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A social-LCA-based case of clothing production

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Monetisation of external socio-economic costs of industrial production: A social-LCA-based case of clothing production

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A R T I C L E I N F O

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A B S T R A C T

The purpose of this study is to benchmark production processes and production chains of clothing products, by means of social life cycle assessment (S-LCA). In this paper we present the socio-economic costs (s-eco-costs) method for monetisation of external socio-economic burden for workers. The method is applied to six cases of garment production chains.

The s-eco-costs are the marginal *prevention* costs to reach a sustainable level (the Performance Reference Point, PRP) for wages and are the monetary *compensation* costs beyond the PRP to account for unacceptable exploitation of workers.

The s-eco-costs (in €) include five sub-indicators, proposed as a base-line for several social issues in S-LCA:

- Minimum Acceptable Wage (based on minimum wages in rich countries and statistics on economic migrants)
- Child Labour (forced labour, not able to attend school)
- Extreme Poverty (derived from World Bank absolute poverty line)
- Excessive Working Hours (forced labour, involuntary)
- Occupational Safety and Health (based on statistics of ILO)

These s-eco-costs have been calculated for cotton T-shirts and pairs of jeans for three garment production chains: USA-Europe (Western 'W'); India-Bangladesh (Asian 'A'); China/India-Bangladesh (Asian Best Practice 'ABP'), revealing the hotspots in these chains, and enabling benchmarking. The total results for the s-eco-costs of T-shirts are: W = € 0.05; A = € 1.46 and ABP = € 0.33. The results for the jeans are: W = € 0.38; A = € 12.56 and ABP = € 2.67. The most important hotspots are in the cotton fields in India and the garment production phase in Bangladesh.

The authors hope that the proposed system will inspire others in the field of S-LCA to proceed with the development of quantitative indicator systems.

1. Introduction

1.1. S-LCA and its role towards sustainable production and consumption

S-LCA (Social Life Cycle Assessment) has to play an important role in the transition towards sustainable production and consumption, by better design of products and better supply chain management (Jørgensen et al., 2009, 2012; Seuring, 2011, Seuring and Gold, 2013; Parent et al., 2010, 2013; Reuter et al., 2010; Vermeulen, 2010, 2015). Parent et al. (2013) and Vermeulen (2015) argue that it is better to make the assessment specific for a production site in the chain, rather than to base benchmarks on statistical probabilities on country levels. By this means S-L A can support product designers, supply chain managers, and customers who buy end-products in the decision making process.

The framework of S-LCA has been defined by UNEP/SETAC (2009, 2011) as well as by Fontes (2016), Sala et al. (2015) and Leadership

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Council of SDSN (2015). These documents can be used to assess – quantitatively as well as qualitatively – several stakeholder categories: Workers/employees, Local community, Society (national and global), Consumers (covering end-consumers as well as the consumers who are part of each step of the supply chain), and Value chain actors (UNEP/SETAC, 2009). The aim is to identify the hotspots of unsustainable aspects in regard to these stakeholders in the production chain. UNEP/SETAC (2009) describes two characterisation methods: the use of impact pathways, which are cause-effect chains (Weidema, 2006), and the use of PRPs (Parent et al., 2010). Parent et al. (2010) argue that the method of the PRPs is preferred for quantitative assessments since "cause-effect relationships are not simple enough, or not known with enough precision to allow quantitative cause-effect modelling" (UNEP/SETAC, 2009: 70).

The number of published papers on practical S-LCA cases are still rather limited (compared to E-LCA), and they all show that there still are many problems in conducting S-LCA. The development of S-LCA is still in its infancy (Mattioda et al., 2015) and consensus of opinion on which indicators should be used, has not been reached yet (Lehmann et al., 2013; Bocoum et al., 2015) and LCI data (Benoît Norris, 2014).

There are some examples of hotspot analyses on roses (Franze and Ciroth, 2011), on laptops (Ekener-Petersen and Finnveden, 2012), on palm oil (Manik et al., 2013), and on fertilizer (Martinez-Blanco et al., 2014) which used the data of the Social Hotspot DataBase (Benoît Norris, 2014). The key problem in all these examples is that data should be available for at least the most relevant specific manufacturing locations in the production chain, and that these specific data are hard to get (Jørgensen et al., 2009; Jørgensen, 2013). Benoît Norris (2014) even argues that comparison (LCA benchmarking) is not possible because of the sensitivity of these specific data. One recent paper on building materials proposes a well-structured panel weighting system for a single score in S-LCA (Hosseinijou et al., 2014), however, it is rather complex for a quick assessment in practice. All these papers on practical S-LCA cases lack a full integration with E-LCA. We argue that this integration is regarded as quite important, since it enables to analyse the trade-off between ecological and social aspects (Hauschild et al., 2008; Vermeulen, 2015).

1.2. The eco-costs as a prevention-based indicator system in E-LCA

This Section provides a short explanation on the eco-costs method, because the s-eco-costs for S-LCA as explained in this paper is closely related to the eco-costs method for E-LCA. The method of the eco-costs was introduced as a 'prevention-based single indicator' (different to the then existing 'damage-based' systems) in the International Journal of LCA (Vogtländer and Bijma, 2000; Vogtländer et al., 2001) and in this journal (Vogtländer et al., 2002). Fig. 1 depicts the structure of the eco-costs together with the structure of the s-eco-costs as described in this paper.

Eco-costs are a measure to express the amount of environmental burden of a product on the basis of prevention of that burden. The practical use of eco-costs is to compare the sustainability of several product types with the same functionality. The advantage of eco-costs is that they are expressed in a standardised monetary value (€) which appears to be easily understood 'by instinct' by consumers, business managers, and designers (Vogtländer et al., 2002). The calculation is transparent and relatively easy, compared to damage based models that have the disadvantage of extremely complex calculations with subjective weighting of the various aspects contributing to the overall environmental burden.

The eco-costs are the marginal prevention costs that should be made to reduce the environmental pollution and materials depletion in our world to a level which is in line with the carrying capacity of our earth. The marginal prevention costs of emissions are derived from the so-called prevention curve as depicted in Fig. 2. The basic idea behind this curve is that a country (or a group of countries, such as the European Union), must take a row of prevention measures to reduce emissions ('curve a' in Fig. 2), since more than one measure is required to reach the target. From the point of view of the economy, the cheapest measures (in terms of €/kg) are taken first. At a certain point at the curve, the reduction of the emissions is sufficient to bring the concentration of the pollution below the so-called no-effect-level. The no-effect-level of CO_2 emissions is the level where the emissions and the natural absorption of the earth are in equilibrium again at a maximum temperature rise of 2° C. The no-effect-level of a toxic emission is the level where the concentration in nature is well below the toxicity threshold (most natural toxic substances have a

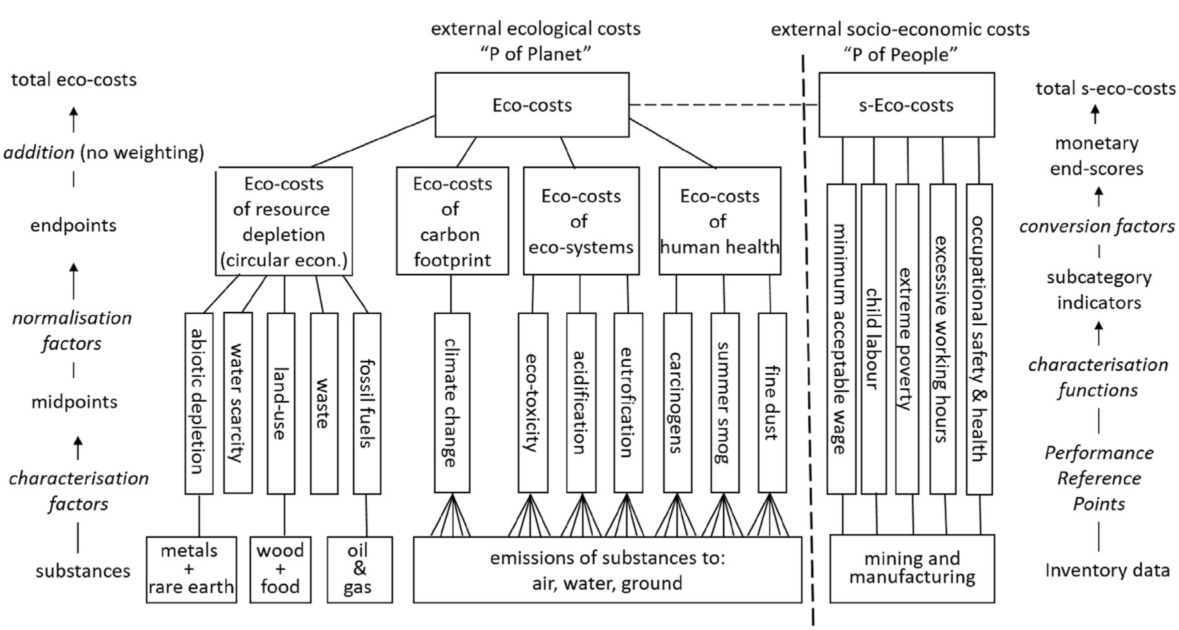

Fig. 1. Structure of the eco-costs and the s-eco-costs.

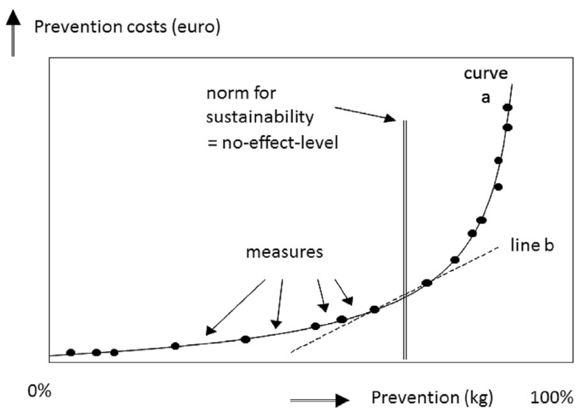

Fig. 2. Eco-costs are based on marginal prevention costs at the no-effect-level (the costs in €/kg of the last required technical measure).

toxicity threshold, below which they might even have a beneficial effect), or below the background level. For human toxicity the 'no-observed-adverse-effect level' is used. The eco-costs are the marginal prevention costs of the last measure of the prevention curve to reach the no-effect-level ('line b' in Fig. 2).

The classical way to calculate a 'single indicator' in LCA is based on the damage of the emissions, derived from a cause-effect analysis. In damage based methods pollutants are grouped in 'classes', multiplied by a 'characterisation' factor to account for their relative importance within a class, and totalised to the level of their 'midpoint' effect (global warming, acidification, nutrification, etc.). The classical problem is then to determine the relative importance of each midpoint effect. This is done by 'normalisation' (= comparison with the pollution in a country or a region) and 'weighting' (= giving each midpoint a weight, to take the relative importance into account) by an expert panel. The problem with the classical cause-effect approach (as applied for damage based methods) is that many assumptions are needed in complex cause-effect computer models, causing a lot of uncertainties, and that the expert panel weighting system introduces undefined subjectivities. The prevention based approach (as applied for the eco-costs method) is less complex and there is no need for a the panel weighting system. This calculation system is in a way similar to the calculation systems that include Performance Reference Points as referred to at the end of the first paragraph of Section 1.1 (Parent et al., 2010).

Equal to damage based methods, the calculation of the eco-costs is based on classification and characterisation tables as well, however has a much simpler, more transparent approach to derive to the endpoint score as explained above, and without subjective panel weighting. The weighting step is not required, since the total result is the sum of the eco-costs of all midpoints. The advantage of such a calculation is that the marginal prevention costs are related to the cost of the most expensive Best Available Technology that is needed to meet the target. It has therefore a direct meaning for business people as the risk of non-compliance with future regulations (under the assumption that our society will strive towards no-effect levels). The eco-costs should be regarded as hidden obligations, also called 'external costs'. As such, the eco-costs are virtual costs, since they are not yet integrated in the real life costs of current production chains (Life Cycle Costs).

The characterisation ('midpoint') tables which are applied in the eco-costs 2012 system are recommended by the ILCD (and brought in line with EN15804): (1) IPPC 2013, 100 years, for greenhouse gasses (2) USETOX, for human toxicity (carcinogens), and ecotoxicity (3) RECIPE, for eutrification, and photochemical oxidant formation (summer smog) (4) CML, for acidification (5) RiskPoll, for fine dust. In addition to abovementioned eco-costs for emissions, there is a set of eco-costs to characterise the 'midpoints' of resource depletion: (6) eco-costs of abiotic depletion (metals, including rare earth, and fossil fuels) (7) eco-costs of land-use change (based on loss of biodiversity, e.g. used for eco-costs of tropical hardwood) (8) eco-costs of water (based on the midpoint Water Stress Indicator - WSI - of countries) (9) eco-costs of landfill.

For example: for each 1000 kg CO_2 emission, one should invest € 135,- in offshore windmill parks (and all other CO_2 reduction systems at that price or less). When this is done consequently, the total CO_2 emissions in the world is expected to be reduced by 65% compared to the emissions in 2008. As a result global warming will stabilise. In short: "the eco-costs of 1000 kg CO_2 are € 135,-".

Similar calculations can be made on the environmental burden of acidification, eutrification, summer smog, fine dust, eco-toxicity (applying the so called no-observed-adverse-effect level as PRP), and the use of metals, rare earth, fossil fuels and land (nature). The eco-costs of a product are the sum of all eco-costs of emissions and use of materials and energy during the life cycle "from cradle to cradle", conform the ISO 14040 and ISO 14044.

The eco-costs have been calculated for the situation in the European Union. It is expected that the situation in some states in the USA, like California and Pennsylvania, give similar results. It might be argued that the eco-costs are also an indication of the marginal prevention costs for other parts of the globe, under the condition of a level playing field for production companies. A more comprehensive summary about the eco-costs method can be found at the internet (https://en.wikipedia.org/wiki/Eco-costs, assessed November 2016) and detailed information in (Vogtländer et al., 2010).

1.3. The structure of this paper

The purpose of this paper is to introduce the s-eco-costs method and to give an example of the application of this method by means of mapping out the textile supply chain. The method has been developed at first instance for the stakeholder category "worker" as an extension of the eco-costs method, but has to be regarded as a first step in monetising more categories and subcategories in S-LCA.

As a validation of the method, we demonstrate how the s-eco-costs can be applied to enable a comparison between different specific textile production chains, where we focus on the social aspects related to the workers in that sector. In developing countries social issues of the textile supply chain arise during cotton production and the subsequent processing steps; and in the final garment production. Many references (Mariani, 2013; ILO, 2014; Kelly, 2014) indicate these garment life cycle phases as the social hotspots, where the unacceptable exploitation of workers takes place. All other negative social effects in the subsequent phases and in background systems are expected to be of less dominance.

We present six cases of standard textile production chains, namely the cases of a cotton T-shirt and a pair of jeans, produced in USA-Europe, India-Bangladesh, or China-India-Bangladesh. See Section 3.2.

Section 2 of this paper describes the method of the s-eco-costs. The details of this method (the choice of (sub)categories, PRPs, the calculation structure of the subcategory-indicators, and the calculation of the end-scores) can be found in Annex 2 of the Supplementary Materials.

In Section 3 we apply the method to 11 textile producing countries (section 3.1), and 2 different products (a T-shirt and a jeans) from 3 different production chains (section 3.2).

The Discussion (Section 4) deals with four issues: the characteristics of the s-eco-costs system (in Section 4.1); to what extent is it allowed to apply s-eco-costs and the relation to the Triple P (in Section 4.2); the combination of E-LCA and S-LCA in the case of clothing and how the and how the s-eco-costs of garment production relate to the actual market price of garments (in Section 4.3).

The Conclusions (section 5) summarise the results of the analysis of the textile chains, and includes suggestions for further development of quantitative S-LCA studies.

2. An indicator system for S-LCA: the s-eco-costs

2.1. Background

The s-eco-costs method is developed in line with the Guidelines for S-LCA of Products (UNEP/SETAC, 2009) and follows the methodological framework as presented in (UNEP/SETAC, 2011). It comprises the subcategories of Minimum Acceptable Wage (as a special aspect of Fair Wage), Child Labour, Extreme Poverty, Excessive Working Hours, and Occupational Safety and Health.

Details on the background of the s-eco-costs can be found in Annex 2 of the Supplementary Material. This Annex describes:

(i) how the most relevant (sub)categories are selected from the comprehensive list of UNEP/SETAC (2009) in order to make S-LCA a practical tool for sustainable supply chain management;
(ii) how the PRPs are chosen;
(iii) how the characterisation function is defined for each subcategory (i.e. how a subcategory-indicator is calculated, see Fig. 1);
(iv) how the monetary end-scores for each subcategory are calculated.

2.2. The s-eco-costs subcategory end-scores

2.2.1. General

The s-eco-costs of a product are based on the salaries per working hour, the working conditions and the required time to make a product. In formula:

'total s-eco-costs of a product' = $\sum$ 'time to make a product' x 's-eco-costs subcategory end-score' (0)

These data must be measured at the factory and based on the actual situation. Data on salaries are to be calculated in Int $ PPP (Purchasing Power Parity), because the normal exchange rates of currencies would give the wrong picture for benchmarking between different countries. In this study s-eco-costs subcategory end-scores are calculated for the price level of 2014, with 1 Int $ PPP = € 0.83.

2.2.2. Minimum acceptable wage subcategory end-score

2.2.2.1. Short description. The Minimum Acceptable Wage is the level of minimum wage in poor countries at which the current unsustainable level of economic migration will probably vanish, even at 'open borders' (i.e. free flow of workers without strict working permits and without borders with fences). This level is based on statistical data, see Supplementary Materials, Annex 2.2.2.

2.2.2.2. Formula.

$$SEC_{MAW} = 0.83(5.79 - S_{hour}) \quad \text{if } S_{hour} < 5.79 \tag{1}$$

$$SEC_{MAW} = 0 \quad \text{if } S_{hour} \geq 5.79 \tag{2}$$

where:

SEC_{MAW} = s-eco-costs of Minimum Acceptable Wage Deficit (€/hr)
S_{hour} = actual salary per hour (Int $ PPP/hr)

2.2.3. Child labour subcategory end-score

2.2.3.1. Short description. The s-eco-costs of Child Labour is calculated on the basis of the 'lost life years' of a child (age below 15 years), where 2240 h of work in manufacturing is set equal to 1 DALY as default value, and 1 DALY is valued at € 80,000. For details see Supplementary Materials, Annex 2.2.3. The situation in industry is calculated slightly different from the situation in agriculture.

2.2.3.2. Formula.

$$SEC_{CLindustry} = 35.71(H_{CL}/2240) \tag{3}$$

$$SEC_{CLagriculture} = 35.71(H_{CL} - 560)/2240 \quad \text{for } H_{CL} > 560 \text{ hours per year} \tag{4}$$

$$SEC_{CLagriculture} = 0 \quad \text{for } H_{CL} \leq 560 \text{ hours per year} \tag{5}$$

where:

$SEC_{CLindustry}$ = s-eco-costs of Child Labour in industry (€/hr)
$SEC_{CLagriculture}$ = s-eco-costs of Child Labour in agriculture, services and domestic (€/hr)
H_{CL} = working hours per child per year (hr/year)

2.2.4. Extreme poverty subcategory end-score

2.2.4.1. Short description. Based on the poverty line of the World Bank (2005, which is the absolute minimum amount of money needed to feed a family) and corrected for the price inflation for food, the absolute minimum wage can be calculated at 0,935 Int $ PPP per hour. For a wage of zero (slavery) the indicator is proposed as 1 DALY/year. The reason for this default value, and the deliberations why, is similar to that of Child Labour (see Section 2.2.3. See for details the Supplementary Materials, Annex 2.2.4).

2.2.4.2. Formula.

$$SEC_{EP} = 35.71(0.935 - S_{hour})/0.935 \quad \text{if } S_{hour} < 0.935 \tag{6}$$

$$SEC_{EP} = 0 \quad \text{if } S_{hour} \geq 0.935 \tag{7}$$

where:

SEC_{EP} = s-eco-costs of Extreme Poverty (€/hr)
S_{hour} = actual salary per hour (Int $ PPP/hr)

2.2.5. Excessive working hours subcategory end-score

2.2.5.1. Short description. This issue is related to the fact that at some production sites workers are forced to work more than 48 h per week, leading to exhaustion. When this is involuntary, it can be regarded as a form of modern slavery. To quantify the Excessive

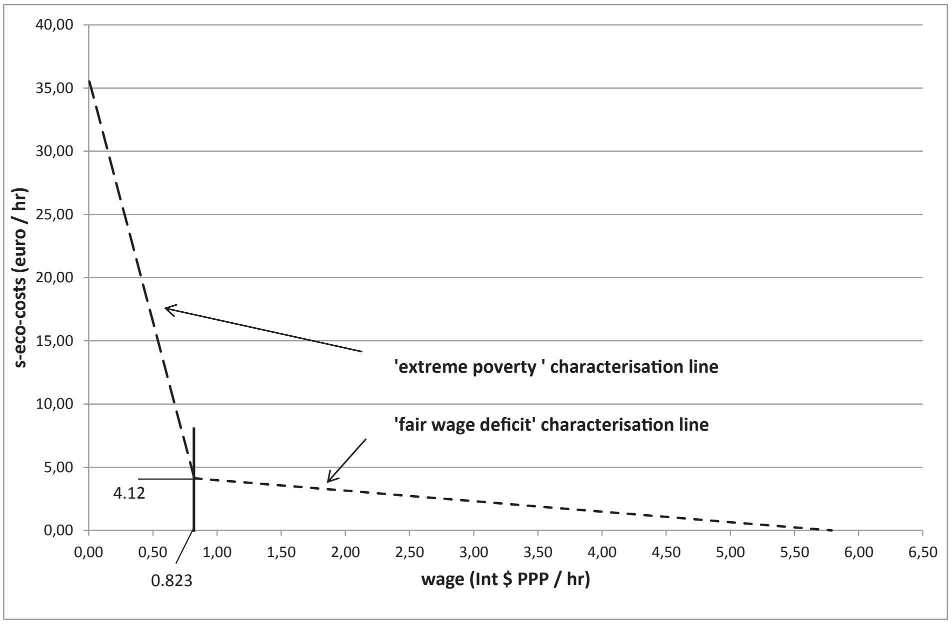

Fig. 3. The s-eco-costs as a function of the wage.

Working Hours we propose the DALY as indicator (as we did in Section 2.2.3 for Child Labour and in Section 2.2.4 for Extreme Poverty. See also Supplementary Materials, Annex 2.2.5).

2.2.5.2. Formula.

$$SEC_{EWH} = 35.71(H_{EWH} - 2240)/2240 \quad \text{only for } H_{EWH} > 2240 \tag{8}$$

where:

SEC_{EWH} = s-eco-costs of Excessive Working Hours indicator (€/hr)
H_{EWH} = working hours per year (hr/year)

In case of very irregular working times, it is advised to do the calculation on a weekly or monthly basis.

2.2.6. Occupational safety and health (OSH) subcategory end-score

2.2.6.1. Short description. This issue is related to the work related safety and health in a company. For detailed information the reader is referred to Supplementary Materials, Annex 2.2.6.

2.2.6.2. Formula.

$$SEC_{OSH} = 35.71(C_A \text{ x } P_A) + (C_M \text{ x } P_M) \tag{9}$$

where:

SEC_{OSH} = s-eco-costs of OSH (€/hr)
P_A = number of accidents and work related illness causing over 4 days' absence per year/number of workers
P_M = number of work related death per year/number of workers
C_A = average lost life year per case (DALY)
C_M = average lost life year per calamity (DALY) = average life expectancy in a country - age of the worker

2.3. The total s-eco-costs end-scores and avoiding of double counting

Fig. 3 shows the characterisation lines for extreme poverty and fair wage deficit. This figure demonstrates that - to avoid double counting - the fair wage deficit should not be accounted for when the wage is lower than 0.823 Int $ PPP per hour, or 0.68 €/hr. In that case only the s-eco-costs of extreme poverty should be taken into account (and the s-eco-costs of fair wage must be left out).

The total s-eco-costs can be calculated as following:

$$\begin{aligned}\text{Total s} - \text{eco} - \text{costs end} - \text{scores} \\ = SEC_{MAW} + SEC_{CL} + SEC_{EWH} \\ + SEC_{OSH} \quad \text{for } S_{hour} > 0.823(\text{Int \$ PPP/hr})\end{aligned} \tag{10}$$

$$\begin{aligned}\text{Total s} - \text{eco} - \text{costs end} - \text{scores} \\ = SEC_{EP} + SEC_{CL} + SEC_{EWH} + SEC_{OSH} \quad \text{for} S_{hour} \\ \leq 0.823(\text{Int \$ PPP/hr})\end{aligned} \tag{11}$$

3. S-LCA case: the supply chain of clothing

3.1. S-LCA case part 1: s-eco-costs on a country level

To show some examples of the application of the s-eco-costs method for the textiles industry on a country level, Table 1 provides the s-eco-costs per hour for some key producing countries of textile products (e.g. China, Bangladesh and Vietnam).

The outcomes in the table are based on the national minimum wages at 2014. The s-eco-costs for the Bangladesh industry in general are much higher than the s-eco-cost for the Bangladesh garment industry, due to a higher legal minimum wage for garment workers in that country.

For new calculations (when the s-eco-costs method is applied in future) the data must be adjusted to the situation at that moment (minimum wages gradually increase, especially in rapidly

Table 1
The s-eco-costs in € per hour for some leading countries in the textile industry.

country	Minimum Wage[a] (int $ PPP/hr)	Min Acc Wage Deficit MAWD (€/hr)	Extreme Poverty EP (€/hr)	Occupational Safety & Health OSH (€/hr)	S-eco-costs Total (€/hr)
Bangladesh general industry	0.25	in Extr. Poverty	26.17	1.61	27.78
Bangladesh garment industry	0.90	4.06	0	1.61	5.67
Belgium	10.31	0	0	0.84	0.84
China	1.99	3.15	0	0.99	4.14
India	1.02	3.96	0	1.19	5.15
Indonesia	1.14	3.86	0	1.14	5.00
Myanmar	0.46	in Extr. Poverty	18.14	1.82	19.96
Pakistan	2.04	3.11	0	1.12	4.23
Sri Lanka	0.81	in Extr. Poverty	4.77	1.14	5.91
Thailand	2.86	2.43	0	1.48	3.91
Turkey	4.30	1.24	0	1.00	2.24
Vietnam	1.52	3.54	0	1.49	5.03
United States	7.25	0	0	0.80	0.80

The countries for the three cases in the final section are in bold.
[a] (Trading Economics, 2015).

advancing developing countries).

The specific LCI data for Child Labour and Extreme Working Hours must be acquired on the level of a specific production chain, since ILO data on child labour and extreme working hours are not yet available for the garment industry as such. In our study we did not encounter these subcategories in the supply chains.

3.2. S-LCA case part 2: two textile products for three different supply chains

3.2.1. Goal and scope of the S-LCA study

The goal of the study is to benchmark production processes and production chains for a T-shirt and a pair of jeans. Three supply chains are analysed: a Western (W) garment chain located with cotton production in the USA and fabric and garment production in Belgium in the EU; an Asian (A) chain in India/Bangladesh (with minimum wages for Bangladesh industry in general); and an Asian Best Practice (ABP) chain in China/India/Bangladesh (with minimum wages for Bangladesh garment industry).

The scope is a cradle-to-gate analysis with a system boundary for the S-LCA, as depicted in Fig. 4.

The declared unit is either one T-shirt as defined in the Supplementary Materials, Table A1.2, or one pair of Jeans as defined in Table A1.3.

The 3 production chains with the geographical locations of each production step are depicted in Fig. 5.

3.2.2. The life cycle inventory and the life cycle impact assessment

The s-eco-costs for the production stages of a T-shirt are calculated from the hours required in the production processes (calculated from Annex A Table A1.4, shown in the first column of Table 2), combined with the s-eco-costs per hour (for country level see Table 1). Table 2 gives the results of these calculations.

In the cases we studied, the companies adhered to the local legislation, so we did not encounter Child Labour and Extreme Working Hours, which is the reason that these subcategories are not included in our study.

The overall calculations for T-shirts (and jeans) are summarised in Table 3 for the production chains as specified in Fig. 5. The difference between Case 2 (the Asian route) and Case 3 (the Best Practice Asian route) is caused by the fact that the workers in the cotton field are better paid in China than in India, and that we assumed that the work in Bangladesh in Case 2 is done by subcontractors which do not pay the minimum wage of garment industry, but pay the minimum wage of the general industry (which is considerably lower, see Table 1).

The calculations which lead to the results for jeans in Table 3 are similar to the calculations of the T-shirts: the difference is that jeans requires more production hours. See Table A1.4 in the Supplementary Materials.

4. Discussion

4.1. The characteristics of the s-eco-costs system

The authors of this paper are aware of the fact that it is an arduous task to quantify S-LCA results in a single indicator, however, quantification can often clarify LCA benchmarking and practical decision taking processes in supply chain management and design, where trade-off of different (sub)categories is often

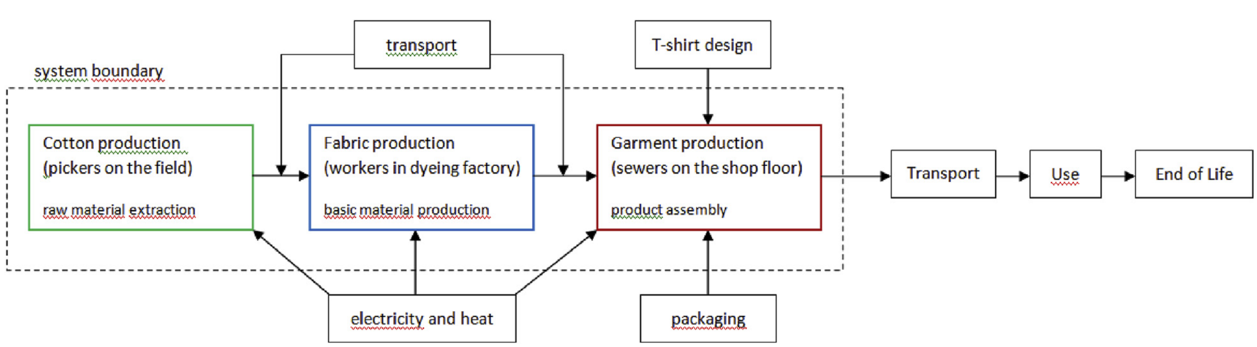

Fig. 4. The S-LCA system under study for a T-shirt (or, similarly, a pair of jeans).

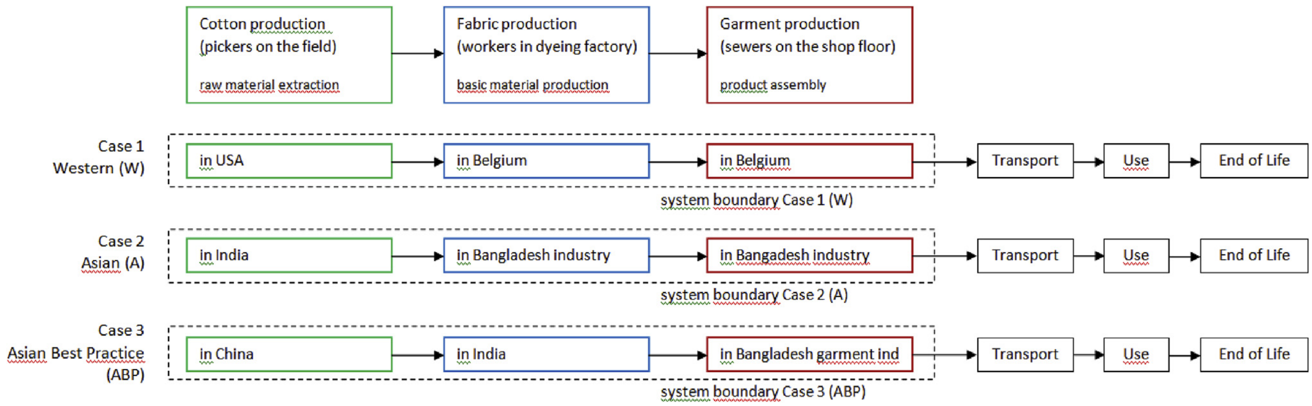

Fig. 5. The 3 different supply chains of the system under study, each with 2 reference flows (1 T-shirt and 1 pair of jeans).

Table 2
The s-eco-costs scores (in €/piece) for specific production stages of a T-shirt.

Process	T-shirts per hour	Min Acc Wage Deficit MAWD (€/T-shirt)	Extreme Poverty (€/T-shirt)	OSH (€/T-shirt)	Total (€/T-shirt)
Cotton production standard, **India**	87.9	0.045	0	0.014	0.059
Bio-cotton production, India	87.9	0.043	0	0.014	0.056
Cotton prod. Best Practice, **China**	87.9	0.036	0	0.011	0.047
Fabric production standard, Vietnam	2016	0.002	0	0.001	0.002
Fabric production standard, **Bangladesh**	2016	in Extreme Poverty	0.013	0.001	0.014
Fabric prod. Best Practice, **India**	2016	0.002	0	0.001	0.003
Garment production stand., **Bangladesh**	20	in Extreme Poverty	1.308	0.081	1.389
Garment prod. min. wage Myanmar	20	in Extreme Poverty	0.907	0.091	0.998
Garment prod.Best Practice **Bangladesh**	20	0.203	0	0.081	0.284

Prod. = production; stand. = standard.
The numbers for the three cases in the subsequent section are in bold.

required. UNEP/SETAC (2009, p.72) allows for quantification: “a scoring system may be used to help assess the ‘meaning’ of the inventory data, based on performance reference points” … “the scoring and weighting system must be well defined and transparent”. The issue is that a transparent system of PRPs and scoring systems is per definition subjective (‘value based’). The consequence is that the s-eco-costs scoring system cannot be seen as ‘the absolute truth’, but must be regarded as a structured calculation method, as good as possible. The consequence is also that the user of the system might deviate from the proposed default multiplication factors and PRPs, when he or she thinks that there is a need for in a specific case.

The most relevant questions with regard to the use of the 5 proposed s-eco-costs subcategories, and its sum in terms of total s-eco-costs are:

1. Are these 5 indicators sufficient?
2. Are these 5 indicators accurate enough?
3. Why are there two different methodologies (marginal prevention costs and marginal compensation costs) and is that not causing overlap?
4. Is it acceptable to monetise or not, and even: can social aspects dealt with by LCA?

The answer to the first question. (“are 5 sufficient?”), in general, is no. The 5 s-eco-costs subcategories must in future be extended with more categories. So this paper must be seen as the start of a development, not as the end. On the other hand, we belief that for this case (i.e. support for design and supply chain management of clothing) these 5 subcategories are among the most important categories to focus on, as has been argued in Annex 2.1.1. of the Supplementary Materials. The same is probably true for supply chains where mining of metals are dominant (a lot of mines have terrible working conditions). For supply chains of clothing we feel that the main missing category is one that should describe possible calamities like the collapse of a building (Rana Plaza), or a sudden break-out of a fire. Our attempt to develop an indicator for safety in buildings failed so far because of two reasons: a simple PRP cannot be defined, and LCA is not suitable to incorporate the risk of a calamity (Risk Analysis software tools can deal with this issue, but cannot be integrated with S-LCA).

The answer to the second question (the accuracy) is that

Table 3
The s-eco-costs (in €/piece) of a T-shirt and a pair of Jeans for different production chains.

Indicator	Case 1 (W) T-shirt (€/T-shirt)	Case 2 (A) T-shirt (€/T-shirt)	Case 3 (ABP) T-shirt (€/T-shirt)	Case 1 (W) jeans (€/jeans)	Case 2 (A) jeans (€/jeans)	Case 3 (ABP) jeans (€/jeans)
Min Acc Wage Deficit	0	0.045	0.241	0	0.135	1.918
Extreme Poverty	0	1.321	0	0	11.668	0
Occ. Safety&Health	0.046	0.095	0.092	0.384	0.759	0.755
S-eco-costs total	**0.046**	**1.461**	**0.333**	**0.384**	**12.561**	**2.674**

Table 4
The eco-costs (in €/piece) of a T-shirt and a pair of jeans, cradle-to-gate.

Indicator	Case 1 (W) T-shirt (€/piece)	Case 2 (A) T-shirt (€/piece)	Case 3 (ABP) T-shirt (€/piece)	Case 1 (W) jeans (€/piece)	Case 2 (A) jeans (€/piece)	Case 3 (ABP) jeans (€/piece)
Human Toxicity	0.03	0.04	0.04	0.08	0.12	0.11
Eco-toxicity	0.11	0.18	0.14	0.34	0.55	0.44
Resource Depletion	0.18	0.21	0.21	0.54	0.64	0.64
Carbon Footprint	0.27	0.31	0.28	0.82	0.93	0.86
Eco-costs total	**0.59**	**0.74**	**0.67**	**1.78**	**2.25**	**2.05**

Table 5
The eco-costs and s-eco-costs (in €/piece) of a T-shirt and a pair of jeans, cradle-to-gate.

Indicator	Case 1 (W) T-shirt (€/T-shirt)	Case 2 (A) T-shirt (€/T-shirt)	Case 3 (ABP) T-shirt (€/T-shirt)	Case 1 (W) jeans (€/jeans)	Case 2 (A) jeans (€/jeans)	Case 3 (ABP) jeans (€/jeans)
Eco-costs total	0.59	0.74	0.67	1.78	2.25	2.05
S-eco-costs total	0.05	1.46	0.33	0.38	12.56	2.67

qualitative indicator methods in S-LCA as well as E-LCA cannot be accurate in the absolute sense. Although the attempt is to make it as accurate as possible, the reality is that there are always a lot of underlying assumptions and normative choices, as we describe in the first paragraph of this Section. The weakest step in the system is the step from an PRP to the DALY. We expect a factor 2 to maximum 4 as uncertainty, but statistical data are lacking. This uncertainty is low in comparison with the best toxicity tables in E-LCA which have an uncertainty at midpoint level of a factor 100–1000 (Rosenbaum et al., 2008). Just like E-LCA this is not a reason to reject the DALY, since a norm is always better than nothing. The monetisation step from DALY to € 80,000 can be considered rather robust. It is not only based on medical practice, but also on the political fact that rich countries spend about 10%–12% of their GDP on health care (OECD, 2015b).

The answer to the third question is that we deliberately apply in our method the two methods: marginal *prevention* costs for Maximum Acceptable Wage, and marginal *compensation* costs for the other 4 categories. The consequence is that we have, deliberately, a kind of overlap (note that double counting of this overlap is avoided, see Section 2.3, Fig. 3). The overlap is related with the fact that when the Minimum Acceptable Wage Deficit is zero, the problem of Extreme Poverty has vanished, and Child Labour and Excessive Working Hours will probably vanish as well. When the user of the s-eco-costs has that opinion, they are free to apply only the 2 categories (Minimum Acceptable Wage and OSH). We feel however, that the rather criminal behaviour of some companies cannot be neglected in the system by the argument that the problem might be resolved in the far future (when extreme poverty is eradicated by salaries which are high enough for everybody).

The answer to the fourth question (on monetising) is a matter of the different Cultural Theory paradigms in the sustainability debate (Tukker et al., 2008; Vogtländer et al., 2010). This theory is about individual attitudes, beliefs and perceptions, and has been used in recent years to analyze policymaking conflicts. The theory distinguishes between 3 types of people (egalitarians, hierarchists, individualists), who think fundamentally different about how to resolve future risks. The philosophy of the marginal prevention costs (the basis of the eco-costs and the s-eco-costs), as a way to resolve the sustainability problem in our future economy, is widely accepted (Vogtländer et al., 2002) by the individualists (the dominant paradigm of business people) and the hierarchists (dominant in governments), but not by the egalitarians. Since the egalitarian paradigm is dominant in the world of LCA scientists (Vogtländer et al., 2010), monetary systems (EPS, 2000, ExternE/NEED, Ecotax, 2002, Eco-costs) are not popular in LCA. In governmental policy analyses, however, monetisation of external costs is quite common.

The discussion on whether or not LCA is applicable to social issues, is mainly focussed on the issue that not everything can be dealt with in LCA, since LCA is highly related to the product and company level, as described in Section 1.1. Most categories and subcategories in UNEP/SETAC (2009) are relevant on the level of a region, which means that the s-eco-costs system needs a vast expansion before it can be made relevant for policy making on the level of a country. This also characterises the difference between the current set of s-eco-costs (developed for design and supply chain management) and the Social Hotspot DataBase and PSILCA.

4.2. The issue long term versus short term and the triple P

A most relevant issue is the question to what extent is it allowed to apply S-LCA.

In Jørgensen et al. (2010) and Jørgensen (2013) the authors argue that an unsustainable supplier might lose its supply contract as a result of S-LCA, which is for Jørgensen (2013) a reason to *refrain* from making an S-LCA (since the positive and negative effects of it are too complex). Indeed the described situation (about the case of Nike) in his paper is negative on micro scale for the local community on the short term; however, it is positive for sustainable suppliers in that country on the long term, which is what we need in the required transition towards a more sustainable society. On the level of countries, the situation is more complex. In the garment industry, there is a severe competition between countries to attract foreign investors. Foreign garment factory owners, however, threaten governments to leave the country when the minimum wages are set too high (Reuters, 2015). This is the classical tension between the 'P of Profit' and the 'P of People' (Elkington, 1997). We argue that the only way out is that big retailers force countries to take action for a better minimum wage and still purchase in that country. Therefore we plead for making S-LCAs, so that the unsocial issues in the production chain become transparent, provided that the use and communication of it will be done with care.

Arvidsson et al. (2015) argue that Child Labour is necessary in extreme poor families to be able to buy enough food, so child labour should *not* be incorporated in S-LCA since this issue is too complex to handle. The argument makes sense on the micro scale of the family and possibly in the short-term. But on a macro scale and in the long run the deployment and exploitation of children in supply chains can not be ignored and must be prevented. Likewise illegal production chains must be eradicated, which can be considered as one of the (corporate social) responsibilities of the retail industry in developed world. Vermeulen (2015) has a plead for an 'all inclusive' approach, preventing that improvement strategies follow short term hypes that tend to shift solutions to problems in other areas. Such an approach should address simultaneously E-LCA, S-LCA and LCC. Hauschild et al. (2008) suggests that often E-LCA and S-LCA point in an opposite direction. However, in the long run both tools provide answers as to what has to be done on the road towards a sustainable economy. As it is written by Brundtland et al. (1987, page xii): *"The downward spiral of poverty and environmental degradation is waste of opportunities and of resources. In particular it is a waste of human resources. These links between poverty, inequality, and environmental degradation formed a major theme in our analysis and recommendations. What is needed now is a new era of economic growth – growth that is forceful and at the same time socially and environmentally sustainable."*. This suggest that the Triple P is not about 'or' but about 'and'.

4.3. The combination of E-LCA and S-LCA in the case of clothing

An important issue is how these s-eco-costs of S-LCA compare to the eco-costs of E-LCA (see Fig. 1).

Data on E-LCA of garments are provided in (Van der Velden et al., 2014) for ReCiPe points, carbon footprint and eco-costs per kg. Estimates of data for a T-shirt and a pair of jeans are provided in Table 4. Table 5 shows an overview of the eco-costs and the s-eco-costs per case study of Fig. 5.

It may be concluded from Table 5 that the social un-sustainability of the Asian production chains seems to be of higher importance than the environmental sustainability from the point of view of external costs, but that does not mean that we should pay less attention to the environmental issue.

Recent LCA studies (Roos et al., 2015a, 2015b; Van der Velden et al., 2014), show the real hotspots in modern garment chains, enable benchmarking, and reveal that the use phase is not anymore the main hotspot, as was claimed by Allwood et al. (2006). The responsibility is widely acknowledged by the garment industry (SAC, 2015), however, until now it is hard to check the reliability of benchmarks (Made-by, 2015; EPL Kering, 2015) and scorecards (Nike, 2015) in the sector, mainly because of in-transparency, lack of underlying data presentation and scientific basis, and system flaws. We would like to argue that it would be beneficial for the garment industry when businesses adopt scientific LCA and eco-design (Van der Velden et al., 2015) as reliable and trustworthy methods rather than developing their own methods and metrics through which sometimes the own products seem to score better than in the scientific LCA indicators.

Another interesting issue is how the eco-costs and the s-eco-costs in Table 5 compare to the price of T-shirts and jeans. The cheapest price for T-shirts in European discount shops is around € 2, the high-end brands sell for € 30–80. When the minimum fair wage is paid to all people in the production chain, we calculated (by taking the difference between the Minimum Acceptable Wage and the actual wage per piece) that the total extra production costs per T-shirt would be around € 0.43 (and € 3.36 for a pair of jeans), excluding VAT and profit margin. This would not be any problem for high-end brands as such: the consumers who buy these brands are, in general, prepared to pay a few cents more for 'clean' clothes. For the discount shops, however, these extra production costs will increase their sales price considerably, which reveals a conflict of interest between the poor people in the developing world and the poor people in Europe who buy these shirts.

Fashion companies have been heavily criticized - mainly by NGOs, but increasingly by authorities and consumers after the Rana Plaza collapse on April 24, 2013 - for unsocial operational management in their upstream supply chain. We would like to highlight here that these companies have restricted purchasing power, because of invisible subcontracting in the textile and garment producing countries: garments are often not made where you think they are made. Exactly the same issue of subcontracting is as well a thread for correct s-eco-costs calculations. Therefore it is important in supply chain management to track and trace the specific garment flow and collect the right data (not only via the management of the suppliers, but also from the workers themselves). It is probably due to this subcontracting that we could not find much evidence that the agreed minimum wage by the big garment companies is really getting in the hands of the shop floor workers.

5. Conclusions

The s-eco-costs system as presented in this paper provides a lot of transparency in the complex issue of social sustainability in the developing world in general, and in the garment production cases under study.

The general assessment based on minimum wages in several countries with textile industry shows that the total s-eco-costs of Bangladesh (€ 27.78 per hour, based on the average minimum wage of 0.25 int $ PPP per hour, paid to workers in Bangladesh) and Myanmar (€ 19.96) substantially exceed those of the other countries (see Table 1). Furthermore the total s-eco-costs (ad € 5.67) of the Best Practice situation in the Bangladesh textile industry (when the workers are paid 0.90 int $ PPP per hour, based on the minimum wage for the garment industry in that country) are on the same level as Sri Lanka, India and Vietnam (€ 5.91; € 5.15 and € 5.03 per hour respectively). Belgium and the USA show the lowest outcomes (€ 0.84 and € 0.80 per hour) due to the s-eco-costs of Occupational Safety and Health only.

On the product-level of a T-shirt, the cradle-to-gate s-eco-costs calculations point out the garment production phase (the sewers on the shop floor) in Bangladesh and Myanmar as the social hotspot (total s-eco-costs per T-shirt are € 1.39 and € 1.00; see Table 2).

The s-eco-costs over the life cycle of a pair of jeans show a similar pattern as the s-eco-costs of a T-shirt. The total s-eco-costs for a pair of jeans are about eight times higher than those for T-shirts (see Table 3). Even for the Asian Best Practice cases for T-shirts and jeans, the total s-eco-costs are relatively high compared to the US/Europe situation (about seven times higher).

With the presentation and validation of the s-eco-costs method in this paper we aim to accelerate further development of the S-LCA method, for hotspot analyses and benchmarking of unsustainable production chains. We realize this study is limited to just one ('worker') of the five stake-holder categories of UNEP/SETAC (2009), but we think that it does make sense to focus on this category at first.

We hope the way of thinking behind this s-eco-costs method will be inspiring for accelerated method development for quantitative assessment of social sustainability aspects of (clothing) products.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jclepro.2017.03.161.

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