Chapter 11
Social and Environmental Life Cycle Assessment (SELCA) Method for Sustainability Analysis: The Jeans Global Value Chain as a Showcase

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Abstract In this chapter the concepts of social life cycle assessment and combined social and environmental LCA were explored through the application of existing LCA methods to the global value chain of jeans. The social and environmental life cycle assessment (SELCA) method resulted from this explorative research that aims to contribute to the battery of impact assessment tools of products whose value chain scope is multinational (global). From a broader perspective, SELCA has a double-folded purpose to (i) identify opportunities for environmental and social improvement at any of the value chain phases of products, for remediation goals, and (ii) predict the environmental and social performance of different ways (scenarios) to produce the same product, using it as a product design tool. To simplify SELCA development, it was decided to use a single product (jeans) as a showcase from the global textile sector. In this showcase, four scenarios for jeans assembly were compared; three of them were defined under the circular economy principles by including recycled materials (cotton, PET and nylon 6) during the yarn production. During the application of the SELCA method, some new challenges were encountered related to inventory analysis, in particular during data acquisition for social inventories. This is later mainly due to the extensive list of key stakeholders

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for the showcase and the qualitative nature of social metrics. This list starts with cotton cultivators from different countries where regulations and codes of conduct seem to have contextualised interpretations and consequently different levels of implementation. In this regard, governmental intervention to instrument the transition towards suitable social/environmental performance along the global jeans value chain was also discussed in this chapter.

Keywords Combined social and environmental life cycle assessment · SELCA · Jeans · Global value chain · Stakeholders · Circular economy

11.1 Introduction

The attention of scholars to the field of social life cycle assessment (S-LCA) has flourished over the last years (Petti et al. 2016). The development of social impact assessment methods is considered to be challenging, especially due to the qualitative and subjective nature of the social conducts. Yet, combined life cycle assessment is considered to be in its infancy until it can be proven that 'it works' (Jørgensen et al. 2013). This interesting gap in the LCA literature inspired this research which resulted in the social and environmental life cycle assessment (SELCA) method. This method combines the goal and scope definition although the social and environmental impacts are differently assessed. Hence SELCA was initially developed to challenge Jorgensen's claim to find out if 'it works'. To do this we used the case study on the global (and partially circular) value chain of denim jeans. Due to the environmental and social controversially textile sector, a pair of jeans were used as a showcase to simplify the social LCA development and the comparison of some of the circular and non-circular jeans scenarios.

The denim jeans were used as a showcase, and four (baseline and recycling) scenarios for the yarn production were assessed: 100% virgin cotton (VC), mix of VC with recycled cotton, mix of VC with recycled PVC and mix of VC with recycled nylon. All scenarios were assessed through the SELCA method. The jeans' value chain goes beyond local conditions with suppliers and production phases outside the consumers' market. Even further, textile (jeans) value chain is the subject of a wide variety of identified actors throughout its life cycle in a global level. Literature already pointed out that in a combined LCA, alignment of the goal, scope definition and the functional unit can be seen as a challenging matter (Macombe et al. 2013). Also, the global value chain raises the issue of the identification of the most important actors and ways of their inclusion in the assessment. The recycling scenarios are evaluated by using the profiling results of the environmental and social dimensions.

The research question driving this work was formulated as the following: *How can social aspects be integrated into (traditional) environmental life cycle assessment by using denim jeans as showcase*? This research was focused to answer this question by using a showcase for the textile sector: jeans. The information gathered and analysed for such purpose is presented in this chapter which started with the literature revision. This was focused on the life cycle assessment and its challenges (Sects. 11.2 and 11.3), and some case studies were explained to illustrate LCA implementation (Sect. 11.4). Based on the state of art of literature, choices were made with regard to the development of the SELCA method and were highlighted in Sect. 11.5. The proposed methodology is explained by means of the application of the jeans case study (Sect. 11.6). Lastly, conclusions and recommendations are presented in Sect. 11.7.

In order to centre the attention on SELCA development, the nexus between LCA and circular economy (CE) does not make part of this particular chapter, but further elaboration on this nexus is referred to Chap. 13.

11.2 The Social LCA and Combined LCA (the Concepts)

In the late 1990s, S-LCA started gaining attention. In 1996 O'Brien (1996) proposed a methodology to integrate the social and environmental dimension, called the 'Social and Environmental Life Cycle Assessment'. They stated that an integrated assessment provided a more complete potential impact assessment of a life cycle. This can be referred to as life cycle thinking. UNEP states: 'Life Cycle Thinking is about going beyond the traditional focus on production sites and manufacturing processes, so that the environmental, social and economic impact of a product over its whole life cycle are also included' (UNEP 2009). This challenges the conventional resources management and pollution prevention mind-set that is present at production sites.

Over the last few years, many paradigms arose that aim to improve the sustainable performance of products and services, socially, environmentally and economically, defined as the green economy (Barbier 2012). UNEP provided a list of practical concepts and approaches of green economy that includes resource efficiency, cleaner production, the waste hierarchy, circular economy, LCA and CBA[1] (UNEP 2011). Some of these concepts are used in the front end of product development, such as circular economy. This concept focusses on improving effective resource use of products and services. For further description of circular economy, see the introduction chapter of this book. Seeing other concepts, such as LCA, are evaluative tools used at the back end, life cycle tools are most commonly used to assess the sustainability of an applied concept, like circular economy.

The first studies of environmental life cycle assessment date back from the 1970s, the period in which environmental issues started drawing public attention (Guinée 2016). Life cycle assessment is defined as a technique that is used to quantify environmental impacts of a product or service over its life cycle, including raw material extraction, manufacturing, distribution, use and disposal (ISO 2006). During the first decade of the twenty-first century, new approaches were developed,

[1] CBA stands for cost-benefit analysis.

drawn on the triple bottom-line approach, and the social LCA (SLCA) and life cycle costing (LCC) methods were proposed. The integrated approach of life cycle thinking with the triple bottom line (Elkington 1994) is referred to as Life Cycle Sustainability Assessment (LCSA) (UNEP 2011). Kloepffer (2008) defines Life Cycle Sustainability Assessment as the formula LCSA = LCA + LCC + SLCA. LCA stands for the ISO 14040 environmental assessment, LCC is a type of assessment focused on the economic dimension and SLCA represents the social dimension. Guinee builds on the definition of LCSA by adding two dimensions: firstly, broadening the level of analysis from product level to sector level and economic level and, secondly, the deepening of the LCA, from physical relations to economic and behavioural relations.

By combining the triple bottom line in an LCA, a truly holistic representation of sustainability of products can be assessed (Kloepffer 2008). The original concept of LCA only dealt with the environmental impact, as defined in ISO 14040, whereas nowadays it rather relates to the concept of LCSA. SLCA is in line with LCA but adapted for the social aspects. Therefore SLCA also consists of the four phases: (i) goal and scope definition, (ii) inventory analysis, (iii) impact assessment and (iv) evaluation (Weidema 2005). Social life cycle assessment is a methodology that aims at assessing the potential social and socio-economic impact, both positive and negative, of products and services from a life cycle perspective (UNEP 2009). The SLCA method uses information from company, plant and process levels for the whole life cycle of a product. SLCA has similar applications to traditional LCA, such as management, labelling and assessment of alternatives (Chhipi-Shrestha et al. 2015). However, in SLCA the ultimate goal is the *well-being of stakeholders* over a product's life cycle (UNEP 2009).

After increasing attention on social assessment, many approaches towards SLCA have been developed (Hunkeler 2006; Weidema 2006; Norris 2006; Dreyer et al. 2006). Jørgensen et al. (2008) and Parent et al. (2010) found that there was a large amount of diversity among existing SLCA approaches. For that reason the 'United Nations Environmental Program' identified the need for the establishment of an international aligned framework to assess social impacts across product life cycles. This resulted in the SLCA guidelines, consisting of 5 stakeholder categories (workers, local community, society, consumers and value chain actors) and 6 impact categories with 31 subcategories, which are characterised using more than 100 inventory indicators (UNEP 2009). The guidelines were followed by the methodological sheets which provide practical guidance for conducting SLCA case studies (Benoît-Norris et al. 2011).

After publication the UNEP guidelines have been widely adopted in the development of social life cycle impact assessment methods (SLCIA) up until now (Chhipi-Shrestha et al. 2015). According to Chhipi-Shrestha et al. (2015), many different impact assessment methodologies have been used due to the lack of specific SLCIA methodology. Mattioda et al. (2015) found that the lack of common approach is due to the *lack of shared ref*erences in the field of SLCA. This brings us to the statement of Jørgensen et al. (2013) saying that SLCA is still in its infancy, since a mature discipline is characterised by a large amount of shared references.

With the purpose to find the differences in approach Parent et al. (2010), compare three different SLCIA methods which all claim to use the UNEP guidelines in their method and their results. It was found that two main impact assessment method (IAM) categories can be observed. Type 1 is the *performance reference point method*, which uses additional information, like international standards. Type 2 is the *impact pathway method*, which translates the inventory indicator into a midpoint and endpoint indicator. With type 1 the outcome will be a social performance along the product life cycle. By use of type 2, one can assess social impact quantitatively related to the functional unit, however for a smaller set of social issues. Chhipi-Shrestha et al. (2015) subdivide these IAM categories. The performance reference point method is of qualitative nature and can distinguish the checklist methods, scoring methods and the social hotspot database method. The impact pathway methods are of quantitative nature, where one can distinguish the empirical method and the environmental LCI database method.

Within this study the UNEP guidelines were used, given the completeness and the wide use of these guidelines among scholars. The scoring method is applied for the assessment of social impact, because it provides the possibility of assessing social conduct without the need for statistical data, which suits the aim of applying the method for a broad, general and indicative purpose.

11.3 Challenges in SLCA and Combined LCA (Developments)

The combined social and environmental LCA has been studied by various scholars who identified multiple challenges during its conceptualisation, development and implementation phases. Those previous works have shaped, to some extent, the approach used in Sect. 11.5 to adapt the LCA method to global value industrial sectors, i.e. the textile case explained in Sect. 11.6.

The social perspective of LCA expands the traditional physical limitations of the product manufacturing to other contextual regions from which resources are extracted and regions where people play a vital role from inside and outside of the manufacturing facilities. Even further, some research has already explored (Sutherland J.W et al. 2016) the effect manufacturing has on society, as a whole. It was found that people have two roles in the value chain. People's needs generate demand that is met by products and services. On the other hand, manufacturing products and services generate employment, which ensures people to be able to sustain their lives. The social conditions behind the life cycle of a product are invisible to the consumers as well as they might be to the producer. Producers often don't even have insight in the practises of their suppliers earlier in the value chain (Dreyer et al. 2010). Though, stakeholders now demand accountability of the company for the behaviour of value chain actors, over which the company obviously has limited control. Since there is more and more pressure on brands to know the social impact of their products, they have to be able to acquire knowledge on the social conduct of the other actors in their value chain.

In addition to this trend, companies become more and more aware of the increasing attention the field of sustainability receives by consumers as well as by competitors. According to Sutherland J.W et al. (2016), there is a high value in integrating the three different dimensions of sustainability in one assessment method. The multiple dimensions provide insight in the interrelatedness of systems. Economic activities, for example, are inevitably related to social and environmental impacts (Sutherland J.W et al. 2016). On the other hand, preserving ecology might go at the expenses of communities. Hence, it can be safe to say that all activities have an economic and social side in addition to the environmental dimension.

Recognising and avoiding trade-offs between the dimensions of a product life cycle may be seen as the goal of the combined LCA. The scope of this study considers the combination of the social and environmental dimension into one LCA, which brings some implications and challenges. As priory mentioned, the level of maturity of the social LCA is very low comparable to the level of the environmental LCA. Therefore this literature review also touches upon the main immaturity issues of the SLCA.

Before the main challenges in literature are identified, it must be noted that the combination of the triple bottom line within one LCA tool is in an early stage of development. The formula for Life Cycle Sustainability Assessment, as defined by Kloepffer (2008), is kept mostly as a concept and does not receive much attention to be further developed or applied. Finkbeiner et al. (2010) do elaborate on this theoretical development by employing the Life Cycle Sustainability Triangle (LCST) and the Life Cycle Sustainability Dashboard (LCSB). However, these two methods try to address the challenge of making LCSA results understandable for its target audience of decision makers and do not focus on actual use of the method. All in all, the three main challenges presented in the following, essentially, are derived from a variety of studies.

First of all, the difference in impact allocation is an obstacle for integration of the environmental and social dimensions into one LCA. It is not yet the intention to discuss about a 'sustainability' LCA which includes also the economic dimension. Impact allocation in the environmental dimension is modelled via scientific supported indicators and pathways. In the social dimension, there is a trade-off between the use of generic data and site-specific data (Dreyer et al. 2006) of quantitative or qualitative nature. Where generic data have an advantage in relation to practicality, only site-specific data offer the proper accuracy according to practitioners (Jørgensen et al. 2008). Some people from companies consider the differences within the product chain as negligible and believe that generic data give a sufficient picture of the associated social impacts, whereas others think each individual company in the product chain has to be assessed, because they all have a different conduct to which the social impact is connected. To add on this, Macombe et al. (2013) find that data and allocation methods are very entity level specific. A company, region and country, all, are interested in different impacts, and therefore all demand a different assessment.

Environmental impacts arise from the nature of the processes, what determines a causal link between the two. Spillemaeckers et al. (2004) and Dreyer et al. (2006) mention that social impact must be seen as something that comes from the conduct of the company (the choices the company makes). Social impact hardly has any relation with the products and processes themselves. The share of the company in the process in the value chain should determine the weight of the conduct that has to be allocated. Often it is even the case that companies cannot control the actions of their foreign suppliers; wherefore Dreyer et al. (2010) in a later paper argued that companies' efforts towards social conduct should be taken into account instead, whereas Kloepffer (2008) and Chhipi-Shrestha et al. (2015) believe the list of social topics must include more issues that relate to products and processes. Schmidt et al. (2004) agree with this focus, because it is used in ELCA[2] as the basis for the assessment too. Most of the indicators apply to countries or regions, and some social indicators even include certain political aspects. The consequence is that indicators of another reference level have to be used and indirectly via methodological assumptions have to be related to the product or process.

Where the ELCA impacts are based on natural sciences, the impact categories of the UNEP guidelines are mainly based upon political consensus, according to Arvidsson et al. (2015). Some social topics defined by these guidelines can be interpreted differently depending on cultural background and on political, ethical and ideological views (Baumann et al. 2013). Non-SLCA social science literature shows that the relationship between social topics and entities is complex. Ambiguousness and complexity of social topics make Arvidsson et al. (2015) question their use in SLCA, what even makes them question the general use of stakeholders and indicators in SLCA. They propose the use of social science sources together with the concept of impact pathways what could lead to scientifically justified topics. In addition, Chhipi-Shrestha et al. (2015) suggest to *combine impact pathways and performance reference points* for further development of the SLCA method.

Secondly, defining the same goal and scope for the SLCA as for the LCA has the advantage of maintaining consistency. Foolmaun and Ramjeeawon (2013) did a study to compare different disposal scenarios of PET bottles using both environmental LCA and SLCA. In this study three different approaches to define the system boundary were explained: (1) narrow the system boundary down to the parts of the life cycle which are directly influenced by the company performing the assessment; (2) include the entire life cycle but exclude processes that do not significantly change the overall conclusions of the study; and (3) only include the organisations that would also be involved in an environmental LCA. When product systems become complex, system boundary inconsistencies between ELCA and SLCA will increase (Wu et al. 2014). For example, transport has to be included in ELCA but cannot be in SLCA. Therefore the challenge is to find a flexible way of defining cut-off criteria (Chhipi-Shrestha et al. 2015). In accordance to Macombe et al. (2013), the system boundary and functional unit can simply not always be the same

[2] In this paper, ELCA corresponds to the LCA focused only on the environmental impact assessment.

among the two dimensions. Also, they claim that the role of the functional unit in a combined ELCA and SLCA is the object of scrutiny.

Thus, there is not yet consensus on cut-off criteria for defining the significant processes, the system boundary and the weighing system (Dreyer et al. 2006). However, in order to make the scope of the inventory analysis workable, prioritisation or cut-off criteria are needed for identifying significant organisations for the side-specific data collection.

The third implication is that the life cycle inventory preferably is the same for the environmental and social LCA (Kloepffer 2008). Yet, what makes this challenging is the difference in nature of societal and environmental data. Data in the social field change faster and therefore require more and regular updates (Wu et al. 2014). Also phenomena like market competition might produce different social impacts from the defined impacts (Dreyer et al. 2006). Whereas environmental LCA strives to generic data which is regionally or globally applicable, the social LCA requires more detail of the contextual resolution of impacts. Additionally, a difficulty in impact assessment in SLCA is the qualitative nature of the indicators as well as the scaling of some of them (knowing what is good and what is bad). On the other hand, quantitative assessment requires generalisation, which is difficult when the impacts resulting from a change differ so much among countries (Macombe et al. 2013). Generic data can be made national, sector or company specific, for example, by the social hotspot database (Hunkeler 2006).The social hotspot database (SHDB) shows value in the case study of Benoit as an innovative tool that offers top-down visualisation of a product supply chain's potential impacts (Benoit-Norris et al. 2012).

To summarise, three main issues for combination of the environmental and social dimension in LCA have been identified. First, the difference in nature of data leads to several implications. The indicators and related impact allocation are for the environmental dimension scientifically justified, whereas for the social dimension, trade-offs have to be made between generic- and side-specific data measured qualitative or quantitatively. Even the justification of the indicators themselves is susceptible to ambiguousness, and measuring them is prone to subjective judgement. Besides, the level of detail of the data and their relation with the product system differ per dimension. Second issue regards the goal and scope definition that has to be equal to both dimensions. Especially the system boundary and the functional unit provide challenges in this. Third and lastly, the process of inventory analysis greatly differs among the two dimensions.

11.4 State of Art of Social and Combined LCA Methods Implementation (Case Studies)

In this section, first, some studies that applied the concept of combined LCA are mentioned. Thereafter the gap in the performed case studies on global value chains is highlighted, followed by the state of the art in indicating social issues in the global textile value chain.

Ciroth and Franze (2011) assessed the social impact for cut roses and compared two types of roses. The assessment was based on the UNEP guidelines via the scoring method. The study was conducted by colour coding for different social impact levels, then weighted and aggregated. These levels were defined on the basis of qualitative data, like internationally accepted minimum performance levels. A different case study on the combined social and environmental LCA was performed by Foolmaun and Ramjeeawon (2013) on the topic of PET bottle disposal alternatives. The study showed that recycling is not only beneficial from an environmental viewpoint but can also contribute to improve social impact.

The case studies above are two examples out of a small collection. For this reason, according to Ramirez P and Petti L (2011), more case studies are needed in order to find out where the SLCA methodology is still weak. Petti et al. (2016) studied the SLCA methodology through its application to case studies and found that there are an increasing number of implemented case studies in the field. It was found that the research object of study is either a product or a service, mostly being in the manufacturing sector (26%) or in the agriculture sector (26%). The study of Wang et al. (2016a) shows that most case studies use country level data, instead of regional or company-related data, to assess the general social impact of the process. According to Petti et al. (2016), the social context of the region (developed or developing country) does not influence the number of case studies. However, 40% of the studies have been conducted in Europe, while in Europe the study contributes less due to the lower level of social concerns. Reason for this could be the higher and easier availability of data. Lack of data is often due to lack of transparency in or no cooperation of companies in the supply chain (Traverso et al. 2016). What is not considered by Petti et al. (2016) is the level of globalisation of the value chain of the product under consideration in the case study. Also the review of case studies in literature of Wang et al. (2016b) does not consider 'level of globalisation of value chain' as a factor.

From this, it was concluded that the global value chain (GVC) is a topic that has received very little attention. However, the GVC is one of the main causes of social issues in product life cycles. Globalisation and liberation of trade have led to the movement of low skill, for instance, an intensive labour of textile value chains in developing countries (Los et al. 2015; OECD 2004). The lowering of prices of textile products makes European retailers put more pressure on suppliers to further reduce costs (Taplin 2006). Suppliers consequently reduce on the aspects which they still have in control such as labour conditions (Taplin 2014).

In addition to the socio-economic impact, the geographical shift in manufacturing also is likely to have an environmental impact (Mair et al. 2016). In the study of Mair et al. (2016), both, environmental and socio-economic, indicators are assessed on impacts of Western European textile and clothing consumption between 1995 and 2009. Whereas literature largely assessed these aspects separately, one of the aims was to find tensions between different sustainability goals. Interesting to note is that the analysis makes use of GVC indicators (Timmer et al. 2013) that assess impacts in the production stages of a product's life cycle.

The review of these case studies in combination with the conclusions drawn from the literature review has helped to construct and support the goals of this study. Besides, based on the challenges and arguments in earlier studies, it was possible to make the needed choices to develop the SELCA methodology.

11.5 Development of SELCA Methodology

The purpose of the suggested methodology is presented firstly here, stressing simultaneously on its relation to current literature. In the paragraphs thereafter, the reasoning behind the construction of the most important parts of the method is given. The constitution of the goal and scope within the SELCA are further discussed in Sect. 11.5.1, while the role of and inconsistencies in the inventory analysis of the SELCA are described in Sect. 11.5.2. To finally the selection of the subcategories and indicators were explained in Sect. 11.5.3, and the development of scorecards associated with social indicators and weighing factors is there given.

The SELCA social impact assessment methodology was primarily developed for initial and broad evaluation of social aspects, such as risk profiles of industries in entire countries. The method needs to allow inclusion of specific inventory when more data become available. Development of the methodology has been done under a set of limited conditions, such as the time constraint of 2 months and the participation of a handful of researchers. For these reasons the methodology was solely meant for explorative use on the GVC textile case study, which takes the attention in Sect. 11.6. The goal of the textile case study was to compile and evaluate the environmental and social consequences of different life cycle scenarios for fulfilling one function. The deployment and application of the methodology aims to add a new perspective to some of the challenges illustrated in the literature review.

11.5.1 Defining Goal and Scope

The application of a combined environmental and social LCA is to compile and evaluate the environmental and social impacts of different life cycle alternatives of a product with a well-defined functionality. For both dimensions the goal and scope definitions should be the same, in order to make impact comparable. Two different inventory analyses are carried out simultaneously followed by a separate impact assessment, typically following the approach of option 1, as stated by Kloepffer (2008).

The functional unit (FU) is the core component of traditional life cycle analysis. It is the common base of fair comparison of different life cycles. Therefore especially in a combined LCA, the FU has a major role, because it has to suit both dimensions. In a traditional LCA by means of the FU, the amount of functionality provided in the life cycle can be scaled on a linear basis. For example, double emissions of

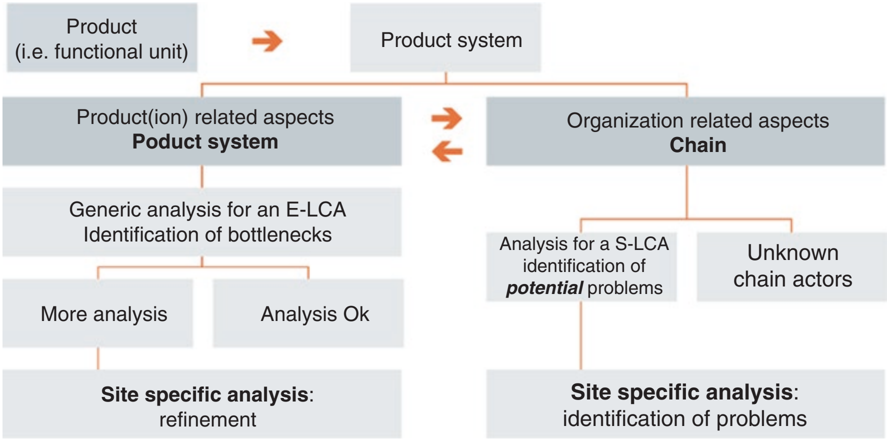

Fig. 11.1 Combined analysis of the product system. (UNEP 2009, p. 38)

CO_2 are likely to result in a doubled impact on the effect of climate change. For social inventory this relation is not always present. For example, 'the grades of customer satisfaction on a scale of 1-10' is not likely to be linearly affected by a change in amount of function required to fulfil the FU. In order to avoid this problem, there are different ways of inventorying social data. One of them is the use of numerical data on social mechanisms such as social metrics as Hunkeler (2006) did. Another is the use of data which is semi-qualitative in nature. The use of numerical data is compatible with the aggregative nature of traditional LCA. However many of the subcategories, as defined in the UNEP guidelines, cannot properly be measured on a quantitative scale. Therefore it is determined to base the SELCA method on the latter method of qualitatively assessing social conduct and by converting this assessment into a quantitative impact profile. The approach for performing this assessment is illustrated in Sect. 11.6.2.

Besides the functional unit, the type of data also influences the level of detail of the LCA. With broad and general data, one can perform an LCA on a broad and indicative level. For environmental LCA, this indicative level means hotspots can already be defined. The level of product detail and the level of inventory together determine the depth of study of an environmental LCA. A broad and indicative level for the social dimension means one can only identify potential problems. In order to specifically identify the problems in the social dimension, one needs detailed site-specific data (see Fig. 11.1). In order to know the type of data that is required, the level of detail of social conduct classification has to be determined upfront. Different levels of detail are (i) sector in a specific region, (ii) industry in a specific region, (iii) organisation-wide or (iv) on site at a specific company or company division, which is, for example, the specific facility responsible for the specific life cycle process.

The validity of the study is closely related to the data requirement and quality. Inventory data in an LCA database can be used by a wide range of practitioners and studies with different scopes. However, the validity of this data, and thereby the validity of this study, strongly varies between geographic, across industries, over time and even between experts. Therefore all limitations encountered and assumptions made have to be systematically recorded. Their effect on the scope and validity of the study has to be carefully considered.

11.5.2 Gathering Data and Performing Inventory Analysis

In the inventory analysis phase, the data are obtained which afterwards are used for the impact assessment. The aim of the SELCA is to be able to simultaneously acquire inventory for social and environmental assessment. However, there exists a difference in nature of these data, respectively, qualitative and quantitative. Social inventory data can be very susceptible to improper or wrong interpretation in spite of accurate descriptions and guidelines. Environmental inventory is mostly based on predefined pathways and has clear indicators which are comparable across process technologies and sectors. By contrast social conduct can vary widely across industries, individual organisations, geographical regions and timeframes. Also, social data can change because of sudden policy changes in social conduct of companies, wherefore system boundaries must be well documented in the goal and scope definition. In social inventory analysis, many implicit assumptions are made, which therefore have to be recorded accurately to reduce the risk of invalidating the impact assessment.

For environmental inventory the interventions are the 'effects' that are caused by 'substances' crossing the system boundary as predefined in impact assessment methods such as ReCiPe[3] (Goedkoop et al. 2009). These environmental interventions can be derived directly from the process tree[4] and are documented in the list of interventions.

The set of social interventions that is included in the SELCA method is defined by social research methods (literature review, interviews to experts and discussions groups). The performance of a social inventory analysis by obtaining social conduct from the associated enterprises, regions or countries is more complex. For every step in the process tree within the cut-off criteria, all relevant social topics/social conduct is indicated. This inventory is documented by the use of the scorecards, where the qualitative social conduct on every social topic is converted into quantitative data. The scorecards define all relevant social topics per process step. These cards have been defined in collaboration with professionals from the textile sector,

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[3] ReCiPe is a methodological approach to quantitatively assess the environmental impacts of the life cycle of products, transforming the long list of life cycle inventory results into a limited number of indicator scores.

[4] The process tree refers to the stepwise description of the value chain needed to manufacture any product. Usually it is represented in a flow diagram which can take the tree form.

i.e. experts of the centre 'Texperium',[5] who were consulted to constitute the scorecards for the different social subcategories. For each social topic, a predetermined description of the social mechanism (UNEP 2009) is followed by the selection criteria for its conduct evaluation.

The conduct evaluation for every social topic is classified into one of the five performance indicator classes. These classes are determined on the basis of performance reference points and are defined to be *ideal*, *positive*, *in accordance with international standards*, *negative* and *unacceptable*. For some social topics, these reference points (selection criteria) were already specified in the *Handbook for Product Social Impact Assessment* by PRé Sustainability (Fontes 2016). The others have been formulated by researchers at the University of Twente.

The level of detail of the inventory analysis must match the determined level of detail of the LCA study. A specific-site evaluation provides an indication on what is happening at the specific enterprise and what requires a single performance classification, whereas an entire industrial sector cannot be classified under one performance but requires a broad conduct profile. This is done by indicating the *risk* of occurrence of the different conducts in an entire sector, industry or geographical region.

11.5.3 SELCA Impact Assessment Method

When an enterprise is evaluated on its environmental impact and its conduct towards the relevant social topics, these values have to be characterised. This step is part of the impact assessment phase, where the environmental and social dimensions are separated. For the environmental dimension, the ReCiPe impact assessment method is applied (Goedkoop et al. 2009). For the social dimension, the SELCA SLCIA[6] method was developed.

Per social topic (social intervention), a set of Conduct Characterisation Factors (CCF) is used to determine the quantitative differences between the conduct performance categories. This set can differ per social intervention according to the sector. Sets of CCFs can have a linear as well as a nonlinear scale, to distinguish between relative impact contributions. Table 11.1 is here given to illustrate the CCFs. Even though these sets are inherently arbitrary, they can be used to distinguish between, or emphasise positive and negative impacts. Note that a value of zero for the category 'in accordance with international standards' inherently is equal to a non-present intervention.

The different sets of weighing factors can be determined using the same approach as in LCA (multi-criteria, expert opinion, panel discussion, ranking, etc.). All 31 social impact categories have a Social Topic Weighting Factor (STWF) assigned. Per stakeholder group the weighted social topics are added up to an aggregated midpoint score. Similarly, the scores of the five stakeholder groups can be aggre-

[5] Textile (Open) Innovation Centre based in the Netherlands

[6] SLCIA stands for social life cycle impact assessment.

Table 11.1 Two examples of Conduct Characterisation Factors sets for SELCA (own contribution)

Conduct performance	C.C.F. set A (linear)	C.C.F. set B (nonlinear)
Ideal	+2	+100
Positive	+1	+10
In accordance with international standards	0	0
Negative	−1	−10
Unacceptable	−2	−100

gated to a single endpoint score. If a certain stakeholder group needs more emphasis, a set of Stakeholder Group Weighting Factors (S.G.W.F.) can be applied. It is also possible to aggregate conduct interventions according to their performance indication. The conduct performance profile can be used to identify the overall performance of the entire life cycle, regardless of the stakeholder group or social topic.

In summary, the SELCA impact calculation goes through the four stages (see Fig. 11.2). The first stage is the qualitative classification of company conduct for each social topic, weighted with CCF. The second stage consists of the aggregation of all conduct for each social topic, weighted with STWF, if desired. The third stage aggregates all social topics related to the different stakeholder groups, again weighted using STWF. The final stage consists of the aggregation of all stakeholder groups into a single score for social impact. Alternatively, all conduct interventions can be aggregated directly for profiling social impact regardless of social topic or stakeholder group.

The impact pathway for the SELCA S-IAM[7] is designed in such a way that the most ‘subjective’ step of conduct classification is concentrated at the start of the impact pathway. This means that the conversion from a qualitative judgement into a quantitative number is performed as early as the inventory stage instead of later stages like in environmental LCA or other methods for social LCA. The anticipated advantage of this choice is that considerations about objectivity can be addressed at the inventory phase instead of the profiling phase.

11.6 The Jeans Case Application on SELCA Method

This study serves as a showcase on the implementation of the SELCA method and to evaluate the proposed methodology on its application to a case with a global value chain. The analysis is limited to four product life cycle scenarios and aims to evaluate the potential, social and environmental problems in the jeans case. For the sake of time and for this study being exploratory, it was crucial to limit the scope of the study. Focus has been put on the regions with stakeholders that have the largest contribution to the global jeans value chain. The results of the combined analysis of the four different recycling scenarios of jeans are discussed in the last section.

[7] S-IAM means here social impact assessment method.

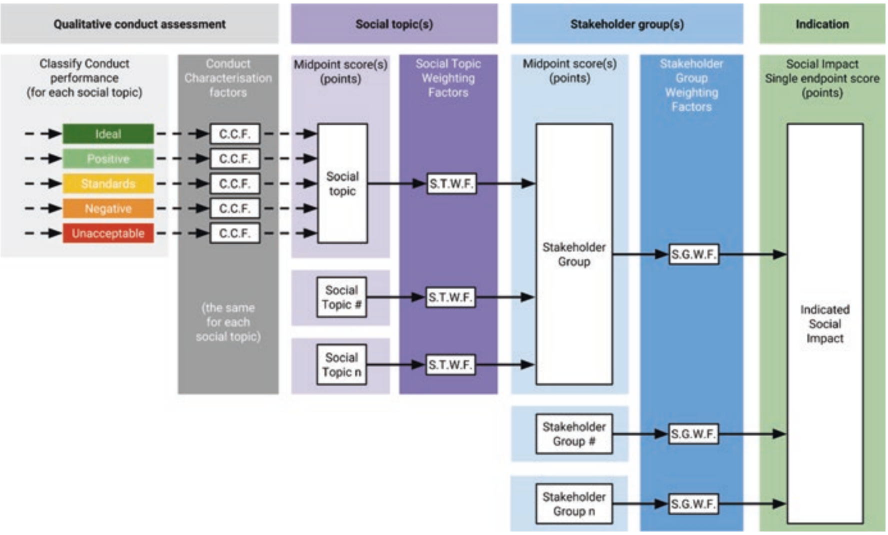

Fig. 11.2 SELCA S-IAM impact calculation pathway (own contribution)

The jeans case has been chosen for two reasons: firstly, because of its global value chain which consists of a wide variety of resources and actors over the product life cycle and, secondly, because of the urge to contribute to the battery of assessment tools to identify the social and environmental impacts of the global textile value chain. Especially with regard to the social dimension, many pressing issues exist. Product lines are refreshed more frequently, life time of clothes reduces and consumption increases. Altogether, this leads to supplier in developing countries to reduce cost and lead times, what consequently worsens the labour conditions in those countries.

11.6.1 Definition of Goal and Scope of Jeans Case

The jeans case explores four different recycling scenarios. Scenarios with partial circularity[8] of materials are compared to a scenario that only uses virgin materials. Here, circularity of materials, what is environmentally in nature, also embraces a social dimension; wherefore, the life cycle assessment of its sustainability can be more holistic.

The functional unit of this case study is defined as: 'To wear denim jeans, bought and used in the Netherlands, 5 days a week, for one year'. All jeans are assumed to

[8] Application of either recovered or recycled materials in the manufacturing phase of new products

have a life span of 10 months of typical wearing, meaning washing every 2.5 days. The depth of study specifies the following life cycle stages: cotton cultivation, yarn production, textile production, jeans production, consumer use and end of life. As cotton can be supplied from many different parts of the world, based on market share and data availability, it is assumed that the cotton cultivation is done in China, where after it is shipped to Bangladesh and America for the subsequent production processes. The consumer use phase and end-of-life phases are restricted to the Netherlands.

As priorly mentioned, four different manufacturing scenarios are used to explore different processes for the production of jeans. The final assessment compared four scenarios (based on materials selection and process conditions) to produce denim fabric: (i) jeans made with 100% virgin cotton, (ii) jeans made with 40% recycled cotton (mechanically recovered), (iii) jeans with recycled PET and (iv) jeans produced with recycled nylon 6, which requires chemical recycling. Regardless of the scenario, a mass ratio of 2:1 of white to blue yarns is assumed for the denim fabric.

11.6.2 Inventory Analysis

The inventory analysis for the environmental part of this combined LCA does not differ from an inventory analysis for a single LCA and therefore is not further elaborated on. As mentioned in Sect. 11.5.2, the inventory analysis for the social LCA is a phase that has to be carried out carefully. Environmental data was sourced from the educational database of the *GaBi* software by the company *Thinkstep*, supplemented with data from the *EcoInvent* database, and social data was based on reports on the social responsibility of the textile sector. Even further, a lack of validated sources for social data has been observed, which can be associated to transparenty issues through the textile value chain. Therefore additional expert knowledge from the centre 'Texperium' has been used. These experts have scored the social issues from different industries and regions on one of the five impact classes.

The end of life of a product is essential for a circular flow of materials and therefore of high importance with respect to the four scenarios. Four end-of-life destinations of the product have been modelled: cloth reuse (10%), garment reuse (7%), new yarn production (14%) and incineration of textile (69%). Finally, the life cycles of each of the four scenarios were simulated. In order to illustrate the needed processes in the cotton-to-jeans life cycle in Fig. 11.3, the scenario of jeans with 40% recycled cotton fibres is presented.

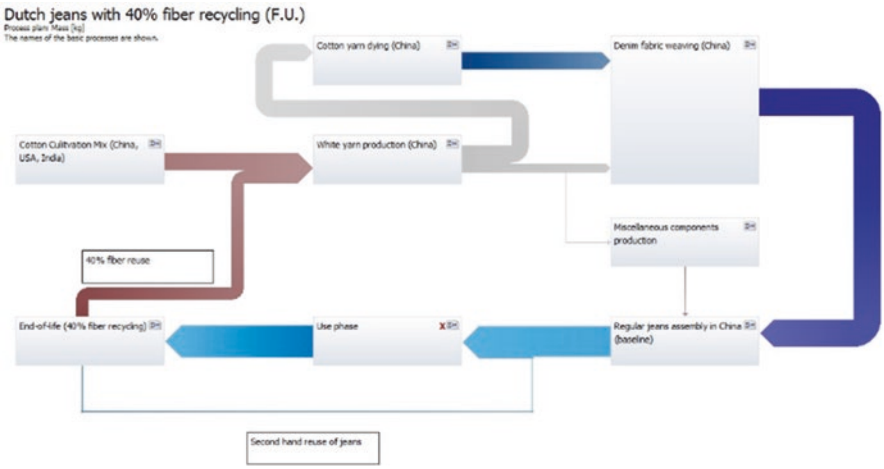

Fig. 11.3 Cotton-to-jeans lifecycle, scenario with 40% recycled cotton fibre

Table 11.2 Example on intervention and characterisation calculation for sector X and company Y

	Intervention profile			Characterised profile	
Performance	Sector X	Company Y	C.C.F.	Sector X	Company Y
Ideal	0.1	0	+2	0.2	0
Positive	0.3	1	+1	0.3	1
Standard	0.4	0	0	0	0
Negative	0.2	0	−1	−0.2	0
Unacceptable	0	0	−2	0	0
				0.3 pts	1 pts

11.6.3 Impact Assessment

For the environmental dimension, impact is assessed using the ReCiPe v1.08 method (Goedkoop et al. 2009). In order to illustrate the method for the social dimension, an example is given in Table 11.2 for the intervention ‘fair salary conduct’ of sector X and company Y. Two different entities have been used to show the possible difference in level of detail. Note: this example is separate from the ‘jeans’ case. A score profile for both entities has been determined during inventory analysis. Next, this profile is characterised via its set of CCFs, which can differ per case. This results in an indicator score for intervention.

Together with the other intervention scores, this score is aggregated into *midpoint* scores (see Fig. 11.2) for the social topic or for the five stakeholder groups. The overall performance endpoint can be calculated by counting the relative presence of conduct performance between the social mechanisms.

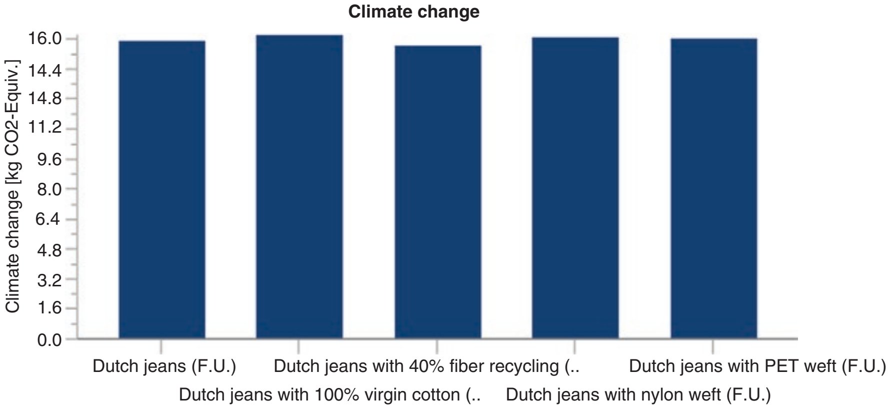

Fig. 11.4 Impact on climate change effect of the baseline and four scenarios

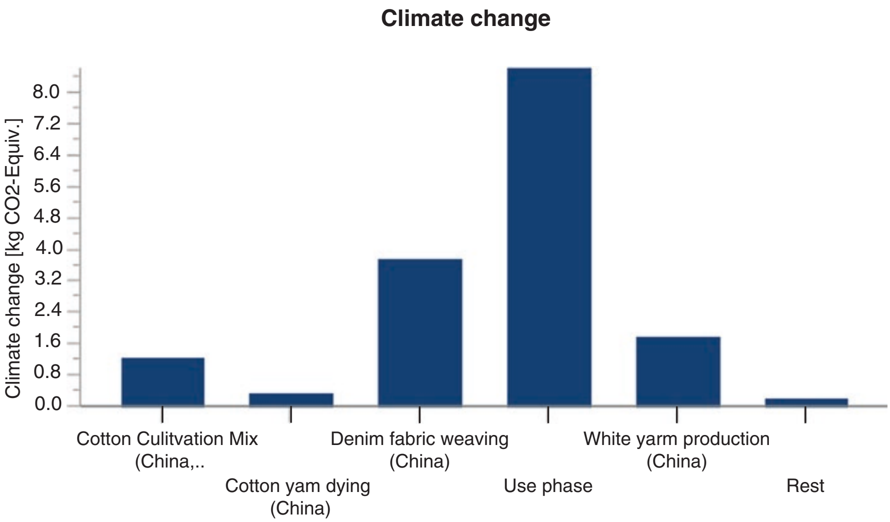

Fig. 11.5 Impact on climate change effect of life cycle phases

11.6.4 Profiling and Evaluation

The environmental impact profiles of the different scenarios show little differences. To illustrate this, the profile of the climate change effect is displayed in Fig. 11.4. Whilst in Fig. 11.5, the impact profile of the average Dutch jeans over the life cycle is indicated. It can be observed that the use phase, the washing, drying and lifespan, causes the highest environmental impact through the whole life cycle of jeans.

The social impact assessment reveals a profile, displayed in Fig. 11.6, where poor worker health and safety have the worst impact, especially during jeans assem-

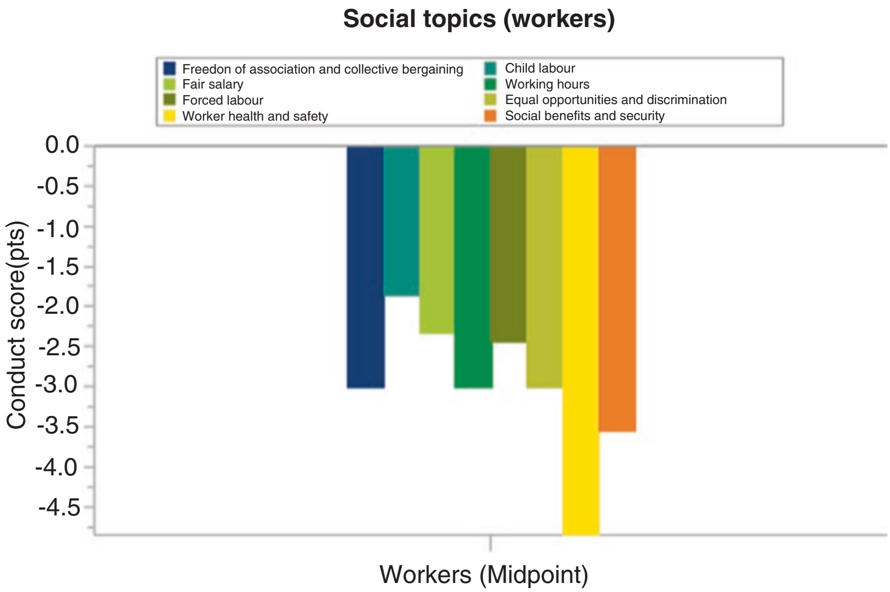

Fig. 11.6 Conduct score of average Dutch jeans on social topic 'workers'

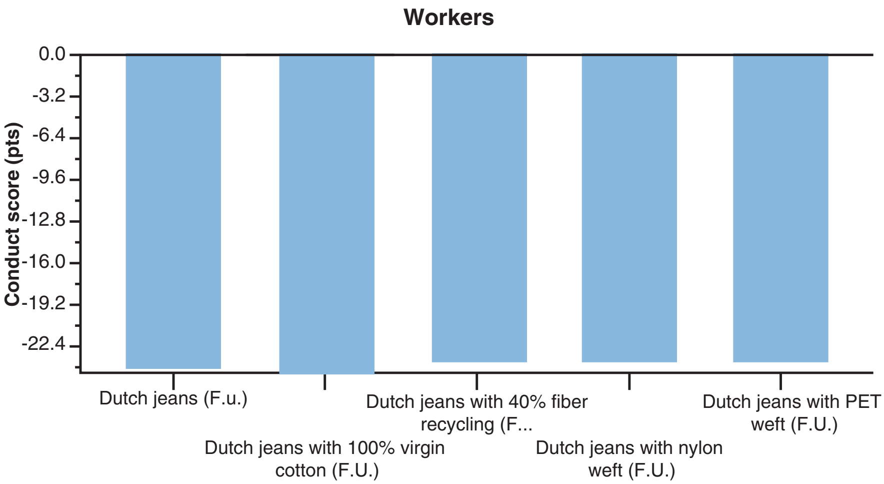

Fig. 11.7 Impact of different scenarios on social topic 'workers'

bly and cotton cultivation. Even further, the impact of the different scenarios on "workers" does not show any significant difference among them (see Fig. 11.7), only a slight bigger impact on the scenario of the Dutch jeans with 100% virgin cotton as functional unit (FU).

When looking at the three scenarios of fibre recycling, for climate change impact, the use of recycled cotton fibres can be considered as the best option, as well as for water depletion. The scenario of recycled nylon fibres proves to be the worst on both impact categories, for climate change, it is even worse than the regular jeans scenario. The social profile shows that the jeans using recycled cotton fibre scores are slightly less bad with −23.4 points compared to −24.4 points for the jeans with only virgin cotton, according to calculations of *GaBi* software used. However, this is a result of scaling and allocation rules by use of the functional unit.

11.7 Conclusions and Recommendations

This section summarises and concludes both the subject matter of the combined social and environmental LCA (SELCA) method and the practical application of this method in a case study on jeans. The research question driving this research (*How can social aspects be integrated into (traditional) environmental life cycle assessment by using denim jeans as showcase?*) was formulated trying to respond to the 'how' question. Considering this type of research, the following aspects were the most prominent.

Due to the infancy of the field, existing approaches for combined social and environmental LCA were not readily available. As existing 'traditional' LCA software is based on linear input-output calculations, they do not allow for 'qualitative' interventions. Based on the current state of the art in LCA literature and best practices (such as the UNEP recommendations), the SELCA approach was developed. SELCA allows for a semi-qualitative assessment of social impact, which makes it suitable for use in conventional LCA software and allows for the combined assessment of both social and environmental impact within the scope of a single study.

Despite the novelty and short development cycle of the SELCA method, it did prove to be a valuable tool during the case study on the life cycle assessment of jeans for predicting performance and identifying improvement opportunities. Regarding the four evaluated scenarios of the case study, it can be concluded that the material recycling of cotton fibres is a substantial measure with respect to the environmental effects on climate change and water depletion. Additionally, the use of water and electricity during the use phase also has a significant impact on the environment, which is mostly determined by consumer behaviour related to washing and drying of their garment. From a social perspective, the bulk of the social impact originates from the global textile supply chain, where the impact on workers was the largest, especially during cotton cultivation, fabric weaving and garment assembly.

The application of SELCA did present a number of noteworthy empirical challenges. From a practical perspective, the inventory analysis of social aspects proved to be difficult due to the lack of transparency in the value chain, which presents a peculiar 'chicken and egg' problem to social LCA. Social inventory also proved to be prone to subjective judgement, despite the careful use of UNEP recommended classification criteria and the use of external documentation during conduct assessment. Time and manpower constraints forced reducing the scope of the LCA analysis to global risk indication due to the labour intensity of gathering social inventory data. During the evaluation of the case study, it was found that the classification of 'standard', 'negative' and 'unacceptable' were prevalent in the impact profiles. Additional case studies could determine if the effect is inherent to this method or if it is symptom of this case study.

A different set of challenges were encountered from a theoretical standpoint, most noticeably, the use of the functional unit (FU) and its role in allocating social impact. Where the FU is designed to linearly scale and allocate environmental impact based on the provided functionality, the same does not necessarily apply to (semi-)qualitative matters such as social impact. This issue is most noticeable in the inclusion of circular principles. In the case study, both recycling and reuse lead to a reduced environmental footprint per FU, but the question remains if these measures should also reduce social impact accordingly. Another challenge was experienced in utilising a consistent scope, system boundaries and cut-off criteria. For some processes in the product life cycle, there was an overlap in environmental and social concerns, as observed in the study in the global textile supply chain. In other occasions, the system boundaries were very dissimilar between environmental and social aspects, as observed in the assessment of the use phase.

The case study on the inclusion of the social dimension into LCA has demonstrated that it is possible to generate a number of valuable insights and preliminary conclusions. However, there remains a need to verify and elaborate on these findings in future research. The foreseeable next step is to evaluate this new approach using an expert panel of various stakeholders in the textile sector.

This study aims to be the starting point of the development of a methodology that contributes towards an integrated assessment on the social, environmental and economical dimension of the life cycle of a product system.

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