10 Result of scenario 3 - small reduction of environmental impact potentials related to chemicals – for translation of Danish terms see glossary in annex 11

This scenario assumes that acid dyes do not add to the toxicological environmental impacts. As data for production is not included in the database, dyes do not appear in the model for this scenario.

It can be ascertained that the contributions of the dyes to toxicological environmental impact potentials are not very important at an overall level. Note that only one acid dye forms the basis for the contribution in the producer reference. Persistent toxicity is reduced by just less than 1 per cent, which is also the case for ecotoxicity. Human toxicity is unchanged.

In the dyeing process alone, the contributions are reduced by approx. 35 per cent. The remaining contribution from the process is due to consumption of electricity and heat.

Conclusion to scenario 3 - obtain more knowledge about acid dyes

Therefore, it can be concluded that the producer should focus on acquiring knowledge on the dyes used and their impact and degradability in the environment. The factors in this tool can be used as standards of reference and can thereby form the basis for choosing more environmentally friendly acid dyes.

Scenario 4: Choice of chemicals - choice of dye: 10 % dyeing

In the producer reference, the microfibre is dyed with 1 per cent acid dye, which corresponds to the amount of dyestuff used to dye in paler shades. This scenario illustrates the impact of a dark dye (worst case) of 10 per cent.

It is assumed that 85 per cent of the dye dose adsorbs to the textile and the remainder is led through wastewater treatment as in the reference scenario. As ten-times as much dyestuff is used in this scenario, ten-times as much dyestuff is discharged than in the reference scenario. The model assumes that dyestuff is not washed out during the use phase.

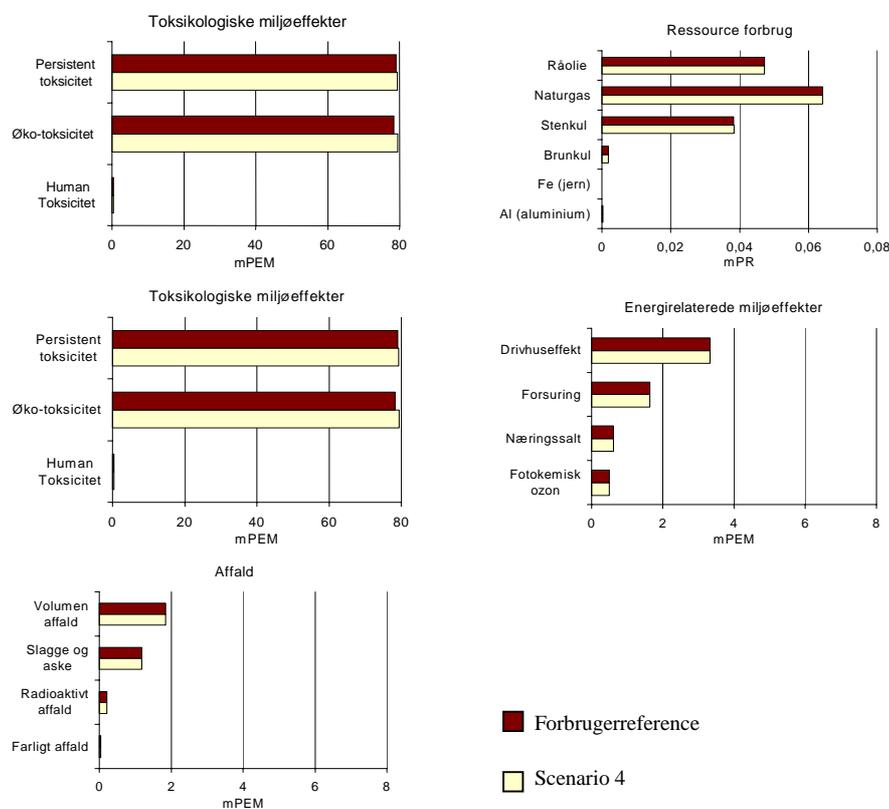


Figure 2.11 Result of scenario 4 - increased contribution to toxicological environmental impact potentials – for translation of Danish terms see glossary in annex 11

It is assumed that the same amount of textile as in the reference scenario can be reused directly from the knitting and making-up phases. As in scenario 2, there is only data for one single acid dye, and therefore the scenario should not be regarded as representative for the whole group of acid dyes.

The graphs show that the larger amount of dyestuff leads to an increase in the total contribution to the toxicological environmental impact potentials of about 1-2 per cent. This does not seem to be a lot, but considering that this is solely due to an increase in the concentration of dyestuff in the outer shell of the jogging suit, this is an important focus point for the producer.

The production of 10 per cent more dyestuff per functional unit leads to an increase of 0.1 per cent in coal consumption. A similar increase is seen for the environmental impact potentials related to energy and for waste categories.

Conclusion to scenario 4 - large impact in dyeing process, less at overall level

It can be concluded that the amount of dyestuff per functional unit has an impact on the overall environmental profile for the product. If we look specifically at the production phase, we see increases of 5-50 per cent, which makes this an important focus point for the producer. The producer can

encourage the supplier of acid dyes in a more environmentally friendly direction by making requirements for the environmental profile of the dyes.

Scenario 5: Choice of chemicals - choice of fabric softener

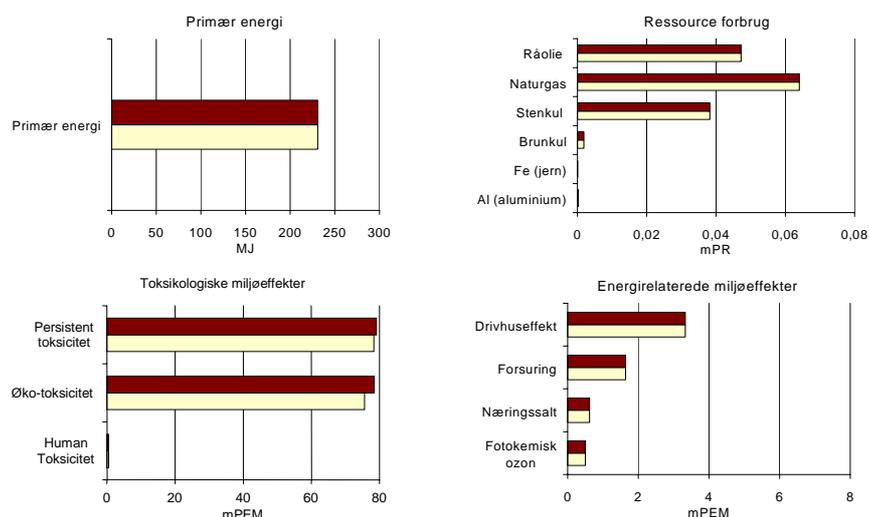
Both cotton and nylon are softened during the production phase. This scenario illustrates the impact of choice of fabric softener as well as the significance of any washing out of the fabric softener in the use phase. The producer reference includes the most commonly used fabric softener in the model for the lifecycle of the jogging suit. This chemical is the most toxic of the two fabric softeners in the EDIPTEX database. It is assumed that 85 per cent of the added amounts adsorbs to the textile and is not washed out in the use phase. It is also assumed that the two types of textiles are softened using the same chemical.

The producer is able to use fabric softeners of any toxicity. Therefore it is assumed that a less toxic chemical is used. Just as in the producer reference, it is assumed that 85 per cent of the chemical added adsorbs to the textile and that the fabric softener is not washed out during the use phase.

The producer has several possibilities to change the softening process, which can be carried out using different techniques.

- Addition of fabric softener in a wet treatment process.
- Fabric softener can be sprayed on the woven or knitted textile through nozzles.
- Lengths of textile can be led through a bath containing fabric softener that adsorbs to the material.
- Mechanical softening of the textile lengths where the fibres are softened through repeated mechanical treatment.

Data for the manufacture of fabric softeners is not included, and therefore only the toxicological environmental impact potentials are changed in relation to the reference scenario.



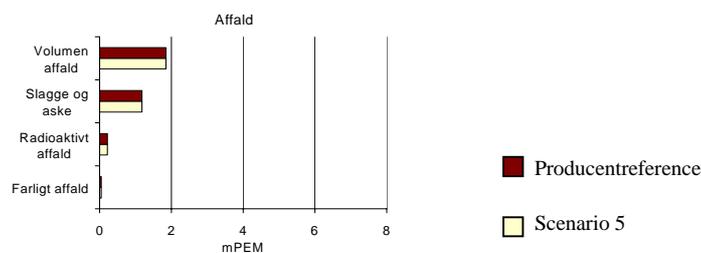


Figure 2.12 Result of scenario 5 - reduced toxicological environmental impact potentials – for translation of Danish terms see glossary in annex 11

The figure shows that the choice of a less toxic fabric softener has a total impact of 1-4 per cent, highest for ecotoxicity. This impact does not seem higher because of the very high contributions to these categories from cotton cultivation. If we only look at the production phase, the toxicological environmental impact potentials are reduced by more than 90 per cent, highest for ecotoxicity.

Conclusion to scenario 5 - choice of fabric softener is important

The choice of fabric softener has a limited effect at an overall level, but the effect is large on the product's environmental profile, if the production phase is regarded separately. Thus, this is an area where the producer has a direct possibility of improving the product's environmental profile.

Legislation on ecolabelling indicates the substances that should be phased out, and those which should be avoided completely from an environmental perspective. This could be a guide for environmental work at the individual enterprise. It should be noted that this scenario only deals with the amount of fabric softener used during the pre-treatment of the textile.

Scenario 6: Choice of chemicals - use of fastness improver

In order to achieve a better quality cotton jogging suit, the textile can be treated with fastness improvers in the same bath as the fabric softener. This process means that the coloured textile retains its colour better during washing than textiles that are not treated with fastness improvers.

In order to illustrate the significance of this process, this scenario includes the assumption that the fastness improver is allocated the same toxicity factors as the fabric softener used in the producer reference, as no equivalency factors have been prepared specifically for fastness improver. It is assumed that 85 per cent of the amounts added adsorbs to the textile, while the rest is led through a treatment plant and discharged into the environment.

It is also assumed that the same chemical can be used for colour fastening of cotton and nylon.

On the basis of previous models for a cotton T-shirt, the use of fastness improver is assessed to have less influence at an overall level, but significant influence in the production phase. Compared with the producer reference, the contribution to ecotoxicity increases by almost 2 per cent, while the contribution to persistent toxicity increases by almost 1 per cent.

As in scenario 3, the contributions are overshadowed by the large environmental impact potentials from fibre manufacture. If the jogging suit

were manufactured from organic cotton, the contribution from the fastness improver would seem more significant.

Conclusion to scenario 6 - reduce use of fastness improvers

The conclusion to scenario 6 is that use of fastness improvers does not change the environmental profile of the jogging suit significantly. However, it should be noted that energy consumption in manufacture of the chemical has not been included in the calculations and therefore use of fastness improvers in industry will influence resource consumption and energy-related environmental impact potentials which are not illustrated here. For the production phase alone, the contribution to the toxicological environmental impact potentials is considerable, and therefore there should be special focus on minimal use of these auxiliary chemicals.

Scenario 7: Choice of chemical - use of knitting oil

In the knitting process for the cotton lining, an easily degradable, vegetable knitting oil is used for the reference product. This scenario will illustrate the influence it would have, if a mineral knitting oil that is difficult to degrade were used.

Data for the manufacture of knitting oils is not included, and therefore only the toxicological environmental impact potentials are changed in relation to the reference scenario.

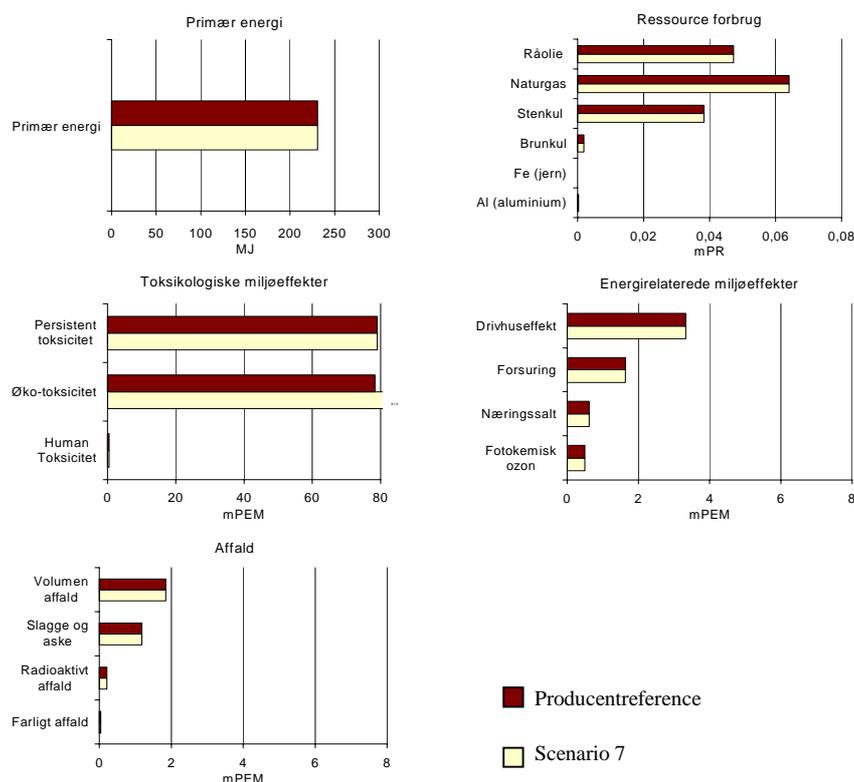


Figure 2.13 Result of scenario 7 – for translation of Danish terms see glossary in annex 11

The figure shows that the use of a mineral knitting oil that is difficult to degrade increases the overall toxicological environmental impact potential of ecotoxicity by 4 per cent. The impact does not seem higher because of the

very high contributions to these categories from cotton cultivation. If we look at the production phase alone, the toxicological environmental impact potentials increase by just under 500 per cent for ecotoxicity.

Conclusion to scenario 7 - use easily degradable vegetable knitting oils

It can be concluded that the use of mineral knitting oils that are difficult to degrade should be limited as much as possible.

Scenario 8: Choice of chemicals - 20 per cent colour wash-out during use phase

A number of residual chemicals that are left in the textile from the production process will often be washed out during the use phase. This also includes dyestuffs. In the producer reference, the nylon microfibre is dyed with 1 per cent acid dye, which corresponds to a minimum of dye. However, there will often still be residual dye in the textile.

In this scenario, the assumption is that 20 per cent of the dyestuff is washed out during the use phase. This corresponds to 17 per cent of the total volume used.

There are only data for one single acid dye, and therefore the scenario should not be regarded as representative for the whole group of acid dyes. Similarly, it is uncertain how much the dye percentage used in production influences the percentage of colour washed out.

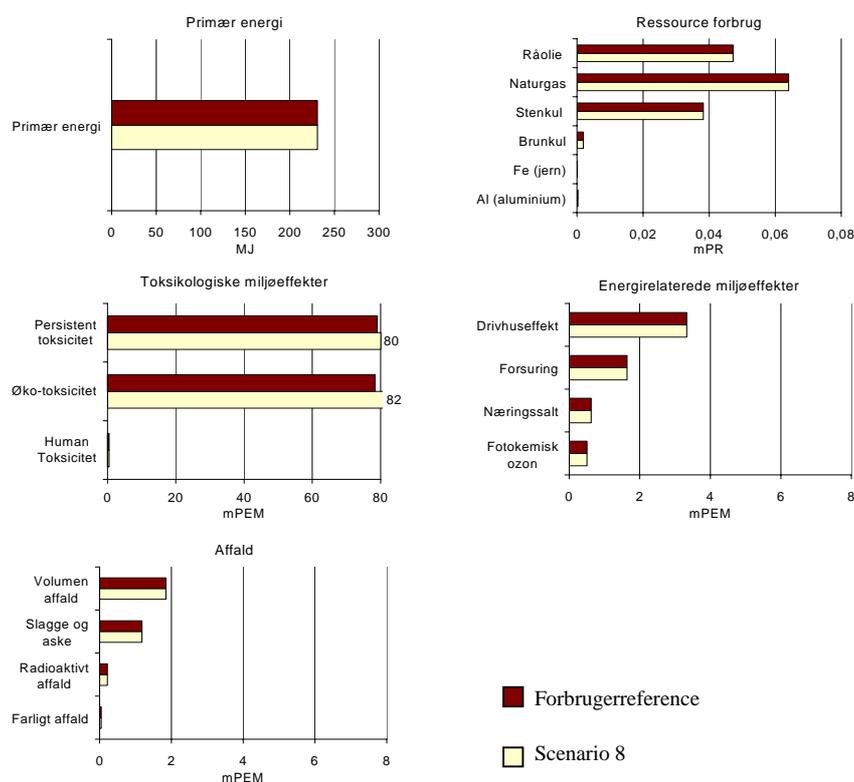


Figure 2.14 Result of scenario 8 - increased contribution to toxicological environmental impact potentials – for translation of Danish terms see glossary in annex 11

The graphs show that the larger amount of dyestuff washed out leads to an increase in the total contribution to the toxicological environmental impact

potentials of about 1-2 per cent. This does not seem to be a lot, but considering that this is solely due to the dyeing method and the choice of dye for the outer shell of the jogging suit, this is an important focus point for the producer.

There are no other changes as the wash-out does not lead to further consumption. However, there will be further savings if the dose of dyestuff can be reduced by changing the production method - and give the same result.

Conclusion to scenario 8

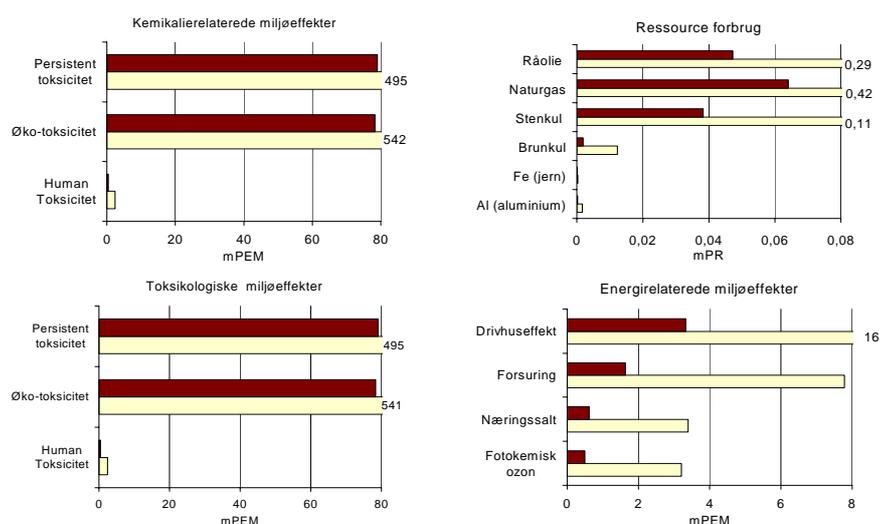
It can be concluded that wash-out of dyestuff in the use phase per functional unit has an impact on the overall environmental profile. If we regard the production phase specifically, it is possible to reduce the use of dyestuffs, and this makes it an important focus point for the producer.

Scenario 9: Influence on product quality - colour staining

The quality of the dyeing, colour fastness, is important for the quality consumers perceive in the product.

This scenario illustrates the impacts on the overall environmental profile of the jogging suit if it ruins an entire machine wash once in its lifetime because the colour migrates to the other textiles in the wash. It is assumed that each wash includes 4.9 kg textiles of the same composition as the jogging suit, i.e. equal amounts of cotton and nylon plus a small amount of polyester. It is also assumed that all the washed textiles are unfit for use after the colour migrates.

The modelling is carried out by assuming that the wash is composed of 7 jogging suits of the type described. Therefore, 7 jogging suits of 706 g each must be produced, transported and disposed of. The use phase of the spoiled textiles is not included in the calculations, i.e. only the use phase for the reference product is included in the model, as it is assumed that it is not spoiled.



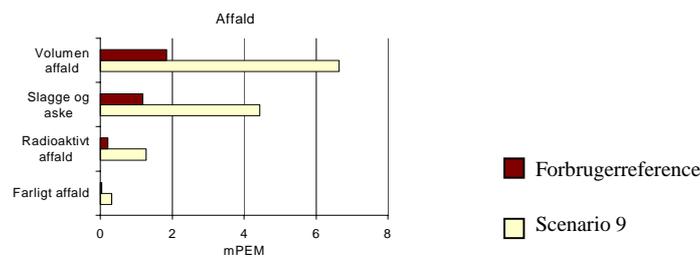


Figure 2.15 Result of scenario 9 – for translation of Danish terms see glossary in annex 11

Production of the increased volume of textiles causes an increase in consumption of primary energy of just under 500 per cent. The toxicological environmental impacts increase by 5-700 per cent, and the same trend is apparent for the remaining categories.

Conclusion to scenario 9 - the contributions from the production processes outweigh the contributions from the use phase.

The scenario indicates that the use phase of the individual jogging suit, otherwise dominant in connection with consumption of fossil fuels and environmental impacts related to energy and waste, is now outweighed by the processes in the production phase.

On the basis of this, it can be concluded that the colour fastness of textiles of this type is very important. Alternatively, the producer can inform consumers about the risk of colour being transferred to other textiles, whereby the consumer is given the responsibility of washing the jogging suit separately one or more times. Then, this should be included in the product's overall environmental profile as a higher impact from washing in the use phase.

Scenario 10: Influence of product quality - reduced lifetime

Product quality influences the lifetime of the product. Colour fastness, durability of the fibre and stitching are examples of areas on which the durability and quality of the product can be judged. In relation to lifecycle assessments, the quality of the product will be important for the manufacture and disposal phases, as these are extended/reduced in order to meet the functional unit.

Scenario 10 is based on halving the lifetime of the jogging suit compared with the producer reference. The assumption results in doubling fibre manufacture, production, disposal and transport as two jogging suits are now required to meet the functional unit.

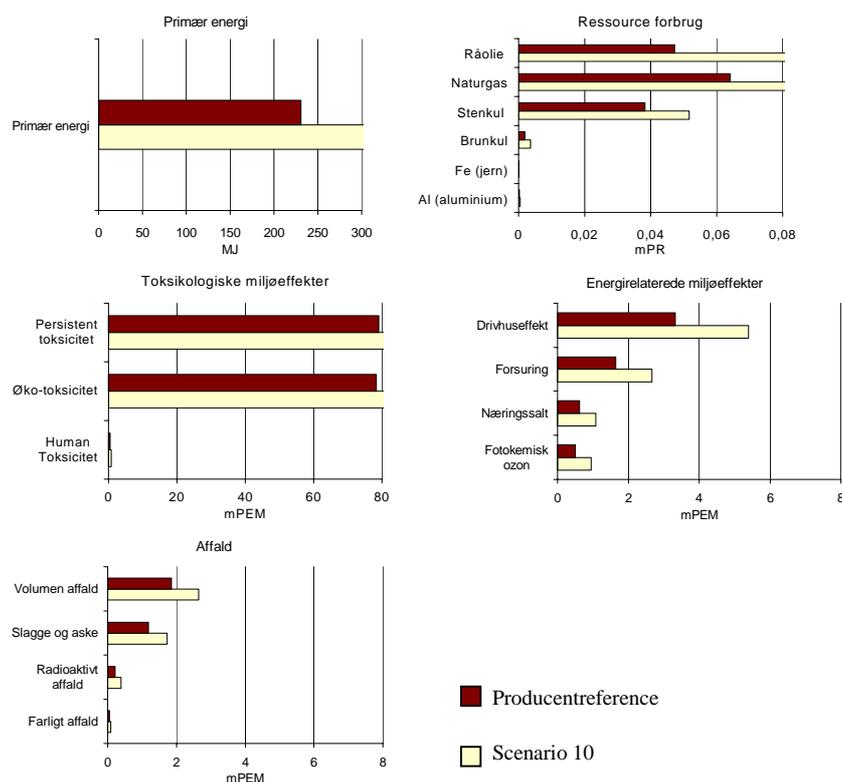


Figure 2.16 The producer reference in relation to the main scenario – for translation of Danish terms see glossary in annex 11

The great importance of lifetime is clear. The consumption of primary energy increases by approx. 30 per cent. Resource consumption is increased correspondingly, crude oil by 66 per cent, natural gas by 76 per cent, and coal by 11 per cent. This is due to increased consumption of electricity for production of the extra jogging suit. The contribution to the energy-related environmental impacts as a consequence of this increases by about 26 - 86 per cent. The waste categories increase by about 30 per cent for the same reasons.

The toxicological environmental impact potentials are increased by 40 per cent, and again the increased production of cotton is the determining factor in this context for the toxicity potentials, and the increased consumption of fabric softeners in the production phase. Contributions from electricity generation to toxicological environmental impact potentials are limited.

Conclusion to scenario 10 - lifetime is important

The conclusion to this scenario is that the quality of the jogging suit is an important focus point for the producer. It is decisive for the overall environmental profile, in particular with regard to consumption of primary energy and thus fossil fuels and the energy-related environmental impacts.

The toxicological environmental impacts also increase considerably, primarily because of the doubling of the amount of cotton per functional unit. One possibility to improve the environmental profile, despite reduced lifetime is organised reuse of the material. As the product consists of two types of textile, a high degree of recycling would require separation of the textile types.

The lifetime of the textile is not only determined by the producer, the consumer also has a great influence on this parameter.

Scenario 11: Influence of the use phase - no tumbler drying

The use phase has a great influence on the overall environmental profile of the jogging suit. Therefore, it is desirable that the producer improve the properties of the product to reduce the environmental impacts in this phase. As can be seen in the producer reference, electricity consumption has most significance, more specifically in the drying process. The producer reference assumes that the jogging suit is dried in a tumbler dryer for half of the washes.

This scenario assumes that the jogging suit is always hung up to dry on a clothesline and drip-dried. Emissions into the air from this process have not been included. The model simulates the change by setting the drying process at zero.

The possibilities for the producer to influence the drying method chosen by the consumer could include processing, weaving, or knitting the textile so that the textile retains less water after centrifuging in the washing machine. This will reduce the need for drying and more consumers will probably drip-dry the product.

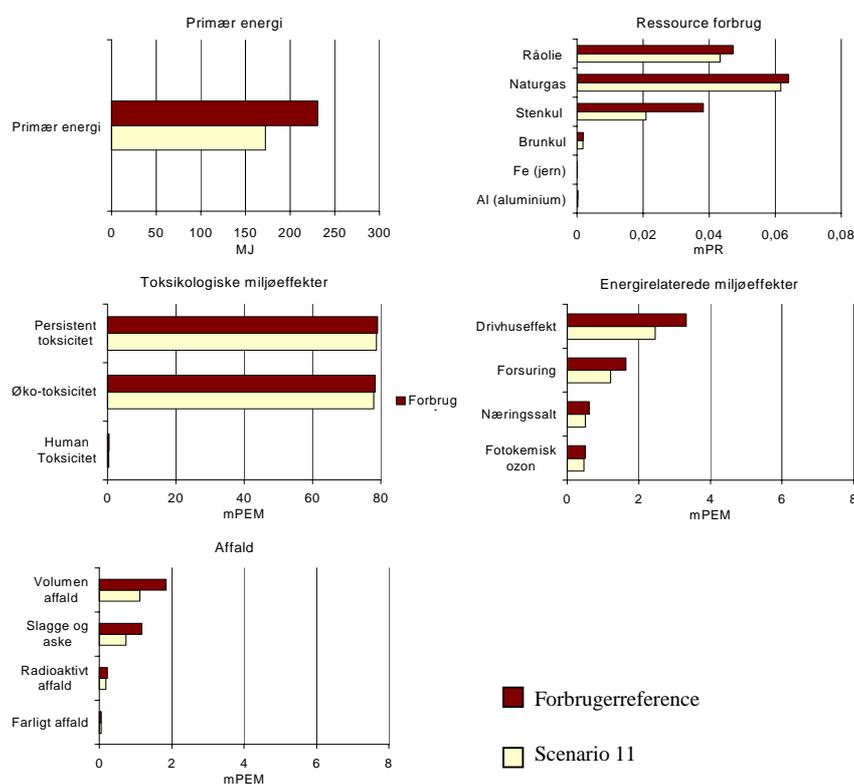


Figure 2.17 Result of scenario 11 - Significant reductions – for translation of Danish terms see glossary in annex 11

The figure shows that drying in a tumbler dryer has a great influence on the overall consumption of primary energy, and this is reduced by approx. 25 per cent. Consumption of resources is also reduced, consumption of crude oil by approx. 10 per cent, natural gas by approx. 5 per cent, and coal by about 50 per cent.

Eliminating drying in a tumbler dryer results in significantly less consumption of Danish electricity. Danish electricity is primarily produced at coal-fired power plants, and therefore consumption of coal is reduced more than crude

oil and natural gas. The energy-related environmental impacts are correspondingly reduced.

The toxicological environmental impact potentials are reduced by just less than 1 per cent, which indicates that electricity consumption does not contribute significantly to this impact category.

Conclusion to scenario 11 - reducing drying needs has a positive impact on the environmental profile

It can be concluded that drying in a tumbler dryer during the use phase has a great influence on the overall environmental profile. It would therefore be an advantage if the producer processed the textile so that water is easier to centrifuge out of the jogging suit. It is necessary to consider the effect of any extra pre-treatment process in relation to savings in the use phase. Another weaving method or surface treatment will require energy, consumption of resources and add to the environmental impacts.

Consequences of choices by the consumer

The consumer reference is based on the main scenario for the lifecycle of 1 jogging suit. The assumptions for the model have previously been described.

The consumer is primarily able to influence the use phase and parts of the transport phase. The other phases can primarily be influenced by the producer. Secondly, the consumer is able to choose producer selectively through, e.g. ecolabel schemes, which can ensure an environmentally correct choice.

The use phase includes washes without prewash and at 40°C, 100 per cent drying. Transport home by car from the shop is included, and the impact is spread over 6 kg goods per jogging suit.

Scenarios - consumer

Scenario 12: Choice of wash - halved washing frequency

Scenario 13: Choice of wash - increased washing temperature from 40°C to 60°C and no prewash

Scenario 14: Choice of wash - use of fabric softener

Drying

Scenario 15: No tumbler drying

- the green consumer's jogging suit

Scenario 16: Half the number of washes, no drying in a tumbler dryer, and produced in organic cotton.

Scenario 12: Choice of wash - halved washing frequency

In the functional unit, the jogging suit is deemed to be used 24 times and washed after each use, i.e. 24 washes. The washing frequency can be affected by the consumer, as this involves consumer habits and consumption patterns. This scenario is to show how much consumer habits influence the overall environmental profile. The following assumes that the jogging suit is washed after being used twice, i.e. half as many washes in private households, resulting in half as many dryings in a tumbler dryer and ironing compared to the consumer reference scenario.

The changes are expected to influence environmental impacts related to energy, resource consumption, as well as toxicological impact types, where use of washing agent has an impact.

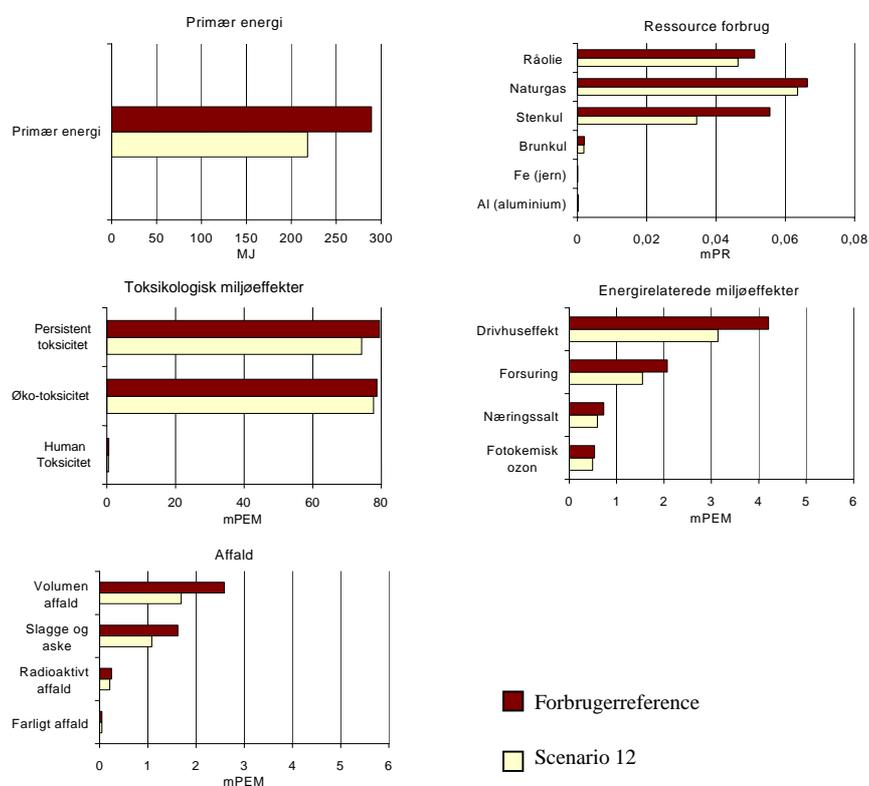


Figure 2.18 Result of scenario 12 - great consumer influence – for translation of Danish terms see glossary in annex 11

Consumption of primary energy is reduced by 24 per cent as a result of lower electricity consumption, primarily for drying. With regard to resources, consumption of fossil fuels is also reduced. The largest reduction is consumption of coal (about 38 per cent). Furthermore, the environmental impacts related to energy are reduced by 7-25 per cent due to a reduction of electricity consumption. As a result of the lower number of washes and consequent lower use of washing agent, there is a slight reduction in the toxicological environmental impacts.

Conclusion to scenario 12

The conclusion to this scenario is that the consumer has a large influence on the overall environmental profile of the jogging suit. A lower number of washes saves the environment from a number of impacts and also increases the lifetime of the jogging suit, provided the assumption that the number of washes wears out the jogging suit is correct. The increased lifetime is not taken into account. This would mean a reduction in the environmental impacts in the manufacturing and production phase.

Scenario 13: Choice of wash - increased washing temperature

Over the last few years, the washing temperature has become a less important parameter for washing effectiveness. Modern washing machines often achieve

the same cleanness at low temperatures. Textiles that are washed at high temperatures for hygiene reasons should be disregarded in this context.

This scenario looks at the consequences of an increased washing temperature. The reference scenario has been prepared on the basis of a 40°C wash programme. In the scenario below, a 60°C washing temperature has been selected on the assumption that it will not affect the quality of the wash.

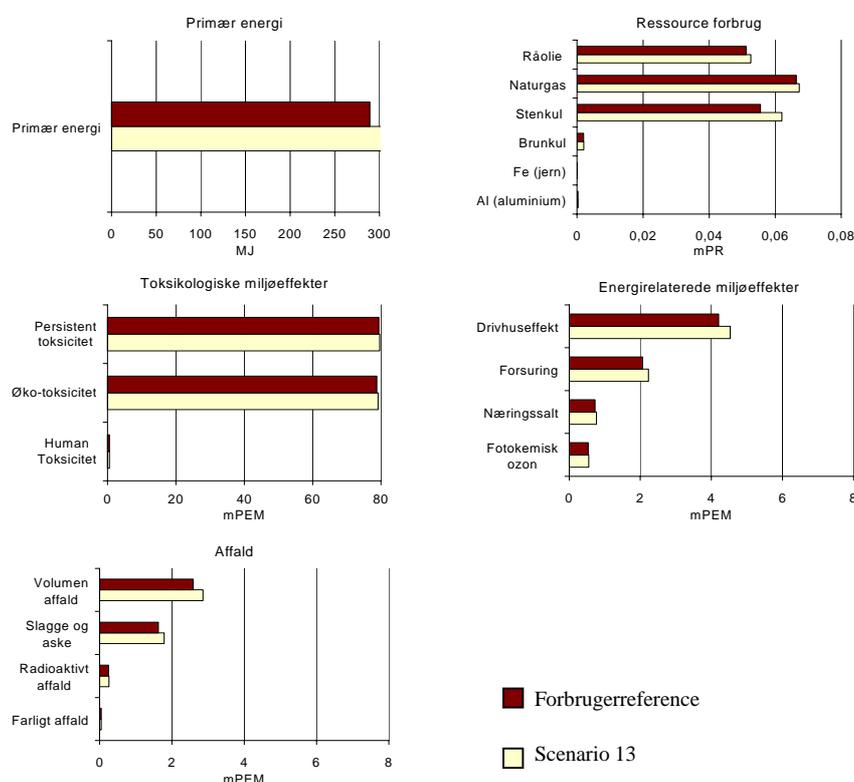


Figure 2.19 Result of scenario 13 - great consumer influence – for translation of Danish terms see glossary in annex 11

The figure shows that the primary energy consumption is increased by approx. 7 per cent when the washing temperature is increased in the use phase. This is due to the energy consumption for hotter washing water. The remaining changes in the environmental profile are directly related to this increased electricity consumption.

As shown before, it is also mainly consumption of coal that increases here, due to Danish electricity generation. Thus, there are also more energy-related impacts and a larger waste volume from incineration. There is also a slight increase in toxicological environmental impacts.

Conclusion to scenario 13

As shown, the consumer holds a large part of the responsibility for the overall environmental profile of a product like the jogging suit. An increased washing temperature would lead to large increases in the environmental impacts related to increased energy consumption, and it is very clear that the consumer has every opportunity to limit the environmental impacts in the use phase by thinking in an environment-friendly manner and by choosing a frugal consumption pattern.

Scenario 14: Choice of wash - use of fabric softener

Fabric softener is primarily used in the production phase, which uses large amounts after dyeing to achieve the quality required for further processing. Moreover, fabric softener is used in many homes as part of an ordinary machine wash. Consumer surveys show that 60 per cent of the Danish population use fabric softener. Fabric softeners in households are not the same as those used by industry, so it is not possible to compare the two processes directly. This scenario has been prepared in order to demonstrate the use of fabric softeners in the home. It is assumed that 3 g of active substance are used per wash. This dosage is different from product to product, but is based on an average. Therefore, it is also assumed that the consumer uses the recommended dose. The database does not include production of the fabric softener, packaging or transport home. Therefore, the only difference is that the toxicological environmental impacts are increased.

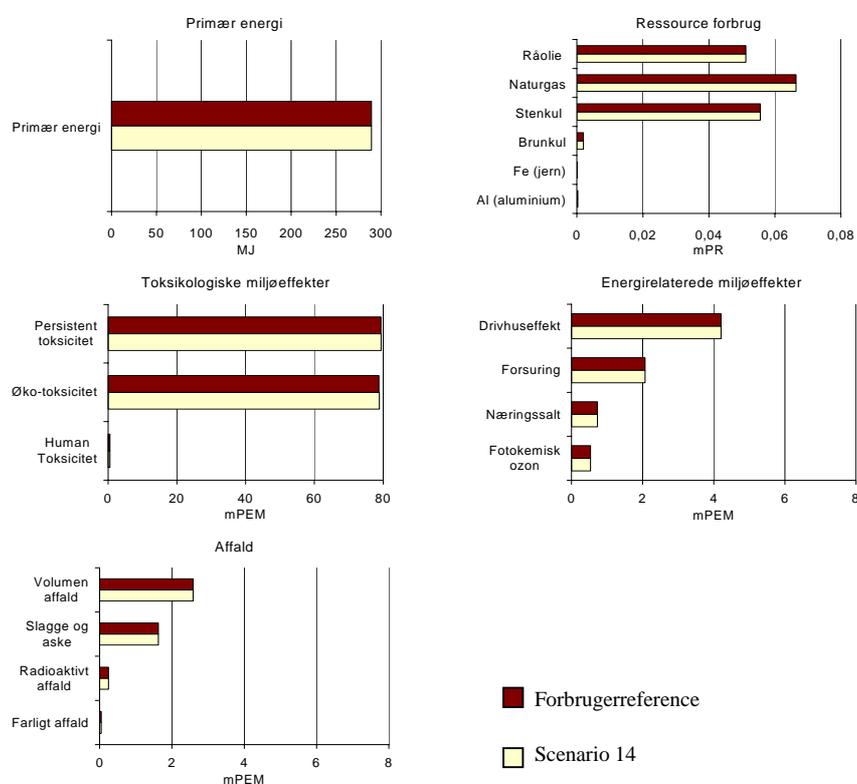


Figure 2.20 Result of scenario 14 - great consumer influence – for translation of Danish terms see glossary in annex 11

There seems to be no significant increase for the persistent toxicity nor for ecotoxicity (0.1 per cent and 0.04 per cent respectively), and human toxicity is unchanged compared with the consumer reference scenario.

If the use of fabric softener is considered in relation to a jogging suit of organic cotton and nylon, the conclusion is very different. Here, the fabric softener contributes with just under 10 per cent to ecotoxicity and 0.7 per cent to persistent toxicity.

Conclusion to scenario 14

The conclusion to this scenario is that the environmental impact from a fabric softener is important. In per cent, the impact seems smallest when the

material contains conventional cotton, as this has very high toxicity factors (see scenario 1).

It is recommended that the consumer does not use fabric softeners. Furthermore, if overdoses are applied there will be greater consequences for the environmental profile and thus even greater toxicological environmental impacts.

Scenario 15: Choice of wash - no use of tumbler dryer

Drying in the home can primarily use two methods. Drip drying on a clothesline and tumbler drying. Often simple factors such as a space, time, and economics determine the method used. A clothesline requires a lot of space, and it may be time demanding in some seasons, e.g. if clothes dry outdoors. Tumbler drying does not require much space in the home and has a constant and short drying time. Conversely, the electricity need is large.

This scenario ignores any wear on the jogging suit from using a tumbler dryer. In such a situation, the scenario would also have to include lifetime and quality. The reference scenario is based on the jogging suit being 100 per cent tumbler dried after washing. This scenario is intended to show the importance of the choice of drying method, and therefore tumbler drying has been excluded. It is assumed that the jogging suit is air-dried.

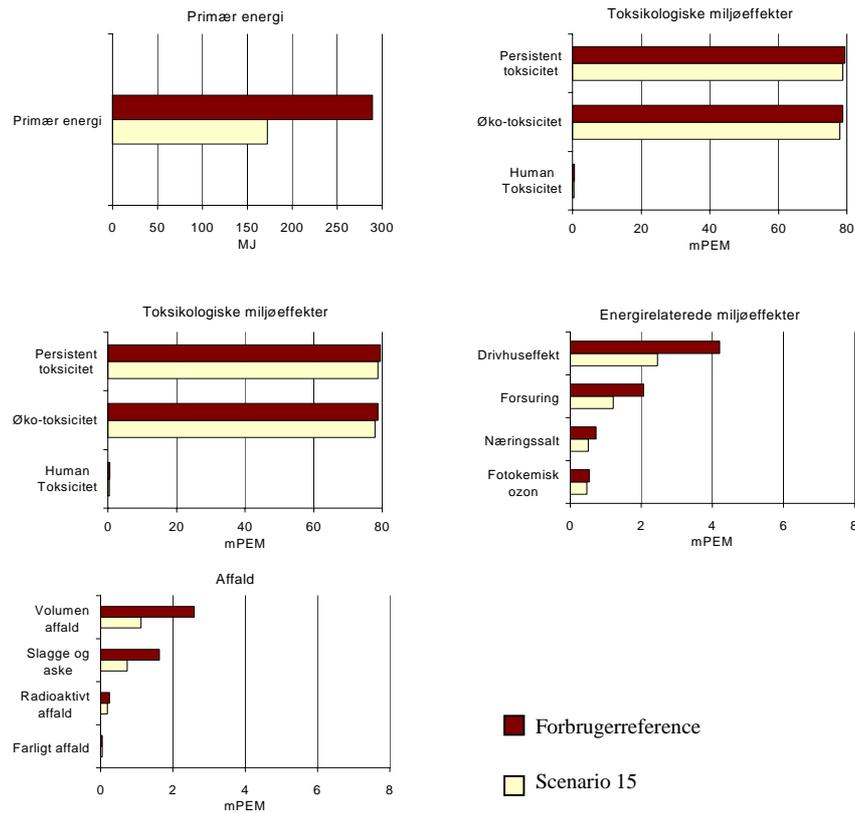


Figure 2.21 Result of scenario 15 - great consumer influence – for translation of Danish terms see glossary in annex 11

The clearest change here is the reduction of primary energy by approx. 40 per cent. Thus, the mechanical drying process contributes considerably to the consumption of primary energy. As a consequence of reduced energy consumption, there is a corresponding fall in the use of coal, which is the

primary energy source in Denmark. This fall is approx. 60 per cent. There is a smaller fall for natural gas and crude oil. When energy consumption is reduced, there will be a similar fall in the environmental impacts related to energy like greenhouse effect and acidification. There is a fall of 10-40 per cent.

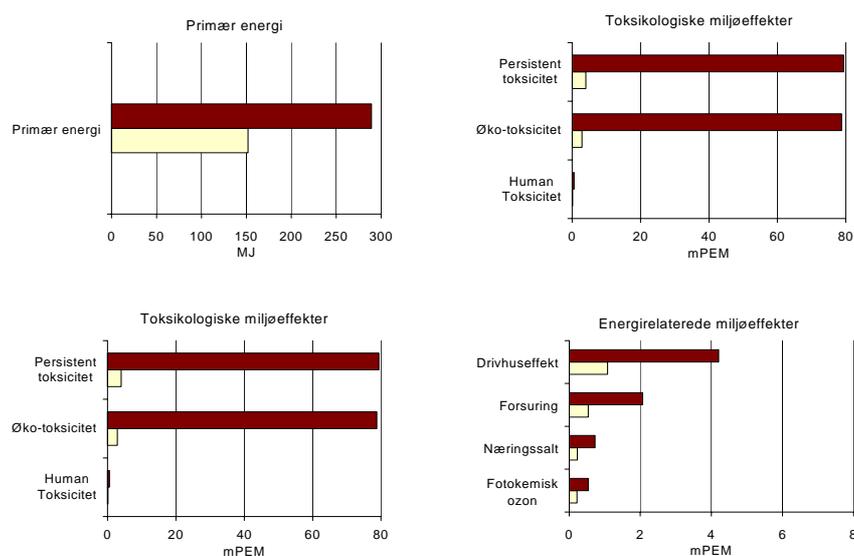
Conclusion to scenario 15

Of all the consumer scenarios in this report, this best illustrates the consumer's possibility of significantly affecting the environmental profile of a textile product, in this case, a jogging suit. The mechanical drying process uses a lot of electrical energy and is therefore resource-intensive and environmentally harmful. The energy saving is up to 40 per cent, and the other factors are reduced by 10-40 per cent. In addition, the lifetime of a product may be extended by avoiding tumbler drying. Increased lifetime has not been taken into account in this scenario, but extended lifetime would mean further reductions for all impacts. When choosing drying method, the consumer has a great influence on the environmental impacts throughout the lifecycle.

Scenario 16: Optimised use phase - organic cotton, half the number of washes, no drying in a tumbler dryer and double lifetime

This scenario attempts to illustrate an optimised use phase, where it is assumed that the consumer takes the greatest possible consideration for the environment, and that the jogging suit is of good quality that increases its lifetime. This optimised scenario includes organic cotton in the materials phase, good product quality, and a use phase that involves less washes and no tumbler drying.

In the preceding scenarios, we have seen how the individual processes contribute to the overall environmental profile. Each scenario elucidates the importance of individual processes in the use phase and of the choice of raw materials. This scenario is intended to show the consumer's overall possibility of influencing the overall environmental profile when selecting materials and an optimal consumption pattern.



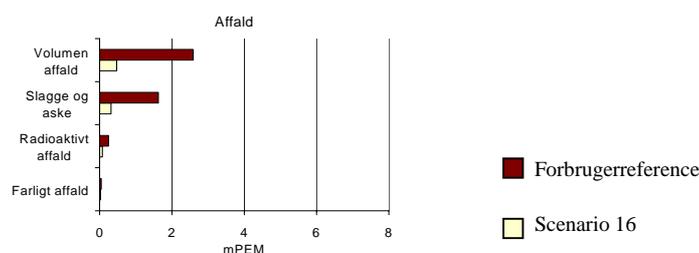


Figure 2.22 Result of scenario 16 - great consumer influence – for translation of Danish terms see glossary in annex 11

The figure shows that the consumer's choices have major consequences for the overall environmental profile. The reduction of primary energy of almost 50 per cent is due to air-drying and a halved number of washes. Moreover, lifetime plays an overall role, as the jogging suit will last two years instead of the one year in the functional unit. This means there is one-half jogging suit per functional unit. As a consequence of reduced energy consumption, there are similar reductions in resources and environmental impacts related to energy. The reduction of toxicological environmental impacts originates from the use of organic cotton instead of conventionally cultivated cotton, which contributes to the environmental profile with its large pesticide consumption. This reduction corresponds to almost 98 per cent of the jogging suit's overall contribution to the toxicological environmental impacts. Finally, there is reduced waste generation as a consequence of reduced energy consumption.

Conclusion to scenario 16

As was said in the introduction to this scenario, the preceding scenarios have helped illustrate how the individual processes are related to environmental impacts. This scenario has shown how far it is possible to go by combining the many possibilities of reducing impacts. The conclusion is that the use phase represents a significant proportion of the overall impact during a lifecycle. This scenario has shown that savings have been achieved for all significant impacts of 45-98 per cent. It shows that the consumer can make large environmental savings by influencing the market towards ecology and quality and by thinking environment-friendly during the use phase. No mechanical drying, fewer washes and purchasing environmentally friendly products.

Background data

System structure in the EDIPTEx database for the jogging suit

	Ref. no.: EDIPTEx database
1 jogging suit, dyed (nylon/cotton)	(TX0-04)
1 materials phase:	(TX6-1-07)
0.402 kg polyamide 6.6 fibres (nylon)	(TX1-06)
0.006 kg plastic zipper (polyester)	(TX29-2-01)
0.583 kg cotton fibres (incl. cultivation and harvest)	(TX1-01-1)
1 production phase:	(TX6-2-20)
<i>(Nylon outer shell)</i>	
4.02 m weaving, no sizing agents	(TX23-2)
0.398 pre-treatment of woven fabric (nylon)	(TX24-2-03)
0.398 kg softening nylon	(TX27-2-02)
0.394 kg drying, final fixing + set of m ² weight (nylon)	(TX27-3-01)
3.88 m ² fabric inspection + rolling onto cardboard roll (nylon)	(TX27-3-08-06-01)
0.398 kg dyeing nylon (acid dye %)	(TX25-06-01)
<i>(Cotton lining)</i>	
0.408 kg yarn manufacturing (cotton yarn)	(TX21-1)
0.402 kg circular knitting, general data	(TX22-1-01)
0.398 kg pre-bleaching with H ₂ O ₂ (knitted cotton)	(TX24-1-03)
0.398 kg softening cotton textile	(TX27-2-01)
0.394 kg drying, final fixing + setting m ² weight	(TX27-3-06)
2.59 m ² fabric inspection + rolling onto cardboard rolls	(TX27-3-08-06)
<i>(Making-up)</i>	
1 jogging suit – laying out and cutting	(TX28-1-01)
1 jogging suit – packing	(TX28-2-03-01)
1 use phase	(TX6-3-05)
16.8 kg household wash, 40°C, normal, no prewash	(TX33-1-101)
8.4 kg tumbler drying (vent) cotton, cupboard-dry	(TX33-2-11)
8.4 kg tumbler drying (vent) synthetic	(TX33-2-13)
1 disposal phase	(TX6-4-05)
0.35 kg waste incineration of cotton	(TX41-1-05)
0.35 kg waste incineration of polyamide (nylon)	(TX41-1-01)
0.006 kg incineration of plastic zipper	(TX41-2-11)
1 Transport phase	(TX6-5-05)
0.07 kg petrol combusted in petrol engine	(E32751)
11660 kg km container ship, 2-t, 28000DWT, terminated	(O3715T98)
830 kg km lorry > 16 t diesel out-of-town, terminated	(O32694T98)
830 kg km lorry > 16 t diesel urban traffic, terminated	(O32695T98)
830 kg km lorry > 16 t diesel motorway, terminated 1 stk.	(O32693T98)
Træningsdragt, farvet (Nylon/Bomuld)	

Details of the jogging suit model in the EDIPTEx database

Assumptions:

- 100 % nylon, microfibre, woven
- 100 % cotton lining (knitted)
- Consists of both top and trousers
- Top includes zipper of polyester (both tape and teeth), 60 cm, zipper weighs approx. 6 g, i.e. 0.1 g per cm
- Dyeing nylon: acid dyes
- Cotton lining is assumed to be prewashed and bleached after knitting

- Washing 40°C
- Tumbler drying
- Ironing not necessary
- Lifetime: 24 washes
- Weight: Top weighs 406 g, of which 6 g is zipper, trousers weigh 300 g. Lining weighs 50 % of total weight, i.e. top: 200 g cotton, 200 g nylon. Trousers: 150 g cotton, 150 g nylon. Total 350 g nylon and 350 g cotton.

Functional unit

The calculations are for "1 jogging suit".

This needs to be converted in relation to lifetime, and the calculations need to be converted to "per year".

It is assumed that the jogging suit can be washed 24 times before it is discarded.

It is assumed that the consumer wears the jogging suit approx. twice per month.

It is assumed that the jogging suit is used once and is then washed.

The lifetime is thus 12 months or approx. 1 year.

The functional unit for a jogging suit is therefore:

"24 days' use of jogging suit washed each time after use".

It is assumed that 24 days correspond to the number of days a consumer wears a jogging suit over the course of 1 year.

For the scenario, this corresponds to 1 jogging suit being completely worn out (in that it is assumed that the jogging suit is washed after use for 1 day).

Disposal:

It is assumed that the jogging suit is sold in Denmark and disposed of through waste incineration. 0.35 kg cotton and 0.35 kg nylon and 6 g polyester (zipper).

Household wash:

It is assumed that the jogging suit can be washed 24 times in its lifetime. This means that $0.35 \text{ kg} * 24 = 8.4 \text{ kg}$ cotton + $0.35 \text{ kg} * 24 = 8.4 \text{ kg}$ nylon (synthetic), total $0.7 \text{ kg} * 24 = 16.8 \text{ kg}$ must be washed. Washing at 40°C, normal, no prewash.

Drying:

It is assumed that the jogging suit is dried in a tumbler dryer. 8.4 kg cotton and 8.4 kg nylon (synthetic).

Packing the jogging suit:

It is assumed that the jogging suit is packed in a thin plastic bag. It is assumed the bag weighs 20 g (twice that of a T-shirt, see annex 1).

Making-up the jogging suit:

A new process has been set up: jogging suit - laying out, cutting and sewing TX 28-1-01. The process is calculated "per jogging suit". It is assumed that energy consumption is approx. twice of what is consumed for a tablecloth, see annex 5.

Waste is estimated at approx. 10 per cent for outer shell, nylon and cotton lining. This means approx. $0.35 \text{ kg} / (1-0.10) = 0.388 \text{ kg}$ nylon and cotton must be used. It is assumed that all the waste is discarded (incinerated at a waste incineration plant).

Nylon outer shell

Dyeing nylon (acid dye) 1 %:

0.388 kg textile must be used per jogging suit for this process. There is no waste of textile in this process.

Pre-treatment of synthetic woven fabric:

Only washing. No bleaching. 0.388 kg textile must be used for this process. There is waste in the process, and therefore 1010 g woven textile must be used per kg pre-treated textile. Therefore, $1.01 \text{ kg} * 0.388 = 0.392$ woven fabric must be used per jogging suit. The waste is incinerated.

Weaving, no sizing agent:

0.388 kg textile must be used for this process.

Polyamide 6.6 fibre (nylon):

0.388 kg textile must be used for this process. Note that in relation to cotton there is no yarn manufacturing, as filament yarns are used and they come directly from the fibre producer.

Cotton lining

Bleaching with H₂O₂ (knitted cotton):

0.388 kg textile must be used for this process.

There is waste in the process, and therefore 1010 g knitted textile must be used per kg bleached textile. Therefore, $1.01 * 0.388 = 0.392$ kg knitted textile is used.

Knitting:

0.392 kg textile must be knitted.

1.015 kg yarn is used per kg circular-knitted textile. Therefore, $1.015 * 0.392 = 0.398$ kg yarn is used.

Yarn manufacturing:

0.398 kg yarn must be used per jogging suit.

1.43 kg cotton fibre is used per kg cotton yarn. Therefore, $1.43 * 0.398 = 0.569$ kg cotton yarn is used for one jogging suit.

Cotton fibre:

0.569 kg cotton fibre is used for one jogging suit.

Standard components, zipper

Plastic zipper:

0.006 kg polyester zipper is used.

Transport:

All transport distances are estimated. See table below.

Transport	Quantity for one jogging suit	Kg km
Nylon outer shell:		
Transport of nylon fibres (filaments) to weaving mill from Germany to Denmark	0.388 kg transported 1000 km by lorry	388 kg km by lorry
Transport of woven fabric from weaving mill to pre-treater and dye house, both in Denmark	0.388 kg transported 1000 km by lorry	77,6 kg km by lorry
Transport of dyed fabric from Denmark to making-up enterprise in Poland	0.388 kg transported 1000 km by lorry	388 kg km by lorry
Cotton lining:		
Transport of cotton from cultivator in China to spinning mill in Poland	0,569 kg transported 20000 km by ship	11380 kg km by ship
Transport of yarn from spinning mill in Poland to knitting mill in Denmark	0,398 kg transported 1000 km by lorry	398 kg km by lorry
Transport of fabric from knitting mill to pre-treater, both in Denmark	0,392 kg transported 200 km by lorry	78,4 kg km by lorry
Transport of fabric from pre-treater in Denmark to making-up enterprise in Poland	0,388 kg transported 1000 km by lorry	388 kg km by lorry
Jogging suit:		
Transport from making-up enterprise in Poland to shop in Denmark, lorry	0,706 kg transported 1000 km by lorry	706 kg km by lorry
Consumer transport*		0,07 kg petrol
Transport of discarded jogging suit (with household refuse)	0,706 kg transported 50 km by lorry	35,3 kg km by lorry

Lorry, total: 2459.3 kg km (assumed 33 per cent urban, 33 per cent out-of-town, 33 per cent motorway).

* Consumer transport: It is assumed that the consumer drives in town by car to buy 1 jogging suit and 5.294 kg other goods. It is assumed the consumer drives 10 km and the car goes 12 km per litre. This means 0.83 l petrol is used (= 0.61 kg petrol, as petrol weighs 0.73 kg per litre). Of this, 0.61 * 0.706/6 is allocated to the jogging suit, i.e. 0.07 kg petrol.

I.e. total transport:

Process no. in EDIPTX database	Name of the process	Transport need
O32715T98	Container ship, 2-t 28000 DWT, TERMINATED	11.660 kg km by ship
O32695T98	Lorry > 16 t, diesel urban traffic, TERMINATED	830 kg km by lorry
O32694T98	Lorry > 16 t diesel out-of-town, TERMINATED	830 kg km by lorry
O32693T98	Lorry > 16 t diesel motorway, TERMINATED	830 kg km by lorry
E32751	Petrol consumed in petrol engine	0,07 kg petrol

Annex 3: Work jacket of polyester/cotton

Work jacket – summary and conclusions

The main scenario for environmental assessment of the work jacket shows that the most significant focus areas are toxicological environmental impacts and resource consumption. The contribution to the toxicological environmental impact potentials originates from fertilizer and insecticides for cotton in fibre production and from production of the artificial fertilizer used. The resource consumption and the contributions to the environmental impact potentials related to energy mainly originate from production of steam for washing and drying at industrial laundries, i.e. during the use phase.

At an overall level, the scenarios indicate that the producer holds the best possibilities for influencing the product's overall environmental profile. This is primarily related to choice of materials and chemicals. The former is clear in the scenarios where organic cotton has been used. By living up to European and Scandinavian ecolabelling criteria and obtaining labelling approval, the producer can signal to the conscious consumer that the product in question has been produced in an environmentally sound manner. Moreover, there are a number of production-related improvements that only the producer can influence. This could be choices related to:

- organic materials
- hard-wearing materials
- choice of carrier for the dyeing process
- non-toxic reactive dyes.

The individual consumer's consumption patterns and environmental awareness are also crucial for the work jacket's environmental profile. Awareness of ecolabelling of products in combination with good habits like:

- choice of the most environmentally friendly washing method (industry/household)
- minimal use of washing agent
- no use of fabric softeners
- no tumbler drying.

Thus, the conclusion is that focus should be on the fibre production phase and the use phase.

Introduction

Lifecycle assessment is a method for identification and evaluation of environmental impact potentials of a product or a service from cradle to grave. This method enables the user to make an environmental assessment and focus on the most important environmental impacts.

lifecycle assessment is an iterative process. The first definition of purpose and delimitations often need to be revised during work with lifecycle assessment. The amount of data available sets limits, and consequently the limits of the system are changed.

The method used in this case for assessment of products is "Environmental Design of Industrial Products" (EDIP) and the associated database and PC tool.

In the EDIPTEX project, sector-specific data have been prepared for the textiles sector in connection with the existing EDIP database. The reports contain environmental assessments for the following textile products:

- T-shirt
- jogging suit
- Work jacket
- Floor covering
- Tablecloth
- Blouse

These environmental assessments are intended to illustrate the scope for application of the EDIPTEX database by using the PC modelling tool and, at a more general level, application of the EDIP method.

Method

The six case stories vary a lot in scope. They can be divided into two main groups - with variations within these two main groups. The two main groups are:

- Group I: The T-shirt, the jogging suit and the work jacket.
- Group II: The floor covering, the tablecloth and the blouse.

The division into groups I and II relates to the scope of the collection of data as well as the quality of data.

For group I, it was possible to collect (and process) data for all significant processes. The data are of such quality that these three products have been selected to illustrate how far it is possible to take lifecycle assessment for textiles and to illustrate all relevant aspects of the EDIP method.

Each of the three group I cases contains:

- Definition of functional unit and reference product
- Modelling of main scenario
- Preparation of producer and consumer references
- Simulation of environmental impacts caused by choices made by producer and consumer respectively.

Work with these cases has been divided into phases as illustrated in figure 3.1.

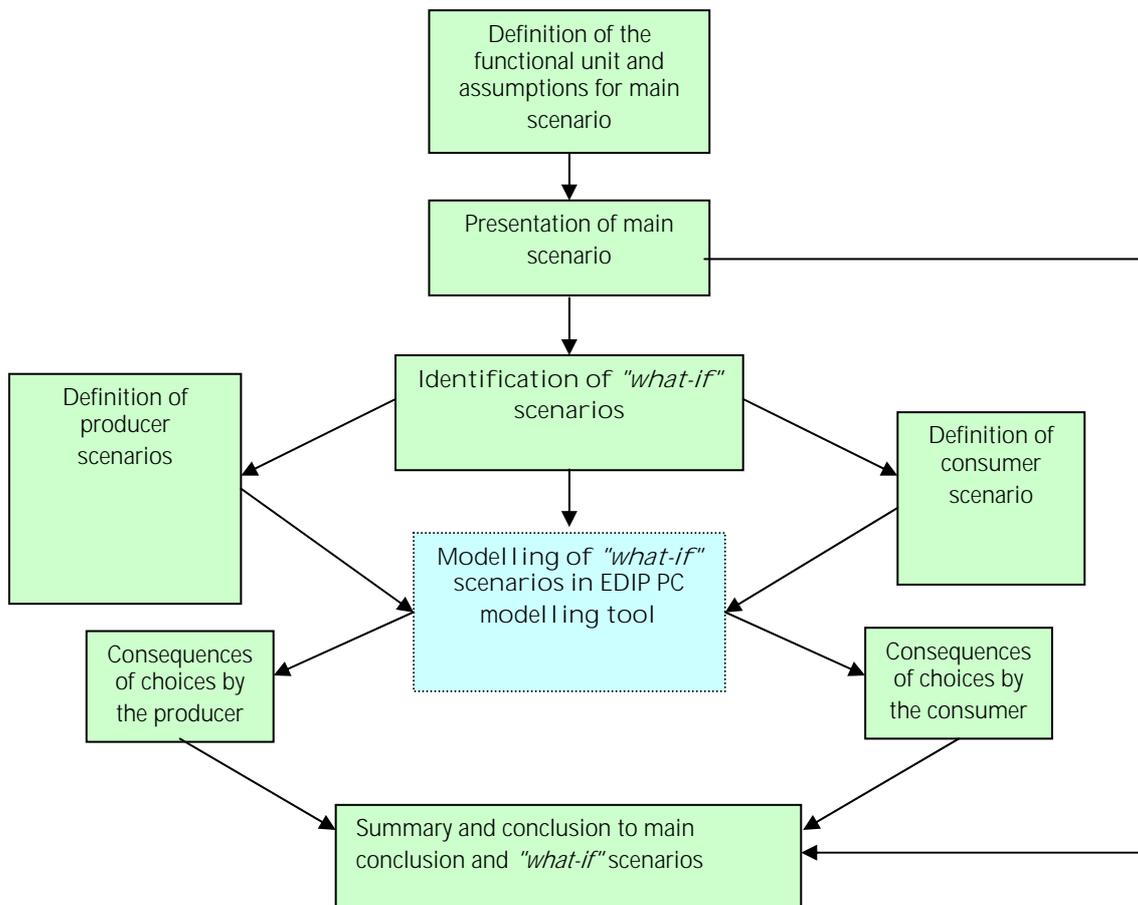


Figure 3.1 EDIPTEX case group I flow diagram

For group II, it was not possible to complete all sub-processes. Although only 1-2 sub-processes for each product have considerable lack of data, these processes are deemed potentially significant for the overall lifecycle assessment. The group II case stories are therefore of an entirely different character than those of group I. The group II cases illustrate that it is possible to tell an interesting and exciting "environment story" based on lifecycle assessment (and EDIP) even though it has not been possible to analyse all aspects of lifecycle assessment data. This situation will arise very often in lifecycle assessment work. However, there is a significant difference in this EDIPTEX connection; it is possible to draw on results from the three lifecycle assessments from case group I (and this has been done), which improves the quality of the case stories.

Comments to the method

Product references

The "what-if" simulations were carried out to elucidate the consequences of possible changes in the product's lifecycle. A special product reference has been defined for the producer scenarios in some of the case stories. The producer only has limited influence on the use phase. In order to take this into account, a product reference has been prepared for the producer scenarios

where only a limited part of the impacts from the use phase has been included in relation to the product reference from the main scenario. This was done in order to give producers a clearer picture of the influence of the production phase on the product's environmental profile in the "what-if" producer scenarios.

Data

With regard to data, it should be noted that the validity of the data in the database varies, depending on the processes considered. A global process like cultivation and harvest of cotton is subject to considerable uncertainty. This is because cotton is produced in countries with very different levels of development. For example, production varies a lot between South America and the US because of large differences in the use of pesticides, crop yields, etc.

This difference has not been taken directly into account in the EDIPTTEX database, but a representative level for the data has been defined. Therefore, the data are very general and not necessarily representative for all lifecycle assessments. Other processes are more exact, such as extraction of crude oil for nylon. This process is well documented, both as regards industrial accidents and as regards resource consumption.

Production data primarily come from Danish enterprises. The number of enterprises involved represents limitations in this connection. For example, only one reactive dye and one acid dye have been studied thoroughly. These two substances represent the entire group of dyes, despite the major differences that may occur.

A large proportion of the environmental impacts come from the consumption of electrical energy. The data currently used in the database originate from the EDIP database, and the reference year is 1990. This area is being studied in order to update this part of the database. It is important to note that this lifecycle assessment was carried out using the 1990 data in all processes that consume electrical energy.

The work jacket

Product description: work jacket of 65 per cent polyester and 35 per cent cotton. Ten brass buttons, one brass zipper and one polyester zipper in pocket are included.

Functional unit

The performance assessed can be described as a "functional unit", comprising a qualitative and a quantitative description, including the product's lifetime. The qualitative description is to define the quality level for the performance, so that products can be compared at a somewhat uniform quality level. The quantitative description is to determine the size and duration of the performance.

In this project, the functional unit is defined as:

"40 days' use of a work jacket washed each time after use, over three years"

Lifetime is defined as 3 years. It is assumed that the work jacket is washed 40 times in its lifetime. This corresponds to approx. 14 washes per year.

Reference product and main scenario

One work jacket is used as reference product. For the reference scenario, the functional unit corresponds to 1 work jacket being discarded every three years.

The following assumptions apply to the assessment and are thus included in the modelling of the main scenario.

The work jacket consists of 65 per cent polyester and 35 per cent cotton, corresponding to approx. 500 g and 270 g respectively. 10 brass buttons are included, each weighing 3.6 g, one brass zipper for the front, approx. 60 cm (40 g), and one polyester zipper in inner pocket, approx. 15 cm (4 g), a total of 80 g extra components.

The work jacket is washed after every use, corresponding to approx. 14 periods of use of the work jacket per year, i.e. approx. 40 times in 3 years, and then it is discarded. These are average data. Some work jackets last 10-12 years, corresponding to the 100-120 washes they can endure, while others are discarded because of damage that is too time-consuming to repair. A scenario will illustrate the consequence of maximum lifetime of the product.

The reference product is also assumed to meet the following criteria:

- The warps are treated with a sizing agent before the textile is woven.
- The woven textile is desized before being dyed.
- Reactive dyes are used for cotton and dispersion dyes are used for polyester.
- The textile is dyed in an atmospheric jigger using a solvent carrier based on dichlorobenzene.
- The textile is finished after dyeing with a sewability improvement agent (softener).
- There is no print on the work jacket.
- The work jacket has ten brass buttons, one brass zipper for the front and one polyester zipper in an inside pocket.
- Lifetime: Three years - key figures from the laundry sector.
- Number of washes during lifetime: 40 - key figures from the laundry sector.
- Washed at 80-95°C and tumbler dried at industrial laundry.
- Ironing not necessary.

A more detailed description of the processes, calculations of volumes, waste, etc. can be found in the section "Background data" at the end of annex 3.

Product system

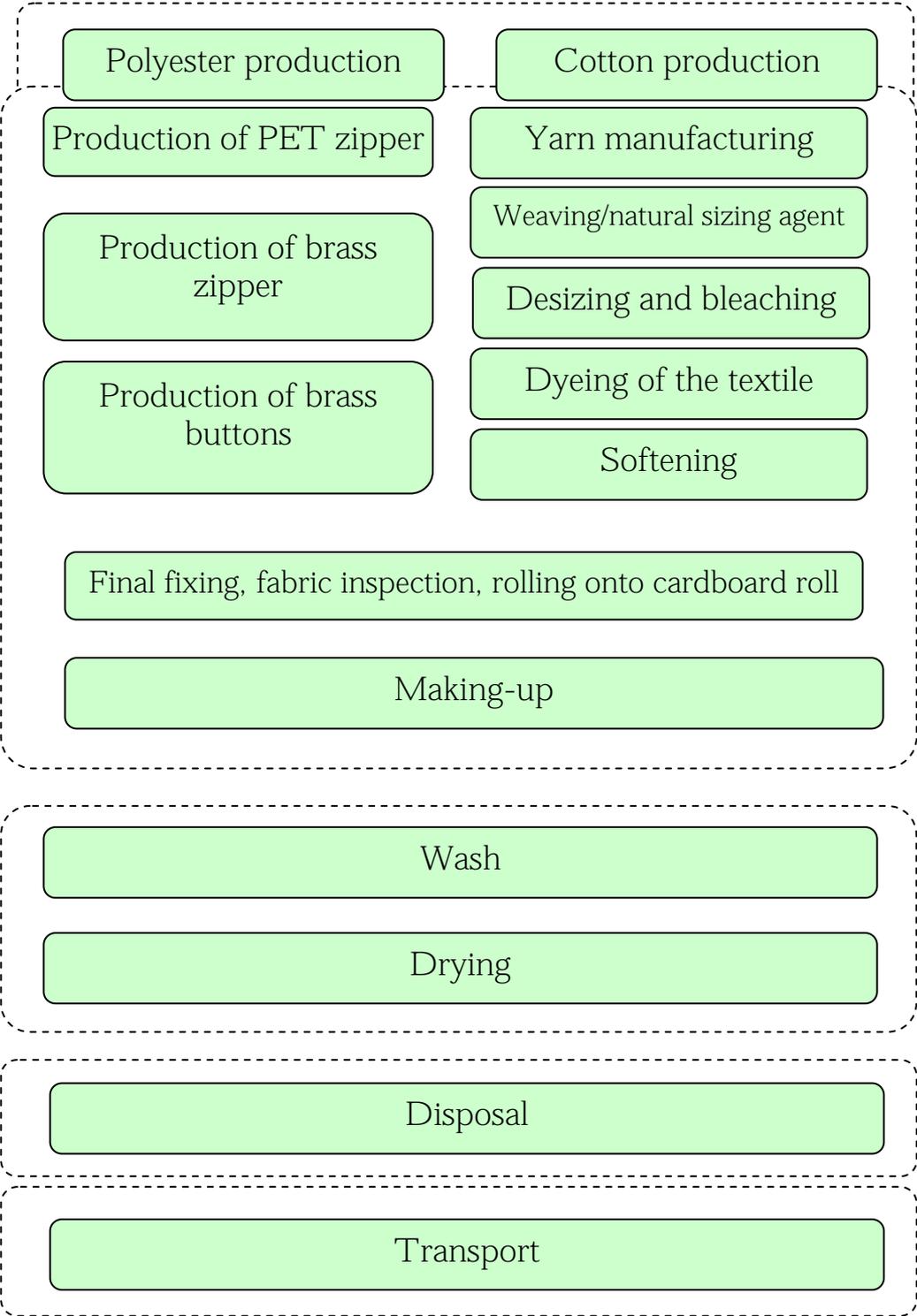


Figure 3.2 Lifecycle, flow and phases

Figure 3.2 describes the lifecycle of the work jacket. From extraction of raw materials to yarn manufacturing, the product has two parallel lifecycles due to the textile composition; cotton and polyester. Manufacture of brass buttons and zipper has been included as secondary factors. This also applies to polyester buttons and zipper. The actual manufacture of buttons and zippers is not included.

The product's lifecycle phases from extraction of raw materials to disposal are described in the following.

Manufacture of raw materials

As mentioned, there are two main materials in the work jacket assessed:

- Cotton
- Polyester.

Cotton manufacture

Cotton is cultivated in many countries under different geographical and climatic conditions. Cultivation often entails a large consumption of artificial fertilizer, large water consumption and a large consumption of pesticides against insect attacks, diseases, worms and weeds. The extent of this depends largely on local conditions. The consumption of pesticides entails an important environmental problem for both human health and nature.

Irrigation and use of artificial fertilizer impact groundwater and surface water resources quantitatively as well as qualitatively. Before picking, it is common to use defoliating agents so that picking can be done mechanically.

Organic cotton

It is normally not permitted to use pesticides and artificial fertilizer in cultivation of organic cotton. Thus, it is only permitted to use a very limited selection of plant protection agents, and only when there is an acute danger for the crop. Organic production of cotton constitutes less than 1 per cent of total cotton production, but organic production is increasing and is expected to increase further due to increased demand.

Production of synthetic fibres

Polyester is produced on the basis of crude oil and natural gas that are converted to plastic through a number of chemical processes. The raw material is a limited resource, and production may lead to impacts on humans and the environment at local, regional and global levels. During processing of the materials into fibres, lubricants are usually added in the form of spindle oil and antistatic agents. Bactericides and fungicides may be added.

Production of the work jacket

Production is divided into several processes: yarn manufacturing, weaving, pre-treatment, dyeing, finishing and making-up.

Yarn manufacturing

The cotton and polyester fibres are normally blended in the desired blending ratio as the first step of the process at the spinning mill. The fibres are then carded, combed and spun into yarns.

Before the cotton can be spun into yarn, the fibres need to be separated from the remaining plant material. One of the largest environmental risks in this process is inhalation of cotton dust. In just a few years, staff can develop the fatal disease Byssinosis (commonly called "Brown Lung"). It is therefore important that machines be closed in so that dust development is minimal. This also applies for the actual spinning process where the fibres are spun into yarns.

Weaving

All weaving mills use agents to reinforce the warp in the actual weaving process - these agents are called sizing agents. Sizing agents may be based on natural starch from e.g. corn, rice or potatoes. They may also be based on synthetic substances like polyvinyl alcohols (PVA) or carboxymethylcellulose (CMC). If synthetic sizing agents are used, they are sometimes reused. However, this requires the desizing process to be carried out near a weaving mill where the sizing agent can be reused.

In the environmental assessment of the work jacket, the assumption is that a natural sizing agent is used in the weaving process. This is because there are no enterprises in Denmark that can reuse the sizing agent. Moreover, the assessment applies data from modern weaving mills that use closed-off high-speed air jet looms.

Pre-treatment

In connection with the pre-treatment of woven products, the sizing agent is always washed out of the woven goods in a desizing process. The cotton also contains some cotton wax, and the polyester yarns contain lubricating oils from production that also need to be removed before it is possible to dye the textiles. Remains of pesticides from cotton cultivation, mainly defoliation agents, are also washed out in this process and then end up in the wastewater.

If the end product is to have a light colour, the natural colour of the fibres can be removed by bleaching them. If chlorine bleaching is used, AOX compounds (adsorbable organic halogens) will be formed and subsequently discharged, and these are harmful to the environment. It is also possible to bleach using hydrogen peroxide that does not cause discharges of AOX compounds.

Desizing using enzymes and washing and bleaching with hydrogen peroxide, which are normal in Denmark, have been used as the basis for the environmental assessment of the work jacket. Moreover, the environmental assessment includes limited discharges of pesticides (0.005 g defoliation agent per kg cotton).

Dyeing

The different types of fibre are dyed separately. Cotton is typically dyed using vat or reactive dyes, and polyester is dyed using dispersion dyes.

The dyeing process for the reference product is defined as being carried out in an atmospheric jigger. In order to dye the polyester part, it is necessary to use carrier solvents to open the polyester fibres to the dispersion dyes. Dyeing with carriers is not normal in Denmark, as it has been ascertained that some of the substances are carcinogenic or harmful to the nervous system. However, carriers are still being used in several places in the world to dye polyester. Therefore, dyeing with carriers has been included to illustrate in a scenario the

significance of transition to more environmentally friendly carrier types or of completely removing them from the process.

Dyes for dyeing textiles are chemically often based on azo groups and may contain heavy metals. Some dyes containing azo groups may release carcinogenic substances of the type arylamines.

Dyes from the group of reactive dyes and dispersion dyes without heavy metals and without arylamine problems have been selected for this environmental assessment. The polyester part has been dyed using a carrier based on dichlorobenzene.

Finishing

Finishing the textiles for a work jacket will normally consist of a treatment with a sewability improvement agent (softening) to facilitate the subsequent making-up stage. Chemicals are also used to give many textiles specific functional properties, such as non-iron, water-repellent and fire-retardant. Auxiliary chemicals in these productions often have many extremely undesirable environmental properties, both for the environment and for occupational health and safety.

The environmental assessment of the work jacket is based on the textiles being finished with a fabric softener.

Making-up

In the making-up stage, there is waste from the cutting-to-size process for the final product. For the work jacket, waste of 10 per cent is assumed. Some of the waste products are reused for products of a lower quality. The main part is sent to waste incineration with heat and energy recovery, which is set off against energy consumption by the production equipment.

Occupational health and safety

The supplier is obliged to reduce the amount of monotonous repetitive work and dust nuisance at work. Cotton dust may cause lung damage, for example.

Distribution

The work jacket is packed in polyester bags and then on a wood pallet. Finally, it is distributed to retail suppliers.

Use phase

In this environmental assessment of the work jacket, the main scenario is that it is washed at 80°C and then tumbler dried at an industrial laundry.

Disposal phase

Textiles must not be landfilled. They must be incinerated at final disposal. In this way, the energy content is recovered and replaces energy sources like oil and natural gas. Incineration of cotton is CO₂ neutral, because the cotton crop has absorbed the same quantity of CO₂ as is released during incineration. The brass buttons and the zippers leave the incineration plant along with the slag, and have an insignificant impact on the environment.

Transport phase

In the environmental assessment of the work jacket, transport scenarios are included to and from the different processing links in the production chain, and finally from the sewing factory to Danish retailers.

Main scenario - results

The results of the main scenario are presented according to processes. The negative contributions that occur in some processes are due to estimated reuse potentials, resource consumption and contribution to environmental impact potentials. In the processes in question, the contributions can be allocated to other products and thus appear as negative contributions in the work jacket's environmental profile.

The values in the five figures are not immediately comparable, as the unit is not the same for the five categories. The consumption of primary energy is calculated in mega-joules (MJ), while the resource consumption is shown in the unit "person-reserves". Person-reserves take into account the supply horizon of the individual resources, calculated on the basis of the reserves available in the world in 1990. It should be noted that the data used here are more than ten years old, and therefore, new knowledge about the world's resources may have become available, but is not yet included in the database. The environmental impact potentials are presented in milli-person equivalents and are directly comparable. Milli-person equivalents are calculated as the direct impact for the year 2000. The weighting factors are based on global (w) or Danish (DK) discharges in the year 2000.

Consumption of primary energy

Figure 3.3 shows that the processes in the use phase represent the majority of the consumption of primary energy. The consumption of primary energy reflects the processes that require a lot of electrical energy or heating air or water. Clearly, washing and drying the work jacket in the use phase represents the main part of the primary energy consumed. The large consumption of electricity and steam at industrial laundries causes this impact. Fibre production is also an energy-consuming process because of the related production of artificial fertilizer and pesticides. Moreover, there is energy consumption for spreading artificial fertilizer and pesticides, but these are not included in the statement.

Resource consumption

The work jacket consumes a relatively large amount of fossil fuels (see figure 3.4), partly because of the energy-intensive processes in its lifecycle, and partly because of the production of 65 per cent polyester. Polyester is produced from crude oil. In the use phase, the large consumption of electricity and crude oil for the steam boilers at the industrial laundry causes the significant consumption of fossil fuels. As it is assumed that the work jacket will be used in Denmark, electricity consumption is primarily based on burning coal at coal-fired power plants. In the disposal phase, some resources are credited because energy is recovered that would otherwise have come from burning fossil fuels.

Environmental impact potentials

Environmental impact potentials related to toxicity

Of the three environmental impact categories, the ones related to toxicity are dominant (see figure 3.5). In the fibre production phase, the large contribution to ecotoxicity is primarily due to the use of pesticides in cotton cultivation. In the pre-treatment processes carriers, dyes and fabric softeners cause the contributions to ecotoxicity and persistent toxicity. The impact potentials in connection with wash of the work jacket primarily originate from detergents in washing agents, which result in potential human and persistent toxicity.

Environmental impact potentials related to energy

The environmental impact potentials related to energy (figure 3.6) are caused by burning fossil fuels in the situations mentioned above. As can be seen in the figure, the use phase impacts the environmental profile of the work jacket the most.

Environmental impact potentials related to waste

The contributions to the waste categories shown in figure 3.7 mainly originate from electricity generation. They are limited in size compared to the above impact categories.

The conclusion of the lifecycle statement is that the product is resource-intensive primarily because of the large consumption of electrical energy and crude oil for steam in the use phase.

Results from modelling and calculation of the main scenario

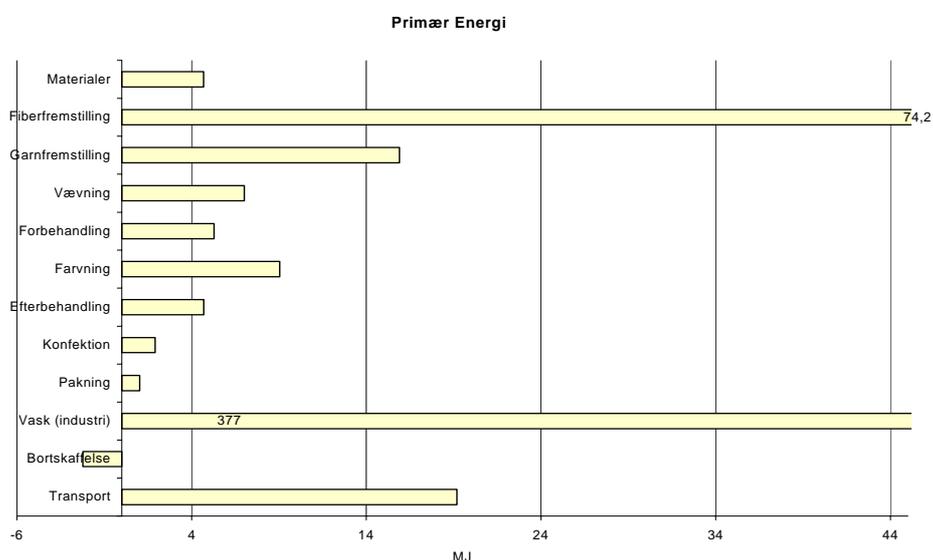


Figure 3.3 Results of main scenario; consumption of primary energy per functional unit – for translation of Danish terms see glossary in annex 11

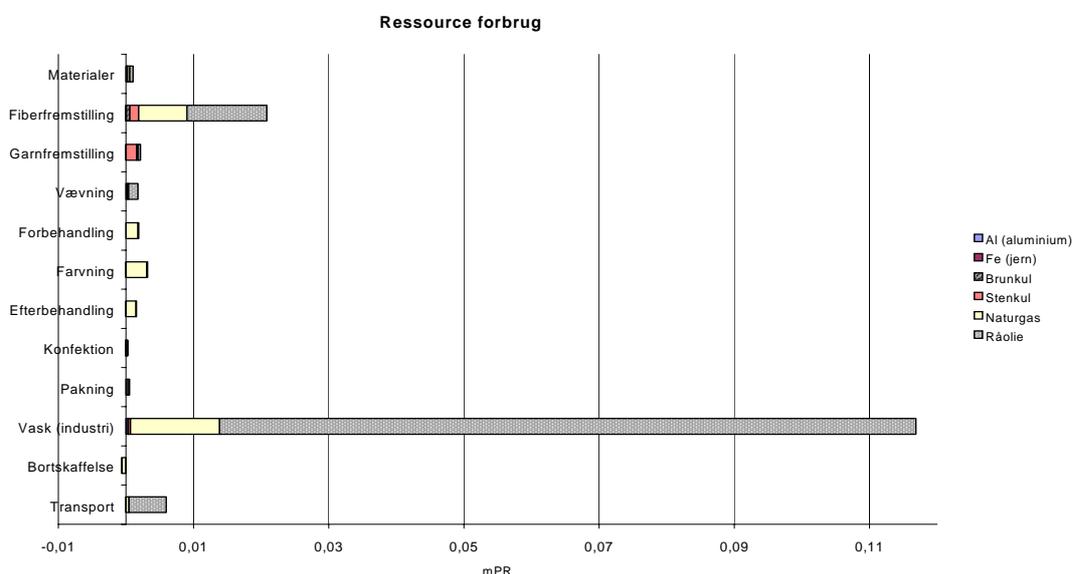


Figure 3.4 Results of main scenario; resource consumption of primary energy per functional unit – for translation of Danish terms see glossary



Figure 3.5 Result of main scenario; toxicological environmental impact potentials per functional unit – for translation of Danish terms see glossary in annex 11

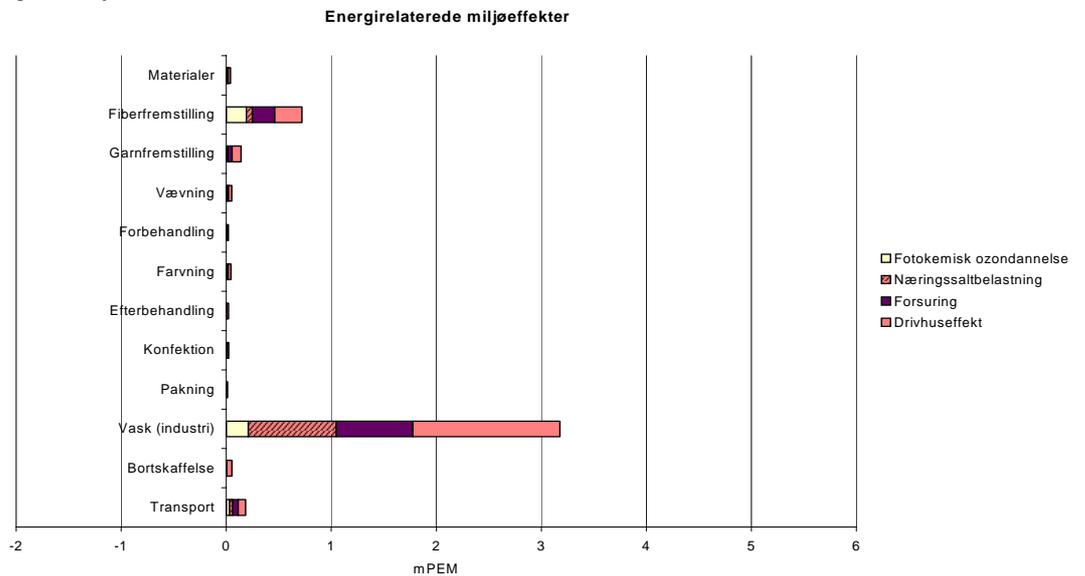


Figure 3.6 Result of main scenario; environmental impact potentials related to energy per functional unit – for translation of Danish terms see glossary in annex 11

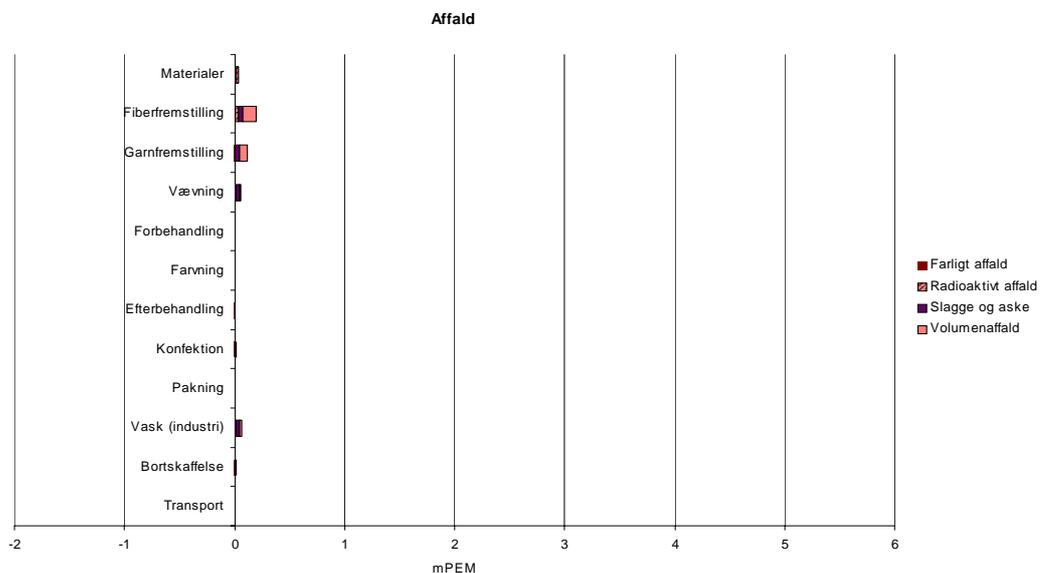


Figure 3.7 Result of main scenario; environmental impact potentials related to waste per functional unit – for translation of Danish terms see glossary in annex 11

What-if simulations

The environmental profile for a given product - in this case a work jacket - can be affected by the choices made by the producer and by the consumer. In order to elucidate the consequences of possible changes in the product's lifecycle, a number of scenarios have been prepared that focus on the producer and consumer respectively.

By changing one or more of the reference conditions, it is possible to form a picture of the scope of the consequences based on the choices made. These changes are illustrated graphically by means of lifecycle statements within five categories, as described in section 5.

Consequences of choices by the producer

The producer influences all processes from extraction of raw materials until the finished product leaves the distribution phase. The producer can affect the processes in the use phase. However, it is not possible for the producer to affect all consumers of the product equally. Contrary to the product dealt with in annexes 1 and 2 - a T-shirt and a jogging suit - there is no producer reference for the work jacket. This is because the main scenario has been prepared on the basis of the producer and a consumer following a uniform and well-known consumption profile in the form of an industrial laundry. Therefore, consumer scenarios as well as producer scenarios will be compared with the same reference. The reference scenario is called the producer reference.

In the following, the results of the producer-related scenarios are presented as summarised contributions over the entire lifecycle and compared with the producer reference scenario.

Scenarios - producer

Raw materials phase

Scenario 1: Choice of raw materials - organic cotton

Production phase

Scenario 2: Choice of chemicals - choice of carrier

Scenario 3: Choice of chemicals - choice of dyes, 10 per cent dyeing

Use phase:

Scenario 4: Influence of product quality - colour staining

Scenario 5: Influence of product quality - increased lifetime

Scenario 1: Choice of raw materials - organic cotton

The toxicological environmental impacts are the environmental impact potentials with the highest weight in the life of the work jacket. The contributions to this category have been ascertained as primarily due to use of pesticides and the energy consumption in production of artificial fertilizer for cotton cultivation.

For conventional cotton cultivation about 18 g pesticides are used per kg cotton in the worst case. The main scenario applies an average from cotton cultivation in the US and South America. The impact of pesticides on the environment has been assessed, and the factors have been included in the

database. Pesticide residues can cause toxic impacts in humans during processing of the cotton fibres, as the oil used in this process is used for cooking in some countries. In this way, the pesticide residues end up in food and thus constitute a health threat to humans. The residues left in the cotton are assumed to be washed out during wet treatment.

In order to assess the toxicological environmental impacts in conventional cotton cultivation, the 35 per cent cotton in the work jacket is changed to organic cotton. In this way, the use of pesticides and artificial fertilizer is avoided and run-off of pesticides during cotton fibre processing is also eliminated. In production of organic cotton fibres, no chemicals are used for bleaching in pre-treatment, and this leads to another reduction of the toxicological environmental impact potentials.

The transport required to spread these substances on the field disappears for organic cultivation. On the other hand, there will often be some sort of mechanical weed control that contributes to the toxicity potentials. This transport is not, however, included in the reference scenario, due to the large differences between the cotton-producing countries and their ways of cultivating cotton. In some countries, vehicles only drive in the fields a few times per cultivation round. In other countries, typically South American countries, it is common to drive more in the fields to secure the crop yield. Generally, less transport reduces consumption of fossil fuels and is therefore also part of the energy-related and toxicological environmental impacts. For this calculation, please see annex 1 for the lifecycle assessment of a cotton T-shirt.

Result of changed choice of raw materials

Consumption of primary energy does not change significantly because of the changes choice of raw materials. This is because most of the energy consumption arises from processes in the production and use phases and these do not change. In total, energy consumption falls by 1 per cent for the changed choice of raw materials.

The toxicological environmental impacts are significantly reduced using organically cultivated cotton. Persistent toxicity and ecotoxicity is reduced by about 80 per cent compared with the reference scenario.

The environmental impacts related to energy, greenhouse effect, nutrient loading, and photochemical ozone formation are reduced by a small percentage, approx. 2-10 per cent. The reason is that there is no longer a contribution to these potentials from production of artificial fertilizer and pesticides. The same applies for the waste categories.

Conclusion to scenario 1

It can be concluded that the producer has great possibilities to influence the overall environmental profile of the textile, especially the toxicological impact potentials. It can be recommended to use organic cotton instead of conventionally cultivated cotton. It should also be considered that many of the agents used during cultivation of cotton are harmful to human health. Incorrect or careless use could mean that suppliers expose themselves and their employees to health hazards.

Pesticide residues washed out in several pre-treatment processes are yet another reason to avoid conventionally cultivated cotton.

Scenario 2: Choice of chemicals - choice of carrier

This scenario is to illustrate the impact of one of the choices of chemicals the producer can make in the production phase.

When polyester is dyed below approx. 130°C, which is the glass transition temperature or T_g for polyester, the polyester fibres are solid and are, at best, only dyed on the surface. By adding a solvent to the dye bath, the polyester fibres are partially softened, and the dyes can penetrate the polyester. When the solvent is removed, the polyester will become solid again, and the dyes are trapped inside the polyester fibres.

The solvent - the carrier of the dye - thus contributes to an even and deep colouring of the polyester and gives a very high degree of colour fastness. Carriers used are typically chlorinated aromates, phenols, benzenes, aromatic hydrocarbons and ethers, and aromatic esters. The substances are known for their harmful impacts on health. The majority are carcinogenic or harmful to the nervous system. A group of carriers that are more environment-friendly and, in particular, better for occupational health and safety has been developed. One of these is based on sodium benzoate, methanol and LAS, and in this case, it has been tested as an alternative to the carrier used in the reference product, which is based on 1,2 dichlorobenzene.

It is assumed that almost 100 per cent of the dose leaves the dye house via wastewater. Data for the manufacture of the carriers is not included, and therefore only the toxicological environmental impact potentials are changed in relation to the reference scenario.

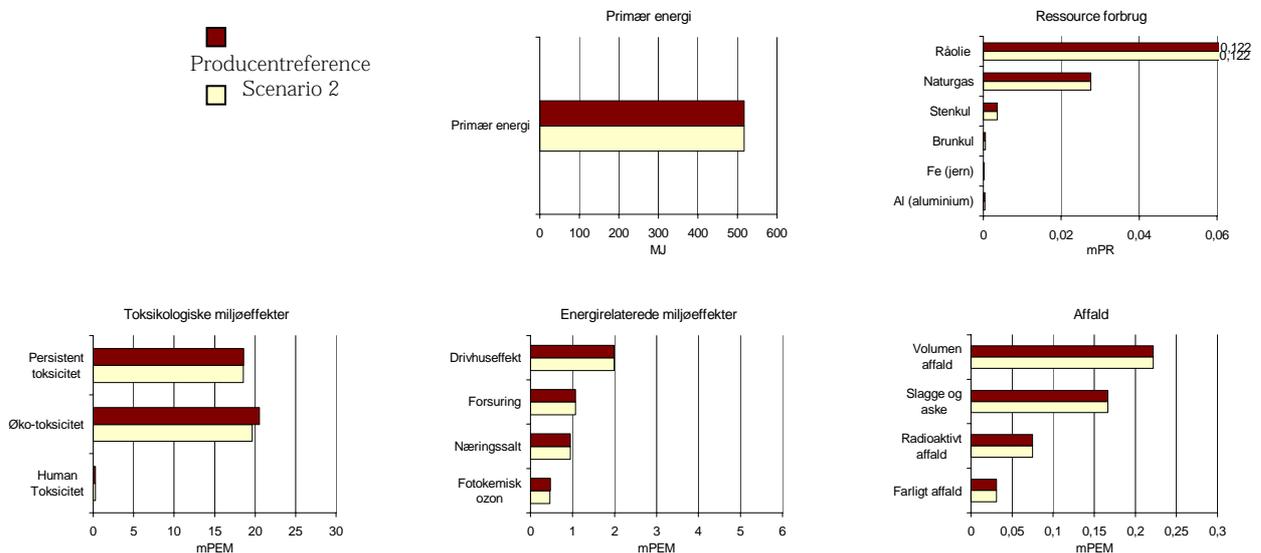


Figure 3.8. Result of scenario 2 shows reduced contribution to the toxicological environmental impact potentials – for translation of Danish terms see glossary in annex 11

The figure shows that the choice of a less toxic carrier has an impact of approx. 5 per cent for ecotoxicity, while it is approx. 1 per cent for persistent toxicity. The impact does not seem higher because of the very high contributions to these categories from cotton cultivation. If we only look at the

dyeing process, the toxicological environmental impact potentials are reduced by up to 95 per cent, highest for ecotoxicity.

By choosing to use high-pressure machines, the use of carriers can be eliminated. By dyeing at a higher temperature than 130°C, typically just less than 140°C, and a similar pressure, T_g is exceeded and the polyester fibres are opened as if there had been a solvent, and the dye can thus be carried out without using a carrier.

Conclusion to scenario 2

The choice of carrier has a limited impact at an overall level, but the impact is large on the product's environmental profile, if the production phase is regarded separately. Thus, this is an area where the producer has a direct possibility of improving the product's environmental profile. The environmental profile of the dye house is improved considerably by using the least toxic carrier or none at all.

Legislation on ecolabelling indicates the substances that should be phased out, and those which should be avoided completely from an environmental perspective. This could be a guide for environmental work at the individual enterprise.

In this connection, it should also be noted that chlorinated carriers of the type mentioned here are no longer being used in Denmark because of their ecotoxicity and human toxicity impacts. The substances are not degraded in the municipalities' wastewater treatment plants, and therefore they are a potential contamination source that should be minimised or avoided.

Scenario 3: Choice of chemicals - choice of dyes, 10 per cent dyeing

In the reference, the work jacket is dyed with a blend of dispersion and reactive dyes for polyester and cotton. The 1 per cent dyeing corresponds to the amount of dyestuff used to dye in paler shades. This scenario illustrates the impact of a dark dye of 10 per cent.

It is assumed that 85 per cent of the dye does adsorb to the textile and the remainder is led through wastewater treatment as in the reference scenario. As ten times as much dyestuff is used, ten times as much dyestuff is discharged than in the reference scenario. The calculations assume that dyestuff is not washed out during the use phase.

It is assumed that the same amount of textile as in the reference scenario can be reused directly from the knitting and making-up phases. There is data for one single acid dye, and therefore the scenario should not be regarded as representative for the whole group of acid dyes.

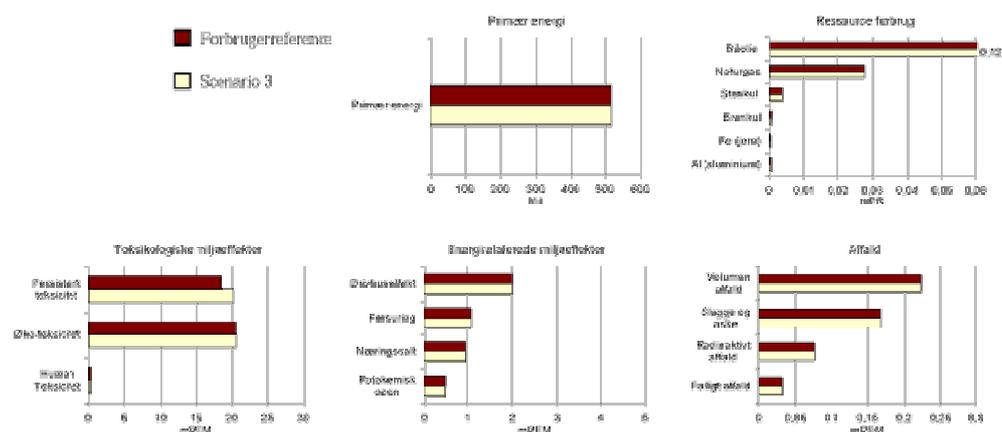


Figure 3.9 Result of scenario 3 - increased contribution to environmental impact potentials related to chemicals – for translation of Danish terms see glossary in annex 11

The graphs show that the larger amount of dyestuff leads to an increase in the total contribution to the toxicological environmental impact potentials of about 1-4 per cent. This does not seem to be a lot, but it should be taken into account that this is solely due to an increase in the concentration of dyestuff. Seen in isolation, the dyeing process represents an increase of 12 per cent. The concentration of dyestuff should thus be a focus point for the producer.

In this scenario, production of the dyestuff is not included. Moreover, process variations in the dyeing process are not taken into account. On the basis of this, the environmental profile of a 10 per cent dyeing would be further impacted.

Conclusion to scenario 3 - large impact in dyeing process, less at overall level

It can be concluded that the amount of dyestuff per functional unit has an impact on the overall environmental profile for the product. If we look specifically at the production phase, we see increases of 10-85 per cent, which makes this an important focus point for the producer. The producer can affect the supplier of dyes in a more environmentally friendly direction by making environmental requirements for the dyes.

Scenario 4: Influence of product quality - colour staining

The quality of the dyeing, colour fastness, is important for the quality consumers perceive in the product. This scenario illustrates the impacts on the overall environmental profile of the work jacket if it ruins an entire machine wash once in its lifetime because the colour migrates to the other textiles in the wash. It is assumed that each wash included 4.5 kg textiles of the same composition as the work jacket, i.e. 35 per cent cotton and 65 per cent polyester. It is also assumed that all the washed textiles are unfit for use after the colour set-off, except the reference product.

The modelling is carried out by assuming that the wash is composed of 6 work jackets of the type described. Therefore, 6 work jackets of 877 g each must be produced, transported and disposed of. The use phase of the spoiled textiles is not included in the calculations, i.e. only the use phase for the reference product is included in the model, as it is assumed that it is not spoiled.

Production of the increased volume of textiles causes an increase in consumption of primary energy of approx. 130 per cent. The toxicological environmental impacts increase by about 500 per cent, and the same trend is apparent for the remaining categories.

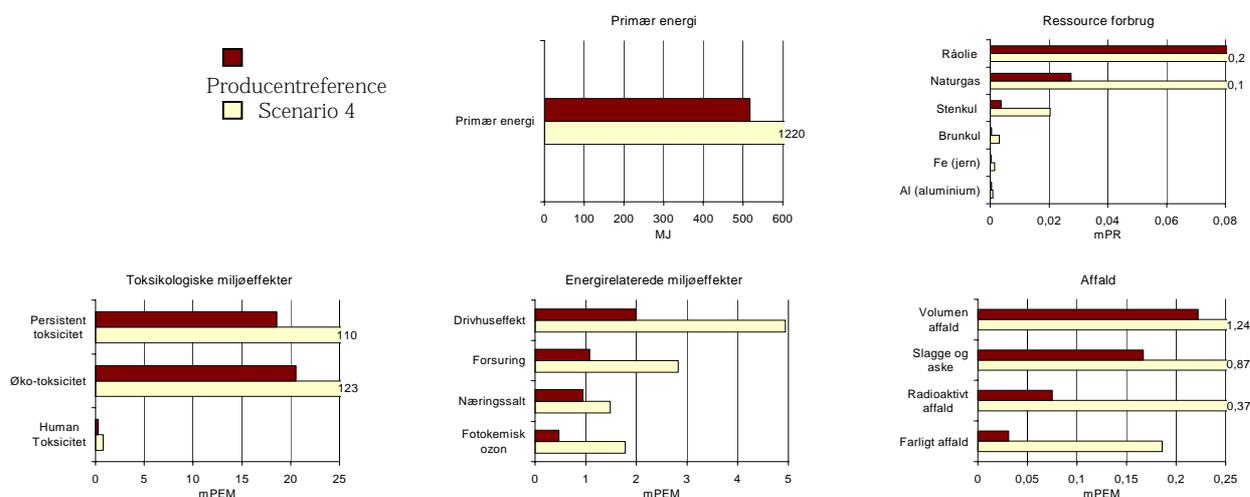


Figure 3.10 Result of scenario 4 – for translation of Danish terms see glossary in annex 11

Conclusion to scenario 4 - the contributions from the production processes outweigh the contributions from the use phase.

The scenario indicates that the use phase of the individual work jacket, otherwise dominant, is now outweighed by the processes in the production phase. On the basis of this, it can be concluded that the colour fastness of textiles of this type is very important. Alternatively, the producer can inform consumers about the risk of colour being transferred to other textiles, whereby the consumer is given the responsibility of washing the work jacket one or more times. This should be included in the product's overall environmental profile as a higher impact from wash in the use phase. If the work jacket is washed at an industrial laundry, there is also a risk that a blue work jacket is washed with light-coloured work clothes, and an entire wash can be spoiled there too. Such an error will probably not happen often. However, as the work clothes are sorted manually, it could occur on a busy day.

A similar scenario could be work jackets that are spoiled because pocket knives, ball-point pens or similar have been left in the pockets. The result could be that the individual work jacket must be disposed of or that other garments washed with the work jacket are damaged.

Scenario 5: Influence of product quality - increased lifetime

Product quality influences the lifetime of the product. Colour fastness, durability of the fibre and stitching are examples of areas on which the durability and quality of the product can be judged. In connection with lifecycle assessments, the quality of the reference product will be important for the manufacture and disposal phases, as these are extended/reduced in order to meet the functional unit.

A work jacket is assessed to endure 100 washes, corresponding to approx. 10-12 years (Bang 2001). In practice however, the work jacket will often be discarded far earlier, namely after approx. 40 washes. This is typically because of damage that is too time-consuming to repair.

Scenario 5 assumes that the work jacket is washed 100 times - corresponding to the estimated maximum lifetime. This assumption means that approx. one-third fibre manufacture, production, disposal and transport is required to meet the functional unit.

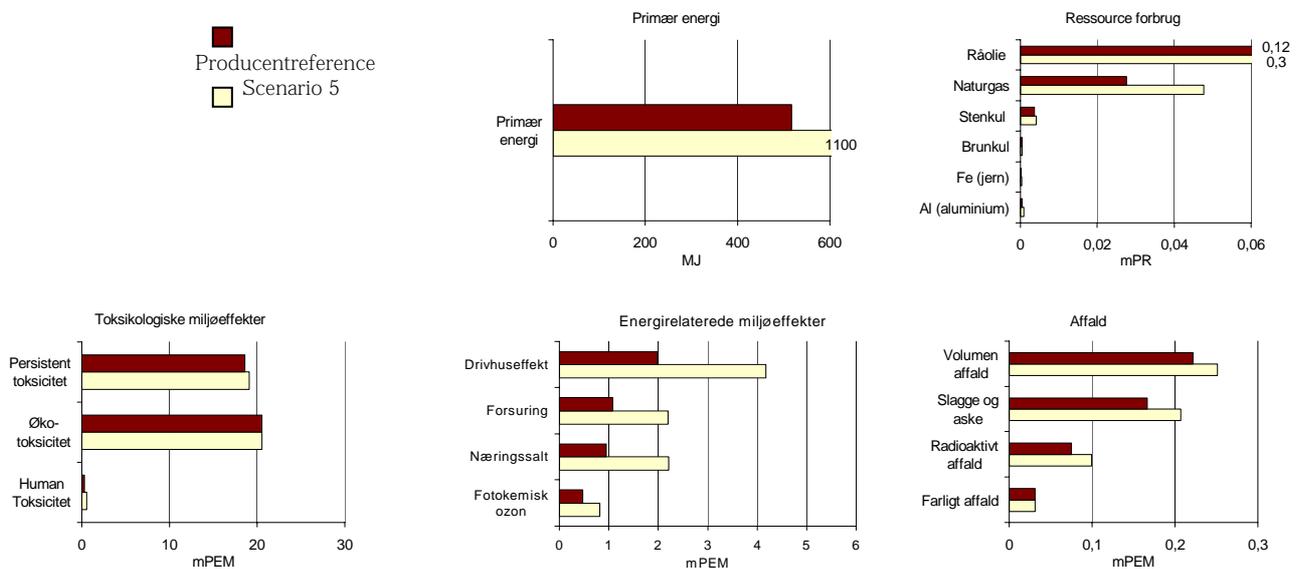


Figure 3.11 Result of scenario 5 – for translation of Danish terms see glossary in annex 11

The great importance of lifetime is clear. The consumption of primary energy is increased by approx. 110%. Resource consumption is increased correspondingly, crude oil by 130 per cent, natural gas by 75 per cent, and coal by 10 per cent. This is due to the extra number of industrial washes and the increased transport volume. The contribution to the energy-related environmental impacts as a consequence of this, increases by 70-130 per cent. The waste categories increase by about 10-30 per cent for the same reasons.

The toxicological environmental impact potentials are affected differently by the increased lifetime of the work jacket. Persistent toxicity increases by 3 per cent, ecotoxicity is unchanged, while human toxicity increases by 100 per cent. Contributions from electricity generation to operation of the washing machines at the industrial laundry and the increased transport volume are the primary causes of the increased toxicological environmental impact potentials.

Conclusion to scenario 5 - lifetime is significant

The conclusion to this scenario is that the quality of the work jacket is an important focus point for the producer. However, it should be taken into account that fatal damage to the work jacket is often caused by external factors. A more wear-resistant material could probably limit such discards.

The quality of the textile is only determined by the producer, while the consumer has a great influence on how long the work jacket will last. There are sectors where work rarely leads to torn jackets or similar, and where the work jacket thus has a longer lifetime, while it must be discarded sooner in other places.

Consequences of choices by the consumer

The consumer is primarily able to influence the use phase and parts of the transport phase. The other phases can primarily be influenced by the producer. Secondly, the consumer is able to choose producer selectively through, e.g. ecolabel schemes.

The use phase for the reference scenario contains drying and washing at a laundry. Transport between producer and laundry as well as transport between consumer and laundry are included.

Scenarios – consumer

As mentioned in the introduction, the reference scenario for consumers and producers is the same.

Scenario 6: Choice of wash - dry cleaning vs. industrial wash

Scenario 7: Choice of wash - household wash vs. industrial wash

Scenario 8: Choice of wash - household wash 2

Scenario 6: Choice of wash - dry cleaning vs. industrial wash

Work clothes are often soiled much more than normal garments. In this scenario, the assumption is that the work clothes have stains after use that are difficult to remove in normal washing. Therefore, the work jacket is dry-cleaned. The dry-cleaning process is regarded as an industrial process organised similarly to the current industrial laundries.

It is assumed that industrial dry-cleaners will pick up the dirty work clothes and return the clean clothes in the same way as industrial laundries do today. There is an increased consumption of chemicals for dry cleaning textiles, while the consumption of other resources such as water is lower. Whereas industrial laundries use crude oil for steam production, the dry-cleaning process in the EDIPTEx database uses electricity. This would probably not be the case if an industrial dry cleaner were to function and compete on equal terms with the laundries. The data for the dry-cleaning process is based on dry-cleaners as they work in Denmark today. It is therefore conceivable that consumption of energy and chemicals could be reduced if the dry cleaning took place on a larger scale and under more uniform conditions, such as same textile type, type of dirt and regular volumes.

Data for the production of the chemical perchloroethylene for the dry-cleaning process has not been included in the lifecycle assessment, and environmental impact potentials have not been assessed. For the industrial washing agent, energy consumption for production of the washing agent has been included, while the environmental impact potentials have not yet been assessed.

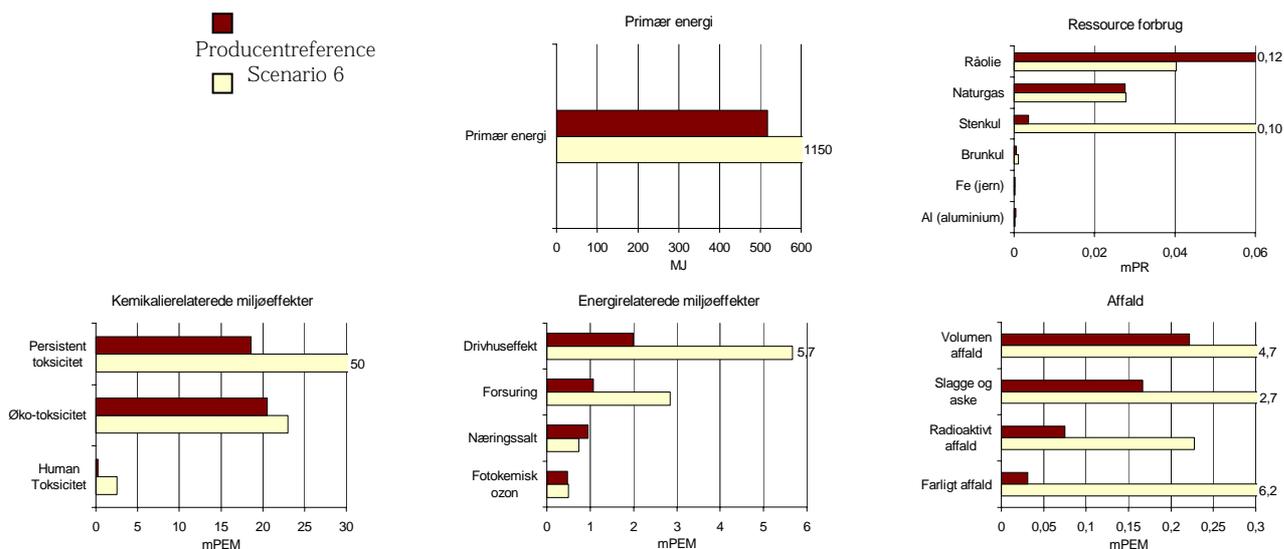


Figure 3.12. Result of scenario 6 – general increases in environmental impact potentials – for translation of Danish terms see glossary in annex 11

The total energy consumption is increased by 120 per cent. This is primarily due to increased consumption of electricity for heating steam. Transport is assumed to be the same for industrial wash and industrial dry cleaning, about 3,000 km during the lifetime of a work jacket. For industrial wash, energy consumption for production of the washing agent is included and this process represents 5 per cent of the total energy consumption in the main scenario.

The resource consumption for the two processes is very different. A lot of crude oil is used in industrial wash for the steam generator that delivers steam for the washing machines. In the dry-cleaning process, consumption of crude oil is reduced by 70 per cent, while consumption of coal is increased considerably. The reason is that Danish electricity is primarily generated at coal-fired power plants.

The toxicological environmental impacts are significantly increased when dry-cleaning is selected instead of industrial wash. Persistent toxicity is increased by about 170 per cent compared with the reference scenario, while ecotoxicity is increased by approx. 15 per cent, and human toxicity is increased by 800 per cent. The increase is merely due to consumption of electricity, as the environmental impact potentials for perchloroethylene have not been included.

For the environmental impacts related to energy, the result is that the greenhouse effect and acidification are increased by 180 per cent and 160 per cent respectively, while the nutrient loading and photochemical ozone formation are reduced by 5-30 per cent. The reason for this is the difference between using electrical energy generated by burning coal and energy generated by an oil-fired steam boiler.

Conclusion to scenario 6

It can be concluded that dry cleaning of work jackets/work clothes has an overall negative influence on the textile's overall environmental profile. The calculations are based on dry cleaning of textiles as the process is today. This means that there would probably be a reduction in some categories, if the process were optimised as an industrial process with associated economies of

scale. The toxicity of washing agents and chemicals for dry-cleaning has not been assessed. This could change the size of the toxicological potentials.

Scenario 7: Choice of wash - household wash vs. industrial wash

The use of work clothes is primarily related to manual jobs. This includes all types of company, from one-man operations to large construction groups. Irrespective of the size of the enterprise, it will attempt to minimise all costs, including costs of washing work clothes. Therefore, it is assumed that the work clothes are only washed privately, when this is the most profitable way.

At industrial laundries, the clothes are washed and dried in the same process. For purposes of comparison, a 60°C wash without prewash and subsequent tumbler drying has thus been used.

It is assumed that large enterprises normally choose to use an industrial laundry and have clean work clothes delivered to the enterprise. Thus, this scenario is primarily aimed at small enterprises and one-man operations. It is assumed that smaller enterprises with less than five employees will wash their work clothes themselves instead of having a laundry pick up and return work clothes for them.

It is assumed that the work jacket is washed with other clothes of the same material, probably several items of work clothing, so that the machine is full when the clothes are washed. In this scenario, the assumption is that there are 4.5 kg clothes in the machine.

The temperature is set at 60°C for household washes here, as washing agents and fabric softeners have been adapted to lower temperatures. It has also been taken into account that water and electricity constitute expenses for the households, and that most people will consequently try to minimise consumption of electricity and water.

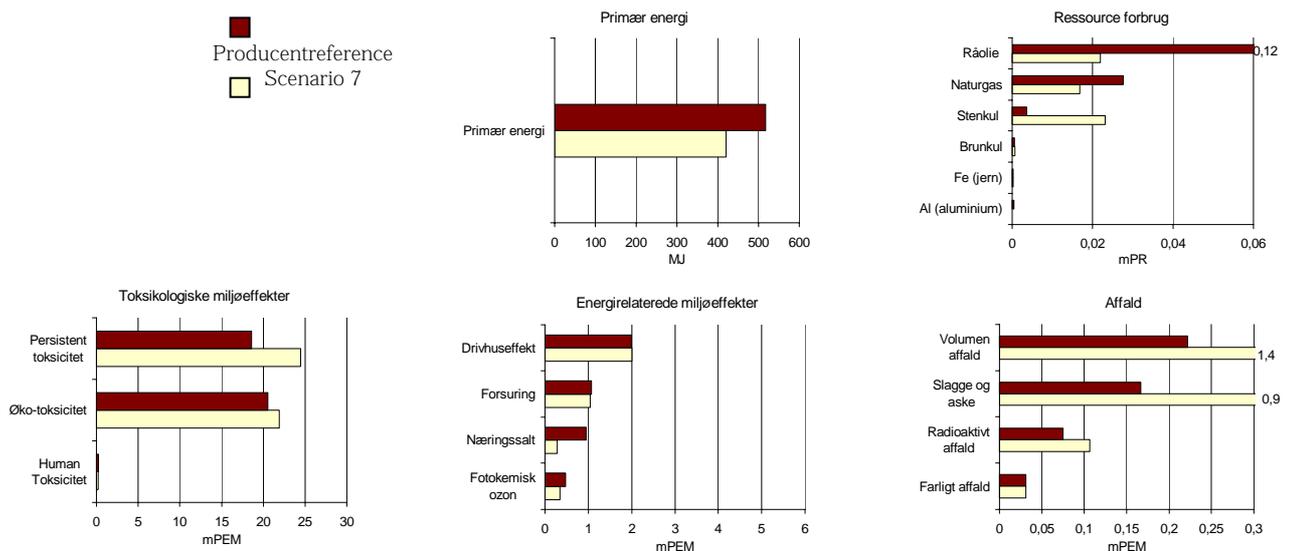


Figure 3.13 Result of scenario 7 – changed resource consumption, increased toxicological environmental impact potentials – for translation of Danish terms see glossary in annex 11

The total energy consumption is reduced by 20 per cent. Some of the explanation for this is the transport to and from the laundry in connection with industrial wash. Over the lifetime of a work jacket, this constitutes about 3,000 km. However, the primary reason is that household washing and tumbler drying is less energy-intensive than the process at an industrial laundry. For industrial wash, energy consumption for production of the washing agent is included, and this process represents 5 per cent. This is not the case with the washing agent used in households.

Resource consumption for the two processes is very different. The industrial wash uses a lot of crude oil for a steam boiler that supplies steam to the washing machines. Household wash and tumbler drying consumes 20 per cent of the amount of crude oil consumed by the industrial washing process. In the other hand, the household wash represents large consumption of coal; over 500 per cent more than industrial wash. Danish electricity is primarily produced at coal-fired power plants. Again, the production of the washing agent for the industrial laundry plays a role.

The toxicological environmental impacts are increased significantly reduced when household wash is chosen over industrial wash. Persistent toxicity is increased by about 30 per cent compared with the reference scenario, while ecotoxicity is increased by approx. 7 per cent, and human toxicity is unchanged.

The toxicity of the washing agent used in households is included in the statement. This is not the case for the industrial washing agent, but here energy consumption for production of the washing agent is included. The increase in toxicity and the changes in resource consumption should therefore be seen in this context.

For the environmental impacts related to energy, the result is that the greenhouse effect is unchanged while the nutrient loading and the photochemical ozone formation are reduced by 5-30 per cent. The reason for this is the difference between using electricity (households) generated by burning coal, and energy (industrial wash) generated by an oil-fired steam boiler.

Conclusion to scenario 7

It can be concluded that the consumer has great possibilities to influence the overall environmental profile of the textile, both as regards total energy consumption, resource consumption, toxicity categories and waste potentials.

Scenario 8: Choice of wash - household wash 2

This scenario builds on the results from scenario 7 where a normal 60-degree household wash followed by tumbler drying is assessed in relation to an industrial wash at a laundry. Instead of a normal 4.5 kg household wash, the work jacket in this scenario is washed alone with a pair of matching trousers, corresponding to a total weight of 1.54 kg. For calculation purposes, this means that the use phase has an extra consumption for the washing process, corresponding to a factor of 2.92 (4.5 kg divided by 1.54 kg). Other assumptions and considerations are the same as in scenario 7.

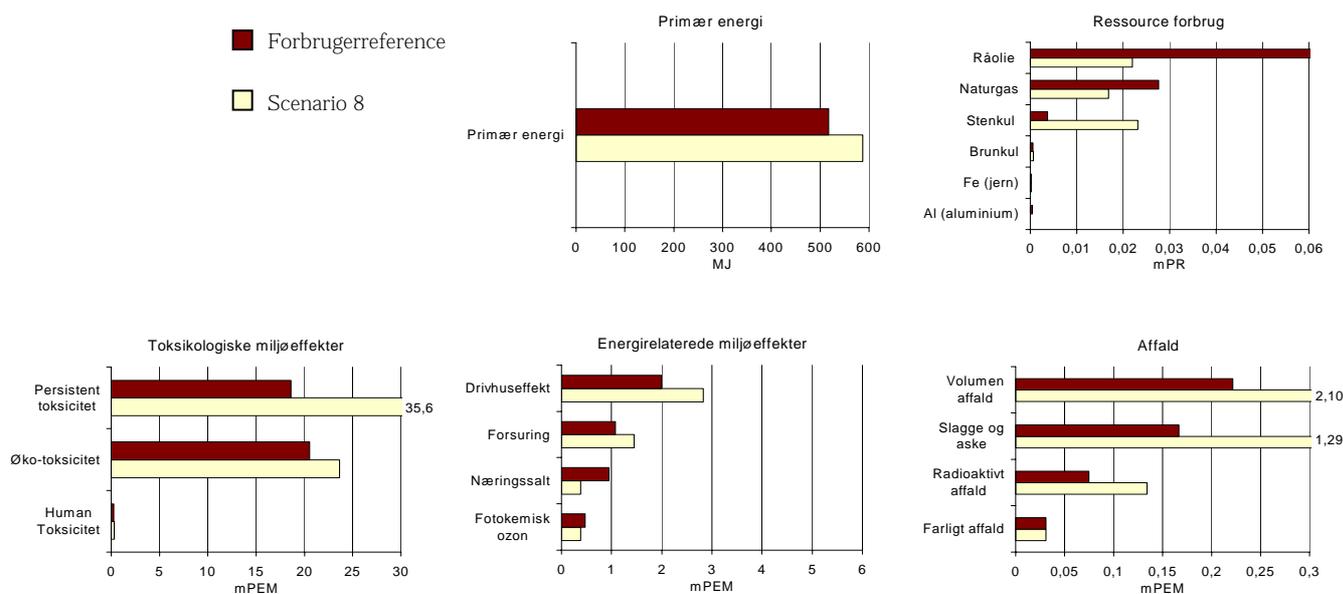


Figure 3.14. Result of scenario 8 – large impact on resource consumption – for translation of Danish terms see glossary in annex 11

As can be seen from the graphs, this type of washing procedure places a strain on the overall environmental profile. However, we can see that consumption of natural gas and crude oil is larger in the reference scenario. Consumption of coal is the only resource increased compared with scenario 7. As described in scenario 7, this is partly due to the different methods of industrial washing and household washing (steam wash vs. electrical wash). Steam wash consumes a lot of crude oil compared to household wash that is powered by Danish electricity, primarily generated by burning coal.

Despite this, consumption of primary energy is increased by 10 per cent compared with the reference scenario. This is despite the fact that the work jacket is transported 3,000 km in a van between the enterprise and the laundry in the reference scenario.

Another aspect that is also mentioned in scenario 7 is the data basis. There is data for the toxicological impacts of household washing agents, but no energy data for the production. Conversely, there is no data for the toxicological impacts of industrial washing agents, but there is energy data for the production of the washing agent. This makes the comparison less clear. An increase in persistent toxicity of 92 per cent is thus not a clear indication of the actual difference between the two washing methods, but merely an indication that there will be increased consumption of washing agent in this scenario and thus increased toxicity.

For the environmental impacts related to energy, the environmental impact is increased as regards greenhouse effect and acidification, but reduced as regards nutrient salts and photochemical ozone. The reason for this difference is the different nature of the resources and the way they are incinerated. It is clear that the changes to the impact potentials related to energy are due to resource distribution.

Conclusion to scenario 8

The conclusion to this scenario is that household wash with one set of work clothes places a strain on the work jacket's environmental profile compared to having it washed at an industrial laundry. If we compare scenarios 7 and 8, it is clear that this type of washing procedure is environmentally inappropriate. The number of clothes washed together is very important. It would probably be advantageous to invest in several sets of work clothes, if they are washed at home, and if the consumer does not wish to mix everyday clothes with work clothes. It is less clear what the picture would have looked like if the data bases for the two washing processes had been the same.

Background data

System structure in the EDIPTEX database for the work jacket

	Ref. nr. UMIPTEX-databasen
1 work jacket, dyed (cotton/polyester)	(TX0-03)
1 materials phase:	(TX6-1-06)
0.439 kg cotton fibres (incl. cultivation and harvest)	(TX1-01-1)
0.626 kg polyester fibres	(TX1-04)
0.04 kg zipper of brass	(TX29-2-02)
0.036 kg button of brass	(TX29-2-03)
0.004 kg zipper of plastic (polyester)	(TX29-2-01)
1 production phase:	(TX6-2-19)
0.877 kg yarn manufacturing (polyester/cotton - 65%/35%)	(TX21-3)
2.97 m ² weaving, natural sizing agent	(TX23-1)
0.877 kg desizing and bleaching PET/CO, jigger	(TX24-2-01-B)
0.877 kg dyeing PET/CO in automatic jigger	(TX25-03)
0.877 kg softening PET/CO in jigger	(TX27-2-03)
0.868 kg drying, final fixing + set of m ² weight (PET/CO)	(TX27-3-06-02)
2.9 m ² fabric inspection + rolling onto cardboard roll (PET/CO)	(TX27-3-08-06-02)
1 work jacket- laying out, cutting and sewing	(TX28-1-03)
1 work jacket- packing	(TX28-2-04)
1 use phase:	(TX6-3-04)
10.78 kg industrial wash, 80 °C + mach. drying cotton	(TX32-1-1)
20.02 kg industrial wash, 80 °C + mach. drying polyester	(TX32-1-2)
1 disposal phase:	(TX6-4-04)
0.27 kg waste incineration of cotton	(TX41-1-01)
0.5 kg waste incineration of polyester	(TX41-1-04)
0.004 kg incineration of plastic zipper	(TX41-2-11)
1 transport phase:	(TX6-5-04)
8780 kg km container ship, 2-t, 28000DWT, terminated	(O32715T98)
1175 kg km lorry > 16 t diesel out-of-town, terminated	(O32694T98)
1175 kg km lorry > 16 t diesel urban traffic, terminated	(O32695T98)
1175 kg km lorry > 16 t diesel motorway, terminated	(O32693T98)
1148 kg km van < 3.5 t diesel, urban traffic, terminated	(O32705T98)
1148 kg km van < 3.5 t diesel, out-of-town, terminated	(O32697T98)
1148 kg km van < 3.5 t diesel, motorway, terminated	(O32698T98)

Details of the work jacket model in the EDIPTEX database

Assumptions:

- 65 per cent polyester/35 per cent cotton, total weight 850 g, of which textiles constitute approx. 770 g (295 g/m²) and extra components approx. 80 g. Approx. 500 g polyester and 270 g cotton.
- 10 buttons in 100 per cent brass - approx. 3.6 g each - total 36 g. In addition, 2 zippers - one brass zipper in front, approx. 60 cm (40 g) and one polyester zipper in inside pocket, approx. 15 cm (4 g). Total approx. 80 g extra components.
- Can be washed at 95°C and can be dry-cleaned chemically.
- Lifetime: the fabric quality used in the reference product in this case is strong enough to last for at least 100 washes; but in practice, the work jackets are discarded far earlier. 40 washes and a lifetime of 3 years is a key figure from the laundry industry. Some work jackets last 10-12 years, corresponding to the 100-120 washes they can actually tolerate. The early discard is typically caused by damage that is too time-consuming to repair.

Functional unit

The calculations are for "1 work jacket". This needs to be converted in relation to lifetime, and the calculations need to be converted to "per year".

It is assumed that the work jacket can be washed 40 times before it is discarded.

Lifetime is approx. 3 years - corresponding to approx. 14 washes per year.

It is assumed that the work jacket is used 1 working day of 8 hours and is then washed.

The functional unit for the work jacket is therefore:

"40 days' use of a work jacket washed each time after use over the course of 3 years".

It is assumed that 40 washes correspond to the number of days a consumer wears a work jacket over the course of 3 years.

For the reference scenario, this corresponds to 1 work jacket being discarded every three years.

Disposal:

It is assumed that the work jacket is sold in Denmark and disposed of through waste incineration. 0.50 kg polyester and 0.27 kg cotton and 76 g brass (buttons and zipper), 4 g polyester (pocket zipper). Extra components of brass are not included in the lifecycle assessment, as brass does not have a calorific value and will leave the incineration plant with the slag and have no significant impact on the environment.

Wash:

It is assumed that the work jacket can be washed 40 times in its lifetime. This means that $0.5 * 40 = 20$ kg polyester and $0.27 * 40 = 10.8$ kg cotton must be washed and dried. Industrial washing at 80°C and household washing at 90°C without prewash. The weight of extra components is not included in this context.

Drying:

For industrial wash, drying is part of the washing process. For households, it is assumed that the work jacket is dried in a tumbler dryer, i.e. 20 kg polyester

(synthetic) and 10.8 kg cotton. The weight of extra components is not included in this context.

Packing the work jacket:

It is assumed that the work jacket is packed in a thin plastic bag. It is assumed the bag weighs 20 g (2 * T-shirt, see annex 1).

Making-up:

A new process has been set up: work jacket - laying out, cutting and sewing TX 28-1-01. The process is calculated "per work jacket". There is no data for energy consumption for a work jacket. It is assumed that energy consumption is approx. 10 times that of a tablecloth (approx. 35 minutes' sewing time vs. approx. 3).

Waste is estimated at approx. 10 per cent. This means approx. 0.77 kg / (1-0.10) = 0.855 kg polyester/cotton fabric, of which 0.555 kg is polyester and 0.300 kg is cotton, must be used. It is assumed that all the waste is discarded (incinerated at a waste incineration plant).

Fabric - inspection and rolling onto a cardboard roll:

There is no company data for woven fabric for a work jacket. It is assumed that data is the same as for woven fabric for a tablecloth (annex 5). Therefore process no. TX 27-3-08-06 is used. Volume: The process is calculated per m². 0.855 kg polyester/cotton fabric is used for making-up the work jacket. An m² weight of 295 g/m² is assumed - this means that 2.90 m² approved textile must be used after the fabric inspection, and this means that the process must use 2.90 m².

Fabric inspection uses 1.015 kg textile per kg approved textile after the fabric inspection. Therefore 1.015 * 0.855 = 0.868 kg textile must be produced (dried and fixed).

Drying, final fixing and setting square-metre weight:

As mentioned above, 0.868 kg textile must be used per work jacket. This corresponds to 2.94 m² textile (dried and fixed) per work jacket weighing 295 g per m².

As there is waste in drying and final fixing, 1010 g dyed fabric per kg dried fabric are used. This means 1.01 kg * 0.868 = 0.877 kg softened textile must be used. This corresponds to approx. 2.97 m² (this figure is needed for weaving, natural sizing agent).

Softening polyester/cotton in jigger:

The process requires 0.877 kg - there is no waste - this means that 0.877 kg coloured textile is needed. This corresponds to approx. 2.97 m² (this figure is needed for weaving, natural sizing agent).

Dyeing polyester/cotton in atmospheric jigger:

0.877 kg is used by this process per work jacket. There is no waste of textile in this process. This corresponds to approx. 2.97 m² (this figure is needed for weaving, natural sizing agent).

Desizing and bleaching of polyester/cotton, jigger:

0.877 kg is used by this process per.

Although the textile loses weight when the sizing agent is washed out (added during weaving process), it is not necessary to adjust for this in the following calculations, as the process weaving, natural sizing agent is calculated as m² - the amount of textile in m² is unchanged. Therefore 2.97 kg woven textile, natural sizing agent is required.

Weaving, natural sizing agent:

This process is calculated per m². As the amount of textile in m² is not changed in this process, although the textile does take up sizing agent during the process, 2.97 m² is required for this process.

As the two processes "weaving, natural sizing agent" and "desizing and bleaching of polyester/cotton, jigger" add and remove the same amount of sizing agent, the start weight of the yarns is 0.877 kg. Thus, 0.877 kg is required for the process "yarn manufacturing (polyester/cotton 65%/35%)".

Yarn manufacturing:

0.877 kg polyester/cotton yarn must be used per work jacket. 0.877 kg textile is required per work jacket for this process - 0.570 kg polyester and 0.307 kg cotton.

For synthetic fibres, waste is approx. 9 per cent. As the yarn contains 65 per cent polyester, $0.570 \text{ kg} / 0.91 = 0.626 \text{ kg}$ polyester fibres is required. For carded cotton, waste is approx. 30 per cent (of the raw cotton weight). This means that $0.307 \text{ kg} * 0.7 = 0.439 \text{ kg}$ cotton fibres are required per kg yarn. The waste of polyester fibres is $0.626 - 0.570 \text{ kg} = 0.056 \text{ kg}$, and waste of cotton is $0.439 - 0.307 = 0.132$.

In: 0.626 kg polyester fibres + 0.439 kg cotton fibres = 1.065 kg total

Out: 0.877 kg yarn + 0.056 kg polyester fibres (waste) + 0.132 kg cotton fibres (waste) = 1.065 kg total.

Cotton fibres (incl. cultivation and harvest):

0.439 kg is used by this process per work jacket.

Polyester fibres:

0.626 kg is used by this process per work jacket.

Extra components

Plastic zipper:

0.004 kg polyester zipper is used.

Brass zipper:

0.040 kg brass zipper is used.

Brass button:

0.036 kg brass buttons is used (10 of 3.6 g each).

Transport:

All transport distances are estimated. See table below.

Transport	Quantity for one work jacket	Kg km
Materials		
Transport of polyester fibres from Germany to spinning mill in Poland	0,626 kg transported 1.000 km by lorry	626 kg km by lorry
Transport of cotton from cultivator in China to spinning mill in Poland	0,439 kg transported 20.000 km by ship	8.780 kg km by ship
Transport of 2 zippers from Germany to making-up enterprise in Poland	0,044 kg transported 1.000 km by lorry	44 kg km by lorry
Transport of buttons from Germany to making-up enterprise in Poland	0,036 kg transported 1.000 km by lorry	36 kg km by lorry
Semi-finished goods		
Transport of yarn from spinning mill in Poland to weaving mill in Denmark	0,877 kg transported 1.000 km by lorry	877 kg km by lorry
Transport of woven fabric from weaving mill to pre-treater and dye house, both in Denmark	0,877 kg transported 200 km by lorry	175 kg km by lorry
Transport of dyed fabric from Denmark to making-up enterprise in Poland	0,855 kg transported 1.000 km by lorry	855 kg km by lorry
Transport from making-up enterprise in Poland to shop in Denmark, lorry (jacket+packaging)	0,870 kg transported 1.000 km by lorry	870 kg km by lorry
Use phase		
Consumer transport*		3.443 kg km by van
Disposal phase		
Transport of discarded work jacket (with household refuse)	0,850 kg transported 50 km by lorry	43 kg km by lorry

*Consumer transport: It is assumed that the consumer has the work jacket delivered by van. It is assumed the supplier drives 50 km (50 km * 0.850 kg = 42.5 kg km by van). As the work jacket is used and washed 40 times during its lifetime, 40 times 50 km transport each way of a work jacket from enterprise to laundry are included (40 * 50 * 2 km = 3,400 kg km by van). Total 3,443 kg km by van.

Lorry, total: 3,526 kg km (assumed 33 per cent urban, 33 per cent out-of-town, 33 per cent motorway). Van, total: 3,443 kg km (assumed 33 per cent urban, 33 per cent out-of-town, 33 per cent motorway).

I.e. total transport:

Process no. in EPIDEX database	Name of process	Transport need
O32715T98	Container ship, 2-t 28000 DWT, terminated	8.780 kg km by ship
O32695T98	Lorry > 16 t, diesel urban traffic, terminated	1.175 kg km by lorry
O32694T98	Lorry > 16 t diesel out-of-town, terminated	1.175 kg km by lorry
O32693T98	Lorry > 16 t diesel motorway, terminated	1.175 kg km by lorry
O32705T98	Van < 3.5 t diesel, urban, terminated	1.148 kg km by van
O32697T98	Van < 3.5 t diesel, out-of-town, terminated	1.148 kg km by van
O32698T98	Van < 3.5 t diesel, motorway, terminated	1.148 kg km by van

Annex 4: Blouse made of viscose, nylon and elastane

The blouse - summary and conclusions

Firstly, it is important to stress the following conditions with regard to lack of data for the model used as the basis for the environmental assessment of the blouse.

- Data on manufacture of elastane fibre was not available. Instead, the model includes a process for elastane in which EDIP data for the process to manufacture polyurethane (flexible foam) is used. Elastane is composed of 85 per cent polyurethane.
- Furthermore, within the framework of the project it has not been possible to calculate an equivalency factor for carbon disulphide, which is used in the manufacture of viscose fibres.

For general, and not product-specific conditions regarding quality of EDIPTEX data, see chapter 4.

The first aspect of data quality is not deemed to have a significant impact on the results statement, as:

- Elastane only makes up 5 per cent of the total weight of the blouse.
- There is no knowledge of elastane giving rise to emissions of more problematic chemicals than those in other synthetic fibres (for which there is data).

On the other hand, there is no doubt that the lack of data for human toxicity, ecotoxicity and persistent toxicity for carbon disulphide could be significant for the overall toxicological environmental profile of the product. Relatively large amounts are used and emitted in the manufacture of viscose.

Because of the lack of data it is difficult to draw any definite parallels to case group I in the scenarios (T-shirt, jogging suit and work jacket).

The only relatively certain standard of reference is the environmental profile for consumption of primary energy. This is very different from the corresponding aspects of case group I products. Energy consumption in the manufacture of fibres is by far the most significant. Compared with the corresponding figures for the main scenarios for case group I products, it is apparent that although fibre manufacture is also very important here, the use phase (washing, drying and ironing) has an even greater significance.

The message to a producer wanting to improve the environmental profile of the blouse is therefore clear: work with reuse of the fibre material - primarily viscose.

Introduction

Lifecycle assessment is a method for identification and evaluation of environmental impact potentials of a product or a service from cradle to grave. This method enables the user to make an environmental assessment and focus on the most important environmental impacts.

Lifecycle assessment is an iterative process. The first definition of purpose and delimitations often need to be revised during work with lifecycle assessment. The amount of data available sets limits, and consequently the limits of the system are changed.

The method used in this case for assessment of products is "Environmental Design of Industrial Products" (EDIP) and the associated database and PC tool.

In the EDIPTEX project, sector-specific data have been prepared for the textiles sector in connection with the existing EDIP database. The reports contain environmental assessments for the following textile products:

- A T-shirt of 100 % cotton
- A jogging suit of nylon microfibres with cotton lining
- A work jacket of 65 per cent polyester and 35 per cent cotton
- A blouse of viscose, nylon and elastane
- A tablecloth of cotton
- A floor covering of nylon and polypropylene.

These environmental assessments are intended to illustrate the scope for application of the EDIPTEX database by using the PC modelling tool and, at a more general level, application of the EDIP method.

Method

The six case stories vary a lot in scope. They can be divided into two main groups - with variations within these two main groups. The two main groups are:

- Group I: The T-shirt, the jogging suit and the work jacket.
- Group II: The floor covering, the tablecloth and the blouse.

The division into groups I and II relates to the scope of the collection of data as well as the quality of data.

For group I, it was possible to collect (and process) data for all significant processes. The data are of such quality that these three products have been selected to illustrate how far it is possible to take lifecycle assessment for textiles and to illustrate all relevant aspects of the EDIP method.

Each of the three group I cases contains:

- Definition of functional unit and reference product
- Modelling of main scenario
- Preparation of producer and consumer references
- Simulation of environmental impacts caused by choices made by producer and

- consumer respectively.

Work with these cases has been divided into phases as illustrated in figure 4.1.

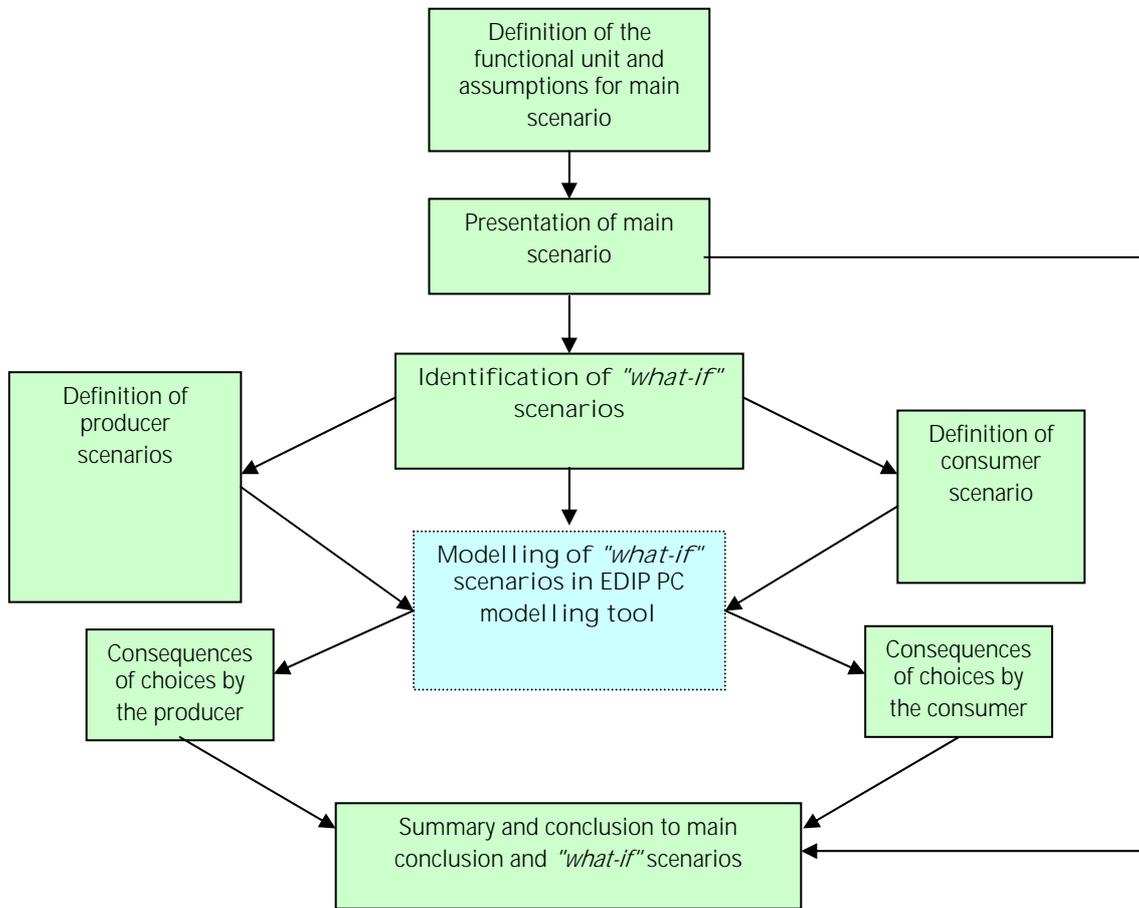


Figure 4.1 EDIPTTEX case group I flow diagram

For group II, it was not possible to complete all sub-processes. Although only 1-2 sub-processes for each product have considerable lack of data, these processes are deemed potentially significant for the overall lifecycle assessment. The group II case stories are therefore of an entirely different character than those of group I. The group II cases illustrate that it is possible to tell an interesting and exciting "environment story" based on lifecycle assessment (and EDIP) even though it has not been possible to analyse all aspects of lifecycle assessment data. This situation will arise very often in lifecycle assessment work. However, there is a significant difference in this EDIPTTEX connection; it is possible to draw on results from the three lifecycle assessments from case group I (and this has been done), which improves the quality of the case stories.

Comments to the method

Product references

The "what-if" simulations were carried out to elucidate the consequences of possible changes in the product's lifecycle. A special product reference has been defined for the producer scenarios in some of the case stories. The producer only has limited influence on the use phase. In order to take this into account, a product reference has been prepared for the producer scenarios where only a limited part of the impacts from the use phase has been included in relation to the product reference from the main scenario. This was done in order to give producers a clearer picture of the influence of the production phase on the product's environmental profile in the "what-if" producer scenarios.

Data

With regard to data, it should be noted that the validity of the data in the database varies, depending on the processes considered.

This difference has not been taken directly into account in the EDIPTTEX database, but a representative level for the data has been defined. Therefore, the data are very general and not necessarily representative for all lifecycle assessments. Some processes are more exact, such as extraction of crude oil for nylon (nylon is contained in the blouse). This process is well documented, both as regards industrial accidents and as regards resource consumption.

Production data primarily come from Danish enterprises. The number of enterprises involved represents limitations in this connection. For example, only one reactive dye has been studied thoroughly (the dye for the viscose part of the blouse). This substance represents the entire group of dyes, despite the major differences that may occur.

A large proportion of the environmental impacts come from the consumption of electricity. The data currently used in the database originate from the EDIP database, and the reference year is 1990. This area is being studied in order to update this part of the database. It is important to note that this lifecycle assessment was carried out using the 1990 data in all processes that consume electrical energy.

This product is different in that data for the manufacture of elastane fibres were not available. However the model does include a process for elastane in which EDIP data is used for the process of manufacturing polyurethane (flexible foam).

Elastane is composed of 85 per cent polyurethane. Furthermore, within the project budget it has not been possible to calculate equivalency factors for carbon disulphide, which is used in the manufacture of viscose fibres. These aspects of data quality mean that focus for this case is on primary energy and environmental impacts for the main scenario. The significance of the lack of data for the statement of results for the main scenario is discussed. Moreover relevant parallels have been drawn with the scenarios in the three group I cases.

The blouse

Product description: the blouse is composed of 70 per cent viscose, 25 per cent nylon and 5 per cent elastane. The assessment does not include multicoloured patterns or prints on the product.

Functional unit

The performance assessed can be described as a "functional unit", comprising a qualitative and a quantitative description, including the product's lifetime. The qualitative description is to define the quality level for the performance, so that products can be compared at a somewhat uniform quality level. The quantitative description is to determine the size and duration of the performance.

In this project, the functional unit is defined as:

"25 days' use of blouse over the course of one year"

Maintenance is assumed to be a wash at 40°C. It is assumed that 25 days correspond to the number of days a consumer wears the blouse over the course of 1 year. Some consumers have an entirely different consumption of blouses. Some almost never wear a blouse, while others often change blouse according to fashion. Therefore the blouse may be discarded because of a change in fashion long before it wears out.

Reference product and main scenario

The reference product is a product that meets the criteria of one functional unit. The project uses a coloured blouse of viscose, nylon, and elastane.

The calculations are carried out for "1 blouse", these need to be converted in relation to lifetime, and the calculations need to be converted to "per year".

It is assumed that the blouse can be washed 25 times before it is discarded. It is assumed that the consumer wears the blouse 25 days per year. It is assumed that the blouse is used 1 day and is then washed.

If the blouse is washed after each use, 25 days' use of the blouse means that 1 blouse is completely used up in one year - or more likely - that a person has 5 blouses that together last 5 years.

The following assumptions apply to the assessment and are thus included in the modelling of the main scenario.

Assumptions for the assessment

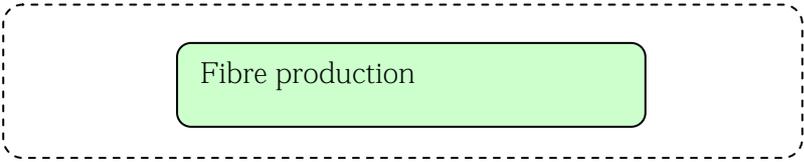
- The blouse is knitted from 70 per cent viscose, 25 per cent nylon and 5 per cent elastane.
- Viscose is dyed with reactive dyes.
- Nylon is dyed with acid dyes.
- Elastane is dyed like nylon.
- Washing 40°C.
- Drip drying on a clothesline.
- Ironing not necessary.

- Lifetime: 25 washes.
- Weight: For this environmental assessment, the assumption is that the blouse weighs 200 g and 125 g per m².

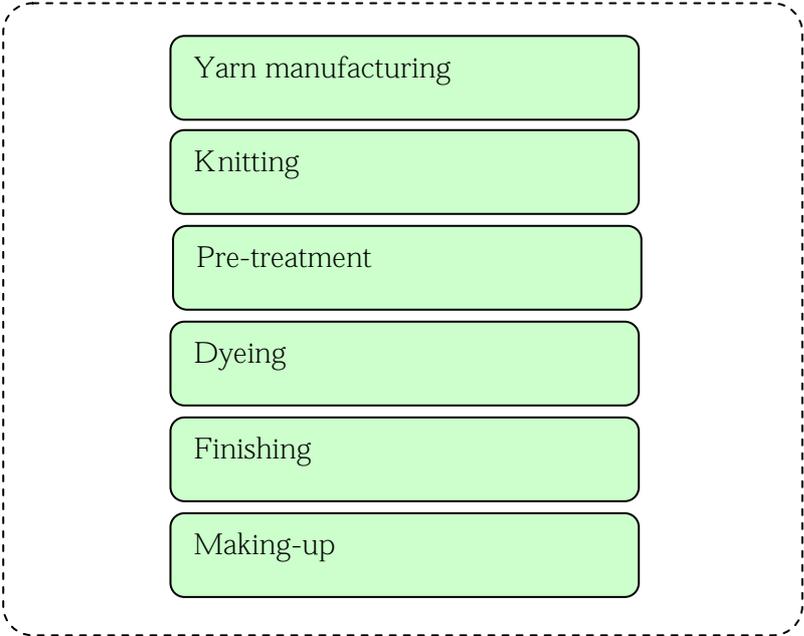
A more detailed description of the processes, calculations of volumes, waste, etc. can be found in the section "Background data".

Product system

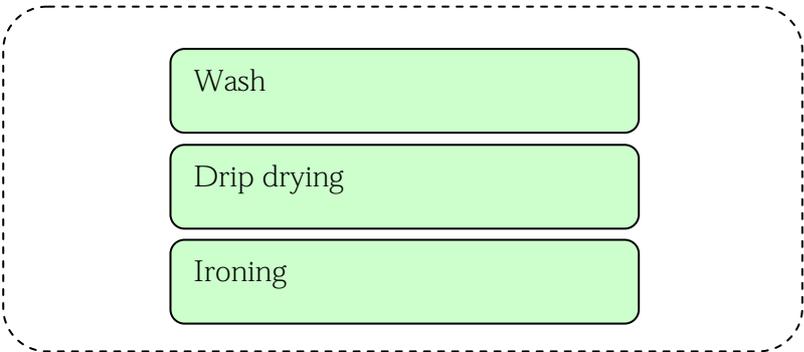
Materials phase



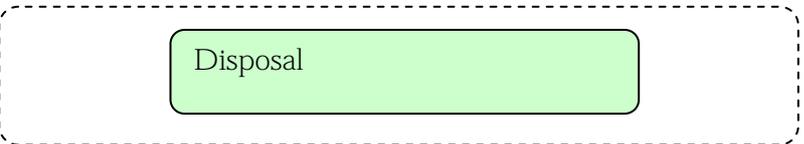
Production phase



Use phase



Disposal phase



Transport phase

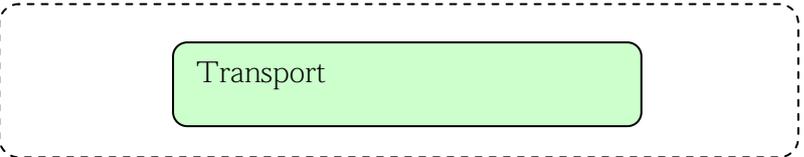


Figure 4.2 Lifecycle, flow and phases

In the following, all phases of the blouse's lifecycle will be described from extraction of raw materials through production to the making-up of the finished blouse.

Manufacture of raw materials

Viscose fibres, which comprise 70 per cent of the weight of the blouse, belong to the group of regenerated fibres. Regenerated fibres are made on the basis of natural chemical compounds - for viscose (and for many other types of fibre such as lyocell and acetate) this is cellulose. Cellulose can be recovered from wood, cotton waste, and similar parts of plants with high cellulose content.

Nylon, which comprises 25 per cent of the weight of the blouse, and elastane, which comprises 5 per cent, are in the group of synthetic fibres and are produced on the basis of crude oil and natural gas, which are converted into plastic through a number of chemical processes. The raw material is a limited resource, and production may lead to impacts on humans and the environment at local, regional and global levels. During processing of the materials into fibres, lubricants are usually added in the form of spindle oil and antistatic agents. Bactericides and fungicides may be added.

Data for the manufacture of elastane fibre have not been available. However, the model includes a process for elastane in which EDIP data for the process to manufacture polyurethane (flexible foam) is used. Elastane is composed of 85 per cent polyurethane. Furthermore, within the framework of the project it has not been possible to calculate an equivalency factor for carbon disulphide, which is used in the manufacture of viscose fibres.

Production of the blouse

Production is divided into several sub-processes: yarn manufacturing, knitting, pre-treatment, dyeing, finishing, making-up and distribution.

Yarn manufacturing

As the blouse is made exclusively from artificial fibres, an actual yarn manufacturing process is not always necessary, as it is to manufacture textiles such as cotton, for example. The model assumes that the yarn is obtained directly from the fibre producer and goes straight to the knitting process.

Distribution

The blouse is packed in polyester bags and then on a wood pallet. Finally, it is distributed to retail suppliers throughout Denmark.

Use phase

The consumption of washing agents and fabric softeners and the consequential discharge of detergents and nutrient salts lead to possible local and regional impacts in the aquatic environment.

Transport

The mode of transport when the blouse is transported from the shop to the buyer's home is also important in connection with the overall environmental profile of the product. Options like driving a car, using public transport or a bike make a significant difference in this part of the product's lifecycle.

The disposal phase

Textiles may not be landfilled. On final disposal, they must be incinerated so that the energy content is recovered and replaces non-renewable energy

sources like oil and natural gas. In some situations, the used blouse will be reused in a third-world country. In such situations, it is not possible to recover energy by incineration in Denmark.

Main scenario - results

The problem with quality of data already mentioned means that there is some reservation regarding the results in the two paragraphs below. The comments to the figures are neutral, i.e. the comments are on the basis of what can be read from the figures, as they appear. The subsequent section (What-if) discusses the significance of the lack of data for the statement of results.

The results of the main scenario are presented according to processes. The negative contributions that occur in some processes are due to estimated reuse potentials and contribution to environmental impact potentials. In the processes in question, the contributions can be allocated to other products and thus appear as negative contributions in the blouse's environmental profile.

The values in the four figures are not immediately comparable, as the unit is not the same for the four categories. The consumption of primary energy is calculated in mega-joules (MJ). The environmental impact potentials are presented as "milli-person equivalents" and are directly comparable. Milli-person equivalents are calculated as the direct impact for the year 2000. The weighting factors are based on global (w) or Danish (DK) discharges in the year 2000.

Consumption of primary energy

The consumption of primary energy reflects the processes that require a lot of electrical energy or heating air or water.

Figure 4.3 (consumption of primary energy per functional unit) shows that manufacture of fibre is primarily responsible for large energy consumption because energy consumption in the industrial manufacture of artificial fibres is so large. Manufacture of viscose fibres is especially significant. Primarily because it makes up 70 per cent of the total weight of the blouse. But also because the calculations using the original EDIP data show that 196 MJ primary energy must be used per kg viscose fibres; a factor approx. two-times larger than, e.g. polyester fibre. The figure is about 30 per cent larger than stated in several places in the literature. EDIP control calculations show that there are primarily inconsistencies in aspects related to the energy content in wood (the basic material for manufacturing viscose). The conclusion to the control calculations is that the correct figure is 196 MJ/kg.

In the use phase, the electricity consumption for washing causes the impacts. When the T-shirt is incinerated in an incineration plant, some energy is recovered and this is credited in the energy accounts.

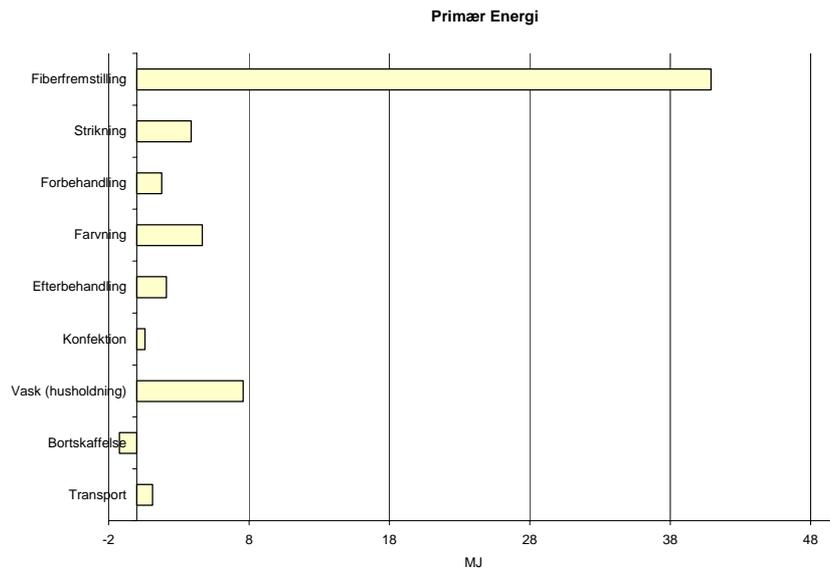


Figure 4.3 Consumption of primary energy per functional unit – for translation of Danish terms see glossary in annex 11

Environmental impact potentials

Figure 4.4 (Toxicological environmental impact potentials per functional unit), figure 4.5 (Environmental impacts related to energy per functional unit) and figure 4.6 (Environmental impacts, waste per functional unit) show that the contributions to the environmental impact potentials primarily originate from the fibre-manufacturing and washing processes.

In the use phase, primarily detergents in washing agents result in potential persistent toxicity. It has been assumed that no users add fabric softener when washing, and therefore the figures probably do not tally with the actual conditions in private Danish households.

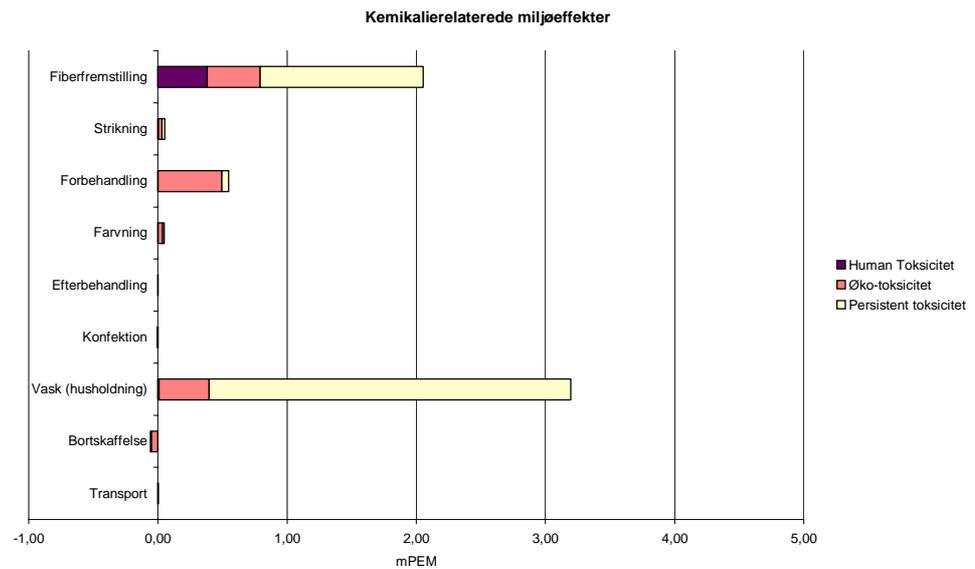


Figure 4.4 Toxicological environmental impact potentials per functional unit – for translation of Danish terms see glossary in annex 11

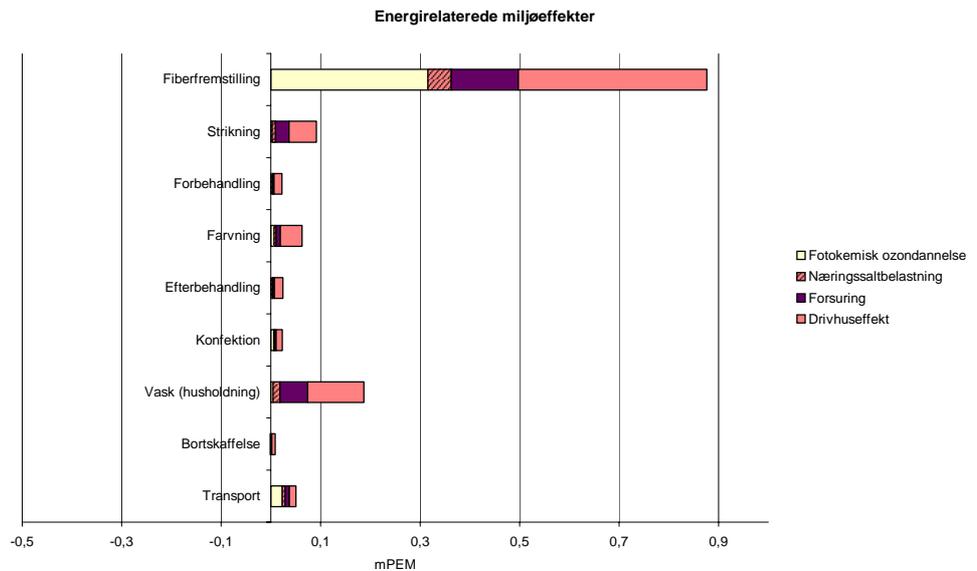


Figure 4.5 Environmental impacts related to energy per functional unit – for translation of Danish terms see glossary in annex 11

The environmental impact potentials related to energy are primarily due to burning fossil fuels.

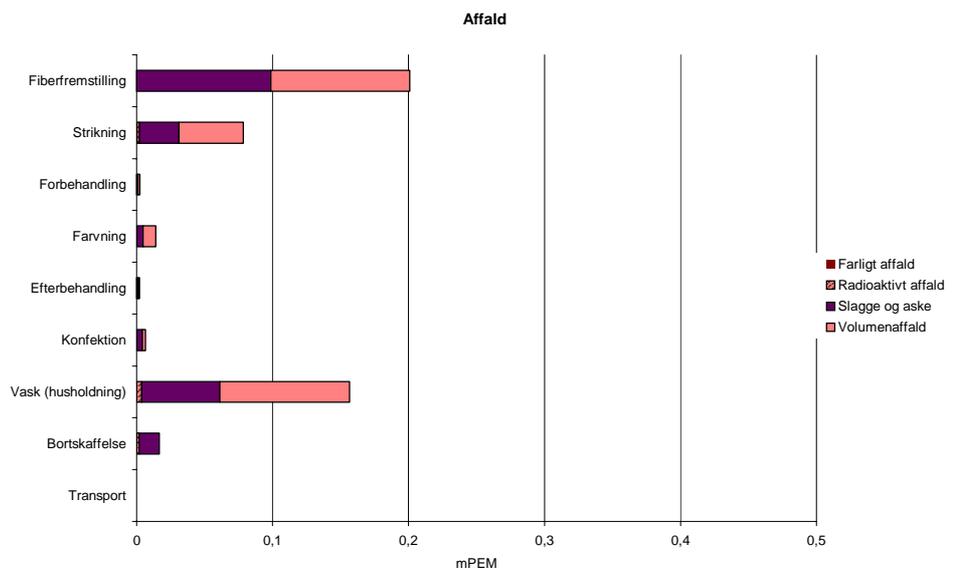


Figure 4.6 Environmental impacts, waste per functional unit – for translation of Danish terms see glossary in annex 11

The contributions to the waste categories shown in the figure originate primarily from generation of electricity. They are relatively limited in size compared with the above impact categories.

What-if discussion

This section will discuss the significance of the lack of data for the statement of results for the main scenario. Furthermore relevant parallels will be drawn to scenarios in the three group I cases (see the section on Method).

The significance of lack of data for the statement of results

As mentioned above, data for manufacture of elastane fibres have not been available and equivalency factors for carbon disulphide have not been included.

As elastane only makes up 5 per cent of the total weight of the blouse and as there is no knowledge of elastane manufacture causing emissions of especially problematic chemicals compared with other synthetic fibres, it is deemed that this has no significant impact on the statement of results.

As all other relevant energy data have been included in the model, it is deemed that the lack of data has no significance for the appearance of figure 4.3 - consumption of primary energy.

The same applies for figures 4.4 and 4.5, which for EDIPTEX primarily relate to environmental impacts resulting from consumption of energy. On the other hand there is no doubt that the lack of data for human toxicity, ecotoxicity, and persistent toxicity of carbon disulphide can be relevant for the appearance of figure 4.6. It is used and emitted in relatively large quantities in the manufacture of viscose.

Parallels to case group I scenarios

Because of the lack of data, it is difficult to draw definite parallels to case group I scenarios (T-shirt, jogging suit, and work jacket).

The only relatively certain standard of reference is the appearance of figure 4.3 - consumption of primary energy. This is very different from the corresponding aspects of case group I products. Energy consumption in the manufacture of fibres is by far the most significant. Compared with the corresponding figures for the main scenarios for case group I products, it is apparent that although fibre manufacture is also very important here, the use phase (washing, drying and ironing) has an even greater significance.

The message to a producer wanting to improve the environmental profile of the blouse is therefore clear: work with reuse of the fibre material - primarily viscose.

Background data

System structure in the EDIPTEx database for the blouse

The figures in column on the right of the table refer to the ID numbers used in the original EDIP PC tool.

	Ref. no.: EDIPTEx database
1 Blouse, dyed (viscose/ nylon/ elastane)	(TX0-01)
1 Blouse - Materials phase:	(TX6-1-05)
0.158 kg Viscose fibres	(TX1-03)
0.056 kg Polyamide 6.6. fibre (nylon)	(TX1-06)
0.011 kg Elastane fibres	(TX1-08)
1 Blouse – Production phase:	(TX6-2-18)
1 Blouse – Knitting	(TX6-2-30)
0.222 kg Circular knitting, Blouse	(TX22-1-03)
1 Blouse – Pre-treatment	(TX6-2-31)
0.222 kg pre-treatment of synthetic knitted goods (blouse)	(TX24-1-04-01)
1 Blouse – Dyeing	(TX6-2-32)
0.222 kg Dyeing viscose/nylon/elastane	(TX25-04)
1 Blouse – Finishing	(TX6-2-33)
0.222 kg Drying, final fixing + set m ² weight (blouse)	(TX27-3-06-03)
1.8 m ² fabric - inspection + rolling onto cardboard roll (blouse)	(TX27-3-08-06-03)
1 Blouse – Making-up	(TX6-2-34)
1 Blouse – Laying out, cutting and sewing	(TX28-1-04)
1 Blouse – Packing	(TX28-2-03-04)
1 Blouse – Use phase:	(TX6-3-03)
5 kg Household wash, 40°C, normal without prewash	(TX33-1-101)
5 kg Hang/drip/lay-drying after wash	(TX33-2-9)
1 Blouse – Disposal phase	(TX6-4-03)
0.140 kg Waste incineration of viscose	(TX41-1-03)
0.050 kg Waste incineration of polyamide (nylon)	(TX41-1-05)
0.010 kg Waste incineration of elastane	(TX41-1-07)
1 Blouse – Transport phase:	(TX6-5-03)
0.01 kg petrol combusted in petrol engine	(E32751)
234 kg km Lorry > 16 t diesel out-of-town, terminated	(O32694T98)
234 kg km Lorry > 16 t diesel urban, terminated	(O32695T98)
234 kg km Lorry > 16 t diesel motorway, terminated	(O32693T98)

Details of the blouse model in the EDIPTEx database

Assumptions:

- The blouse is knitted from 70 per cent viscose, 25 per cent nylon and 5 per cent elastane.
- Viscose is dyed with reactive dyes.
- Nylon is dyed with acid dyes.
- Elastane is dyed like nylon.
- Washing 40°C.
- Drip drying on a clothesline.
- Ironing not necessary.
- Lifetime: 25 washes.
- Weight: For this environmental assessment, the assumption is that the blouse weighs 200 g and 125 g per m².

Functional unit

For the blouse, the functional unit is defined as:

"25 days' use of blouse over the course of one year"

Maintenance is assumed to be a wash at 40°C. It is assumed that 25 days correspond to the number of days a consumer wears the blouse over the course of 1 year. Some consumers have an entirely different consumption of blouses. Some almost never wear a blouse, while others often change blouse according to fashion. Therefore the blouse may be discarded because of a change in fashion long before it wears out.

The calculations are carried out for "1 blouse", this needs to be converted in relation to lifetime, and the calculations need to be converted to "per year".

It is assumed that the blouse can be washed 25 times before it is discarded. It is assumed that the consumer wears the blouse 25 days per year. It is assumed that the blouse is used 1 day and is then washed.

If the blouse is washed after each use, 25 days' use of the blouse means that 1 blouse is completely used up in one year - or more likely - that a person has 5 blouses that together last 5 years.

Disposal:

It is assumed that the blouse is sold in Denmark and disposed of through waste incineration. This means approx. 140 g viscose, 50 g nylon and 10 g elastane must be incinerated.

Household wash:

It is assumed that the blouse can be washed 25 times in its lifetime. This means that $0.2 \text{ kg} * 25 = 5 \text{ kg}$ must be washed in the lifetime of the blouse. I.e. viscose: $0.14 \text{ kg} * 25 = 3.5 \text{ kg}$ + nylon and elastane (synthetic) : $0.06 \text{ kg} * 25 = 1.5 \text{ kg}$, washed at 40°C normal without prewash.

Drying:

It is assumed that the blouse is dried on a clothesline. This is also 5 kg.

Packing the blouse:

It is assumed that the blouse is packed in a thin plastic bag. It is assumed the bag weighs 10 g.

Laying out, cutting and sewing the blouse:

There is no company data for a blouse. A new process has been set up: "Blouse - Laying out, cutting and sewing the blouse. TX28-1-04". The process is calculated "per blouse". It is assumed that energy consumption is the same as for a tablecloth (for which there is company data).

According to Laursen et al. 1997, waste is 6-25 per cent. For a blouse it is assumed that waste is 10 per cent as a blouse is one of the simplest garments for cutting and sewing. This means $0.20 \text{ kg} / (1-0.1) = 0.222 \text{ kg}$ textile must be used. It is assumed that the waste is discarded (incinerated at a waste incineration plant).

Fabric - inspection and rolling onto a cardboard roll

There is no company data for knitted fabric for a blouse. It is assumed that data is the same as for woven fabric for a tablecloth. Therefore process no.

TX27-3-08-06 is used. Amount: see previous process: 0.222 kg approved textile after the fabric inspection. It is assumed there is no significant waste from this process.

Therefore 0.222 kg textile must be produced (dried and fixed).

Drying, final fixing and setting square-metre weight:

As mentioned above, 0.222 kg textile must be used per blouse. This corresponds to 1.8 m² textile (dried and fixed) per blouse weighing 125 g per m².

It is assumed there is no significant waste from this process. This means 0.222 kg dyed textile must be used.

Dyeing viscose/nylon/elastane textile:

0.222 kg is used by this process per blouse. There is no waste in the process.

Pre-treatment of synthetic woven fabric:

Only washing. No bleaching. It is assumed there is no significant waste from this process. Therefore 0.222 kg is used by this process per blouse.

Knitting:

0.222 kg textile must be knitted per blouse.

1.015 kg yarn is used per kg circular-knitted textile. Therefore 0.225 kg yarn must be used per blouse. The waste is disposed of via incineration.

Viscose fibres

0.225 * 0.70 kg (the blouse is composed of 70% viscose) is used in this process (per 0.158 kg). Note that unlike cotton there is no yarn manufacturing, as filament yarns are used and they come directly from the fibre producer.

Polyamide 6.6 fibre (nylon)

0.225 * 0.25 kg (the blouse is 25 per cent nylon) is used in this process (per 0.056 kg). Note that unlike cotton there is no yarn manufacturing, as filament yarns are used and they come directly from the fibre producer.

Elastane fibres

0.225 * 0.05 kg (the blouse is 5 per cent elastane) is used in this process (per 0.011 kg). Note that unlike cotton there is no yarn manufacturing, as filament yarns are used and they come directly from the fibre producer.

Transport

All transport distances are estimated. See table below.

Transport	Quantity for one blouse	Kg km
Transport of viscose fibres from fibre manufacturer in Germany (D) to a knitting mill in Denmark (DK).	0,158 kg transported 1000 km by lorry	158 kg km by lorry
Transport of nylon fibres from fibre manufacturer in D to a knitting mill in DK.	0,056 kg transported 1000 km by lorry	56 kg km by lorry
Transport of elastane fibres from fibre manufacturer in D to a knitting mill in DK.	0,011 kg transported 1000 km by lorry	11 kg km by lorry
Transport of fabric from knitting mill to dye house in DK	0,222 kg transported 200 km by lorry	44,4 kg km by lorry
Transport of dyed fabric from dye house in DK to making-up enterprise in Poland	0,222 kg transported 1000 km by lorry	222 kg km by lorry
Transport from making-up enterprise in Poland to shop in Denmark, lorry	0,200 kg transported 1000 km by lorry	200 kg km by lorry
Consumer transport*		0,02 kg petrol
Transport of discarded blouse (with household refuse)	0,200 kg transported 50 km by lorry	10 kg km by lorry

* Consumer transport: It is assumed that the consumer drives in town by car to buy 1 blouse and 5.8 kg other goods. It is assumed the consumer drives 10 km and the car goes 12 km per litre. This means 0.83 l petrol is used (= 0.61 kg petrol, as petrol weighs 0.73 kg per litre). Of this, 0.61 * 0.2/6 is allocated to the blouse, i.e. 0.02 kg petrol.

Lorry, total: 701.4 kg km (assumed 33 per cent urban, 33 per cent out-of-town, 33 per cent motorway). I.e. total transport:

Process no. in EDIPTX database	Name of process	Transport need
O32695T98	Lorry > 16 t, diesel urban traffic, TERMINATED	234 kg km by lorry
O32694T98	Lorry > 16 t diesel out-of-town, TERMINATED	234 kg km by lorry
O32693T98	Lorry > 16 t diesel motorway, TERMINATED	234 kg km by lorry
E32751	Petrol consumed in petrol engine	0,02 kg petrol

Annex 5: Tablecloth - cotton and dirt-repelling

The tablecloth - summary and conclusions

Firstly, it is important to stress the following conditions with regard to lack of data for the model used as the basis for the environmental assessment of the tablecloth:

- Chemical emissions to the air while drying after pigment printing have been difficult to ascertain. Only emissions of formaldehyde have been included in the model.
- The same applies for chemical emissions to water when washing printing equipment.
- Furthermore, it has not been possible to obtain data to enable calculation of equivalency factors for an important finishing chemical.

As all relevant energy data have been included in the model, the lack of data has no significance for the appearance of the statements of consumption of primary energy and environmental impacts related to energy.

On the other hand the effect of the lack of data for amounts of human toxicity and ecotoxicity is somewhat uncertain for the statement of the environmental impacts related to chemicals. However, it has been estimated that fibre manufacture of cotton will be by far the most important for these impacts. For general and non-product-specific aspects regarding quality of EDIPTEx data, see chapter 4.

In summary, and in comparison to the case for the T-shirt, it can be concluded that the tablecloth and the T-shirt belong in the same product family.

The overall conclusions for many of the scenarios for the T-shirt relating to consumption of energy and toxicological environmental impacts can therefore be transferred to the tablecloth.

The main scenario shows that the most significant contributions to the environmental impact potentials related to chemicals originate from cotton cultivation.

At an overall level, the results indicate that the consumer holds the best possibilities for influencing the product's overall environmental profile. This is due to the dominant use phase. The individual consumer's consumption patterns and environmental awareness are therefore crucial, i.e. awareness of ecolabelling of products in combination with good habits like:

- minimal use of washing agent
- no use of fabric softeners
- no ironing.

The producer is primarily able to affect the tablecloth's environmental profile through choice of materials. - choice of organic cotton. By living up to European and Scandinavian ecolabelling criteria and obtaining labelling approval, the producer can signal to the conscious consumer that the product in question has been produced in an environmentally sound manner.

Introduction

Lifecycle assessment is a method for identification and evaluation of environmental impact potentials of a product or a service from cradle to grave. This method enables the user to make an environmental assessment and focus on the most important environmental impacts.

Lifecycle assessment is an iterative process. The first definition of purpose and delimitations often need to be revised during work with lifecycle assessment. The amount of data available sets limits, and consequently the limits of the system are changed.

The method used in this case for assessment of products is "Environmental Design of Industrial Products" (EDIP) and the associated database and PC tool.

In the EDIPTEX project, sector-specific data have been prepared for the textiles sector in connection with the existing EDIP database. On the basis of the data collected, environmental assessments were prepared for the textile products.

- A T-shirt of 100 % cotton
- A jogging suit of nylon microfibres with cotton lining
- A work jacket of 65 per cent polyester and 35 per cent cotton
- A blouse of viscose, nylon and elastane
- A tablecloth of cotton
- A floor covering of nylon and polypropylene.

These environmental assessments are intended to illustrate the scope for application of the EDIPTEX database by using the PC modelling tool and, at a more general level, application of the EDIP method.

Method

The six case stories vary a lot in scope. They can be divided into two main groups - with variations within these two main groups. The two main groups are:

- Group I: The T-shirt, the jogging suit and the work jacket.
- Group II: The floor covering, the tablecloth and the blouse.

The division into groups I and II relates to the scope of the collection of data as well as the quality of data.

For group I, it was possible to collect (and process) data for all significant processes. The data are of such quality that these three products have been selected to illustrate how far it is possible to take lifecycle assessment for textiles and to illustrate all relevant aspects of the EDIP method.

Each of the three group I cases contains:

- Definition of functional unit and reference product
- Modelling of main scenario
- Preparation of producer and consumer references
- Simulation of environmental impacts caused by choices made by producer and consumer respectively.

Work with these cases has been divided into phases as illustrated in figure 5.1.

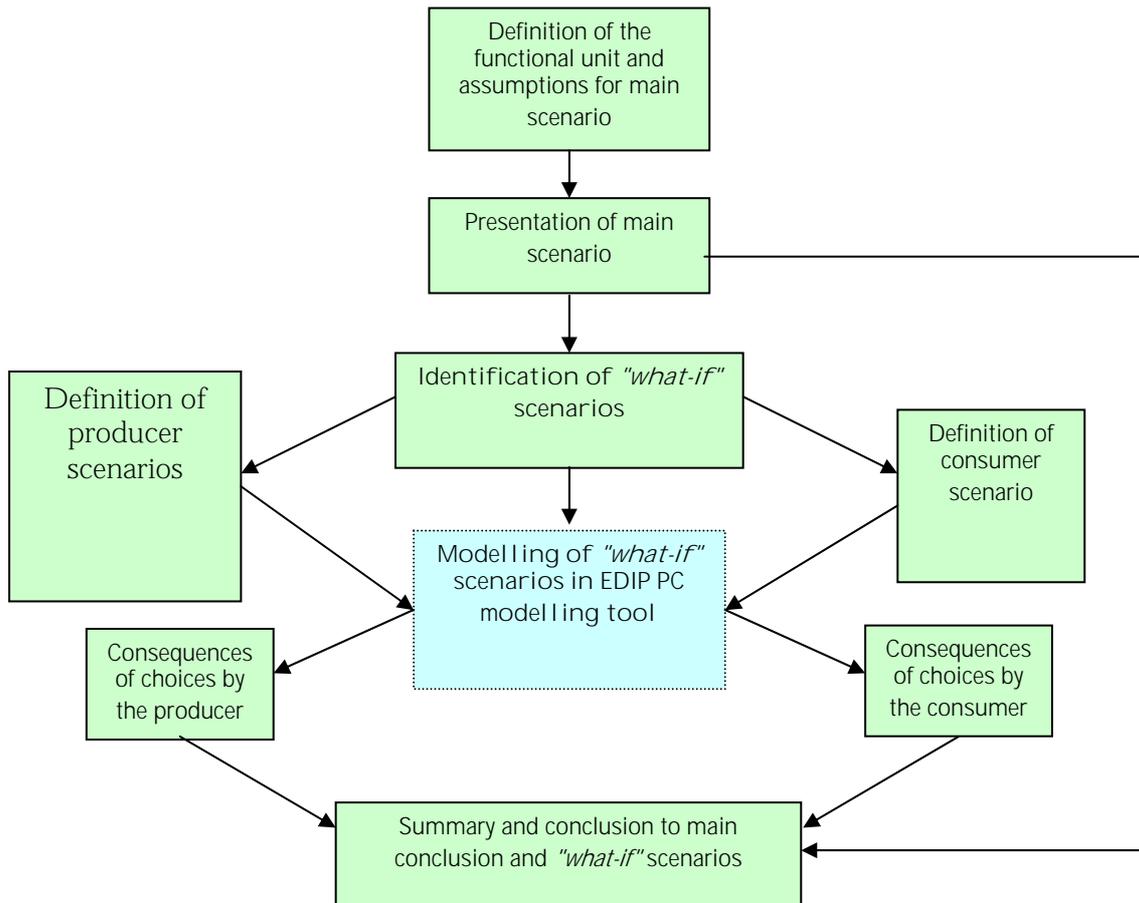


Figure 5.1 EDIPTEX case group I flow diagram

For group II, it was not possible to complete all sub-processes. Although only 1-2 sub-processes for each product have considerable lack of data, these processes are deemed potentially significant for the overall lifecycle assessment. The group II case stories are therefore of an entirely different character than those of group I. The group II cases illustrate that it is possible to tell an interesting and exciting "environment story" based on lifecycle assessment (and EDIP) even though it has not been possible to analyse all aspects of lifecycle assessment data. This situation will arise very often in lifecycle assessment work. However, there is a significant difference in this EDIPTEX connection; it is possible to draw on results from the three lifecycle assessments from case group I (and this has been done), which improves the quality of the case stories.

Comments to the method

Product references

The "what-if" simulations were carried out to elucidate the consequences of possible changes in the product's lifecycle. A special product reference has been defined for the producer scenarios in some of the case stories. The producer only has limited influence on the use phase. In order to take this into account, a product reference has been prepared for the producer scenarios where only a limited part of the impacts from the use phase has been included in relation to the product reference from the main scenario. This was done in order to give producers a clearer picture of the influence of the production phase on the product's environmental profile in the "what-if" producer scenarios.

Data

With regard to data, it should be noted that the validity of the data in the database varies, depending on the processes considered. A global process like cultivation and harvest of cotton is subject to considerable uncertainty. This is because cotton is produced in countries with very different levels of development. For example, production varies a lot between South America and the US because of large differences in the use of pesticides, crop yields, etc.

This difference has not been taken directly into account in the EDIPTTEX database, but a representative level for the data has been defined. Therefore, the data are very general and not necessarily representative for all lifecycle assessments. Other processes are more exact, such as extraction of crude oil for nylon. This process is well documented, both as regards industrial accidents and as regards resource consumption.

Production data primarily come from Danish enterprises. The number of enterprises involved represents limitations in this connection. For example, only one reactive dye and one acid dye have been studied thoroughly. These two substances represent the entire group of dyes, despite the major differences that may occur.

A large proportion of the environmental impacts come from the consumption of electrical energy. The data currently used in the database originate from the EDIP database, and the reference year is 1990. This area is being studied in order to update this part of the database. It is important to note that this lifecycle assessment was carried out using the 1990 data in all processes that consume electrical energy.

For this product in particular, chemical emissions to the air during drying after pigment printing have been difficult to ascertain. Only emissions of formaldehyde have been included in the model. The same applies for chemical emissions to water when washing printing equipment. Furthermore, it has not been possible to obtain data to enable calculation of equivalency factors for an important finishing chemical.

These aspects of data quality mean that focus for this case is on primary energy and environmental impacts for the main scenario. The significance of the lack of data for the statement of results for the main scenario is discussed. Moreover relevant parallels have been drawn with the scenarios in the three group I cases.

Tablecloth

Product description: The tablecloth is made of 100 per cent cotton. The tablecloth is printed with pigments and has been finished to make it easier to maintain. The tablecloth can often be cleaned with just a wet cloth.

Functional unit

The performance assessed can be described as a "functional unit", comprising a qualitative and a quantitative description, including the product's lifetime. The qualitative description is to define the quality level for the performance, so that products can be compared at a somewhat uniform quality level. The quantitative description is to determine the size and duration of the performance.

In this project, the functional unit is defined as:

"150 times use of tablecloth over the course of 2½ years"

Cleaning/maintenance of the tablecloth are assumed to comprise only wiping with a cloth and (every six times) washing at 60°C. It is also assumed that the tablecloth is dried on a clothesline and it is ironed. Under these conditions, 150 times' usage (25 washes) is assumed to be a realistic lifetime. Other possible maintenance such as pressing and rolling has not been included in the project.

Reference product and main scenario

The reference product is a product that meets the criteria of one functional unit. Here, we have chosen a tablecloth.

The calculations are carried out for "1 tablecloth", these need to be converted in relation to lifetime, and the calculations need to be converted to "per year".

It is assumed that the tablecloth can be washed 25 times before it is discarded. It is assumed that the tablecloth is used six times before each wash. It is assumed that the tablecloth can be used 60 times each year.

If the tablecloth is used 60 times per year, and if the tablecloth is used six times before it is washed, the tablecloth will be washed 10 times per year. If the tablecloth can be washed 25 times before discarding, it will be completely worn out after 2½ years.

The following assumptions apply to the assessment and are thus included in the modelling of the main scenario.

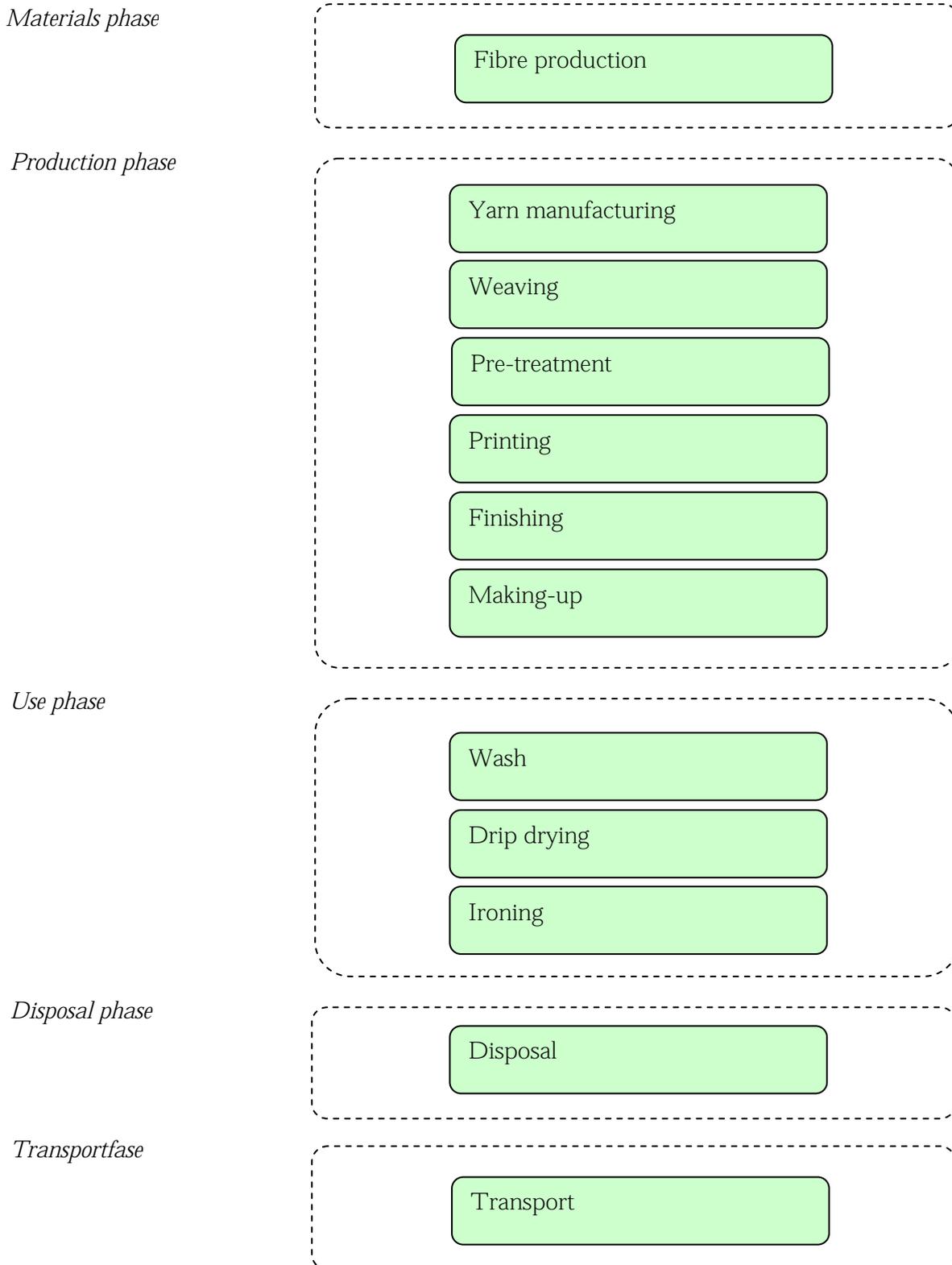
- 100 per cent woven cotton.
- Printing with pigments.
- Washing 60°C.
- Drip drying on a clothesline.
- Ironed after each wash. It is assumed it takes about 10 min. to iron the tablecloth each time.
- Lifetime: 25 washes.

- Size and weight (based on company data): the tablecloth is assumed to measure 2.65 m². The tablecloth weighs 145 g per m². This means that the tablecloth weighs approx. 384 g.

A more detailed description of the processes, calculations of volumes, waste, etc. can be found in the section "Background data" at the end of this annex.

Product system

Figure 5.2 Livecycle, flow and phases



In the following, all phases of the tablecloth's lifecycle will be described from extraction of raw materials through production to the making-up of the finished tablecloth.

Manufacture of raw materials

The tablecloth consists solely of cotton. Cotton is cultivated in many countries under different geographical and climatic conditions. Cultivation often entails a large consumption of artificial fertilizer, large water consumption and a large consumption of pesticides against insect attacks, diseases, worms and weeds. The extent of this depends largely on local conditions. The consumption of pesticides entails an important environmental problem for both human health and nature.

Irrigation and use of artificial fertilizer impact groundwater and surface water resources quantitatively as well as qualitatively. Before picking, it is common to use defoliating agents so that picking can be done mechanically.

It is normally not permitted to use pesticides and artificial fertilizer in cultivation of organic cotton. Thus, it is only permitted to use a very limited selection of plant protection agents, and only when there is an acute danger for the crop. Organic production of cotton constitutes less than 1 per cent of total cotton production, but organic production is increasing and is expected to increase further due to increased demand.

Production of the tablecloth

Production is divided into several sub-processes: yarn manufacturing, weaving, pre-treatment, printing, finishing, making-up and distribution.

Chemical emissions to the air during drying after pigment printing have been difficult to ascertain. Only emissions of formaldehyde have been included in the model. The same applies for chemical emissions to water when washing printing equipment. Furthermore, it has not been possible to obtain data to enable calculation of equivalency factors for an important finishing chemical.

Yarn manufacturing

By using long cotton fibres, a more durable product is obtained and thus it is possible to extend the lifetime of the product. Prior to weaving, the warp is covered with a sizing agent to reduce the friction in the weave. Sizing agents can be based on natural or synthetic substances.

Occupational health and safety

The supplier is obliged to reduce the amount of monotonous repetitive work and dust nuisance at work. Cotton dust may cause lung damage, for example.

Distribution

The tablecloth is packed in polyester bags and then on a wood pallet, after which it is distributed to retail suppliers throughout Denmark.

Use phase

The consumption of washing agents and fabric softeners and the consequential discharge of detergents and nutrient salts lead to possible local and regional impacts in the aquatic environment.

Transport

The mode of transport when the tablecloth is transported from the shop to the buyer's home is also important in connection with the overall environmental profile of the product. Options like driving a car, using public transport or a bike make a significant difference in this part of the product's lifecycle.

Disposal phase

Textiles may not be landfilled. On final disposal, they must be incinerated so that the energy content is recovered and replaces non-renewable energy sources like oil and natural gas.

Main scenario - results

The results of the main scenario are presented according to processes. The negative contributions that occur in some processes are due to estimated reuse potentials and contribution to environmental impact potentials. In the processes in question, the contributions can be allocated to other products and thus appear as negative contributions in the tablecloth's environmental profile.

The values in the four figures are not immediately comparable, as the unit is not the same for the four categories. The consumption of primary energy is calculated in mega-joules (MJ). The environmental impact potentials are presented as "milli-person equivalents" and are directly comparable. Milli-person equivalents are calculated as the direct impact for the year 2000. The weighting factors are based on global (w) or Danish (DK) discharges in the year 2000.

Consumption of primary energy

The consumption of primary energy reflects the processes that require a lot of electrical energy or energy to heat air or water.

Figure 5.3 (consumption of primary energy per functional unit) shows that the processes in the use phase (washing and ironing) represent most of the consumption of primary energy. In the use phase, the electricity consumption for washing and ironing cause the impacts. Manufacture of the cotton fibres accounts for the largest single contribution, however. Furthermore, processing into yarn makes a large contribution.

When the tablecloth is incinerated in an incineration plant, some energy is recovered and this is credited in the energy accounts.

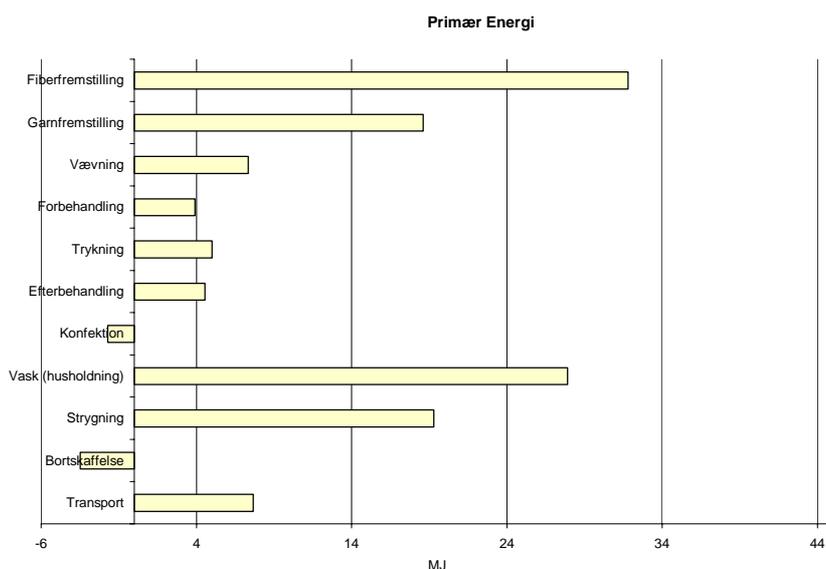


Figure 5.3 consumption of primary energy per functional unit – for translation of Danish terms see glossary in annex 11

Environmental impact potentials

The problem with quality of data already mentioned (chemical emissions to the water and air from printing) means that there is some reservation regarding the results below. The comments to the figures are neutral, i.e. the comments are on the basis of what can be read from the figures, as they appear. The subsequent section (What-if) discusses the significance of the lack of data for the statement of results.

Figure 5.4 (Toxicological environmental impact potentials per functional unit), figure 5.5 (Environmental impacts related to energy per functional unit) and figure 5.6 (Environmental impacts, waste per functional unit) show that the contributions to the toxicological and environmental impact potentials dominate. Particularly ecotoxicity and persistence toxicity are very high, primarily because of the pesticides that are spread on the cotton fields during the cultivation process.

The data used to determine the pesticide volumes per hectare are based on a worst-case assumption. The focus in this phase is to reduce pesticide consumption during cultivation of cotton.

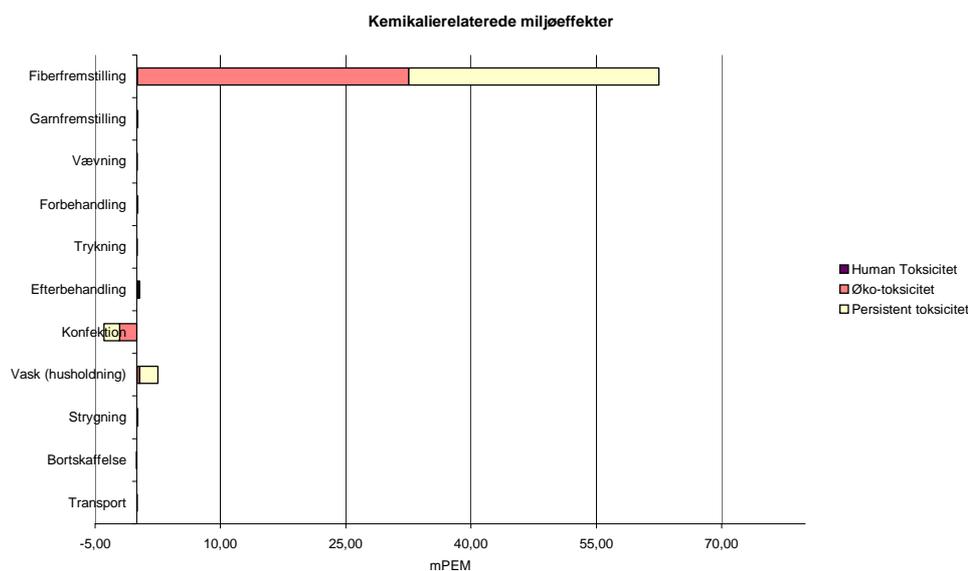


Figure 5.4 Toxicological environmental impact potentials per functional unit – for translation of Danish terms see glossary in annex 11

In the use phase, primarily detergents in washing agents result in potential persistent toxicity. It has been assumed that no users add fabric softener when washing, and therefore the figures probably do not tally with the actual conditions in private Danish households. The contributions to the waste categories (figure 5.6) mainly originate from electricity generation.

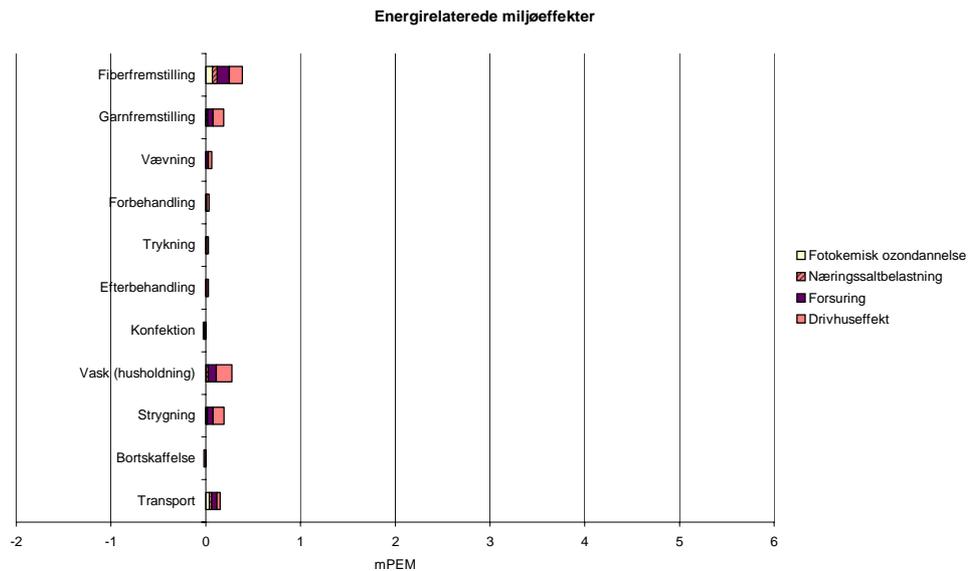


Figure 5.5 Environmental impacts related to energy per functional unit – for translation of Danish terms see glossary in annex 11

The environmental impact potentials related to energy are primarily due to burning fossil fuels.

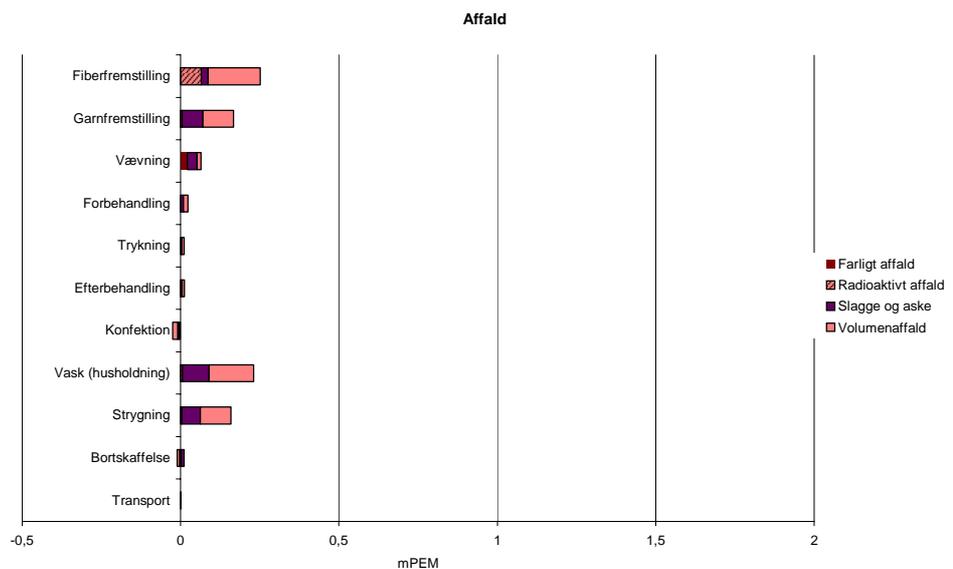


Figure 5.6 Environmental impacts, waste per functional unit – for translation of Danish terms see glossary in annex 11

The contributions to the waste categories shown in the figure originate primarily from generation of electricity. Like the energy-related impacts, they are relatively limited in size compared with the toxicological impact categories.

What-if discussion

This section will discuss the significance of the lack of data for the statement of results for the main scenario. Moreover relevant parallels will be drawn with the scenarios in the three group I cases.

The significance of lack of data for the statement of results

As mentioned above, the following conditions relating to the quality of data specifically for the tablecloth have been revealed:

- Chemical emissions to the air while drying after pigment printing have been difficult to ascertain. Only emissions of formaldehyde have been included in the model.
- The same applies for chemical emissions to water when washing printing equipment.
- Furthermore, it has not been possible to obtain data to enable calculation of equivalency factors for an important finishing chemical.

As all relevant energy data have been included in the model, it is deemed that the lack of data has no significance for the appearance of figure 5.3 - consumption of primary energy.

The same applies for figures 5.5 and 5.6, which primarily relate to environmental impacts resulting from consumption of energy.

On the other hand, there is some uncertainty of the significance of the lack of data for the above on the amount of human toxicity, ecotoxicity and persistent toxicity for the appearance of figure 5.4. However, it is estimated that manufacture of fibre will be dominant.

Parallels to case group I scenarios

As there was no lack of data on energy consumption in the assessment of the tablecloth, relatively certain comparisons can be made with environmental profiles for other textile products prepared using the same principles. Looking at the energy profile of the tablecloth in figure 5.3 and comparing this with the corresponding profile for a cotton T-shirt, for example, as in figure 5.7, the difference is remarkable.

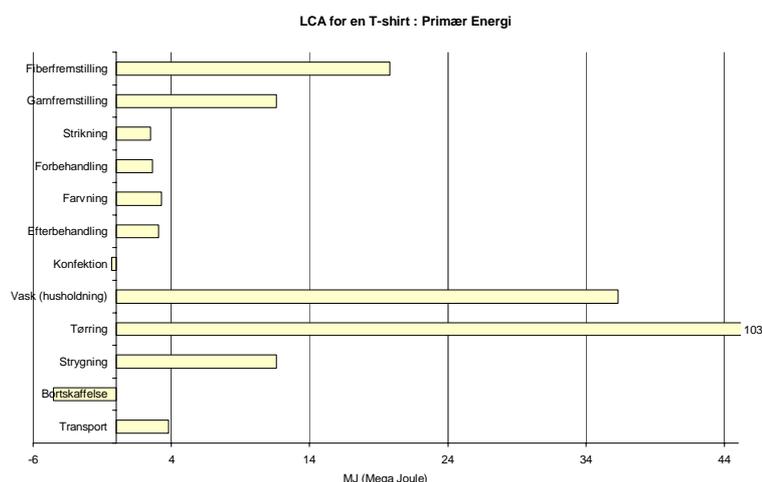


Figure 5.7 Consumption of primary energy per functional unit – for translation of Danish terms see glossary in annex 11

The use phase (washing and ironing for the tablecloth; washing and tumbler drying for the T-shirt) is the most important phase for the statement of primary energy. The drying process is dominant for the T-shirt, and this would also apply for the tablecloth, if drying were part of the model. The model does not include drying because it is assumed that the tablecloth has

been finished to make maintenance easier (e.g. a wax tablecloth). This type of tablecloth dries very easily and tumbler drying is not necessary.

The statements of the toxicological environmental impacts (figure 5.4 for the tablecloth and 5.8 for the T-shirt below) are even more convergent (note that the scales on the x axes are very different). This is because both products are made of 100 per cent cotton. The toxicological impacts of the use of pesticides are extremely prominent.

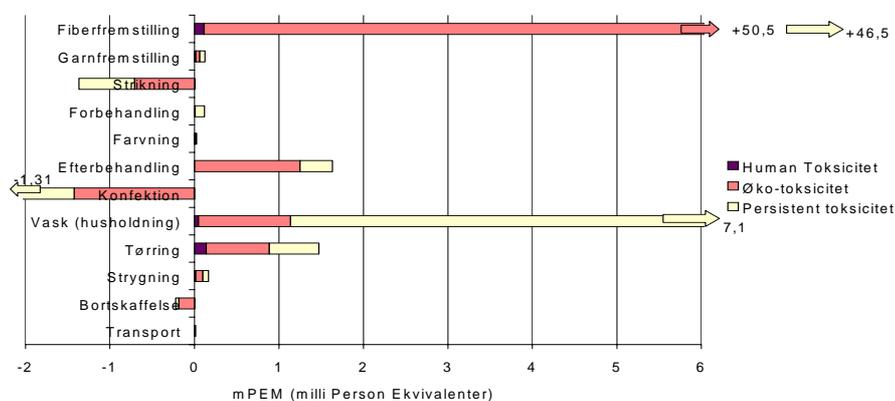


Figure 5.8 Toxicological environmental impact potentials per functional unit for a T-shirt – for translation of Danish terms see glossary in annex 11

The overall conclusions to the many scenarios for the T-shirt relating to consumption of energy and toxicological environmental impacts can therefore be transferred to the tablecloth. Therefore, it can be concluded that the products belong to the same product family.

This applies as a minimum to the overall conclusions in the following T-shirt producer scenarios:

Choice of raw materials:

Scenario 1: Choice of raw materials - organic cotton

Scenario 2: Choice of raw materials - halved cotton waste

The use phase:

Scenario 6: Use phase - extended textile lifetime

Scenario 7: Use phase - colour staining

And as a minimum the following T-shirt consumer scenarios:

Scenario 10: Choice of wash - halving wash frequency

Scenario 12: Choice of wash - use of fabric softener

Scenario 14: No ironing

Scenario 15: Transport home - car with shopping.

This observation leads to the overall conclusion that the consumer holds the best possibilities for influencing the product's overall environmental profile. This is due to the dominant use phase. The individual consumer's consumption patterns and environmental awareness are therefore crucial, i.e. awareness of ecolabelling of products in combination with good habits like:

- minimal use of washing agent
- no use of fabric softeners
- no ironing.

The producer is primarily able to affect the T-shirt's environmental profile through choice of materials - choice of organic cotton.

Background data

System structure in the EDIPTEx database for the tablecloth

The figures in column on the right of the table refer to the ID numbers used in the original EDIP PC tool.

	Ref. no.: EDIPTEx database
1 Tablecloth, pigment printed (cotton)	(TX0-05)
1 Tablecloth – Materials phase: 0.644 kg Cotton fibres (incl. cultivation and harvest)	(TX6-1-08) (TX1-01-1)
1 Tablecloth – Production phase: 1 Tablecloth – Yarn manufacture 0.45 kg Yarn manufacture (cotton yarn)	(TX6-2-21) (TX-2-23) (TX21-1)
1 stk. Tablecloth – Weaving 3.103 m ² Weaving, natural sizing	(TX6-2-24) (TX23-1)
1 stk. Tablecloth – Pre-treatment 0.446 kg Desizing (persulphate) of woven cotton	(TX6-2-25) (TX24-2-02)
1 stk. Tablecloth – Printing 3.075 m ² Application and fixing printing paste	(TX6-2-26) (TX26-2-01)
3.075 m ² Wash 9 templates incl. auxiliary eqt. 3.075 m ² Overhead use for printing	(TX26-2-02) (TX26-2-03)
1 Tablecloth – Finishing 3.075 m ² Finishing and drying on stretching frame	(TX6-2-27) (TX27-2-30-1)
3.075 m ² Pressing 3.075 m ² Condensation of impregnation on stretching frame	(TX27-1-01) (TX27-2-30-2)
3.03 m ² Fabric – inspection and rolling onto cardboard roll	(TX27-3-08-06)
1 Tablecloth – Making-up 1 Laying out, cutting and sewing the tablecloth	(TX6-2-28) (TX28-1-06)
1 Tablecloth, pigment printed – Packing	(TX-28-2-03-06)
1 Tablecloth – Use phase: 9.6 kg Household wash, 60 °C with prewash 9.6 kg Hang/drip/lay dry after wash 250 minutes ironing cotton and other cellulose	(TX6-3-06) (TX-1-202) (TX33-2-9) (TX33-3-01)
1 Tablecloth – Disposal: 0.384 kg Waste incineration of cotton	(TX6-4-06) (TX41-1-01)
1 Tablecloth – Transport phase: 12880 kg km Container ship, 2-t, 28000DWT, Terminated 470 kg km Lorry > 16 t diesel out-of-town Terminated 470 kg km Lorry > 16 t diesel urban Terminated 470 kg km Lorry > 16 t diesel motorway Terminated 0.04 Petrol combusted in petrol engine	(TX6-5-06) (O32715T98) (O32694T98) (O32695T98) (O32693T98) (E32751)

Details of the tablecloth model in the EDIPTEx database

Assumptions:

- 100 per cent woven cotton.
- Printing with pigment.
- Washing 60°C.
- Drip drying on a clothesline.
- Ironed after each wash. It is assumed that it takes about 10 min. to iron the tablecloth each time.
- Lifetime: 25 washes.

- Size and weight (based on company data): the tablecloth is assumed to measure 2.65 m². The tablecloth weighs 145 g per m². This means the tablecloth weighs 384 g.

Functional unit

For the tablecloth, the functional unit is defined as:

"150 day's' use of tablecloth over the course of 2½ years"

Cleaning/maintenance of the tablecloth are assumed to include drying (every six washes) and washing at 60 °C. It is also assumed that the tablecloth is dried on a clothesline and it is ironed. Under these conditions it is estimated that 150 times' usage (25 washes) is realistic for a lifetime. Other possible types of maintenance such as pressing and rolling have not been included in this project.

The calculations are carried out for "1 tablecloth", these need to be converted in relation to lifetime, and the calculations need to be converted to "per year".

It is assumed that the tablecloth can be washed 25 times before it is discarded. It is assumed that the tablecloth is used six times before each wash. It is assumed that the tablecloth is used 60 times per year.

If the tablecloth is used 60 times each year, and if the tablecloth is used six times before it is washed, the tablecloth will be washed 10 times a year. If the tablecloth can be washed 25 times before discarding, it will be completely worn out in 2½ years.

Disposal:

It is assumed that the tablecloth is sold in Denmark and disposed of through waste incineration. This means that 384 g cotton must be incinerated (the weight of the tablecloth).

Household washing:

It is assumed that the tablecloth can be washed about 25 times in its lifetime. This means that 0.384 kg * 25 = 9.6 kg cotton must be washed in the lifetime of the tablecloth.

Drying:

It is assumed that the tablecloth is dried on a clothesline. This is also 9.6 kg cotton.

Ironing:

The tablecloth must be ironed after each wash. It is assumed that it takes 10 minutes each time to iron the tablecloth. 10 minutes * 25 = 250 minutes.

Packing the pigment-printed tablecloth:

The tablecloth measures 2.65 m². A pigment-printed tablecloth weighs 145 g per m². This means that the tablecloth weighs about 384 g.

Laying out, cutting and sewing the tablecloth:

OUT: The process is calculated "per tablecloth" out of the process.

IN: During the process "laying out, cutting and sewing of tablecloth" there is waste from cutting and mistakes. This means that 3.03 m² fabric is required per tablecloth.

Fabric - inspection and rolling onto a cardboard roll:

OUT: The process is calculated "per m² inspected and approved textile" (i.e. the amount out of the process). As mentioned above, "3.03 m² inspected and approved textile" must be used per tablecloth.

IN: During the inspection of fabric about 0.015 m² textile are discarded to waste. This means that 1.915 m² textile must be used within the process for each 1 m² inspected and approved textile, corresponding to $3.03 \text{ m}^2 * 1.015 = 3.076 \text{ m}^2$ in.

Condensation of impregnation on steamer:

As mentioned above, 3.075 m² textile must be used from this process for one tablecloth. The process involves neither shrinking, waste, nor discarding of textile, and therefore the same number of m² go out as come in.

Pressing:

As mentioned above, 3.075 m² textile must be used from this process for one tablecloth. The process involves neither shrinking, waste, nor discarding of textile, and therefore the same number of m² go out as come in.

Finishing and drying on stretching frame:

The textile shrinks by about 4.5 per cent in this process. This is because the material is stretched in the other processes. There is max. 5 per cent stretching and shrinking and overall the material shrinks by less than 2 per cent from when the goods go into the printers to when they are inspected in the fabric inspection. This stretching and shrinking has been ignored as it is relatively little, and as it is estimated that it is within the uncertainties always connected with data for lifecycle assessments. This means that the calculations have not included adjustments for stretching and shrinking the textile. As there is no waste of the textile in this process, it is assumed that just as many m² enter the process as come out.

Application and fixing printing paste, washing nine templates incl. auxiliary equipment, and overheads from printing:

All these processes are calculated per m² pigment-printed textile (after application and fix of printing paste). As there is no waste of textile in the process, just as many m² enter the process as come out. With a m² weight of 145 g/m², this corresponds to $3.075 \text{ m}^2 * 145 \text{ g/m}^2 = 446 \text{ g}$ textile per tablecloth.

Desizing (persulphate) woven cotton:

Data for this process is calculated per kg desized textile.

Because of waste, 1010 g woven cotton textile is used per kg washed woven goods. This means that for one tablecloth $446 \text{ g} * 1.01 = 450 \text{ g}$ woven textile must be used. $450 \text{ g} / 145 \text{ g per m}^2 = 3.103 \text{ m}^2$ textile.

Weaving:

This process is calculated per m² woven textile. According to Grenaa Danpvæveri, the waste of yarn, plastics, cardboard, paper, and iron totals 1.89 g per m². Assuming that 1 m² weighs 145 g, this gives a max. waste of yarn of $1.89 \text{ g} / 145 \text{ g} = 1.3$ per cent. From this, it is assumed that the waste is insignificant and ignored. Therefore, 3.103 m² is used in this process.

Spinning:

This process is calculated per kg finished yarn. 450 g yarn is required for a tablecloth. Therefore, 450 g is used in this process.

Cotton fibres:

Because of waste, 1.43 kg cotton fibre is used per kg finished yarn. This means $450 \text{ g} * 1.43 = 644 \text{ g}$ cotton fibres are required for one tablecloth.

Transport:

All transport distances are estimated. See table below.

Transport	Quantity for one tablecloth	Kg km
Transport of cotton from cultivator in China to spinning mill in Poland	0,644 kg transported 20000 km by ship	12880 kg km by ship
Transport of yarn from spinning mill in Poland to weaving mill in Denmark	0,45 kg transported 1000 km med lorry	450 kg km by lorry
Transport of fabric from weaving mill to pre-treater, both in Denmark	0,45 kg transported 200 km by lorry	90 kg km by lorry
Transport of fabric from pre-treater and printer, both in Denmark	0,45 kg transported 200 km by lastbil	90 kg km by lorry
Transport of printed fabric from printer in Denmark to making-up enterprise in Poland	0,384 kg transported 1000 km by lorry	384 kg km by lorry
Transport from making-up enterprise in Poland to shop in Denmark, lorry	0,384 kg transported 1000 km by lorry	384 kg km by lorry
Consumer transport*		0,04 kg petrol
Transport of discarded tablecloth (with household refuse)	0,384 kg transported 50 km by lorry	19,2 kg km by lorry

* Consumer transport: It is assumed that the consumer drives in town by car to buy 1 tablecloth and 5.616 kg other goods. It is assumed the consumer drives 10 km and the car goes 12 km per litre. This means 0.83 l petrol is used (= 0.61 kg petrol, as petrol weighs 0.73 kg per litre). Of this, $0.61 * 0.384/6$ is allocated to the tablecloth, i.e. 0.04 kg petrol.

Lorry, total: 1417.2 kg km (assumed 33 per cent urban, 33 per cent out-of-town, 33 per cent motorway).

I.e. total transport:

Process no. in ediptex-database	Name of process	Transport need
O32715T98	Container ship, 2-t 28000 DWT, TERMINATED	12880 kg km by ship
O32695T98	Lorry > 16 t, diesel urban traffic, TERMINATED	470 kg km by lorry
O32694T98	Lorry > 16 t diesel out-of-town, TERMINATED	470 kg km by lorry
O32693T98	Lorry > 16 t diesel motorway, TERMINATED	470 kg km by lorry
E32751	Petrol consumed in petrol engine	0,04 kg petrol

Annex 6: Floor covering of nylon and polypropylene

The floor covering – summary and conclusions

Firstly, it is important to stress the following conditions with regard to lack of data for the model used as the basis for the environmental assessment of the floor covering.

It has not been possible to procure enough data for:

- Production of face material of polypropylene fibres.
- Emissions of chemicals into air during production of the floor covering at the producer.
- Discharges of chemicals into water from dyeing the surface of the floor covering (face material).

However, it has been possible to collect energy data for all significant processes.

For general, and not product-specific conditions regarding quality of EDIPTEX data, see chapter 4.

It can be concluded that the energy profile for a floor covering is very different from that of garments. The use phase does not have the same importance at all. The consumer would have to vacuum the floor covering about 20 times per month for the use phase to outweigh the materials phase (fibre production).

The energy profile of the floor covering clearly shows that the floor covering producer holds the best possibilities for influencing the product's overall environmental profile. The producer should primarily focus on reuse of fibre material, as fibre materials represent a very large part of the total energy consumption during the lifetime of the floor covering.

Introduction

Lifecycle assessment is a method for identification and evaluation of environmental impact potentials of a product or a service from cradle to grave. This method enables the user to make an environmental assessment and focus on the most important environmental impacts.

Lifecycle assessment is an iterative process. The first definition of purpose and delimitations often need to be revised during work with lifecycle assessment. The amount of data available sets limits, and consequently the limits of the system are changed.

The method used in this case for assessment of products is "Environmental Design of Industrial Products" (EDIP) and the associated database and PC tool.

In the EDIPTEX project, sector-specific data have been prepared for the textiles sector in connection with the existing EDIP database. On the basis of the data collected, environmental assessments were prepared for the textile products.

- A T-shirt of 100 % cotton
- A jogging suit of nylon microfibres with cotton lining
- A work jacket of 65 per cent polyester and 35 per cent cotton
- A blouse of viscose, nylon and elastane
- A tablecloth of cotton
- A floor covering of nylon and polypropylene

These environmental assessments are intended to illustrate the scope for application of the EDIPTEX database by using the PC modelling tool and, at a more general level, application of the EDIP method.

Method

The six case stories vary a lot in scope. They can be divided into two main groups - with variations within these two main groups. The two main groups are:

- Group I: The T-shirt, the jogging suit and the work jacket.
- Group II: The floor covering, the tablecloth and the blouse.

The division into groups I and II relates to the scope of the collection of data as well as the quality of data.

For group I, it was possible to collect (and process) data for all significant processes. The data are of such quality that these three products have been selected to illustrate how far it is possible to take lifecycle assessment for textiles and to illustrate all relevant aspects of the EDIP method.

Each of the three group I cases contains:

- Definition of functional unit and reference product
- Modelling of main scenario
- Preparation of producer and consumer references
- Simulation of environmental impacts caused by choices made by producer and consumer respectively

Work with these cases has been divided into phases as illustrated in figure 6.1.

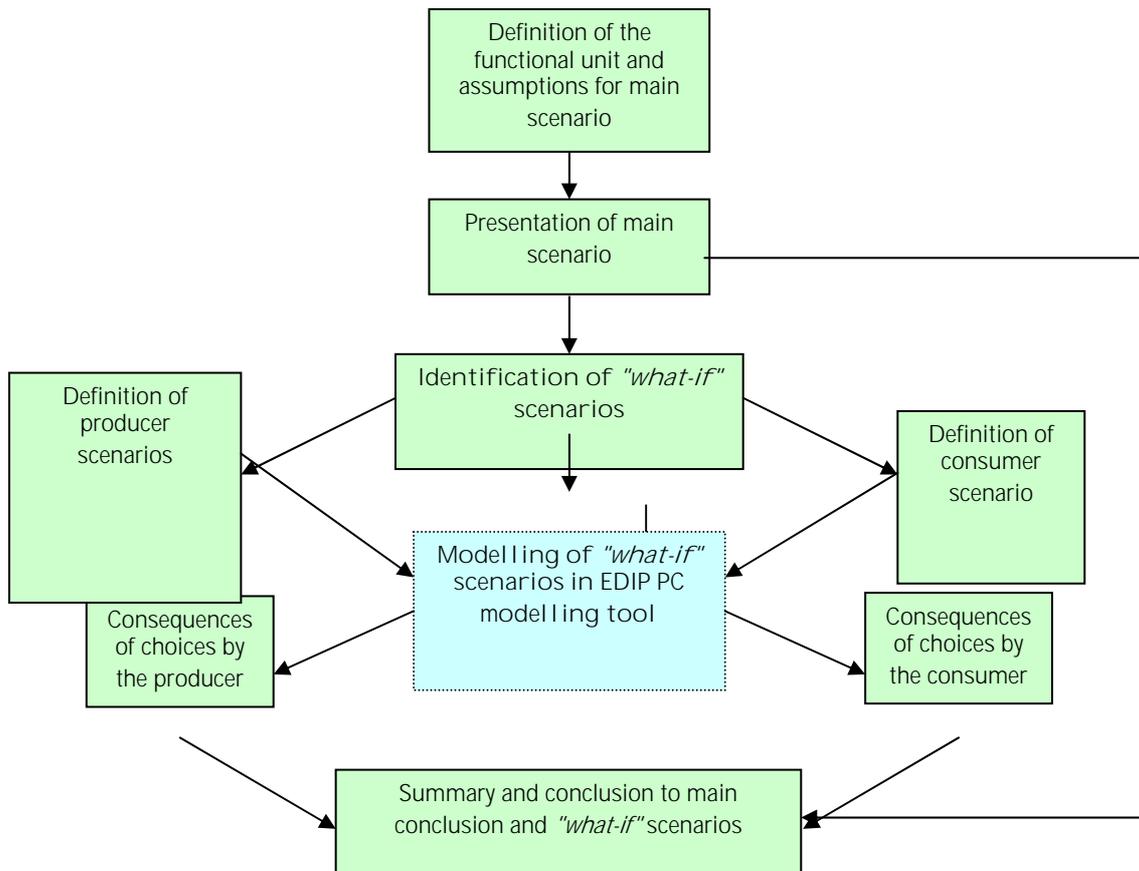


Figure 6.1 EDIPTEX case group I flow diagram

For group II, it was not possible to complete all sub-processes. Although only 1-2 sub-processes for each product have considerable lack of data, these processes are deemed potentially significant for the overall lifecycle assessment. The group II case stories are therefore of an entirely different character than those of group I. The group II cases illustrate that it is possible to tell an interesting and exciting "environment story" based on lifecycle assessment (and EDIP) even though it has not been possible to analyse all aspects of lifecycle assessment data. This situation will arise very often in lifecycle assessment work. However, there is a significant difference in this EDIPTEX connection; it is possible to draw on results from the three lifecycle assessments from case group I (and this has been done), which improves the quality of the case stories.

Comments to the method

Product references

The "what-if" simulations were carried out to elucidate the consequences of possible changes in the product's lifecycle. A special product reference has been defined for the producer scenarios in some of the case stories. The producer only has limited influence on the use phase. In order to take this into account, a product reference has been prepared for the producer scenarios where only a limited part of the impacts from the use phase has been included in relation to the product reference from the main scenario. This was done in order to give producers a clearer picture of the influence of the production

phase on the product's environmental profile in the "what-if" producer scenarios.

Data

With regard to data, it should be noted that the validity of the data in the database varies, depending on the processes considered.

Production data primarily come from Danish enterprises. The number of enterprises involved represents limitations in this connection. For example, only one acid dye has been studied thoroughly. This substance represents the entire group of acid dyes, despite the major differences that may occur.

A large proportion of the environmental impacts come from the consumption of electrical energy. The data currently used in the database originate from the EDIP database, and the reference year is 1990. This area is being studied in order to update this part of the database. It is important to note that this lifecycle assessment was carried out using the 1990 data in all processes that consume electrical energy.

Particularly for this product, it has not been possible to obtain data for production of the primary backing material of polypropylene fibres. At an overall level, this process corresponds to the process "weaving" for the tablecloth case. Therefore, the floor covering model is based of data for weaving, which seems to be a reasonable assumption.

Moreover, emissions of chemicals into the air during production of the floor covering have turned out to be difficult to ascertain, and have thus not been included in the model. However, energy consumption during the processes has been included. The same applies for discharges of chemicals into water from dyeing the surface of the floor covering. However, this is of less importance as the model assumes that a chemical precipitation system is connected (as is seen in the floor covering industry).

These aspects of data quality (particularly emissions of chemicals into air during production of the floor covering) mean that focus for this case is on primary energy and environmental impacts for the main scenario. The significance of the lack of data for the statement of results for the main scenario is discussed. Moreover relevant parallels have been drawn with the scenarios in the three group I cases.

The floor covering

Product description: The floor covering consists of pile (the surface) of 100 per cent nylon, a primary backing material of 100 per cent polypropylene (to which the pile is stitched), and the actual backing of latex foam.

Functional unit

The performance assessed can be described as a "functional unit", comprising a qualitative and a quantitative description, including the product's lifetime. The qualitative description is to define the quality level for the performance, so that products can be compared at a somewhat uniform quality level. The quantitative description is to determine the size and duration of the performance.

In this project, the functional unit is defined as:

"10 years' use of floor covering - corresponding to guaranteed lifetime"

It is assumed that the floor covering can be used for ten years before it is discarded.

It is assumed that the consumer vacuums the floor covering once per month, i.e. 120 times during the entire lifetime. No other maintenance is carried out.

Reference product and main scenario

The reference product is a product that meets the criteria of one functional unit.

Here, we have chosen a composite floor covering.

The calculations are carried out for "1 floor covering", these need to be converted in relation to lifetime, and the calculations need to be converted to "per year".

Quality floor coverings last longer than 10 years - up to 15 years is not unusual. Similarly, the lifetime of floor coverings of poorer quality can be significantly shorter.

Moreover, maintenance of floor coverings may also involve shampooing with an extraction cleaner (vacuum suction) - but this is not included in this project.

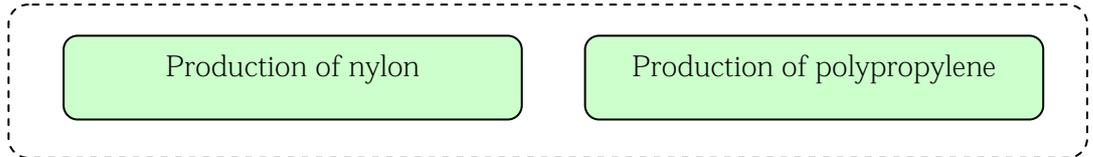
The following assumptions apply to the assessment and are thus included in the modelling of the main scenario.

- The floor covering is a composite - the pile is made of 100 per cent nylon, the primary backing material is made of 100 per cent polypropylene, and the back is made of latex foam.
- Lifetime is 10 years.
- The pile is dyed with acid dyes.
- Maintenance involves vacuuming.
- The total weight of the product is 2,633 g/m² - of which the pile weighs 1,100 g/m², the primary backing material weighs 133 g/m², the back weighs 1,400 g/m².

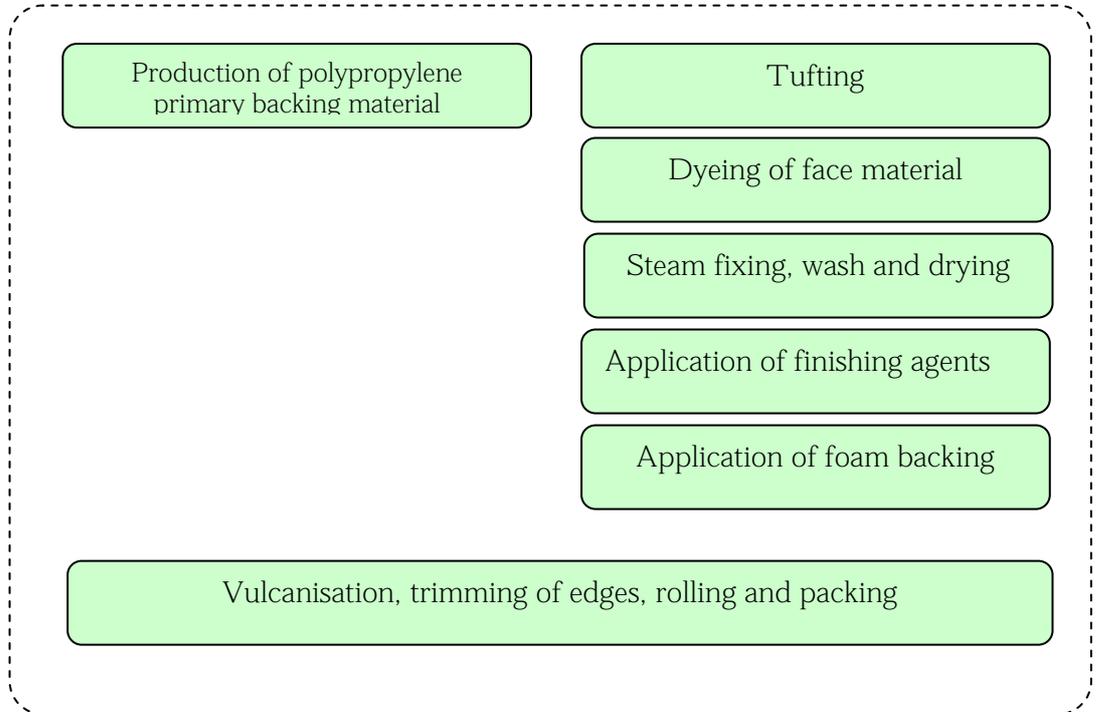
A more detailed description of the processes, calculations of volumes, waste, etc. can be found in the section "Background data".

Product system

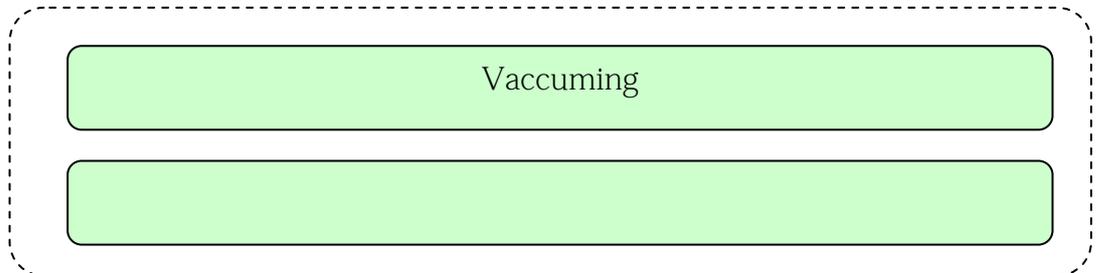
Materials phase



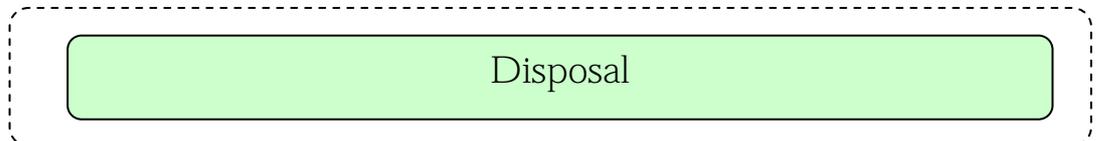
Produktionsfase



Use phase



Disposal phase



Transport phase

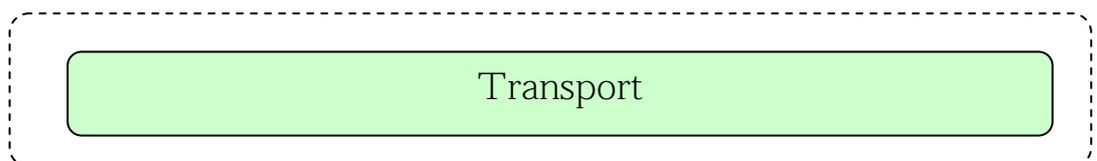


Figure 6.2 Livcycle, flow and phases

In the following, all phases of the floor covering's lifecycle will be described from extraction of raw materials through production to the cutting of the finished floor covering.

Manufacture of raw materials

Nylon and polypropylene fibres belong to the group of synthetic fibres and are produced on the basis of crude oil and natural gas that are converted to plastic through a number of chemical processes. The raw material is a limited resource, and production may lead to impacts on humans and the environment at local, regional and global levels. During processing of the materials into fibres, lubricants are usually added in the form of spindle oil and antistatic agents. Bactericides and fungicides may be added.

Production of the floor covering

Production is divided into several sub-processes:

- production of polypropylene backing (the primary backing material)
- tufting (nylon fibres that constitute the actual surface of the floor covering are stitched to the primary backing material)
- dyeing of face material (the nylon surface)
- steam fixing, wash and drying
- application of finishing agents
- application of foam backing (latex foam)
- vulcanisation (heat treatment)
- edge trimming, rolling and packing.

In principle, vulcanisation is treatment of crude rubber (caoutchouc) with sulphur which gives the rubber better elastic properties and improves its resistance to many chemicals, temperature fluctuations and influence by the air, makes it impenetrable by water, air (partly), and gives it good insulating properties.

It has not been possible to collect data for the production of the primary backing material of polypropylene fibres. At an overall level, this process corresponds to the process "weaving" for the tablecloth case. Therefore, the floor covering model is based of data for weaving, which seems to be a reasonable assumption.

Moreover, emissions of chemicals into the air during production of the floor covering have turned out to be difficult to ascertain, and have thus not been included in the model. However, energy consumption during the processes has been included.

The same applies for discharges of chemicals into water from dyeing the surface of the floor covering. However, this is of less importance as the model assumes that a chemical precipitation system is connected (as is seen in the floor covering industry).

Distribution

The floor covering is packed in polyethylene plastic foil and then it is distributed to retail suppliers throughout Denmark.

Use phase

It is assumed that maintenance only involves vacuuming - other possibilities would be shampooing with an extraction cleaner (vacuum suction).

Transport

The mode of transport when the floor covering is transported from the shop to the buyer's home is also important in connection with the overall environmental profile of the product. Options like driving a car or using public transport make a significant difference in this part of the product's lifecycle.

Disposal phase

Textiles may not be landfilled. On final disposal, they must be incinerated so that the energy content is recovered and replaces non-renewable energy sources like oil and natural gas.

Main scenario - results

The results of the main scenario are presented according to processes.

The production processes are collected in two main groups: own production and other production in Denmark, although the model divides them into more processes, cf. the overview in the section "Background data". Own production includes all production processes except production of polypropylene backing, which is referred to as other production in Denmark.

The values in the three figures are not immediately comparable, as the unit is not the same for the four categories. The consumption of primary energy is calculated in mega-joules (MJ). The environmental impact potentials are presented as "milli-person equivalents" and are directly comparable. Milli-person equivalents are calculated as the direct impact for the year 2000. The weighting factors are based on global (w) or Danish (DK) discharges in the year 2000.

Consumption of primary energy

The consumption of primary energy reflects the processes that require a lot of electrical energy or heating air or water.

Figure 6.3 (consumption of primary energy per functional unit) shows that manufacture of fibre is primarily responsible for large energy consumption because energy consumption in the manufacture of fibres is so large. In the use phase, the electricity consumption for vacuuming causes the impacts. The difference means that the consumer would have to vacuum the floor covering about 20 times per month for 10 years in order for the use phase to outweigh the fibre production.

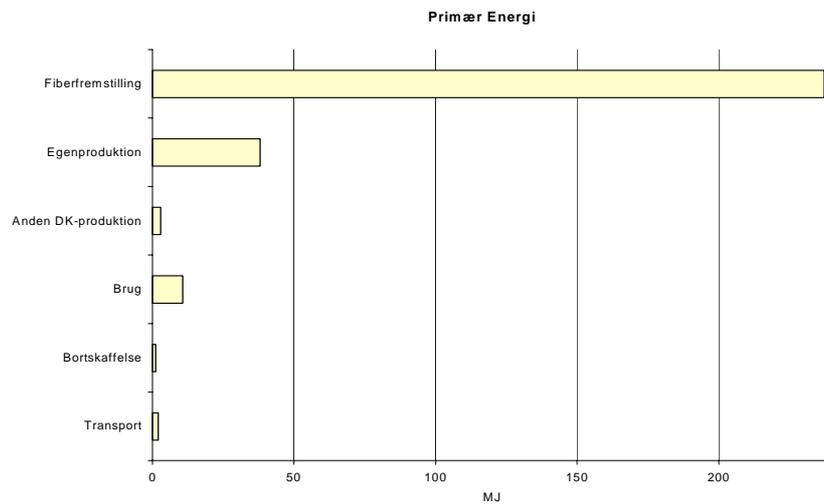


Figure 6.3 Consumption of primary energi per functional unit – for translation of Danish terms see glossary in annex 11

Environmental impact potentials

The problem with quality of data already mentioned (particularly emissions of chemicals into the air during production of the floor covering) means that there is some reservation regarding the results in the text below. The comments to the figures are neutral, i.e. the comments are on the basis of what can be read from the figures, as they appear. The subsequent section (What-if) discusses the significance of the lack of data for the statement of results.

Figure 6.4 (Toxicological environmental impact potentials per functional unit), figure 6.5 (Environmental impacts related to energy per functional unit) show that the contributions to the environmental impact potentials primarily originate from the fibre-manufacturing process

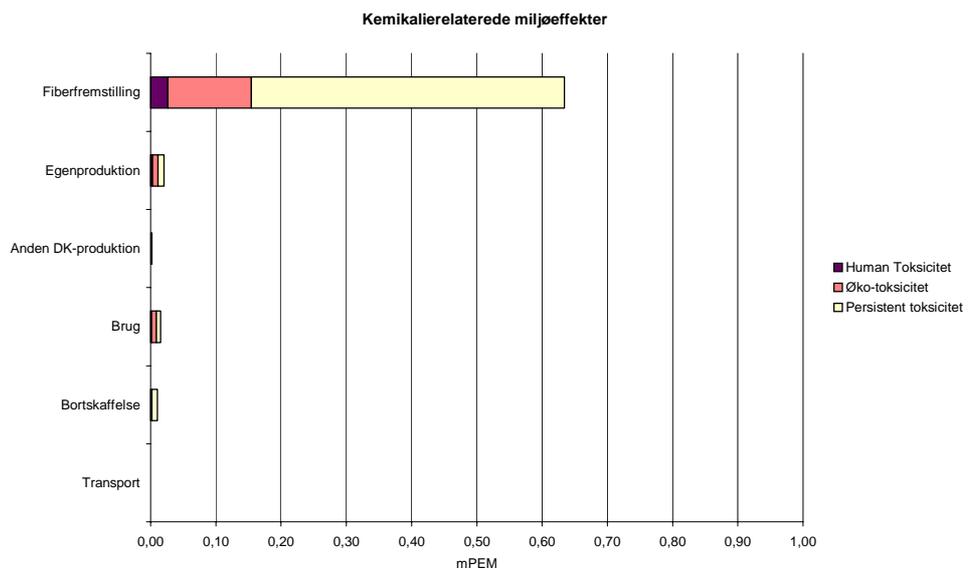


Figure 6.4 Toxicological environmental impact potentials per functional unit – for translation of Danish terms see glossary in annex 11

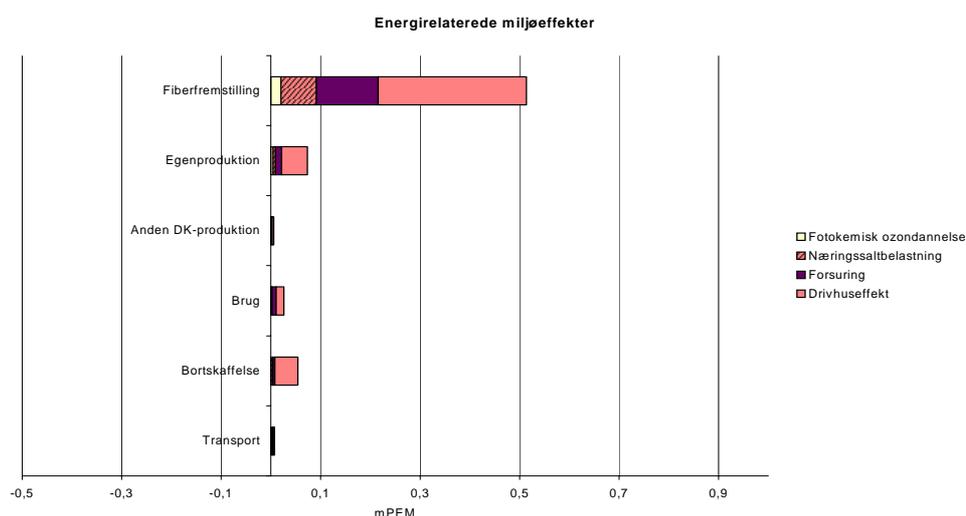


Figure 6.5 Environmental impacts related to energy per functional unit – for translation of Danish terms see glossary in annex 11

The environmental impact potentials related to energy are primarily due to burning fossil fuels.

What-if discussion

This section will discuss the significance of the lack of data for the statement of results for the main scenario. Moreover relevant parallels have been drawn with the scenarios in the three group I cases.

The significance of lack of data for the statement of results

As all relevant energy data have been included in the model, it is deemed that the lack of data has no significance for the appearance of figure 6.3 - consumption of primary energy.

The same applies for figure 6.5, which for EDIPTEX primarily relates to environmental impacts related to energy.

However, the importance for figure 6.4 of lack of data for human toxicity and ecotoxicity from emissions of chemicals from the production of the floor covering is uncertain. In this connection, it is important to note that the floor covering's lifetime is 10 years, and any impacts measured as mPEM (milli person equivalents measured) should thus be distributed over a fairly long period of time.

However, there is no doubt that a similar lack of data for discharges of chemicals into water from dyeing (and washing) the floor covering does not mean so much. Firstly, the model includes a chemical precipitation system (as is common in the floor covering industry). Secondly, the environmental assessment of the jogging suit (where acid dyes are also used) shows that the effect of dyeing nylon with acid dyes is limited.

Parallels to case group I scenarios

The lifecycle of a floor covering is very different from that of garments.

As all the products in case group I are garments, the number of parallels it is possible to draw from their environmental assessments is limited.

This can be seen in the appearance of figure 6.3 - consumption of primary energy - which is very different from the corresponding case group I products (T-shirt, jogging suit and work jacket). Energy consumption in the manufacture of fibres is by far the most significant. Compared with the corresponding figures for the main scenarios for case group I products, it is apparent that although fibre manufacture is also very important here, the use phase (washing, drying and ironing) has an even greater significance.

The message to a floor covering producer wanting to improve the environmental profile of the floor covering is therefore clear: work with reuse of the fibre material.

Background data

System structure in the EDIPTEx database for the floor covering

The figures in column on the right of the table refer to the ID numbers used in the original EDIP PC tool.

	Ref. no. : EDIPTEx databasen
1 floor covering, dyed	(TX0-06)
1 floor covering – Material s phase: 1.386 kg polyamide 6.6 fibres (nylon) 0.160 kg polypropylene fibres	(TX6-1-09) (TX1-06) (TX1-07)
1 floor covering – Production phase: 1.2 m2 polypropylene backing (floor covering) 1.2 m2 tufting face material, floor covering 1.2 m2 dyeing and drying face material, floor covering 1.2 m2 tip shearing, floor covering 1,2 m2 application of Scotchgard and backing, floor covering 1 m ² rolling, cutting and packing, floor covering	(TX6-2-22) (TX1-07-2) (TX24-2-80) (TX25-80) (TX27-2-80) (TX27-2-81) (TX28-1-08)
1 floor covering – Use phase: 120 m ² Vacuum of floor covering	(TX6-3-07) (TX34)
1 floor covering – Disposal phase: 0.133 kg waste incineration of polypropylene 1.1 kg waste incineration of polyamide (nylon) 1.4 kg waste incineration of latex foam	(TX6-4-07) (TX41-1-08) (TX41-1-05) (TX41-1-09)
1 floor covering – Transport phase: 740 kg km Lorry > 16 t diesel out-of-town, terminated 740 kg km Lorry > 16 t diesel urban traffic, terminated 740 kg km Lorry > 16 t diesel motorway, terminated	(TX6-5-07) (O32694T98) (O32695T98) (O32693T98)

Details of the floor covering model in the EDIPTEx database

Assumptions:

- The floor covering is a composite - the pile is made of 100 per cent nylon, the primary backing material is made of 100 per cent polypropylene, and the back is made of latex foam.
- Lifetime is 10 years.
- The pile is dyed with acid dyes.

- Maintenance involves vacuuming.
- The total weight of the product is 2,633 g /m² - of which the pile weighs 1,100 g/m², the primary backing material weighs 133 g/m², the back weighs 1,400 g/m².

Functional unit

For the floor covering, the functional unit is defined as:

"10 years' use of floor covering - corresponding to guaranteed lifetime"

It is assumed that the floor covering can be used for ten years before it is discarded.

It is assumed that the consumer vacuums the floor covering once per month, i.e. 120 times during the entire lifetime. No other maintenance is carried out.

The calculations are carried out for "1 floor covering", these need to be converted in relation to lifetime, and the calculations need to be converted to "per year".

Quality floor coverings last longer than 10 years - up to 15 years is not unusual. Similarly, the lifetime of floor coverings of poorer quality can be significantly shorter.

Moreover, maintenance of floor coverings may also involve shampooing with an extraction cleaner (vacuum suction) - but this is not included in this project.

Disposal:

It is assumed that the floor covering is sold in Denmark and disposed of through waste incineration. This means that 1,100 g/m² nylon, 133 g/m² polypropylene and 1,400 g/m² backing (latex foam) need to be incinerated.

Vacuuuming:

It is assumed that the floor covering is vacuumed 120 times in its lifetime. This means that 120 m² must be vacuumed in the lifetime of the floor covering.

Rolling, cutting and packing, floor covering:

1 m² is used by this process (the volume is always based on outgoing volume for the process). During cutting (trimming of edges), there is waste of approx. 0.8 m² for every approx. 4.1 m² floor covering (company data), corresponding to approx. 0.2 m² for each square metre. The waste per m² of nylon, polypropylene and latex foam is thus 220 g (0.2 * 1,100), 26.6 g (0.2 * 133) and 280 g (0.2 * 1,400). It is assumed that the waste is disposed of via incineration. There is no data for volumes and types of packaging during further transport - this is not included in the model.

Application of Scotchgard and backing, floor covering:

As mentioned above, this process requires 1.2 m². This process adds weight to the product (the latex backing), but as calculations are made in m², 1.2 m² is still needed from the preceding process. This is allowed as long as the weight increase has been taken into account in other data for the process.

Tip shearing, floor covering:

As mentioned above, this process requires 1.2 m². This process removes some weight from the product (tip shearing of nylon pile), but as calculations are made in m², 1.2 m² is still needed from the preceding process. There is no company data for the pile waste - it is assumed to be approx. 5 per cent of nylon for the finished floor covering. The estimated nylon waste is thus $(1.2 * 1.1) * 0.05 = 66$ g.

Dyeing and drying face material, floor covering:

This process requires 1.2 m². It is assumed there is no significant waste from this process.

Tufting of face material, floor covering:

This process requires 1.2 m². It is assumed there is no significant waste from this process.

Polypropylene backing, face material (floor covering):

There is no data for this process. At an overall level, this process corresponds to the process "weaving" for the tablecloth. Therefore, the floor covering model is based on data for weaving, which seems to be a reasonable assumption. It is assumed there is no significant waste from this process. This process requires 1.2 m².

Polyamide 6.6 fibres (nylon):

This process is calculated per kg. Calculation of the volume of nylon fibres for production of 1 m² finished floor covering is done by adding up the waste from the above production processes and then adding the figure to the volume of nylon in 1 m² finished floor covering:

1,100 g nylon is included in each m² finished floor covering.

For the process "Rolling, cutting and packing, floor covering", waste is 220 g.

For the process, "Tip shearing, floor covering", waste is 66 g.

Thus, this process requires 1.386 kg.

Polypropylene fibres:

As for nylon, this process is calculated per kg.

133 g polypropylene is included in each m² finished floor covering.

For the process "Rolling, cutting and packing, floor covering", waste is 26.6 g.

Thus, this process requires about 0.160 kg.

Transport:

All transport distances are estimated. Calculations are per m² floor covering. See table below.

Transport	Quantity for one floor covering	Kg km
Transport of nylon fibres from fibre producer in Germany to floor covering producer in Denmark	1,386 kg transported 1000 km by lorry	1386 kg km by lorry
Transport of polypropylene fibres from fibre producer in Germany to producer of polypropylene backing in Denmark	0,160 kg transported 1000 km by lorry	160 kg km by lorry
Transport of polypropylene backing from producer to floor covering producer, both in Denmark	0,160 kg transported 100 km by lorry	16 kg km by lorry
Transport from floor covering producer to shop in Denmark, lorry	2,633 kg transported 100 km by lorry	263,3 kg km by lorry
Consumer transport - from shop to consumer	2,633 kg transported 100 km by lorry	263,3 kg km by lorry
Transport of discarded floor covering (with household refuse)	2,633 kg transported 50 km by lorry	131,6 kg km by lorry

Lorry, total: 2220.02 kg km (assumed 33 per cent urban, 33 per cent out-of-town, 33 per cent motorway). I.e. total transport:

Proces no. in EPIPTEx database	Name of process	Transport need
O32695T98	Lorry > 16 t, diesel urban traffic, TERMINATED	740 kg km by lorry
O32694T98	Lorry > 16 t diesel out-of-town, TERMINATED	740 kg km by lorry
O32693T98	Lorry > 16 t diesel motorway, TERMINATED	740 kg km by lorry

Annex 7: Management of chemicals in UMIPTEx

When the EDIP PC tool and associated database are used for calculation of the overall statement for a product system, it is possible to calculate the overall potential impact on the different environmental impact categories at the same time. This calculation follows a common principle for all environmental impact categories. The specific contribution to the environmental impact potential is determined in the form of an equivalency factor for each substance being emitted or discharged during the course of the lifecycle and for each environmental impact category. This equivalency factor is expressed in the same unit for all substances so that it is possible to add them up. When this specific equivalency factor is multiplied by the amount of substance emitted or discharged, the substance's contribution to the environmental impact potential is obtained. When all these contributions are added up, one single impact potential for the environmental impact category is obtained.

General information on management of chemicals in lifecycle assessment

Most impact categories in lifecycle assessment are only affected by a limited number of chemicals. This applies to greenhouse effect, stratospheric ozone depletion, acidification, nutrient loading and photochemical ozone formation. The chemicals and groups of chemicals that contribute to these impact categories are listed in the EDIP method book (Wenzel et al., 1996). The calculation of the functional unit's overall impact on these impact categories is carried out automatically by the EDIP PC tool.

For several reasons, the impact categories ecotoxicity and human toxicity constitute a special challenge. In principle, all chemicals are toxic if exposure is sufficiently high. Therefore, the group of chemical substances that contributes to these impact categories is not limited. Moreover, no one single, well-defined impact mechanism forms the basis for toxic impacts. This is a large group of different basic impact mechanisms that all have the characteristic that they can lead to toxic impacts on ecosystems or humans.

Toxic impacts and assessment of them in lifecycle assessment will be in focus in the following sections. The first section describes how chemicals are handled in a more or less qualitative "matrix lifecycle assessment". The subsequent section describes how chemicals are assessed and how their impact potential is calculated in the quantitative EDIP model and in the EDIP PC tool.

Chemicals are assessed in a more or less stepwise approach, depending on the depth of the lifecycle assessment (matrix - detailed).

In the first step, where an overview of the products' environmental impacts during the lifecycle is created by means of a matrix lifecycle assessment, time does not reasonably permit in-depth chemical assessment. On the basis of the

information available, an overview is generated of whether the product's lifecycle involves chemicals that authorities already regard as hazardous.

The next step depends on the current need. Are large amounts of specific chemicals being used or discharged that ought to be studied further, or are there other parameters during the product's lifecycle that should be in focus? Then, the product's lifecycle is modelled in more detail. Equivalency factors already exist for a number of commonly occurring emissions and for emissions that were assessed in connection with previous EDIP projects. However, equivalency factors have not been calculated for a wide range of emissions. If these emissions are to contribute to the product's total contribution to the impact categories as regards toxic impacts, equivalency factors for the substances need to be calculated. These equivalency factors must be entered in the PC tool. The calculation of equivalency factors should be carried out by experts, but the principles are briefly reviewed in a subsequent section.

Assessment of chemicals in matrix lifecycle assessment

Chemicals in the lifecycle assessment matrix include chemicals used in production, as either raw materials or auxiliary materials, as well as discharges into air, water and possibly soil. The primary purpose of assessment of the chemicals in the matrix is to ensure that no significant environmental and health impacts are overlooked. Many of the chemicals are used in production and will probably primarily cause risks in relation to occupational health and safety. Occupational health and safety is currently not a routine part of the lifecycle assessment. Therefore, it is possible that the matrix will include chemicals that do not appear in the subsequent more detailed modelling of the lifecycle in a PC tool. However, the inclusion of chemicals in the matrix facilitates a qualitative assessment of the use of chemicals during the lifecycle, i.e. it makes it possible to assess whether the potential problems caused by the use of the chemicals have been addressed. If, for example, large amounts of solvents are used, have the appropriate health and safety considerations been taken, and can this be seen from the enterprise's emissions - or are there effective recovery and/or cleaning systems?

Principles of the assessment

At least 20,000 different chemical substances are being used in Denmark (Bro-Rasmussen et al., 1996), and they are all different as to their harmful properties for the environment and health. Therefore, it does not make sense to enter all chemicals that occur during the lifecycle of the studied product in the lifecycle assessment matrix. Firstly, such a list would not contribute to the assessment, as many substances are relatively harmless, and secondly, it would become difficult to assess. It is necessary to make a preliminary assessment of whether the substances have special harmful impacts on the environment or health. Two principles are applied to make such an assessment:

1. Whether the substances are included on lists of substances that are harmful to health and the environment.
2. Whether the products/auxiliary substances are danger-labelled with specific risk indications (R phrases).

Moreover, it should be considered whether large amounts of chemicals are used that do not appear on these lists, but which may constitute a problem due to the large amounts used.

Occurrence on lists

Lists of substances that are considered harmful to the environment and/or health have already been made.

The List of Undesirable Substances and the List of Effects

The Danish EPA has prepared a list of substances that are undesirable in products because of their impact on humans and/or the environment. This List of Effects forms the basis of the List of Undesirable Substances and contains approx. 1,100 substances. The List of Undesirable Substances contains approx. 100 substances, selected from the List of Effects because they are used in large volumes. This list represents substances the use of which Danish authorities wish to limit.

The List of Undesirable Substances and the Danish EPA's Advisory List for Self-classification of Dangerous Substances

The EU list of hazardous substances follows criteria laid down for classification of hazardous substances. Substances classified as hazardous to health and/or the environment should be included in the lifecycle assessment matrix. The Danish EPA has also prepared a list with guideline danger classifications for approx. 20,000 substances. This list was prepared on the basis of estimated effects, calculated on the basis of structural similarities between the substances.

Lists of substances that are regarded as harmful to health at work

The Danish Working Environment Authority and the National Institute of Occupational Health regularly assess the harmful impacts on health of various substances. There has been special focus on substances that are potentially carcinogenic, that may cause damage to the nervous system, and that may impair fertility. Substances that are assessed to be harmful to health and that should be included in the lifecycle assessment matrix are included in the following lists:

Cancer:

List of substances considered carcinogenic. WEA-GUIDE C.0.1, October 2000. [All substances on this list are included].

Damage to reproduction:

Reproduktionsskadede kemiske stoffer i arbejdsmiljøet (chemical substances at work that are harmful to reproduction). NIOH report no. 35/1991 (only available in Danish). [Substances with "extensive and limited evidence" have been included, i.e. substances from groups 1 and 2].

Damage to the nervous system:

Nervesystemskadende stoffer i arbejdsmiljøet - en kortlægning (survey of substances at work that are harmful to the nervous system). WEA report no. 13/1990 (only available in Danish). [Substances from groups 3, 4 and 5 have been included].

Occupational neurotoxicity. Evaluation of neurotoxicity data for selected chemicals. Nordic Council of Ministers. Danish Working Environment Authority. National Institute of Occupational Health, 1995. [Substances in groups 1, 2A, 2B and 3 have been included].

Lists of substances that are assessed to be harmful to the environment and health when discharged into the environment

A number of substances potentially have harmful impacts on the environment and health when discharged into the environment. Therefore, limit values have either been set for them or it has been decided that they should be given special priority when discharges are assessed. This applies to the substances on the following lists:

Air emissions

The Danish EPA's table of B values. 1997.

Wastewater

VKI - Institute for the Water Environment draft guidelines on connection of industrial wastewater to public wastewater treatment plants. Draft Danish EPA guidelines.

EU list 1 (Directive 76/464/EEC)

Bro-Rasmussen et al., 1994: EEC Water Quality Objectives for Chemicals Dangerous to Aquatic Environment (List 1). Reviews of Environmental Contamination and Toxicology, Vol 137, 1994.

Danger classification

Enterprises will often experience that they do not know the composition of the products/auxiliary substances used in production. In such situations, it is obviously not possible to assess whether there are substances that should be included in the lifecycle assessment matrix. However, products with a specified percentage content of hazardous substances must be classified and labelled with risk and safety phrases according to current regulations.

Table 7.1: Risk phrases that mean the product/chemical substance should be mentioned in the lifecycle assessment matrix

R23 Toxic by inhalation	R49 May cause cancer by inhalation
R24 Toxic in contact with skin	R50 Very toxic to aquatic organisms
R25 Toxic in contact with skin	R51 Toxic to aquatic organisms
R26 Very toxic by inhalation	R53 May cause long-term adverse effects in the aquatic environment
R27 Very toxic in contact with skin	R54 Toxic to flora
R28 Very toxic if swallowed	R55 Toxic to fauna
R33 Danger of cumulative effects	R56 Toxic to soil organisms
R34 Causes burns	R57 Toxic to bees
R35 Causes severe burns	R58 May cause long-term adverse effects in the environment
R39 Danger of very serious irreversible effects	R59 Dangerous for the ozone layer
R40 Limited evidence of a carcinogenic effect	R60 May impair fertility
R41 Risk of serious damage to eyes	R61 May cause harm to the unborn child
R42 May cause sensitization by inhalation	R62 Possible risk of impaired fertility
R43 May cause sensitization by skin contact	R63 Possible risk of harm to the unborn child
R45 May cause cancer	R64 May cause harm to breastfed babies
R46 May cause heritable genetic damage	R65 Harmful: may cause lung damage if swallowed
R48 Serious damage to health by prolonged exposure	

Several screening methods apply the classification criteria to prioritise substances, and one is EDIP (Hauschild, 1996). In this connection, we have applied the criteria of the EDIP screening method as our basis. R-phrases that result in an impact score of 4 or more in the EDIP screening method are shown in table 7.1, and a few newer R-phrases have been included. Thus, if

the product is labelled with one or more of the R-phrases mentioned in table 7.1, they should be included in the lifecycle assessment matrix.

Procedure

A list must be prepared with all chemicals used and known discharges. Volumes used should be included as far as possible, and it should be noted whether it is a discharge or a substance used in production. If products are used and their composition is unknown, the products' danger labelling should be noted. On the basis of this list, chemicals and discharges are divided into three categories:

- **Category 1** includes substances on the Danish EPA list of undesirable substances.
- **Category 2** includes all other substances on the overall list as well as products that are labelled with one or more of the R-phrases mentioned above.
- **Category 3** includes all other substances. Category 3 substances are not included in the lifecycle assessment matrix.

Thus, the lifecycle assessment matrix includes, at best, a complete list of category 1 and 2 substances. If it turns out to be impossible to obtain information about used/discharged volumes, a number of substances will be included from both category 1 and 2.

Assessment of chemical substances in the EDIP model

For environmental impact categories other than toxic impacts, it has been possible and expedient to express the potential environmental impact of each emission in relation to a reference substance, i.e. how much more, or less, the specific substance contributes compared to the reference. Thus, the impact potential for greenhouse effect is expressed as CO₂ equivalents. As regards toxic impacts where there are many different impact mechanisms, it is hard to compare all substances to one reference substance, as the impact mechanisms for the specific substance and the reference substance may differ. Put simply, we have therefore decided to express the equivalency factor of a substance for toxic impacts as the amount of soil, water or air needed if 1 g of the substance is to be diluted enough so as not to have toxic impacts.

The substances for which there are no equivalency factors in the EDIP PC tool do not contribute to the assessment of the lifecycle's overall impact on the impact categories ecotoxicity and human toxicity. Therefore, it is necessary to calculate equivalency factors for the substance's contribution to these impact categories, particularly if the substance occurs in category 1 or 2 in the matrix lifecycle assessment. The following sections describe how the equivalency factors are calculated (and how the equivalency factors that are already in the EDIP PC tool are calculated).

It is important to note that, until now, the method has only been operationalised for discharges into the environment, i.e. toxic impacts on humans during use of the product, including occupational health and safety, and indoor climate are not being assessed in this method.

The transport and transmission factor T is only applied in the equivalency factor for human toxicity. T_c is introduced to consider accumulation or dilution of the substance in the medium ingested by humans. For example, a substance that ends up in the sub-environment surface water may be accumulated in fish or shellfish, which may be eaten by humans at a later time. The bioconcentration factor BCF is used to describe how much of the chemical substance is accumulated in fish and shellfish.

The ingestion factor I_c shows values for the daily average ingestion of meat, milk, vegetable crops, fish and shellfish, water, soil and air. Average values for Denmark are used.

The biodegradability factor BIO shows how easily the substance is degraded in the environment. BIO can have the values 0.2, 0.5 or 1, corresponding to easily biodegradable, biodegradable and non-biodegradable. Substances are characterised using these designations when their biodegradability is studied according to OECD or EU guidelines.

The toxicity factor HTF shows the toxic impact of the substance on humans. The toxic impact is studied in animal test studies that attempt to determine which doses of the substance cause toxic impacts immediately (acute) or in long-term studies. Data from such studies are available in databases like RTECS (1999), HSDB (1999) and IRIS (1999). On the basis of such data and some fixed assessment factors, the daily dose (HRD or HRC) not expected to give long-term toxic impacts in humans is determined. HTF is defined as the reciprocal of this value.

The ecotoxicity factor ETF shows the substance's toxic impact on organisms in the environment. Studies of the toxic impact are normally carried out on organisms that live in water (algae, crustaceans and fish) to determine which concentrations of the substance (in the water) cause toxic impacts. Data from such studies can be found in databases like AQUIRE (1992), RTECS (1999) and HSDB (1999). On the basis of such data and some fixed assessment factors, the concentration of the substance not expected to cause toxic impacts in the environment (PNEC) by acute and chronic exposure is determined. ETF is defined as the reciprocal of PNEC.

The bioconcentration factor BCF shows the substance's ability to accumulate in living organisms. This is normally determined by checking whether fish contain a higher concentration of the substance than the water in which the fish live. In general, the substance is bioconcentrated if the concentration in the fish is 100 times higher than in water. This ability is often connected to the fat solubility of the substance and can therefore be estimated on the basis of the substance's octanol-water partition coefficient ($\log P_{ow}$). As can be seen from the expression for the equivalency factor $EF(et)_c$, the bioconcentration factor is normally not present. This is because, in long-term studies, fish are expected to accumulate the chemical substance and this means that bioconcentration has been included when the toxic impact is determined. If PNEC is determined on the basis of short-term studies, BCF should be included.

A great deal of physical and chemical data about the substance is needed, in order to determine the distribution factor, the transport and transmission factor and often also the bioconcentration factor. These data can often be

found in the databases mentioned or be estimated from the substance's structural similarities to other substances (QSAR methods).

The above is an overall description of the procedure for determination of equivalency factors. A detailed description of calculations and assessment principles is in the EDIP method (Hauschild, 1996). Determination of equivalency factors requires expertise, and it is recommended that qualified consultants be contacted if relevant. Determination of equivalency factors takes an estimated average of 6-8 hours per substance.

When equivalency factors exist for all substances being discharged during the lifecycle of the product considered, the EDIP PC tool will calculate the overall impact of the product system on the environmental impact categories human toxicity and ecotoxicity. This is done by multiplying the volumes of chemicals being discharged by the relevant equivalency factor, and the impact on the environmental impact categories is stated as a number of m³ (can be interpreted as the number of m³ of soil, water or air the product system contaminates up to a No Observed Adverse Effect Level).

Normalisation

In the normalisation process, the product's total contribution to each impact type is related to the overall impact on this impact type. The overall impact on society is calculated and divided by the relevant number of people (for global impacts, the world's total population, and for regional and local impacts, Denmark's population). The result is the overall impact per person (person equivalent). The product's contribution can thus be presented as a number of person equivalents. Normalisation has three purposes:

- Comparison of environmental impact categories using person equivalents.
- Error check. The assessment can be reviewed with a view to checking calculations and statements, if the product contributes remarkably more to an impact type than others, or in relation to what is expected.
- Pure presentation technique. When the same unit is used, the impacts can be presented together.

Normalisation of toxic impacts is carried out on the basis of an estimate of discharges of toxic chemical substances in Denmark.

Weighting

Normalisation provides a uniform basis for comparison of all the environmental impact categories, because they are all related to the extent of the product system's impact compared with the overall impact. However, it may also be necessary to assess the environmental importance of the impact (what is worst; acidification or nutrient loading). This is a very tough assessment to make, and there is no conclusive answer. The EDIP method applies the politically determined targets for reduction of environmental impacts as an indication of the importance of the environmental impact. The normalised impact potentials are thus weighted using a factor that indicates the importance of the relevant environmental impact category in Danish and international policies. For toxic impacts, the weighting factor is the ratio between the toxic impact potential of the actual discharges in 1990 and the toxic impact potential of the target discharges in 2000.

Pesticides

Calculations of equivalency factors for ecotoxicity and human toxicity have been carried out in accordance with the EDIP method as described in Hauschild et al. (1998a) and Hauschild et al. (1998b).

The principles of the TGD (EC, 1996, part II appendix II) have been applied to estimate the fate of the substances in wastewater treatment plants (estimated distribution factors for wastewater treatment plants). In situations where the use of these principles, which are based on the SimpleTreat model, would be extensively flawed (e.g. for detergents where the fate cannot be based on log Kow), measured distribution values have been applied. These values have been found in scientific articles through literature searches.

Only log Kow values have been used for estimates of equivalency factors for human toxicity (as prescribed in EDIP), as hardly any relevant measured distribution factors exist. The estimated equivalency factors for human toxicity as regards amphiphile/polar substances (e.g. detergents) are thus subject to significantly more uncertainty than the remaining equivalency factors.

When estimating the fate of pesticides when e.g. a cotton field is sprayed, the principles of Hauschild (2000) have been applied with the modification that the amount of pesticides evaporating from the field is regarded as emission into air. In this way, the pesticide's half-life in the air is considered.

The data basis for the calculated equivalency factors primarily comes from "substance databases" and reference handbooks such as the database EUCLID (1996) and the handbook "Nikunen" (Nikunen, 1990). For physical/chemical data, the SRC log P database (1999) and Howard (1989) have been used, and for ecotoxicology impact data, the database AQUIRE (1999) has been used. The sources RTECS (2000) and HSDB (2000) can be mentioned for human toxicological impacts.

The equivalency factors (in m³/g) calculated under EDIPTEX with associated relevant distribution factors for wastewater treatment plants (emission from wastewater treatment) and for spraying fields (emission from technosphere) can be found in the database.

List of references for calculation of equivalency factors

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Annex 8: Data for cotton cultivation and harvest

Several references have been reviewed to find the best and most recent figures for consumption of fertilizer, insecticides, herbicides, fungicides, growth enhancers and defoliation agents (in connection with harvest), water and energy for cultivation, harvest and ginning (mechanical separation of the fibres from the seeds). Moreover, data for crop yields, waste volumes, coproducts (cotton seeds for feed, cotton seeds for oil) are important.

Crop yield

It should be noted that crop yields and consumption of fertilizer and chemicals differ a lot from country to country and even from one region of a country to another. ICAC (1993) states that the best crop yield of 1992/93 was the one in Brazil (West Minas Gerais region) which was 2,154 kg/ha, and the poorest one was in Uganda (BPA Zone) of 133 kg/ha! Therefore, we have to apply world averages, or a country/region can be selected for which the data is applied. We have chosen the latter solution as lack of data in several areas makes it practically impossible to obtain reasonable, applicable estimated averages for all data types. The calculation principles below for the US can be applied for other countries provided basic data is available. China and the US are, by far, the two largest producers, with approx. 16 per cent each of world production in 1991/92 (TAS, 1992). In 1995/96, the distribution was 20 per cent and 23 per cent respectively (Melliand, 1996).

In 1992/93 (ICAC, 1993), the average crop yield in the US (four regions) was approx. 785 kg packed raw cotton/ha.

Consumption of fertilizer

The following amounts of fertilizer were used per hectare: approx. 106 kg nitrogen/ha ($\sigma = 25$, where σ is the standard deviation), phosphorus approx. 63 kg P₂O₅/ha ($\sigma = 12$) and potassium approx. 64 kg K₂O/ha ($\sigma = 28$). Or per kg packed raw cotton: 0.14 kg N, 0.08 kg P₂O₅ and 0.08 kg K₂O.

Consumption of other chemicals

As for other chemicals, such as insecticides, there are countless different agents against countless insect species. The same applies to herbicides against weed and agents against various types of potential damage like fungus. We have decided to include a representative chemical from each of the five main categories insecticides, herbicides, fungicides, growth enhancers and defoliation agents. Table 8.1 shows some examples, and in 1997/98, they were all very common in the US (USDA, 1999). The table also states the dose per chemical (active substance). The volume indicated takes into account that the substance may be added in several operations. The dose has been converted to "per kg packed raw cotton" (g per kg). The average crop yield in the US in 1992/93 has been used for the conversion, i.e. approx. 785 kg packed raw cotton per hectare.

Table 8.1 Consumption of chemicals - cotton cultivation

Type	Active substance	Dose per chemical (active substance) ¹	Dose per kg packed raw cotton (g/kg)
Insecticide	Methyl Paration	1,88 kg/ha	2,5
	Aldicarb	0,72 kg/ha	1
	Malathion	5,5 kg/ha	7
Herbicide	Trifluralin	0,85 kg/ha	1
	Fluometuron	0,81 kg/ha	1
	Glyphosate	1,15 kg/ha	1,5
Fungicide	Quintozene(PCNB)	0.75 kg/ha	1
	Captan	-	-
Growth enhancer	Ethephon	1,10 kg/ha	1,5
Defoliation agent	Paraquat	0,34 kg/ha	0,5
	Natrium Chlorat	2,83 kg/ha	3,5

It is difficult to assess the dosage of chemicals. If focus is on the dose of the individual chemical, the above volumes are correct. But as cotton may be attacked by many different kinds of insect and inhibited by many different types of weed, several types of chemical will typically be used. This means that the total dose of particularly insecticides and herbicides is much higher than the dose for an individual substance. According to Coupe et al. (1998), insecticides and herbicides are used up to approx. 5 kg/ha and 7 kg/ha.

For EDIPTEX, it has been decided to apply the following substances and volumes in the calculations:

- Insecticide: 6 g Esfenvalerate per kg cotton
- Herbicide: 9 g Trifluralin per kg cotton
- Fungicide: 1 g Captan per kg cotton
- Growth enhancer: 1.5 g Ethephon per kg cotton
- Defoliation agent: 0.5 g Paraquat per kg cotton.

Thus, production of 18 g "pesticides" is required per kg cotton.

According to USDA (1999), the insecticide Esfenvalerate was not among the most common ones, but it was used. This insecticide has been selected for EDIPTEX, as it was not possible to obtain enough data for calculation of equivalency factors for the most common insecticides.

Energy consumption

As for energy consumption for cultivation and harvest, it has not been possible to find good data that are newer than those calculated and stated in Van Winkle et al. (1978). In recent times, both Kallila, E. (1997) and Laursen, S.E. et al. (1997) have reviewed literature thoroughly without finding newer and better data. Data from other sources, such as Svensson (1995), are not deemed correct.

Van Winkle et al. (1978) states energy consumption of 49 MJ/kg packed raw cotton. This figure includes electricity and fuel for cultivation, harvest and ginning. Moreover, energy for production of fertilizer and pesticides is included in Van Winkle's data.

In order to estimate the energy consumption for production of organic cotton however, it was necessary to calculate the energy consumption for production of fertilizer and pesticides in separate processes.

In table 1, Van Winkle et al. (1978) state the energy consumption for cultivation and harvest of cotton. Van Winkle states the data in "kWh equivalents per lb lint cotton", and the kWh equivalents correspond to "fossil fuel equivalents", corresponding to the level called "primary energy" in the EDIP method. Van Winkle states that consumption of electricity has been multiplied by 3 to convert it to "fossil fuel equivalents".

Here, these "fossil fuel equivalents" have been converted in order for them to be applicable in accordance with the EDIP method. In order to be able to calculate the emissions, resource consumption and waste volumes resulting from generation of energy, it has been necessary to estimate how much energy cotton producers recover per kg harvested cotton - calculated as the kWh electricity and kg oil. Van Winkle's data have been converted from lb to kg, and electricity consumption was converted to the recovered amount of electricity by dividing by 3. The remaining energy consumption has been converted to the amounts of energy resources used.

The following energy content has been used for the calculation: 53.49 MJ per kg natural gas, 46.4 MJ per kg LP gas, 45.85 MJ per kg diesel oil and 46.89 MJ per kg petrol.

With these modifications, Van Winkle's data can be converted to the following: For cultivation and harvest of cotton (excluding energy consumption for production of pesticides and fertilizer) the following is used:

- Electricity: 0.91 kWh per kg harvested cotton
- Natural gas: 0.152 kg per kg harvested cotton
- LP gas: 0.027 kg per kg harvested cotton
- Diesel oil: 0.235 kg per kg harvested cotton
- Petrol: 0.108 kg per kg harvested cotton

The energy consumption for production of pesticides and fertilizer can be seen in the processes TX-K-05, TX-K-06, TX-K-07 and TX-K-08, and perhaps it should be noted that this energy consumption tallies well with the energy consumption stated by Van Winkle, although much newer references have been applied.

Water consumption

The reality of water consumption is just as complicated as that of chemicals. In some regions, it is not even necessary to irrigate artificially as the region has enough rain. The following calculation has been made:

Cotton needs approx. 50 cm water during one growth season - either in the form of rain or irrigation (Lee et al., 1984). This is approx. 5,000 m³ per hectare. In 1992/93, artificial irrigation was only carried out on approx. 43 per cent of areas in the US. The use of irrigation varied a lot in the areas where irrigation was actually used. An average weighting of more than 30 per cent of the total area with total irrigation is therefore not deemed reasonable. For the US, with an average crop of approx. 785 kg/ha in 1992/93, we get an estimate of $5,000 * 0.3/785 =$ approx. 2 m³ water per kg packed raw cotton. This is the assessed minimum required in the US. Marini (1996) states that the actual water consumption could reach as much as 29 m³ per kg packed raw cotton in some areas of the world.

Allocation

Approx 2 kg cotton seeds come from each kg cotton produced. Cotton seeds can be used for oil or feed. This means that cotton seeds do not constitute an actual waste product, but what is called a "coproduct" in lifecycle assessment terms. This represents a value for the cotton cultivator, but there is no doubt for the cotton cultivator that cotton is the main product. The financial value of cotton seeds only represents about 20 per cent of the total revenue (Van Winkle et al., 1978). We have therefore decided to allocate the entire environmental burden to the fibre production.

Waste volumes

The waste volumes from ginning - mainly plant residues - vary a lot according to harvesting methods. When the cotton is picked by hand, waste is very limited, only about 0.03-0.32 kg/kg raw cotton. There are two methods of mechanical cotton picking: "Machine-picking" and "Machine-stripping". The corresponding waste figures are 0.09-0.42 and 0.95-2.91 kg/kg raw cotton (Lee et al., 1984). In the US, all conventional cotton is picked by machines, and the distribution between the methods was 79 per cent and 21 per cent respectively in 1992/93 (ICAC, 1993). This gives an average of approx. 0.7 kg waste per kg raw cotton.

Chemical residues on cotton fibres

The last aspect that requires some consideration is the amount of cultivation chemicals that may cling to the surface of the raw cotton. In theory, these chemicals can (if they occur in sufficiently large amounts) cause problems for occupational health and safety during handling of the raw cotton and environmental problems because they will be washed out during the subsequent wet treatment in connection with textile production. There is very little literature in this area. Henry et al. (1991) studies the problematic use of the defoliation agent arsenic acid. Arsenic acid used to be the most common defoliation agent. In 14 batches of raw cotton, an average of approx. 100 ppm was found with levels ranging from approx. 1 to 325 ppm, but there was significantly more in vegetable waste. The study also showed that the arsenic acid is no longer traceable in the fibres after the cotton is washed during pre-treatment. Analogous studies of wool reach the same conclusion (pesticides are often applied to sheep, primarily to protect them against parasites). After the fibres are washed during the textile wet treatment, there are normally no residues of pesticides in the fibres.

Which pesticides are found in raw cotton, and how much? If we assume that the pesticides cling to the fibres, it is not realistic to find traceable amounts of pesticides used in early growth phases of the cotton plant when no fibres have yet been formed or when fibres are protected inside the seed pods. It should therefore be reasonable to assume that there will only be traces of defoliation agents and no other agents.

The use of arsenic acid as a defoliation agent has been more or less phased out in the US. At least, the substance does not appear on the most recent list of common agents (USDA, 1999). As there are no studies available, we assume that in the individual worst case chemicals scenarios, there is approx. 0.005 g defoliation agent per kg cotton on the cotton fibres. This volume is passed on to the textile where it is assumed that everything is washed out during pre-treatment.

List of references for data for cultivation and harvest of cotton

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Annex 9: Data for spinning

This paper covers ring spinning and OE spinning of cotton or synthetic fibres or blends thereof in the cotton system. The references in this annex's list of references form the basis of this paper.

Yarns are divided according to two functions: yarns for knitwear and woven yarns. Manufacture of spun knitwear yarns and weaving yarns from the same fibre type is very similar within the individual spinning systems. Roughly speaking, the only difference in manufacture is the number of twists (ply) applied towards the end of the manufacturing process. Knitwear yarns have the lowest number of twists. This means that a production line set up for knitwear yarns is relatively easy to convert to production of weaving yarns. This is not done in practice due to production speed considerations.

There are relatively few important environmental aspects to consider for a spinning mill in an lifecycle assessment context. These include:

- Energy consumption for the spinning line and for air conditioning (air humidity and temperature)
- Fibre waste during spinning processes
- Any use of spindle oils for the spinning processes
- Cotton dust - may cause the lung disease Byssinosis

Energy consumption

Calculations for electricity consumption have been made on the basis of Hammond et al., 1980 and are shown in table 9.1 below.

Table 9.1 Electricity consumption (all energy data for processes in kWh per kg spun yarn)

Process	Ring spinning			OE spinning		
	100 % carded cotton or 100 synthetic, Ne 16s	100 % carded cotton or 100 synthetic, Ne 24s	67 % polyester and 33 % cotton, Ne 36s (carded)	100% carded cotton or 100% synthetic, Ne 10s	100% carded cotton or 100% synthetic, Ne 16s	100% carded cotton or 100% synthetic, Ne 24s
Opening	0.20	0.20	0.25	0.20	0.20	0.20
Carding	0.18	0.18	0.27	0.16	0.17	0.17
Pre-blending	-	-	0,13	-	-	-
Stretching	0.06	0.06	0.09	0.06	0.06	0.07
Roving	0.24	0.32	0.28	-	-	-
Spinning	1.12	1.95	2.83	0.60	1.11	2.04
Air conditioning (only humidity) ¹	0.21	0.31	0.47	0.10	0.16	0.24
Light ¹	0.09	0.12	0.19	0.04	0.06	0.08
Total in kWh/kg yarn	2.10	3.14	4.51	1.16	1.76	2.80
Total MJ/kg Yarn	7.6	11.3	16.2	4.2	6.3	10.1

⁽¹⁾: The reason these figures are different is that it does not take the same amount of time to produce one kg of the different types of yarn.

Company data for spinning processes

The figures in the above table differ somewhat from the company data (De Danske Bomuldsspinderier - Danish cotton spinning mills):

Energy consumption is calculated according to the following formulas based on experience:

- Ring yarn 100 per cent synthetic (in MJ/kg): $E = 3.6 * (0.6 + 0.05 * (75 - \text{tex}))$, tex-interval 13 - 60, i.e. $E = (5 - 13 \text{ MJ/kg})$
- Combed ring yarn 65/35 Polyester/cotton: $E = 3.6 * (0.75 + 0.05 * (80 - \text{tex}))$, tex-interval 13 - 60, i.e. $E = (6 - 15 \text{ MJ/kg})$
- Combed 100 per cent cotton, ring yarn: $E = 3.6 * (0.8 + 0.05 * (80 - \text{tex}))$, tex-interval 13 - 60, i.e. $E = (6 - 15 \text{ MJ/kg})$

For all yarn types, the conditioning system uses:

- Energy: natural gas $0.017 \text{ Nm}^3/\text{kg}$ i.e. with 38.9 MJ/m^3 approx. 0.6 MJ/kg
- Water: 2.2 litres/kg

As can be seen, the company figures are very similar to those from the literature.

From manufacture of carded cotton, there is about 15 per cent waste and about 9 per cent waste from carded synthetic. For combed cotton, there is about 30 per cent waste (15 per cent from combing alone, figures from Roberts (1980)). Particularly during manufacture of combed cotton and synthetic, it is possible to use the fibre waste for lower quality yarn. However, we have decided to assume that the fibre waste is not recirculated, as not enough information is available to estimate the proportion of recyclable waste.

No spindle oils are used to spin cotton. Spindle oils may be used at the spinning mill to spin synthetic, but it is more common to apply spindle oil to the synthetic fibres during fibre production.

There is currently no data for dust at cotton spinning mills.

List of references for spinning

Hammond N., et al., 1980. Energy consumption in yarn manufacturing processes. Paper presented at the 12th Shirley International Seminar 16-18 September 1980. Shirley Institute Publication S40.

Roberts, DR. J.G., 1980. Energy audits. Paper presented at the 12th Shirley International Seminar 16-18 September 1980. Shirley Institute Publication S40.

Personal talks, 1999, with Anders Hedegaard, De Danske Bomuldsspinderier A/S.

Annex 10: Data for buttons and zippers

Buttons

Buttons can be divided into three main groups:

- Plastic
- Metal
- Natural materials

Plastic buttons are probably the most common, in the form of nylon buttons and polyester buttons.

They may be mass coloured where plastic granulates containing pigments are cast, or uncoloured/white buttons may be coloured in an aqueous dye bath.

Other types of plastic like melamine and urea, ABS (acrylonitril/butadiene/styrol) and MABS (methylmethacrylate/acrylonitril/butadiene/styrol) are not as common.

The weight will depend on size/shape/design: 0.2 - 1.2 g (a shirt button 0.2 - 0.4 g).

Metal buttons may consist of different alloys, sometimes with surface treatment (nickel plating, chromium plating, oxidised "antique" silver/brass/gold).

Some of the metals we have observed in metal buttons are:

- Zamak (zinc, approx. 93-97 per cent with a little aluminium, magnesium and possibly a little copper)
- Magnesite (magnesium carbonate)
- Brass (copper approx. 85 per cent, zinc approx. 15 per cent)
- German silver (copper approx. 64 per cent, zinc approx. 24 per cent, nickel approx. 12 per cent).

Weight will depend on size/shape/design and material: 1-5 g (one jacket button approx. 4 g).

Buttons of natural materials: wood, coconut, corozo nut (vegetable ivory), bamboo, mother of pearl, horn, leather. These materials are normally not dyed, i.e. they are used as they are, possibly with a varnish or other surface finish. However, corozo nut is sometimes also dyed (in aqueous dye baths). Mother of pearl is sometimes also dyed, and a metal eye may be glued on instead of drilled holes.

Zippers

Fabric tapes of polyester or cotton are used. Teeth, slider, pull tab, bottom stop and top stop may be made of metal or plastic.

Plastic teeth may be moulded or made of a coil (polyester and/or nylon).
Zippers with a plastic coil and polyester tape are the lightest type, approx. 1 g per 10 cm; 30 cm zipper weighs approx. 3 g.

Annex 11: Glossary

Danish

affald
akut
anden DK-produktion
aske
atmosfærisk deposition
biokoncentreringsfaktor
bionedbrydelighed
bortskaffelse
brug
brunkul
byggeklodser
drivhuseffekt
effekt
effektfaktor
effektovervejelser
efterbehandling
egenproduktion
energi
energirelaterede miljøeffekter
enhedsproces
farligt affald
farvning
fiberfremstilling
forbehandling
forbrug
forbrugerreference
fordampning
forsuring
fotokemisk ozon
fotokemisk ozondannelse
garnfremstilling
hovedscenario
human toksicitet
husholdning
iboende egenskaber
industri
ingen udvaskning
jern
jord
kemikalier
kemikalierrelaterede miljøeffekter
konfektion
kronisk
kvantificeret
materialer
mennesker

English

waste
acute
other DK production
ash
atmospheric deposition
bioconcentration factor
biodegradability
disposal
use
lignite
building blocks
greenhouse effect
impact
equivalency factor
impact considerations
finishing
own production
energy
environmental impacts related to energy
unit process
hazardous waste
dyeing
fibre production
pre-treatment
consumption
consumer reference
evaporation
acidification
photochemical ozone
photochemical ozone formation
yarn manufacturing
main scenario
human toxicity
household
inherent properties
industry
no washing out
iron
soil
chemicals
environmental impacts related to chemicals
making-up
chronic
quantified
materials
humans

mild	mild
miljø	environment
miljøeffekter	environmental impacts
mængde	volume/amount
naturgas	natural gas
næringssalt	nutrient salt
næringssaltbelastning	nutrient loading
pakning	packing
persistent toksicitet	persistent toxicity
PNEC for relevante delmiljøer	PNEC for relevant sub-environments
primær energi	primary energy
proces	process
producentreference	producer reference
produkt	product
produktion	production
produktsystem	product system
radioaktivt affald	radioactive waste
renseanlæg	treatment plant
ressourceforbrug	resource consumption
råolie	crude oil
råvarer	raw materials
skæbneovervejelser	fate considerations
slagge	slag
slutfordeling mellem delmiljøer	final distribution between sub-environments
stenkul	coal
stof	substance
strikning	knitting
strygning	ironing
toksicitetsdata for oral indtagelse og inhalation	toxicity data for oral ingestion and inhalation
toksicitetsdata for organismer i miljøet	toxicity data for organisms in the environment
toksikologiske miljøeffekter	toxicological environmental impacts
tolerabel indtagelse hos mennesker	tolerable ingestion by humans
transport	transport
transport, overførsel og indtagelse hos mennesker	transport, transfer and ingestion by humans
trykning	printing
tørring	drying
udledninger	discharges/emissions
udvaskning	washing out
vand	water
vask	wash
volumenaffald	bulky waste
vævning	weaving
økotoksicitet	ecotoxicity