The Environmental Impact Valuation as Scientific Basis for a Sustainable Apparel Strategy

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1. Background

Nowadays, the concept of the Environmental Footprint is well established, when impacts on the environment along the life cycle of a product are to be measured – from raw materials, the treatment of raw materials, production, distribution and end of life. However, Life Cycle Assessments (LCA), which serve as the basis for the measurement of an Environmental Footprint, are subject to limitations resulting from insufficient consistency and comparability.

For this reason, HUGO BOSS, the team of Rainer Zah, at that time at EMPA (Swiss Federal Laboratories for Materials Science and Technology), and Andreas Rizzoli from the University of Applied Sciences and Arts of Southern Switzerland started to develop the online database EcoLogTex for the collection of supplier-specific production data from 2009 onwards. The database was further extended in the context of the cradle-to-cradle project EcoShoe, which was also initiated by HUGO BOSS, the team of Rainer Zah, now at Quantis (Environmental Life Cycle Asssessment Consultants), and other experts, such as members of UNIC, the Italian Tanners Industry Association. In the context of the project EcoShoes, data from the life cycles of leather products have been included in the database.

Overall, EcoLogTex enabled HUGO BOSS to systematize its LCAs in a scientific way. The database serves as a tool for the harmonization of data collection not only for HUGO BOSS but also for all interested parties. Moreover, it promotes transparency and can be used as a reference when deciding on the choice of different material or transportation modes. With the help of EcoLogTex, designers and other parties involved in product development gain insights into the environmental impact e.g. of the materials and processes used that can be included in their decision-making processes.

During the development of the database, HUGO BOSS conducted various Life Cycle Assessments. One of the main challenges during research was the adequate measurement and comparison of the impacts on the environment (e.g. energy, water or land use), which occur at the different stages of a life cycle. Although Life Cycle Assessments aim at measuring the environmental impact along the life cycle of products and therefore cover various environmental issues with specific metrics (such as kg CO^2-eq for climate change and m^3 water-eq for water resource depletion) to quantify their impact, they usually suffer from a lack of comparability. Therefore, an approach was needed, which not only allows to identify hotspots within the life cycle of a product but which also measures the respective impacts in a way to make them comparable to one another.

One approach to make the different eco-system services (such as energy, water consumption or land use) measurable and comparable is to translate them in a common unit. With its Natural Capital Protocol, the Natural Capital Coaliton provides a framework to follow this approach. It makes the use of eco-system services measurable and comparable with the help of monitization. This way, various environmental indicators can be categorizised according to the quantified impacts which are caused in the respective stage of the life cycle (e.g. raw material cultivation, production, distribution).

Based on the framework of the Natural Capital Protocol and data entered in EcoLogTex, HUGO BOSS started to monetize two representative value chains - one value chain of a cotton t-shirt and a value chain of wool knitwear.

This paper presents the efforts made during seven years of research on environmental impacts along value chains including the valuation of these impacts with the help of monetization as well as the conclusions which can be drawn from the results.

2. Life Cycle Assessments at HUGO BOSS

Since 2009, HUGO BOSS and its partners (i.e. Italien Università Politecnica delle Marche, Swiss Federal Laboratories for Materials Science and Technology of the ETH Zürich, Helvetas Swiss Intercooperation, Quantis) have conducted numerous LCAs for products, which have been certified in compliance with ISO 14044.[1] In total, 96 Life Cycle Inventories (LCIs) were collected (31 in the leather sector and 65 in textiles). They provide detailed tracking of all flows in and out of the production process, including raw materials, water, energy by type, as well as emissions to air, water and land by specific substance. The first LCA of HUGO BOSS was based on a wool sweater and was calculated with data from the entire value chain in order to consider all impacts caused by manufacturing, distribution, use phase and end of life. Additional analyses were done on trimmings and specifically on the process of dyeing (Faist et al., 2012).

Since the data collection of globally stretching supply chains is a complex and time-consuming task, which involves many stakeholders, HUGO BOSS and its partners initiated the research project EcoLogTex. As already stated, EcoLogTex has developed to a comprehensive database, comprising large sets of data of value chain specific information (Rizzoli et al., 2013). Follow up projects of EcoLogTex enabled HUGO BOSS to extend the scope of its LCAs e.g. by including cotton shirts and leather products as well as the introduction of a traceability module that allows to track the information of one shoe or shoe production lots througout the supply chain.

In total, HUGO BOSS completed Life Cycle Assessments for the following product categories:
- T-shirts
- Shirts
- Wool knitwear

Additional Life Cycle Assessments were conducted for:
- Leather shoes (completed)
- Jeans
- Leisure trousers
- Jersey

[1] ISO 14044:2006 describes principles and the framework for Life Cycle Assessments (LCA) including: the definition of the goal and scope of the LCA, the Life Cycle Inventory Analysis (LCI) phase, the Life Cycle Impact Assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for the use of value choices and optional elements.

The analyzed life cycle stages were:

- Cotton cultivation or sheep farming
- Spinning
- Weaving
- Scouring and top-making
- Knitting
- Bleaching and dyeing
- Finishing
- Assembly
- Use phase
- End of life

The identified hotspots were:

- Climate change (above all in bleaching and dyeing)
- Human toxicity (above all in cotton cultivation, sheep farming and bleaching and dyeing)
- Acidification (above all in sheep farming, bleaching and dyeing)
- Freshwater eutrophication (above all in cotton cultivation, sheep farming and bleaching and dyeing)
- Marine eutrophication (above all in cotton cultivation, sheep farming)
- Freshwater ecotoxicity (above all in cotton cultivation)
- Water resource depletion (above all in cotton cultivation, sheep farming)
- Ozone depletion (above all in bleaching and dyeing)
- Particulate matter (above all in bleaching and dyeing, weaving)
- Ionizing radiation (above all in sheep farming, bleaching and dyeing, weaving)
- Photochemical ozone formation (above all in sheep farming, bleaching and dyeing, weaving)
- Terrestrial eutrophication (above all in cotton cultivation, sheep farming)
- Land use (above all in cotton cultivation)
- Minerals, fossils and renewables resource depletion (above all in bleaching and dyeing)

In 2014, as part of the initiative “Product Environmental Footprint (PEF)” launched by the European Commission, HUGO BOSS further engaged in the analyses of two different supply chains for the production of t-shirts. These analyses were cross checked with tools like “Simapro” with secondary data taken from “Ecoinvent!”.

These analyses were the first to be conducted under the framework of the Natural Capital Protocol (NCC, 2015) established by the Natural Capital Coalition. The framework defines requirements and provides principles for the monetization of eco-system services (or natural capital). The knowledge gained from the LCAs, especially regarding the impacts on the environment at the various life cycle stages served as basis for the economic evaluation of eco-system services and the identification of hotspots.

In total, HUGO BOSS monetized the impact categories with the help of the Natural Capital Protocol of the following product category:

- T-shirts and cotton shirts (very similar to the t-shirt)
- Wool knitwear

The following impacts categories were monetized:

- Climate change
- Human health
- Ecosystem quality
- Water withdrawal

The identified hotspots were:

- For the t-shirt: cotton cultivation and specific refinement process
- For the wool knitwear: sheep farming and specific refinement process

3. Methodology

Every Life Cycle Assessment has been conducted according to recognized standards (i.a. International Reference Life Cycle Data System (ILCD), 2010; International Organization for Standardization (ISO), 2006).

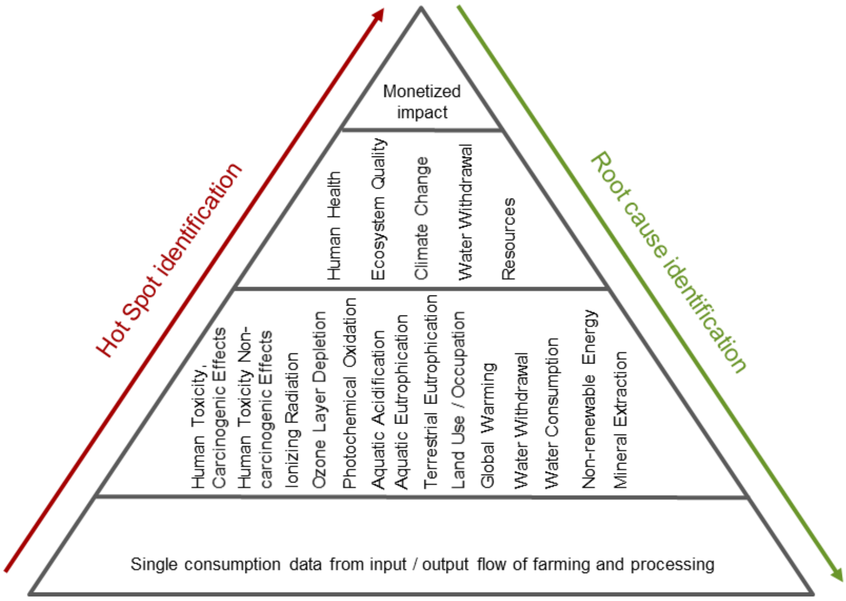
System boundaries:
The conducted analyses included all stages of a product's life cycle – from procurement (e.g. cotton cultivation) to disposal and the final utilization.

Examined systems:
In the course of this study, the value chains of a cotton t-shirt, a cotton shirt and wool knitwear have been explored.

Impact assessment methods:
The study is based on the mid-point environmental impact assessment framework proposed by the International Reference Life Cycle Data System (ILCD, 2010). The ILCD provides a common basis for consistent, robust and quality-assured life cycle data, methods and assessments. In a Life Cycle Assessment, the emissions and resources consumed by a specific product are compiled and documented in a Life Cycle Inventory (LCI). Moreover, a full aggregation of the impacts was conducted by applying a monetization method according to the rules of the Natural Capital Protocol (NCC, 2015).

Monetization framework:
The different impact assessment indicators have been aggregated using recognized methods and factors to a single monetized impact (see Graph 1: Aggregation levels of the Natural Capital Evaluation). The last step of monetization serves also as weighting of the environmental impacts acknowledging the specific value of ecosystem services (e.g. the value of water in different zones, water scarcity). Therefore, this approach allows the identification of environmental hot-spots among the various indicators. As the monetization process has been implemented in a transparent way, the framework can also be used to identify the root causes of the monetized impact.

Graph 1 Aggregation levels of the Natural Capital Evaluation



Natural Capital Evaluation
applying "monetizing factors" which take into account local characteristics.

Damage categories
according to the impact 2002+ methodology

Midpoint categories
according to the ILCD methodology

Process data
Low level process data resulting from the single input/output flows.

Statistical analysis:
For each manufacturing step, minimum, mean and maximum values from all corresponding Life Cycle Inventories (LCI) were calculated in order to get an understanding of the statistical variance. For the major hotspots, sensitivity analyses were carried out. This is conducive for trackbacking the root causes. Sensitivity analyses were elaborated by applying different energy sources (fossil based versus renewable) to a specific manufacturing process, changing the transport modes (airfreight versus sea freight) or comparing different irrigation methods.

4. Findings from Life Cycle Assessments

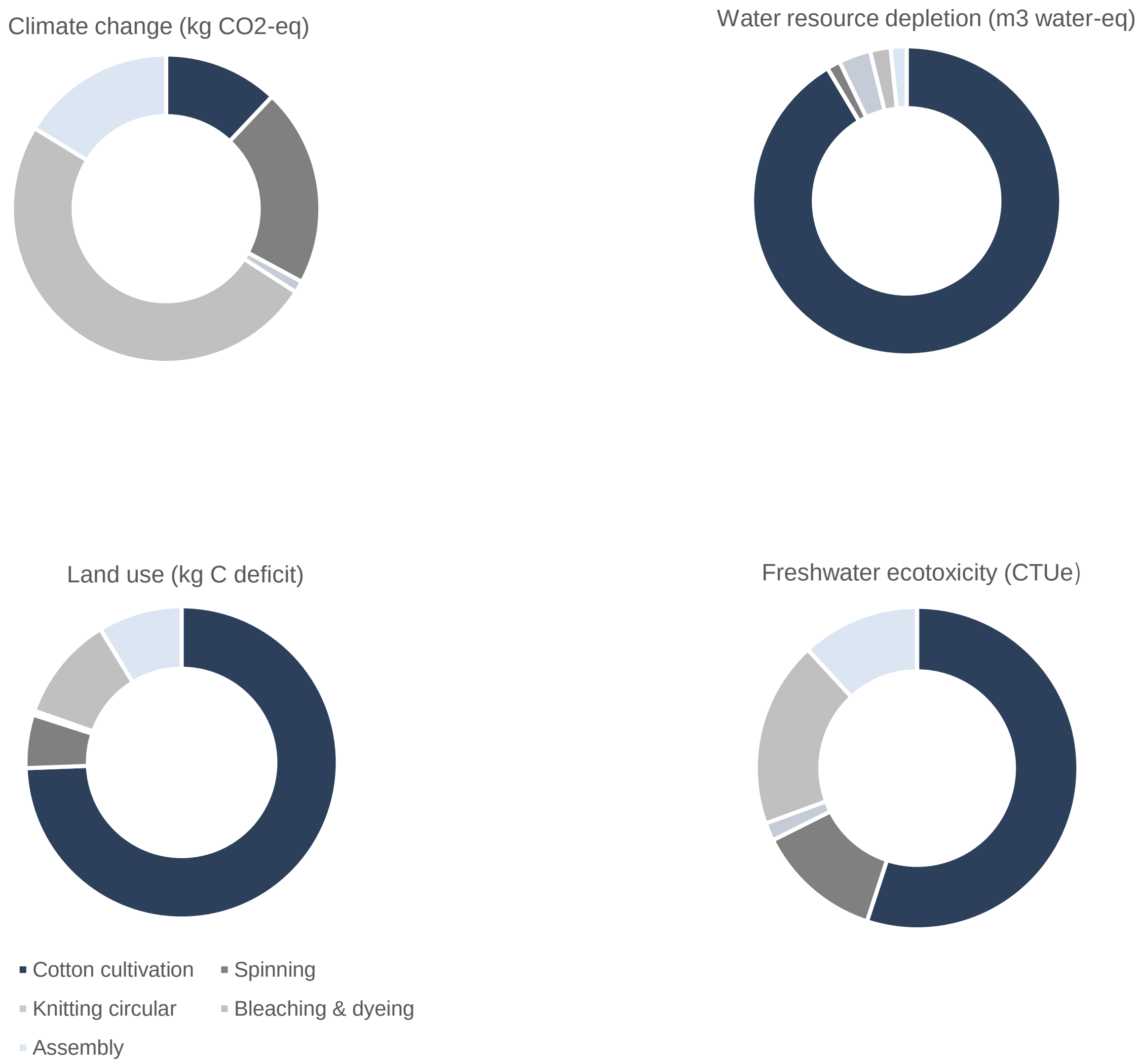
a) Cotton t-shirt and its supply chain

Annex 1.1 shows the environmental impact of an average cotton-based t-shirt at its respective manufacturing stages (cotton cultivation, spinning, knitting (circular), bleaching and dyeing and final assembly). The impacts are indicated as a percentage of the respective impact category.

This analysis allows to identify the hotspots of the examined supply chain most affecting the environment. The specific hotspots of the t-shirt supply chain are bleaching and dyeing, followed by cotton cultivation. The chemical processes of bleaching and dyeing have an impact on ten of sixteen environmental indicators (climate change human toxicity, acidification, freshwater eutrophication, ozone depletion, particulate matter, ionizing radiation (HH and E), photochemical ozone formation, resource depletion) - especially linked to contamination and energy use. The stage of cotton cultivation affects indicators linked to land use, eutrophication and water scarcity. Due to the use of pesticides, cotton cultivation ultimately affects human health (see annex 1.1)

As illustrated in figure 1.1, cotton particularly affects aspects related to water (i.e. depletion and eco toxicity) as well as land use, whereas climate change is pressured by energy intensive manufacturing processes, especially through bleaching and dyeing as well as spinning.

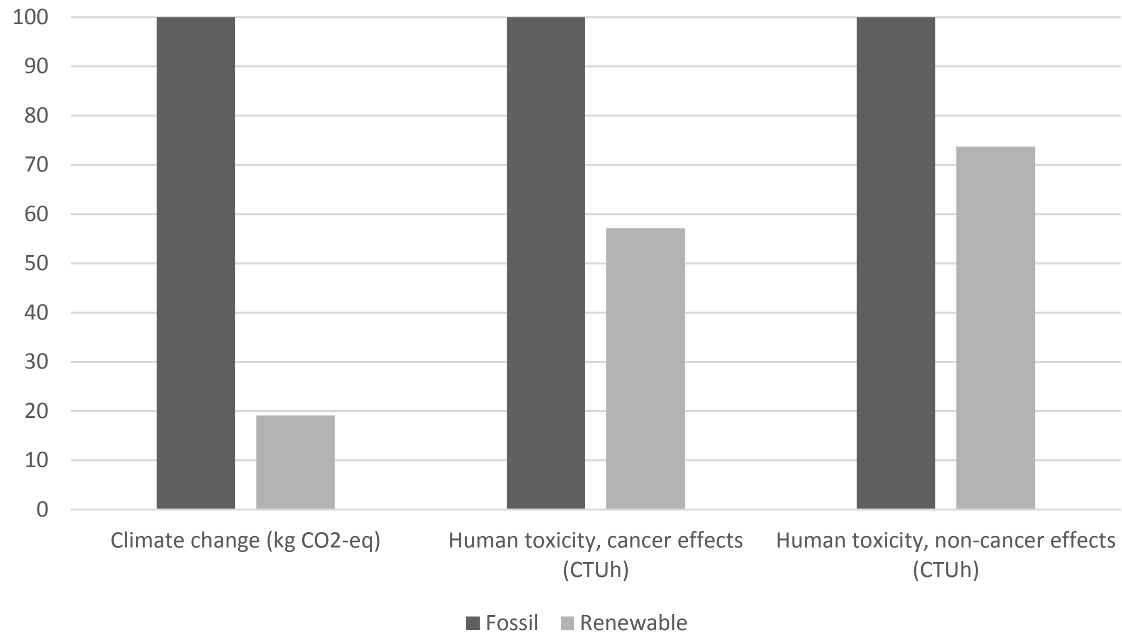
Figure 1.1 Environmental impact at the respective life cycle stages



Source: World Apparel & Footwear Life Cycle Assessment Database (WALDB)

In order to get a better idea of the implications of the findings, HUGO BOSS and its partners developed a scenario in which the original fossil-based energy source was replaced by an electricity mix typically available in Switzerland (see figure 1.2). This mix usually consists of hydropower and nuclear energy. The analysis revealed that the mix of energy used has an impact on climate change as well as human toxicity (cancer and non-cancer effects): Using renewable energy is crucial for reducing the impact on climate change (80%) as well as human health (40%).

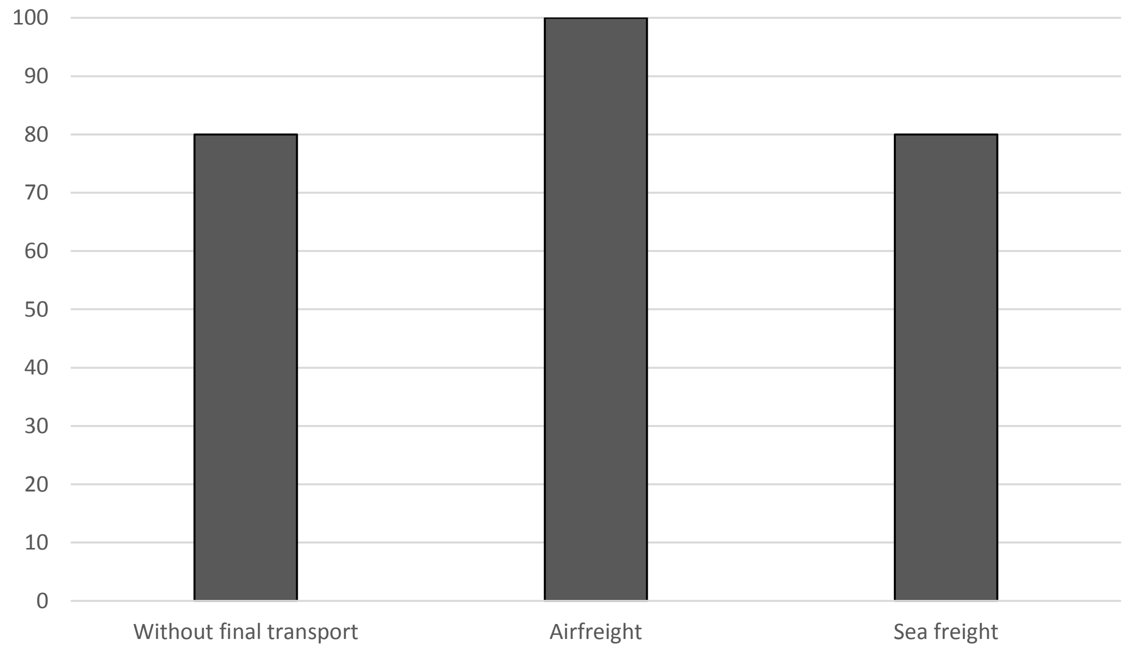
Figure 1.2 Impact of energy sources in %



Source: World Apparel & Footwear Life Cycle Assessment Database (WALDB)

Moreover, as long as using transport modes like sea freight or rail, the impact on climate change is "not significant", whereas airfreight accounts for 20% of the climate change impact of a garment.

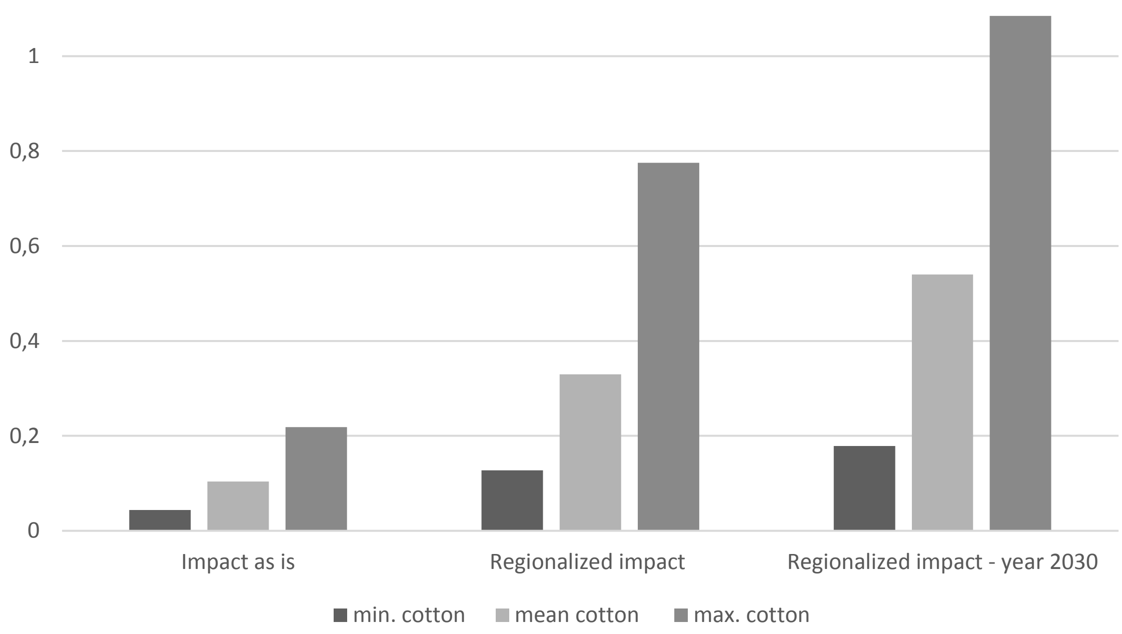
Figure 1.3 Impact of transport mode in %



Source: World Apparel & Footwear Life Cycle Assessment Database (WALDB)

As illustrated before, cotton cultivation mostly affects indicators related to water scarcity and eutrophication. There is a substantial difference between the different modes of irrigation. Replacing classical irrigation modes based on rainwater through advanced irrigation modes leads to an overall decrease in impact (see figure 1.4).

Figure 1.4 Water resource depletion (m^3)



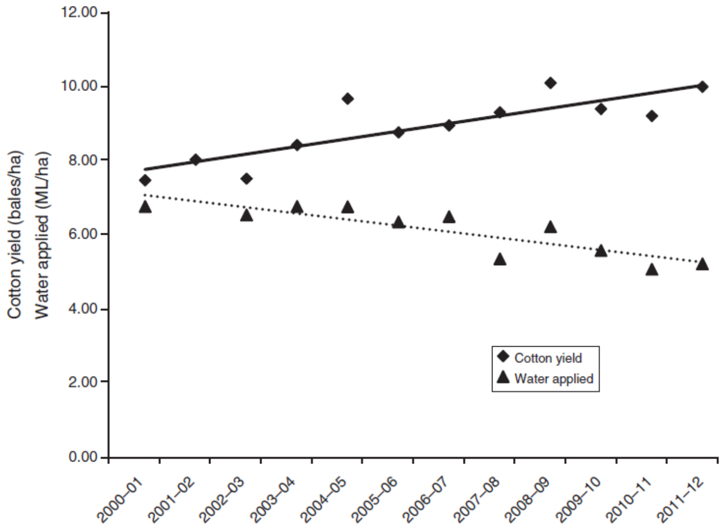
Source: World Apparel & Footwear Life Cycle Assessment Database (WALDB)

The calculation of the scenario is based on the water stress factors of the Water Risk Atlas Aqueduct from the World Resources Institute. The atlas covers physical (e.g. flood occurrence), regulatory and reputational risks (e.g. access to water; media coverage). The data are used to measure and characterize water scarcity in different world regions, since the same rate of water consumption may have different impacts depending on the climatic characteristics of a particular region. The comparison of the status by now to the forecast 2030 shows that specific regions will be facing more problems with water depletion. This is especially the case when the process of cotton farming is based on inefficient technology (see figure 1.5). The results of the scenario-building process confirm the previous made observations of the conducted Life Cycle Inventories. An ecological relief from water depletion can be reached by implementing the latest and most efficient farming technology. This approach also helps to reduce the use of agrochemicals and therefore to reduce the impacts related to toxicity.

Indeed, in the mid-1990s cotton accounted for about 24% of global pesticides sales, whereas in 2009 the sales rate stands at 6% (ICAC Expert Panel on the Social, Environmental and Economic Impacts of cotton Production (SEEP) Fact Sheet, Pesticide use in cotton production, 2012).

Hence, the usage of efficient technology can both increase the lint yield per hectare of cotton as well as reduce the total water use per hectare. This leads to significant improvements in water productivity, as indicated in figure 1.6.

Figure 1.6 Water-use efficiency



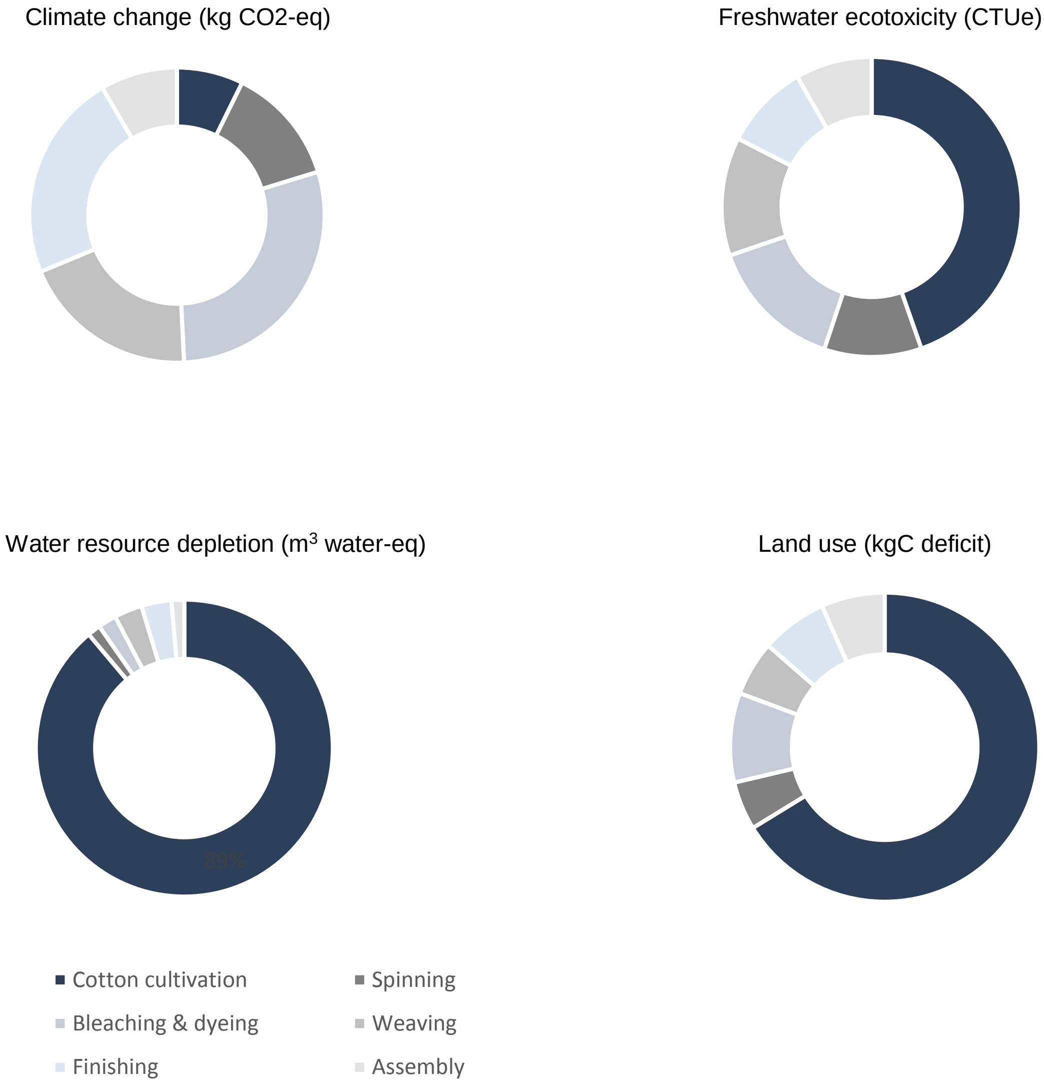
Source: Water-use efficiency and productivity trends in Australian irrigated cotton: a review by Guy Roth, Graham Harris, Malcolm Gillies, Janelle Montgomery and David Wigginton (Journal of Crop & Pasture Science Volume 64, Issue 12 (2013) at pp. 1033-1048).

b) Cotton shirt and its supply chain

Similar conclusions as for the cotton t-shirt can be drawn from the analysis of the cotton shirt's supply chain. Annex 1.2 highlights the impacts of a cotton shirt linked to its specific manufacturing stage. All impacts are indicated in percentage per impact category. As with the supply chain of a t-shirt, the stage of cotton cultivation affects environmental indicators linked to eutrophication (marine, freshwater and terrestrial), land use, water scarcity and human toxicity. Chemical and industrial processes such as spinning, bleaching and dyeing or weaving highly affect indicators related to the use of fossil energy (annex 1.2).

As illustrated in figure 2.1, the process of cotton cultivation is the main hot spot for indicators related to water and land use. The impact on climate change is nearly equally distributed between the energy-intensive manufacturing process of bleaching and dying, weaving and finishing for which the use of fossil-based energy is a major root cause.

Figure 2.1 Life cycle stages and their impacts on ecological indicators



Source: World Apparel & Footwear Life Cycle Assessment Database (WALDB)

Overall, the biggest lever for environmental optimization along the supply chain of cotton-based apparel is the reduction of water consumption and pollution during the cultivation of cotton as well as the use of renewable energy in order to avoid harmful impacts on human health resulting from the combustion of fossil fuels.

c) Wool knitwear and its supply chain

Additionally to cotton-based products, HUGO BOSS analyzed the supply chain of wool knitwear, another natural fiber.

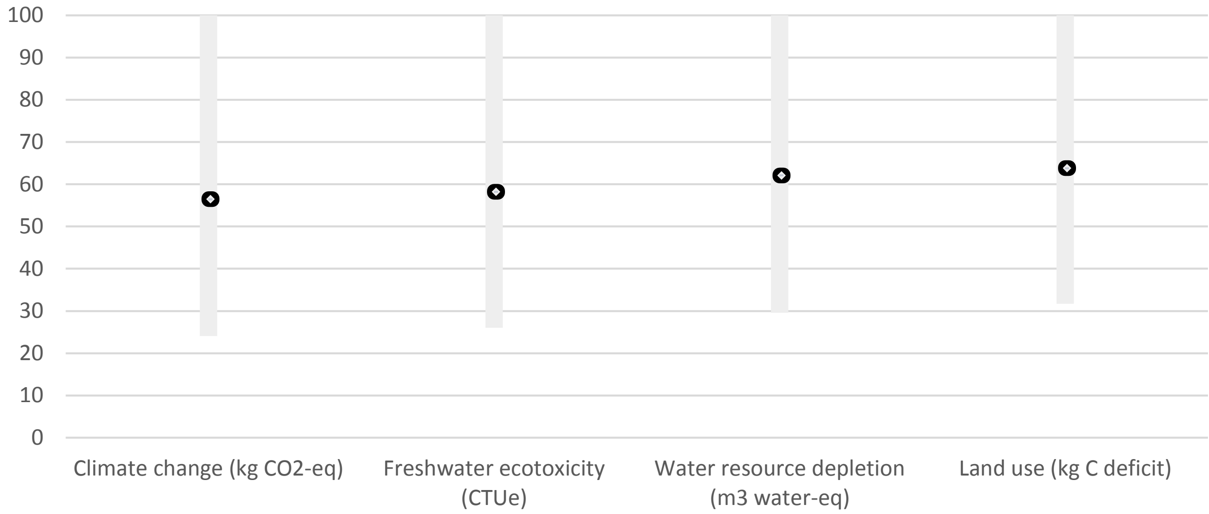
The host spots of the supply chain of wool knitwear are attributed to the farming procedure, chemical processes like bleaching and dyeing, followed by spinning (see annex 1.3). The process of sheep farming highly affects environmental indicators linked to eutrophication, land use and water scarcity, whereas dyeing and spinning procedures mainly affect indicators related to the specific form of energy supply (fossil energy). Figure 2.2 highlights four impact categories, which were identified as largest hotspots.

Figure 2.2 Life cycle stages and their impacts on ecological indicators

Source: World Apparel & Footwear Life Cycle Assessment Database (WALDB)

Similar to cotton- based products, water scarcity and land use issues are closely linked to the farming process whereas bleaching and dyeing lead to freshwater eco toxicity and further contribute to climate change due to generated CO^2 emissions.

Figure 2.3 Wool knitwear's impact variation (min, median, max)



The variation from the maximum impacts compared to the minimum impacts of a high efficient farming and manufacturing shows a difference of up to 70%. The median values show an improvement in comparison to the maximum impact values of roughly 40%.

In sum, applying efficient farming and manufacturing methods is crucial for reducing main impact on the environment. This way already a median performance reduces the impact by nearly a half.

Advanced technology combined with the use of renewable energy as well as taking into account local conditions especially regarding farming techniques are key factors for improving products towards sustainability.

5. Natural Capital Evaluation of Textile Products

Life Cycle Assessments are crucial for identifying environmental impacts. However, comparing these different impacts to each other requires a "normalization step" so that climate change impacts can be put in relation to eco toxicity impacts. In this respect, it was fundamental to redefine nature in a way that would enable companies to not only identify environmental impacts but also to measure nature's services by monetizing these.

The Natural Capital Coalition, a global multi-stakeholder forum collaboration, offers such an approach by monetizing eco-system services. The Natural Capital Protocol offers guidelines for harmonizing approaches to natural capital. HUGO BOSS and its partners started to apply the idea of natural capital's monetization to its previously conducted Life Cycle Assessments.

The first step was to assign the identified impacts of the LCIAs according to the Life Cycle Inventory methodology IMPACT 2002+ vQ2.2 (see figure 1.1). This methodology is based on a combined midpoint/damage-category oriented approach.[2]

LCA midpoint impacts comprise all harmful impacts in the various flows of Life Cycle Inventory. Examples include terrestrial ecotoxicity, acidification or eutrophication. These midpoint categories are assigned to damage categories, which reflect the damages to human health, to the environment, to the resources' stock, water withdrawal or climate change. The publicly available

[2] See for further explanation of a midpoint/damage-oriented approach

monetizing factors have been applied to these damage categories in order to transform damages to monetary expenses.[3]

HUGO BOSS has applied the monetizing factors available for the midpoint categories calculate form the LCAs studies explained in the section before. The work was done for a cotton t-shirt and a wool knitwear. With this approach, the different hot spot areas can be quantified and can be made comparable. It should be noted, that this has to be seen as first attempt – further studies are required as well as finding scientifically robust factors for sector independent application.[4]

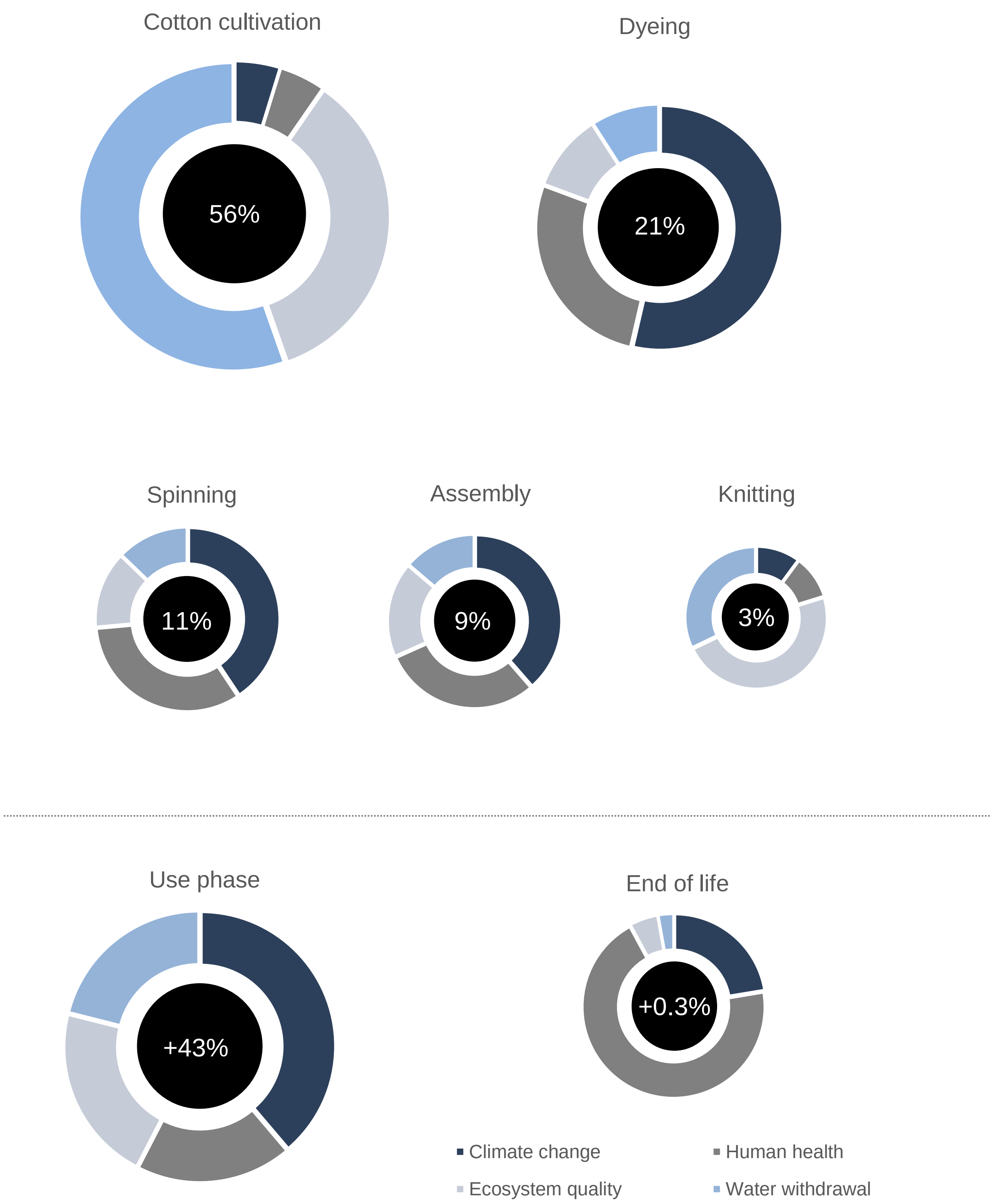
[3] To give an example: The human health impact is measured in DALY – Disability-Adjusted Life Years (see http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/) and the monetizing factor used is 90’000 chf/DALY. Hence, the damage is quantified in Swiss Francs.

[4] For the resources category, a monetizing factor is not yet available.

a) Cotton t-shirt

The monetized impacts of the cotton t-shirt value chain are shown in relative values in figure 3.1.

Figure 3.1 Monetized impacts of the cotton t-shirt's life cycle in %



The use phase is based on a theoretical assumption of 52 amount of cleaning processes, which adds 43% of impact due to water and energy use, while the end of life only accounts for an additional 0.3 % of the product‘s total impact.

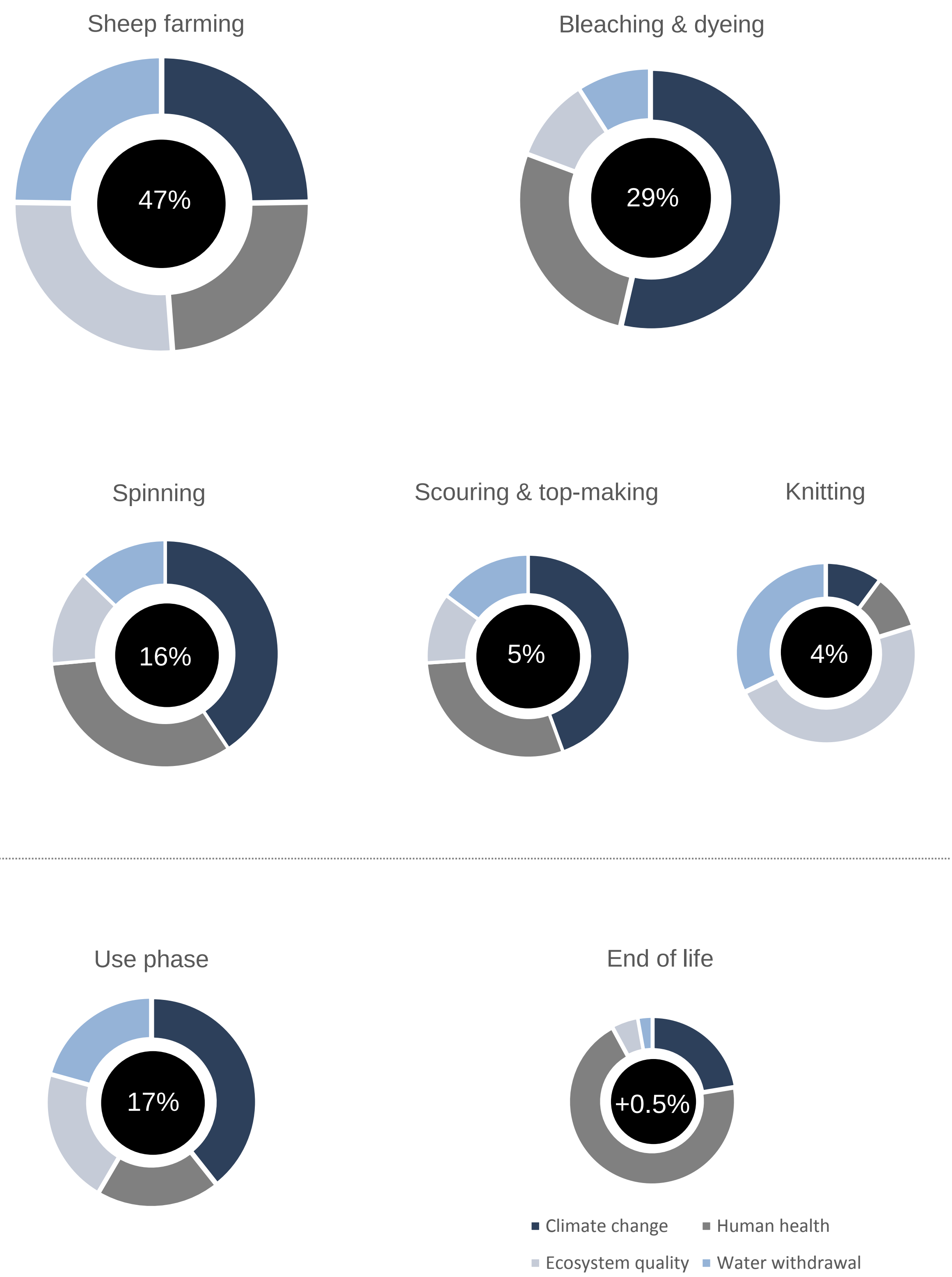
Normalizing the impacts by using monetizing factors underscores the major findings of the conducted Life Cycle Assessments: raw material and its “hot spots” like the water consumption are crucial for a sustainable production and therefore efficient cultivation methods are required.

The additional key learnings from the natural capital evaluation of a representative t-shirt are that the ecosystem quality impacts (e.g. land use, eco toxicity) are important for the cotton cultivation. Furthermore, the type of energy or specific chemicals used for the refinement processes are decisive at the stage of dyeing and spinning.

b) Wool knitwear

The impacts of the wool knitwear are illustrated in figure 3.2.

Figure 3.2 Monetized impacts of the wool knitwear's life cycle in %



The impact of the various manufacturing processes are: sheep farming 48%, scouring and top-making 5%, spinning 16%, bleaching and dyeing 28% and knitting with 4% that gives the 100% impact of the supply chain. The use phase is based on a theoretical assumption of 15 amount of cleaning processes, which adds 17% impact, while the end of life only accounts of an additional 0.4% of impacts. The lower relative impact of the use phase compared to the cotton chain is due to the lower temperature used for the washing of woolen garments and the lesser cleaning processes. For this typical wool product, the sheep farming shows a distributed impact in all four categories, whereas the hot spot bleaching and dyeing shows its fossil energy based impact areas, which are climate change but also human health.

6. Conclusions and Next Steps

This paper presents an overview of seven years of research in the area of sustainable supply chain management. Some important conclusions can be made:

Life Cycle Assessments (including Life Cycle Inventories) offer important insights into impacts on the environment caused by the specific characteristics of a life cycle stage. Cotton cultivation and chemical processes are of particularly relevance in respect to the environment. In order to reduce impacts at these stages it is necessary to make use of advanced technology and renewable energy. Moreover, local conditions are to be considered before developing new cotton farms. HUGO BOSS will use these results and the expertise of scientific partners for the development of a sustainable cotton strategy and the mitigation of impacts throughout all refinement processes with adequate technology wherever possible.

The approach of monetizing eco-system services provides a tool to compare the various impacts on the environment with each other. Hotspots become more visible. The combination of Life Cycle Assessments and monetization helps to define priorities and tangible mitigation programs based on scientific facts.

These years of research further revealed the need for a systematized and harmonized data collection process. For this reason HUGO BOSS is co-founder of the World Apparel and Footwear Life Cycle Assessment Database (WALDB). The further development of the database is one of the main goals at HUGO BOSS.

To conclude, HUGO BOSS and its partners aim to further explore the possibilities of the monetizing approach in order to establish a fact-based evaluation method. Such a method is not bound to a sector and also replicable by non-professionals. HUGO BOSS will be further promoting the approach of the Natural Capital Coalition by conducting additional in-depth analyses so as to find ways to efficiently reduce impacts on ecosystem services. This corresponds with the European Commissions' initiative "Product Environmental Footprint".

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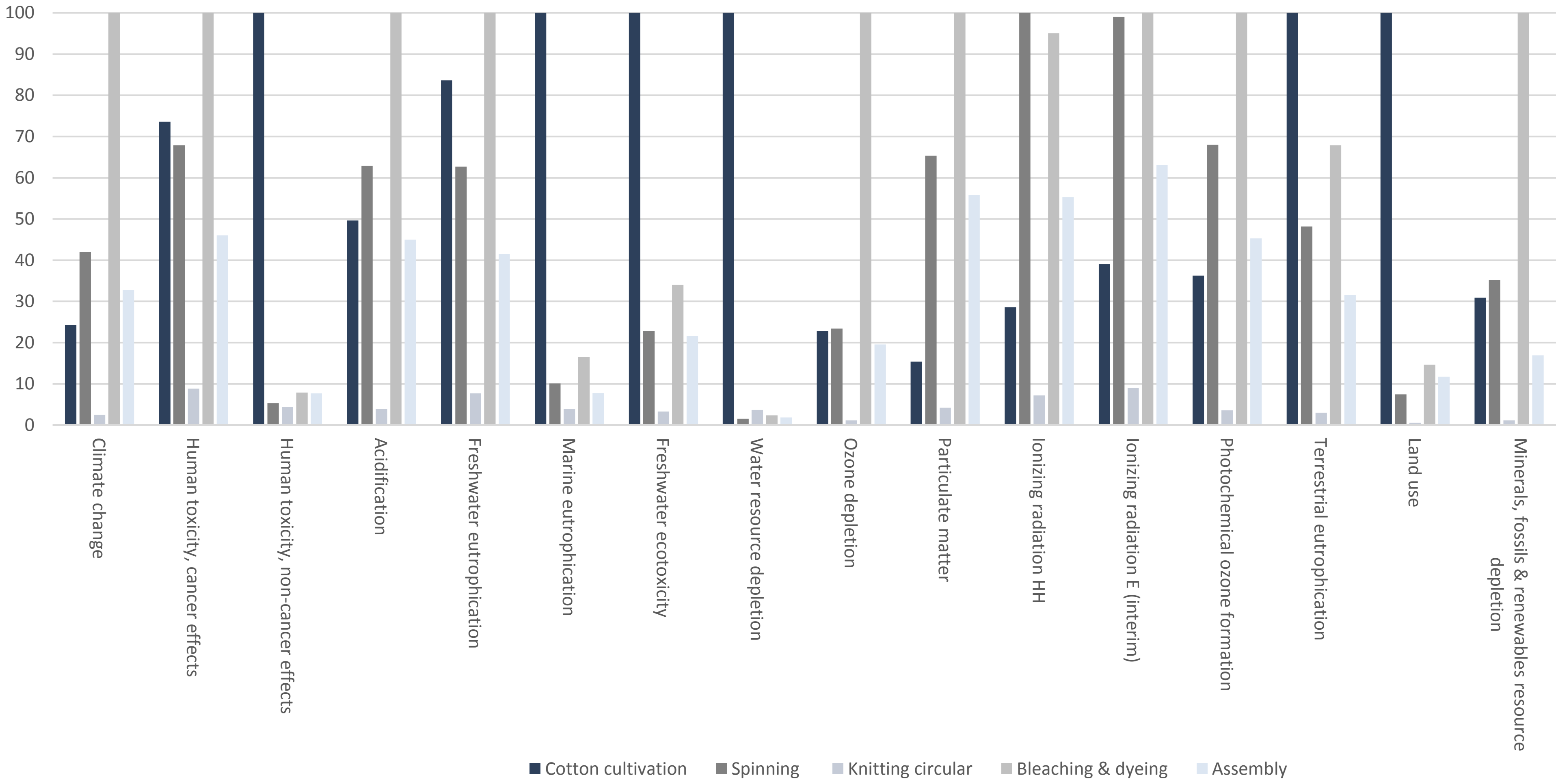
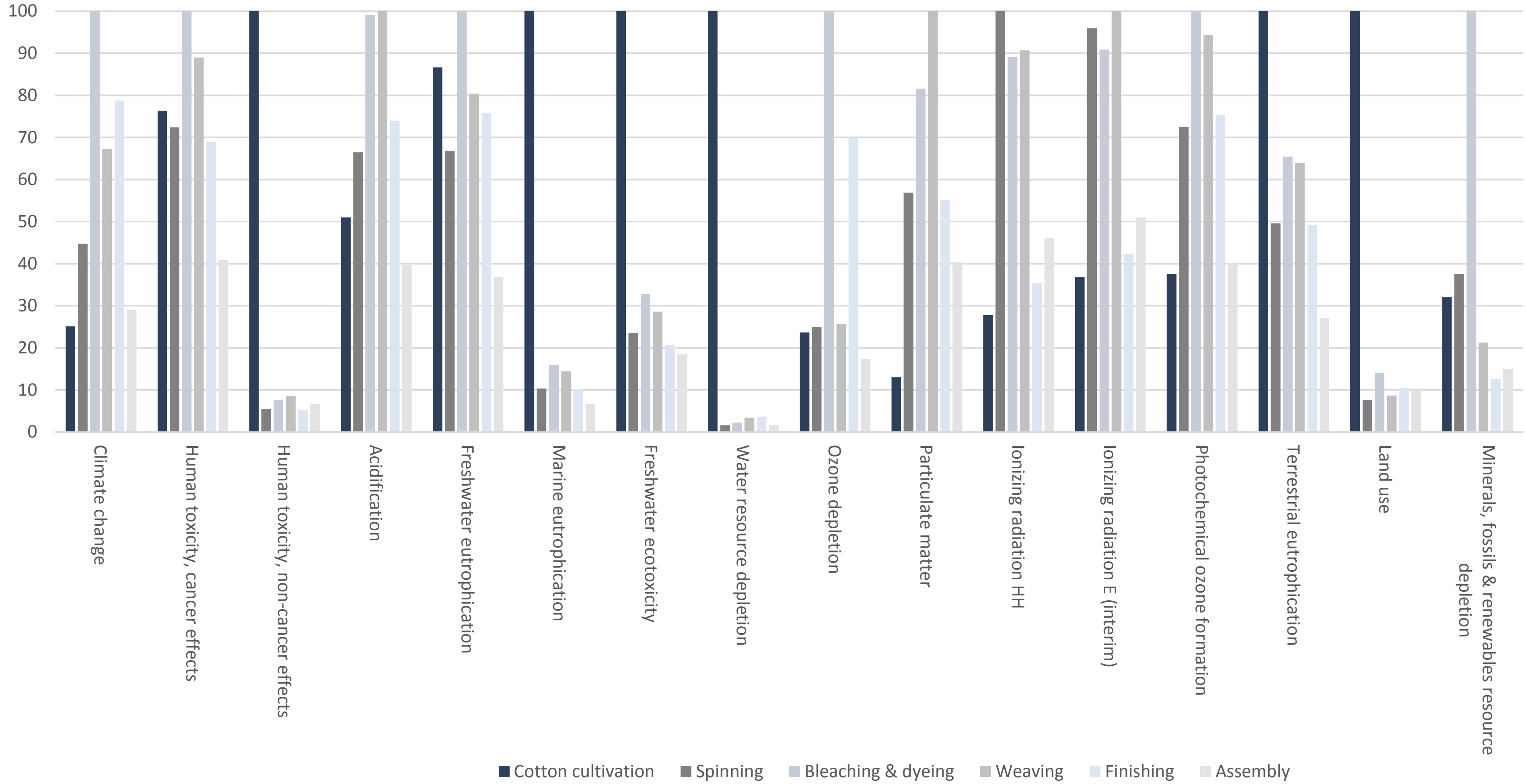
Appendix

Annex 1.1 Cotton t-shirt, median ecological impacts along the supply chain in %



Annex 1.2 Cotton shirt, median ecological impacts along the supply chain in %



Annex 1.3: Wool knitwear, median ecological impacts along the supply chain in %