Critique of selected peer-reviewed publications on applied social life cycle assessment: focus on cases from developing countries

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Received: 12 June 2018 / Accepted: 8 November 2018 / Published online: 17 November 2018
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Abstract

The social aspect of sustainable and ‘clean’ production/manufacturing technologies is researched and understood by means of social life cycle assessment (S-LCA), a life cycle sustainability assessment (LCSA) tool, which is still in its infancy. In this paper, a search for all peer-reviewed publications on applied Social LCA, which have appeared in scientific journals, between O’Brien et al. (Int J Life Cycle Assess 1(4):231–237, 1996) and the latest one at the time of writing (April 2018), was carried out, using Scopus as the repository and using ‘S-LCA’ or ‘SLCA’ or ‘Social LCA’ or ‘social life cycle assessment’ as search phrases in title, abstract and keywords of publications, separately. Overall, 213 publications were unearthed, and the trend shows that there has been a near-exponential increase over time. A little over 55% of these publications—121 to be precise—were applications of S-LCA—often in combination with environmental LCA and life cycle costing analysis, in an LCSA. This paper discusses the contributions of a selected subset of these 121 publications to the body of S-LCA knowledge, with the focus being restricted to applications in developing and transition economies of the world, on the premise that there is a more urgent need to understand social aspects of production and manufacturing in these parts of the world. A SWOT analysis of S-LCA has been carried out towards the end. There is a consensus among many researchers that while LCC and E-LCA have matured a lot over time, S-LCA, the newest of the trio, is evolving slowly to become a harmonised tool which can serve as an effective complement to the aforesaid two, in LCSAs of products and processes in industry.

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s10098-018-1644-x>) contains supplementary material, which is available to authorized users.

Extended author information available on the last page of the article

Graphical abstract

Keywords Life cycle sustainability assessment · Social life cycle assessment · S-LCA · S-LCA · Social LCA

Introduction

The aspect of ‘cleanness’ in production is twofold—social (moral, ethical) and environmental (techno-physical). This is restricted not merely to the production/manufacturing stage of a product’s life cycle but also to the upstream (supply of raw materials and components) and the downstream (use and end-of-life handling). The social aspect is researched and understood by means of social life cycle assessment (S-LCA), a life cycle sustainability assessment (LCSA) tool, which is still in its infancy (Mattioda et al. 2015). As

observed by Bocoum et al. (2015), researchers are yet to arrive at a consensus regarding the selection of the right indicators. Along with the better-entrenched environmental life cycle assessment (E-LCA, its environmental counterpart) and life cycle costing (LCC), S-LCA makes a triple-bottom-line approach to LCSA of products, processes and projects, possible (Alanne and Mälikki 2016). The focus of this article is not on the operational combination of the three tools referred to, to analyse the sustainability of production processes. Readers may refer to Alanne and Mälikki (2016) for a clearer understanding of the same. Figure 1 depicts the

Fig. 1 E-LCA, LCC and S-LCA and the combinations in which they can be used in sustainability studies

combinations of tools used to carry out uni-dimensional, double-bottom-line and holistic sustainability analysis of systems. E-LCA traces its origin to the late 1960s as far as the ideation is concerned and to 1991 as far as the christening as LCA is concerned (Baumann and Tillman 2004). LCC also established itself as a decision-making tool in the 1970s, while S-LCA is the newest of the trio, which made its first appearance in the literature in the second half of the 1990s.

In the two decades after the very first paper on S-LCA was published (O'Brien et al. 1996), a few reviews have appeared in peer-reviewed journals (Petti et al. 2018; Arcese et al. 2018, for example). Russo Garrido et al. (2018) critically reviewed 32 selected publications from the period 2006–2015 and analysed the plethora of approaches adopted by researchers performing type I S-LCA. Three years before that, Chhipi-Shrestha et al. (2015) had concluded *inter alia* that the diversity of S-LCA methods/approaches may be misleading, as they would lead to different results that would confuse decision-makers. In that very year, Bocoum et al. (2015) had recommended consensus among S-LCA researchers as regards the standardisation of indicators, a point which was taken up later again by Kühnen and Hahn (2017) who believed that such standardisation was indispensable for what they termed as the 'maturation and establishment' of S-LCA. There have also been some reviews focusing on the need for application of S-LCA to specific sectors and product groups—like the information, communication and technology sector (Arushanyan et al. 2014); automotive sector (Tarne et al. 2017; Zanchi et al. 2018); waste-to-energy sector (Zhou et al. 2018); road infrastructure sector (Hamdar et al. 2016); bio-based value chains or the bioeconomy (Macombe et al. 2013; Martin et al. 2018; the latter reviewing indicators from a Swedish perspective alone); and the agribusiness sector (Delcour et al. 2015; De Luca et al. 2017). Mancini and Sala (2018) reviewed the published literature to identify and discuss about relevant S-LCA indicators for the mining sector.

For this paper, the author first read peer-reviewed publications on applied Social LCA, in scientific journals, between O'Brien et al. (1996) and the latest one at the time of writing (April 2018), before selecting a subset of the papers read, for a more detailed review. The methodology adopted is first described briefly, and then, it is followed by a structured and systematic presentation of the results and findings. The novelty of this review process is the classification of the papers on the basis of the sectors to which S-LCA has been applied, selection of a subset on a well-defined premise and a discussion centred around some 'talking points' raised in the publications relevant to future developments in the theoretical, methodological and application-related aspects of this sustainability analysis tool. In addition, the paper also provides a good overview of the temporal (historical trend) and geographical spread of S-LCA publications till date,

their distribution among different scientific journal publications and a SWOT analysis of S-LCA in "Discussions" section, based on the observations made by researchers in their publications.

Methodology

Source

Scopus was the only repository the author availed of, to obtain a list of, and access therefrom, to publications focusing on S-LCA in general. The search was conducted in the second week of April 2018. The basic premise for selecting Scopus was the well-known fact that Scopus is the largest database in vogue, and therefore, there is a likelihood of most (if not all) publications related to known fields of research like S-LCA, being accessible using it. Of course, there may be some journals and therefore publications which may tend to get left out, but this may be small fraction and therefore negligible. A claim of comprehensiveness is therefore not being made here. The range is certainly limited by the choice of the source and the rationale behind it. Scopus, however, accounts for 14,000 journal titles from 4000 publishers, and hence, it was considered safe to rely on it for this review paper.

Search

The search phrase used was 'S-LCA' or 'SLCA' or 'Social LCA' or 'social life cycle assessment' in title, abstract and keywords separately. Only peer-reviewed scientific journal publications were considered; conference proceedings, editorials, letters, notes and books/book chapters were excluded from the analysis. There were of course some papers which figured in any two or all three of these lists. To a great extent, it can be assumed that all papers which have any of the above terms—full acronyms, partial acronyms or the entire expansion—in their respective titles restrict their focus to social life cycle assessment, or that social life cycle assessment is one of the many foci of the publications (in which a double-bottom-line or a complete life cycle sustainability assessment has been carried out). 'Social life cycle assessment' was also used as a part of the search phrase, bearing in mind that the acronym might not have been as popular, as it is today, in the past.

Screening and elimination

(It was observed that s-LCA (with a lower-case 's') has also been used as an acronym for *simplified* life cycle analysis, *screening* life cycle analysis, *static* life cycle analysis and *streamlined* life cycle analysis in some publications, where

the analysis referred to is environmental and not social; it is also an acronym used in medicine to abbreviate lymphotoxicity screening assay and is commonly used in informatics and computing to denote smallest lowest common ancestor, or in cellular manufacturing for single-linkage cluster analysis.) All the matches were therefore carefully screened. The Venn diagram in Fig. 2a is a useful illustration which categorises the 213 publications—applied S-LCA and otherwise—into seven different categories, with respect to the search terms and the title, keywords and abstract. The focus was subsequently narrowed down to the applied S-LCA publications, and Fig. 2b categorises them in vein similar to Fig. 2a.

Scoping and subset for review

In order to narrow down the scope further, for the sake of brevity, the spotlight was cast on S-LCA application papers

originating from (and focusing on products and systems in) the developing and transition economies (identified by excluding the 39 developed economies defined by the International Monetary Fund in IMF (2016)). The rationale behind this choice is intuitive—there is a more pressing need for understanding social aspects of production chains in these parts of the world, vis-à-vis the developed countries, relatively speaking. A limitation here would be the exclusion of most papers published by researchers based in the developed countries and focusing on geographically spread-out supply chains extending to the developing and transitional countries as well. However, some papers of this nature have been included in the analysis.

Among the list of 213 publications, the following countries belong to one of the two categories mentioned above, either as countries of origin of the publications (Table 1) or as case study locations for papers originating in the developed world—Algeria, Bangladesh, Brazil, Cameroon,

Fig. 2 A summary of the search results, with the intersection sets. **a** All publications on Social LCA. **b** Only applied Social LCA publications

Table 1 Geographical distribution of all the S-LCA publications

Region/continent	Countries which figure in the list as <i>places of origin</i>	# countries	# publications
North America	Canada, USA	2	24
South and Central America	Brazil, Peru	2	7
West, East, Central and Southern Africa	Ghana, Mauritius, South Africa, Uganda	4	5
Middle East and North Africa (MENA)	Algeria, Kuwait, Lebanon, Iran, Israel, Turkey	6	12
South Asia	Bangladesh, India, Pakistan	3	3
Western and North Europe	Austria, Belgium, Denmark, Finland, France, Germany, Ireland, the Netherlands, Norway, Sweden, UK	11	92
East and Southern Europe	Greece, Italy, Poland, Portugal, Spain, Switzerland	6	45
East Asia	China, Japan, Taiwan	3	16
ASEAN and Australasia	Australia, Indonesia, Malaysia, New Zealand, Philippines, Thailand	6	9
Total		43	213

China, (Democratic Republic of) Congo, Ecuador, Ghana, India, Indonesia, Iran, Kenya, Kuwait, Lebanon, Malaysia, Mauritius, Mongolia, Pakistan, Peru, the Philippines, Sierra Leone, South Africa, Thailand, Turkey, Uganda and Western Sahara which is now a disputed territory governed by Morocco. This subset was whittled down in the last step to include only the application-related publications (Table 2).

Literature review and analysis

Trend over the years: all publications and journals

This section presents information about all the 213 publications first, before delving deeper into the whittled down subset for a more detailed analysis and discussion. O'Brien et al. (1996) coined a new acronym, which perhaps has not been used so often over the last 22 years. SELCA, which is present in the title of O'Brien et al. (1996), stands for social and environmental life cycle assessment. On date, there are 89 publications (of the 213, as shown in Fig. 2a) which have one of the search terms referred to in "Methodology" section, in their respective titles. 'Social LCA', 'SLCA', 'S-LCA' and 'social life cycle assessment' were used for the first time in paper titles by Yamaguchi et al. (2002), de Haes (2008), Ying and Yang (2014) and Jørgensen et al. (2009), respectively.

Only 14 publications appeared in the first 14 years—1996–2009, before a conspicuous increase in the annual output was noticed. In Fig. 3, the time period 2006–2018

has been considered, with 2006 being designated as year zero ($x=0$, in the best-fit curve equation shown in the figure). A very clear exponential increase is seen over this period of time. In 2017, there were 39, and in 2018, fifty-six papers have already been accepted/published. Figure 4 which includes all the 213 publications also gives one the impression that S-LCA is slowly but surely gaining popularity as more and more journals seem to be accepting publications related to the development of this tool or its application. From just two journals in 2011, the number of journals with S-LCA papers rose to 14 in 2017. Only four of the 45 odd journals have published 10 or more S-LCA papers thus far, the International Journal of Life Cycle Assessment accounting for nearly 50% of the total of 213, followed by the Journal of Cleaner Production (22), Sustainability (21) and the Journal of Industrial Ecology (10)—refer Fig. 5 which depicts the spread of these 157 publications over time.

Geographical distribution

All the 213 publications were first sorted based on where the case study was conducted (where applicable), otherwise based on the country in which the first author's university/institute/organisation is located. (For the source data, please refer to Supplementary Material.) Table 1 shows the region-wise distribution of all the 213 publications.

Eleven countries in Western and North Europe—dominated by Germany—account for 92 of the 213 publications (43.2%), while Eastern and Southern Europe (led by Italy, which equals Germany in the total number of publications,

Table 2 Sectors focused on, in the selected applied S-LCA publications originating from (and/or focusing on) the developing and transition economies of the world

Sector	Publication/s with full or partial focus—review and applications
Agriculture, forestry and dairy farming	Bouزيد and Padilla (2014), Cardoso et al. (2018), Cortez et al. (2015), Feschet et al. (2013), Franze and Ciroth (2011), Prasara-A and Gheewala (2018), Zortea et al. (2018)
Building and construction	Hosseiniyou et al. (2014), Babashamsi et al. (2016), Dong and Ng (2016), Hossain et al. (2017)
Chemicals, cosmetics and pharmaceuticals	Brent and Labuschagne (2007), Xu et al. (2017)
Energy and fuels	Ren et al. (2015), Ghaderi et al. (2018), Ekener-Petersen et al. (2014), Ekener et al. (2018)
Equipment, machinery, automobiles and white goods	Arvidsson et al. (2018), Dreyer et al. (2010), Islam et al. (2018), Pastor et al. (2018), Reuter (2016), van Kempen et al. (2017)
Fashion and jewellery	Arvidsson et al. (2018)
Food and beverages	Bouزيد and Padilla (2014), Prasara-A and Gheewala (2018)
Mining and metalworking	Singh and Gupta (2018)
Society and households	Fan et al. (2018)
Textiles and related consumer goods	Lenzo et al. (2017), Musaazi et al. (2015), van der Velden and Vogtländer (2017)
Transportation	Agyekum et al. (2017), Arvidsson et al. (2018), Ekener-Petersen et al. (2014), Ekener et al. (2018)
Waste management/recycling	Foolmaun and Ramjeawon (2013a, b, c), Aparcana and Salhofer (2013b), Hu et al. (2013), Umair et al. (2015), Teah and Onuki (2017), Aleisa and Al-Jarallah (2017), Mirdar Harijani et al. (2017)

Fig. 3 Increase in the number of Social LCA publications over time follows depicts a clearly exponential trend (years 2006–2018 shown; refer Supplementary Material for source data)

Fig. 4 Number of journals in which the Social LCA publications were published increased over time, indicating the growing popularity of this nascent field of research (refer Supplementary Material for source data)

with 32) contribute 21%. Mauritius leads the African quartet (Algeria being counted among the MENA countries) pack with two publications, and Brazil the South and Central American duo with 6 publications. The top ten countries (as shown in Fig. 6) account for 70% of the total.

Applications to sectors: in developing and transitional economies

Table 2 summarises the foci adopted by the selected applied S-LCA publications (originating in the developing and

Fig. 5 Four journals with 10 publications or more each, over the period 1996–2018, accounted for over 73% of the total number of all the Social LCA publications

Fig. 6 Top ten countries in the list of 43, led by Italy and Germany

transition economies). Some papers may have multiple foci—for instance, the Algerian study by Bouzid and Padilla (2014), which focuses on not just tomato cultivation but also the food processing sector. It is seen that this is a tiny subset of the larger set of 121 applied S-LCA publications from the period 1998 to 2018 (April), consisting of only 41 publications (about 34%). The subsections below present an analysis of the important findings and recommendations from these publications, followed by a discussion of some important

‘talking points’ culled from these as well as the other papers read, in the form of a SWOT analysis of S-LCA.

Society and households

In a very recent Chinese case study, Fan et al. (2018), focusing on green buildings (or green residential areas), interviewed stakeholders identified as ‘real estate developers’, ‘construction companies’ and ‘local government’ (all three

comprising value chain actors), and the residents (consumers in this case). They then used the analytic hierarchy process (AHP) method to obtain weighting factors for the social themes defined. All the stakeholders accounted for were in favour of improving the living conditions in green residential districts—in other words, they deciphered a willingness to spend (among the residents) and a willingness to invest (among the construction companies and the real estate developers). The top-down support—from the local government—was also strong enough, indicating no conflicts of any kind in going ahead with such improvements. Housing retrofits generate some employment in the building and construction sector and depending on what is/are being retrofitted may have a slightly negative impact on the disposable income of the households. This may be more than offset by the positive impact on indoor air quality and the health of the inhabitants. Of course, it would be necessary to perform an LCSA to verify the assumed offset and determine the environmental impacts (avoided and caused) by the retrofitting operations, and that brings weighting factors for the three dimensions into the picture. The AHP method used by the authors for weighting the different social themes can be extended to the other two dimensions of sustainability and the criteria thereof.

Process and manufacturing sectors

Chemicals In a relatively older publication—vis-à-vis the others in the subset being reviewed—the South African process industry was advised by Brent and Labuschagne (2007) to proactively include social sustainability thinking in the initial phases of their projects. This paper was more of a demonstration of the usefulness of S-LCA as a tool, rather than a full-fledged application.

Dreyer et al. (2010) considered the four ‘worker’ impact categories—forced labour, child labour, discrimination and freedom of association—and chose six different companies from six different countries. Two of these were from the developing world—Malaysia and Brazil. The authors derived a cumulative so-called company risk score—between zero and one—and ended up with the result that the Brazilian firm with 0.46 had the highest risk, followed by the Malaysian (0.42), while the other four which were based in the developed world scored between 0.14 and 0.34. Dreyer et al. (2010), of course, narrowed the scope of their paper to include only the Worker category, but this, rather than being considered as a limitation, ought to be looked upon as a well-intended focus on the lot of workers in developing and developed countries. It clearly communicates the differences between them, using aggregated single scores.

A method similar to the one developed by Schmidt et al. (2004) for the German chemicals major BASF (*Badische Anilin und Soda Fabrik*)—SEEBalance®—was

used by Xu et al. (2017) in China, to compare and rank three different ammonia production routes—coal–syn-gas–ammonia, nuclear energy–hydrogen–ammonia and hydropower–hydrogen–ammonia.

Food and beverages The paper by Bouzid and Padilla (2014) encompasses both the agricultural and the food processing sectors, as it studies the supply chain of canned tomatoes in Algeria. On the downstream, at the cannery and nursery stages of the chain, the working conditions are favourable. This is in stark contrast to what prevails at the farm-level upstream. The farm work environment is marked by hard labour with negative impacts on worker health, the absence of the freedom to form trade unions and the presence of child labour. Having identified the impact categories here on the upstream, the recommendations for improvement must be fairly straightforward. However, S-LCA here is merely a tool which can be used to communicate the status quo to decision-makers and advise them on the measures which could be taken to truncate the social footprint of the products/services in question. LCSA carried out to optimise social welfare, economic development and the health of the environment will lead to desirable changes, only if it is subsequently supported by effective policy-making and good governance.

Textiles and related products Lenzo et al. (2017) have used the subcategory assessment method (SAM) developed by Ramirez et al. (2014) and availed of the social hot spots database (SHDB) (Benoit Norris 2014), to study the social impacts of garment production in Italy which imports cashmere from Mongolia. (This method–database combo is analogous to how E-LCA is conducted and the choice of one or the other is motivated by the suitability to the case study.) The risk values for the Mongolian end of the chain for almost all the social themes are quite high (child labour in particular). The question, however, is whether the Italian garment manufacturer can exert pressure on the Mongolian supplier/s and promote social responsibility. Here, one can recall the decision-maker analysis which is a part of the interpretation step of an E-LCA, where the ability of the final producer in the chain to influence the environmental sustainability of the players in the supply chain is analysed. The authors have not availed of the worker hours table in the SHDB to weight the cumulative risk values for each player in the supply chain and determine the ‘hot spots’ with regard to the product of the risk value and the percentage contribution to the total labour hours per unit output. This, in the opinion of this author, may be looked upon as a drawback of this paper, as following through till the end and expressing the contribution of all the players to the total social impact, and also relative to the Mongolian supplier, could

have provided additional useful and easily communicable information.

Just as there are eco-costs or ecological costs which are externalities that need to be internalised into the life cycle costs of a product, van der Velden and Vogtländer (2017) have developed a methodology for determining socio-economic costs and applied the same to compare three supply chains for T-shirts and jeans. This is an ingenious approach which at once provides a monetary value to the social damages caused by the supply chain, and informs any top-down (taxes) or bottom-up (voluntary contributions by the consumers) efforts which could be made to allay the damages upstream. One of these is entirely in the Western world (USA–Belgium), and the other two are based in Asia (China, India and Bangladesh). By factoring five subindicators encompassing child labour, fair wages, working hours and poverty, the authors determined the socio-economic externalities for the chosen products. They ranged between € 0.05 and € 1.46 for T-shirts, and between € 0.38 and € 12.56 for a pair of jeans, with the all-Western supply chain performing the best in both cases (in other words, having the least socio-economic costs). The supply chains in this paper have been assiduously chosen to drive home the differences among the developed and developing countries on the one hand, and the effect of improvement in standards in the developing world courtesy consumer demands and top-down regulations.

In an extremely enlightening and practical analysis, Musaazi et al. (2015) have compared indigenously manufactured sanitary pads with imported ones in a Ugandan case study. Making sure that it is both available and affordable to everyone in Uganda is a social (health-related) imperative. Additionally, manufacturing within the country for the domestic market contributes to employment generation and therefore socio-economic well-being and economic development. The authors also showed that it is not just the improvement in the socio-economic aspect but also the decrease in the environmental impacts, which make the locally produced MakaPads more holistically sustainable than the imported Libresse alternative. In this study, the results of the S-LCA happen to complement those of the E-LCA, each playing the role of being a sustainability (or suitability) ‘verifying tool’, in a ‘confirmatory test’, so to say.

Mining and metallurgy In the first-ever elaborate S-LCA publication originating in India, Singh and Gupta (2018) have chosen a case study from the steel sector. This analysis is characterised by its comprehensiveness with regard to the selection of stakeholders, impact categories and indicators to be measured. Singh and Gupta (2018) have stressed on the need to collect data at a more granular local level and use it in concert with regional-level data from government reports. The geographical spread of

the stakeholders even within India implies great diversity, and that necessitates the use of site-specific data to reduce uncertainties which arise due to generalisations using proxies. The authors believe that S-LCA results when clearly communicated to companies can aid them in designing and initiating social projects and awareness drives. The uncertainties associated with the subjectivity of the weighting factors which are needed for the aggregation of the impacts are a ‘necessary evil’, which can at best be handled by performing an uncertainty analysis to inform the end-user accordingly. Singh and Gupta (2018) hopefully will set a trend for S-LCA research in India, a developing country which needs to make concerted efforts to balance social welfare with economic development and environmental upkeep in this century.

Equipment, components and jewellery Arvidsson et al. (2018) have, *inter alia*, studied the supply chain of gold jewellery—to estimate the human health impacts (both environmental and social) in terms of net DALY or disability-adjusted life years. The methodology for estimating the DALY related to environmental emissions during the product life cycles, accidents, injuries and deaths in workplaces, and also the presence of conflicts (minor skirmishes to civil wars) in the regions where the players in the supply chain are located, has been clearly explained. The authors have concluded that the net DALY for the gold jewellery is positive, making it a health-taker, while the catalytic converter studied in both Arvidsson et al. (2018) and Islam et al. (2018) could be either a health-taker or a health-giver depending on the degree of recycling and the duration of the use phase. However, the focus in Arvidsson et al. (2018) has been only on health impacts on stakeholders, and not on other social themes like contribution to economic development, fair wages and child labour. This may seem to be a limitation, as the negatives with respect to health, tend to get unduly magnified, if one does not consider any possible positive trend in any of the other social themes. However, in this particular case, when the Democratic Republic of Congo is one of the sources of gold in Arvidsson et al. (2018) and also the supplier of cobalt in the comparative analysis of lithium–nickel–manganese–cobalt (Li-NMC) and lithium–iron–phosphorus (LiFeP) automotive batteries, done by Reuter (2016), one may safely assume that apart from the absence of fair wages and the persistence of child labour, there is no contribution as such to meaningful economic development in that country. The mining of both gold and cobalt is associated with a host of social ills in this conflict-ridden, war-torn country where human rights abuses have been rampant. Just as the gold jewellery (with gold being mined in the DRC) was a health-taker in Arvidsson et al. (2018), the Li-NMC battery scores poorly vis-à-vis the LiFeP alternative in Reuter (2016).

In Schau et al. (2011), the remanufacturing of alternators in Germany, India and Sierra Leone was studied. The S-LCA results showed that the social risks associated with siting the plant in India and Sierra Leone were considerable, and if these countries wished to compete with Germany, they would need to truncate their social footprint considerably. Supply chains converging to automotive manufacturing firms have their own water (and carbon) footprints. Even though the total consumption of water (or energy) during the life cycle may be more or less the same for supply chains of similar automotive parts, the geographical locations of the players in the chains determine the relative degrees of criticality of water (or energy) usage. Here is where Pastor et al. (2018) have applied the Social Water Scarcity Index to assess instrument panel suppliers based in South Africa, Germany and China to the German automotive industry. The index relates to the risk of exposure of the local community and society to deteriorating water supply and sanitation facilities, for which the industrial water user may be partially responsible. This risk is the highest when the component is sourced from China, and tapers down appreciably if the assembler decides to source from the German supplier. The narrowing down of the scope in Pastor et al. (2018) to calculate what they have termed as a Social Water Scarcity Index is something quite novel, and seems to be driven by an interest in understanding the competing uses of water and its uneven distribution in the world.

van Kempen et al. (2017) applied LCSA to compare the supply chains of kitchen sets from India and Kenya, distributed in two refugee camps in Kenya. Socially and environmentally, the results favoured local sourcing, quite similar to what Pastor et al. (2018) found out in their case study of instrument panel supplies to the automotive sector in Germany. The complementary nature of the socio-economic and environmental aspects in this Kenyan case study is similar to that uncovered by Musaazi et al. (2015) for a case study in a neighbouring country—Uganda. In general, local enterprises are favoured for the lower-end developing countries in Africa, Asia and Latin America, from a sustainability point of view.

Agriculture, forestry and dairy farming

Cut roses have a burgeoning market worldwide and play an important part in the socio-economic development of many countries. Franze and Ciroth (2011) have chosen Ecuador and the Netherlands and performed a double-bottom-line (socio-environmental) comparative analysis, following the UNEP/SETAC guidelines. The social issues in Ecuador raise red flags. While employment generation is highly desirable, efforts ought to be made, according to the authors, to ensure that child labour is discouraged and international conventions and codes of conduct are not violated in this South

American country. This paper again brings out the stark differences between the developing and the developed world, when it comes to the social aspects of production of similar products for the global market. Even if the environmental footprints of similar products originating from two different parts of the world may be more or less the same, there could be conspicuous differences in their social footprints.

An interesting observation from Cardoso et al. (2018) in their holistic, triple-bottom-line analysis of sugarcane cultivation in Brazil is the two-faced nature of automation—low employment rate on the one hand and a negligible accident/injury rate on the other. Quite like sugarcane, soybeans are also raw materials for both the food and fuel sectors in Brazil. Brazilian soybean cultivation is the focus of Zortea et al. (2018). In a very insightful LCSA, the authors have concluded that while the environmental sustainability can be regarded as good, the social and economic aspects need to be improved. In the S-LCA, they have tried converting qualitative measures to semi-quantitative ones and have identified that as a limitation which needs to be overcome. While fertiliser and pesticide use, quite intuitively, is the environmental hot spots demanding attention, Zortea et al. (2018) have identified the lack of adequate education and training of value chain actors and workers as a concern which needs to be overcome. Among all the stakeholders considered, the local community and society fares the poorest.

Sugarcane has a history associated with slave labour all over the world, and it is a known fact that the populations of many countries that were colonised in the past are comprised of a significant proportion of descendants of slave labourers on fields and farms. Slave labour or otherwise sugarcane cultivation is a labour-intensive process. Prasara-A and Gheewala (2018), working against the challenges imposed by difficulty in data collection and poor data quality for the Thai sugar industry, have concluded that sugarcane trash burning, which affects local health and safety, low wages and violation of land and water rights are aspects which deserve immediate attention. Farmers are the focus of the study carried out by Cortez et al. (2015), in the manila hemp farming sector of the Philippines, in which the authors have recommended the provision of earplugs to the farmers to counter the risk of loss of hearing and have observed that the farmers do not receive their fair share of the proceeds from the sales of the farm outputs.

Energy, infrastructure, transport and service sectors

A double-bottom-line approach was adopted by Hosseini et al. (2014)—a paper which has been cited prominently by Singh and Gupta (2018) in their steel sector case study—to compare the life cycles of steel and concrete as inputs to the building and construction sector in Iran, from raw material acquisition to disposal, from environmental and social

perspectives, using material flow analysis (MFA), E-LCA and S-LCA as tools. Steel emerged as the better overall alternative, with a lower social footprint, though the authors identified that human rights and working conditions (accidents, low wages and absence of job security) need to be redressed in the future, in the Iranian steel sector. Concrete production on the other hand was seen to have a more adverse impact on living conditions (noise pollution, destruction of natural habitats, etc.), for people in the local community, vis-à-vis steel production. How the different social themes or for that matter environmental impact categories are prioritised for the analysis plays a key role in determining which of the two alternatives is socially/environmentally more sustainable.

Dong and Ng (2016) have reiterated what Arcese et al. (2013) wrote about the strength of quantitative and semi-quantitative indicators over the qualitative ones when it comes to the effectiveness of communicating the results to stakeholders, in their paper which presents a social impact model for construction (SMoC) (also discussed in Dong and Ng (2016) as a tool in LCSA for buildings), and applies it to a construction project in Hong Kong. Irrespective of whether indicators are quantitative, qualitative or semi-quantitative, the difficulty in precisely defining what a social impact is and how to estimate it is according to Babashamsi et al. (2016), a major weakness of S-LCA which needs to be overcome, if it could serve its purpose effectively as an appraisal tool in pavement project management.

The bicycle is rightly touted as an environment-friendlier and health-positive means of transport. While that is true in the use phase of the bicycle, it is important to study its life cycle from cradle to cradle (including the recycling of its component parts at the end of life). Agyekum et al. (2017) have compared the use of steel, aluminium and bamboo as possible materials for the bicycle frame, and concluded that environmentally, bamboo is well and truly the best alternative. They, however, have observed that safety gear is not provided to workers during harvesting operations and this has a detrimental impact on 'safe and healthy working conditions'. However, the authors have set the system boundary for the S-LCA around the life cycle of the bamboo components of the bicycle and excluded the supply chains of the China-centred aluminium and steel alternatives, which may very well have larger social footprints. A more holistic LCSA would provide more information about the relative benefits of the alternatives over each other. Nevertheless, the main purpose of this paper was to provide practical advice to the value chain actors (business owners) in Ghana, who could contribute to truncating the social footprint of the bamboo bicycle frames, as much as possible.

Brazil has been in the forefront in sugarcane-based bioethanol production, just as it also has a fair share in cultivating the raw material for soybean-based biodiesel. Souza et al. (2018) differentiate between the original

first-generation bioethanol production and the prospective second-generation technology in which both sugarcane and straw recovered from the fields are inputs to the biorefinery, and conclude that the former contributes more to employment generation in the agricultural sector, while the latter has the added advantage of generating employment in the secondary and tertiary sectors of the Brazilian economy as well. In these sectors, according to the authors, wages and working conditions are likely to be better and work-related health impacts lesser. While the focus of Souza et al. (2018) was only on the social dimension of sustainability, analysis of the other two dimensions—environmental and economic—will provide a more holistic outlook of sustainability. Biogas is a renewable form of 'carbon-neutral' energy and finds favour with decision-makers keen on truncating the carbon footprint of a country's energy sector.

Environmental analyses of fossil fuels (gasoline and diesel) vis-à-vis biodiesel and bioethanol are more common than a comparative S-LCA between these two families of automotive fuels. Ekener-Petersen et al. (2014) in the first-ever such comparative study used the SHDB (Benoit Norris 2014) to study eight different supply chains originating in crude oil (Norway, Russia, Nigeria) and biofuel crops (France—maize and wheat, USA—maize, Brazil—sugarcane, and Lithuania—oil seeds) and involving domestic or international transport after or before the refining processes. The findings were extremely insightful and showed that biofuels too display high risks of adverse social impacts. The country of origin of the crude oil or the biofuel crop played an important part in the severity of these impacts. Four years later, in Ekener et al. (2018), which can be looked upon as a development over Ekener-Petersen et al. (2014), the authors narrowed down the focus to gasoline from Nigerian and Russian oil, and bioethanol from Brazilian sugarcane and US corn. An LCSA was carried out using multi-criteria decision analysis which studied the effect of four different weighting schemes—egalitarian, hierarchist, individualist and equal weighting—on a sustainability index incorporating the three dimensions of sustainability. Bioethanol from Brazilian sugarcane emerged as the most sustainable option, holistically, while bioethanol from US corn ended up being the least sustainable in all but one weighting scheme. This just goes to show that one cannot generalise that biofuels are more sustainable than fossil-based transportation fuels. A holistic sustainability assessment needs to be carried out on a case-by-case basis. Arvidsson et al. (2018) in their study of the life cycles of catalytic converters, airbags and gold jewellery (the last named has been discussed earlier in this article) make an observation with respect to 'positive social impacts' being exported by the developing world to the developed world, while the negative impacts are borne by the upstream of the product's life cycle which happens to be concentrated in the developing world—this is true for

biofuels consumed in the developed world, but originating from fuel crops cultivated in the developing world.

It is clichéd that data uncertainty plagues life cycle assessments, be they E-LCA or S-LCA. The reliability of the final results and the recommendations made therewith, are highly dependent on the quality of data—its consistency, relevance with regard to time and geography, reproducibility, completeness, representativeness and precision (Baumann and Tillman 2004). Ghaderi et al. (2018) have found a way around data uncertainty issues in LCSA (of which S-LCA is a part), by applying multi-objective robust possibilistic programming to holistically analyse a switchgrass-based bioethanol supply chain in Iran. In Ren et al. (2015), wheat, corn and cassava were compared as potential sources for bioethanol production in China. A multi-criteria decision-making method, in combination with AHP and VIKOR (*Vlsekriterijumska Optimizacija I Kompromisno Resenje*, which in Serbian means multi-criteria optimization and compromise solution), with a weighting factor of close to 60% to the environmental dimension and about 16% to the social, put bioethanol from cassava right on top. Cassava, most notably, unlike wheat, is not a common food crop in China, and hence, food security is not hampered in any way by utilising more of it for other purposes. For wheat, food security was accorded the highest weighting factor among the three social criteria considered—contribution to economic development, employment benefits and food security.

Waste management and recycling

The informal recycling sector in the developing world is a source of employment and income to many poor families. This is the main reason why governments of developing countries are wary of dismantling it. Any disruption of the informal sector which may result from efforts made by the government or the private sector to ‘formalise’ it can be disastrous for several families. However, there often are social issues in this sector, which raise red flags. Umair et al. (2015) have studied the social impacts of informal recycling of electronic wastes (a good proportion of which is imported) in selected big cities in Pakistan, on four stakeholder categories (the consumer phase was excluded) and 15 social themes among them. They have qualitatively determined (exactly like Franze and Ciroth 2011 did for cut roses) that the final rating is ‘very negative’ for eight of the social themes, while positives to salvage from this sector include a contribution to economic development, absence of forced labour, decent wages which enable sustenance to some degree and also the fact that there is no discrimination of any kind when it comes to employment in the sector. It is interesting to note that these positives do not exist in the gold mining sector in the Democratic Republic of Congo, studied in Arvidsson et al. (2018). Aparcana and Salhofer

(2013b) applied the methodology developed and presented by them elaborately in Aparcana and Salhofer (2013a)—which incidentally appeared in the same issue as the sequel mentioned—for three recycling systems in Peru, considering 3 impact categories, 9 subcategories and 26 indicators. The recommendations, which the authors have given, to truncate the negative social footprint of the informal recycling sector in this South American country include the improvement in anti-discrimination policies (note the contrast to the Pakistan case study in Umair et al. (2015), where there is no discrimination), employment terms, occupational health and safety training and adult education.

Foolmaun and Ramjeawon (2013a, b, c) had focused on the end-of-life handling of another polymer—polyethylene terephthalate (PET)—in Mauritius from a double-bottom-line perspective—environmental and social. In the S-LCA conducted for four different scenarios—landfilling, incineration + landfilling, recycling + landfilling (two different splits)—for three stakeholder categories (consumers and value chain actors were excluded) and eight social themes, the scenario in which 75% of the PET waste was recycled and 25% landfilled emerged as the best alternative, socially and environmentally. Including the economic dimension to convert this to a holistic sustainability analysis, by also factoring in possible top-down interventions like taxes and subsidies, would have made a substantial addition to the significance of this paper for waste management researchers and also for decision-makers in Mauritius.

One of the strengths of S-LCA, despite the lack of consensus among researchers as far as the impact assessment methods and the choice of indicators are concerned, is its ability to communicate results qualitatively or semi-quantitatively to decision-makers. (Of course, this may not be as effective as communicating results quantitatively, with the aid of well-defined indicators and measurement techniques.) This is what Teah and Onuki (2017) have done to stress on the indispensability of increasing the degree of phosphorus recycling from sludge and manure in Japan. While abiotic depletion of the phosphate ores and the environmental impacts associated with the mining and processing of the same can be analysed using E-LCA as a tool, and the concept of scarcity rent can be used to inform the unavoidable rise in the cost of extraction and refining and therefore in the prices farmers have to pay for synthetic fertilisers, the human rights violation in the Western Sahara region (one of the major exporters of phosphate rock to the world), which is the highlight of Teah and Onuki (2017), makes the dependence on phosphate ores undeniably and indisputably unsustainable on all counts. However, as a sequel to this publication, one must also analyse the sustainability of different methods of phosphorus recovery in Japan from different waste streams—from a triple-bottom-line point of view. Highlighting the possible net socio-economic benefits, the

Japanese farmers may enjoy and hereby will present phosphorus recovery from waste streams to reduce the dependence on imports of mineral phosphates from Western Sahara, in a very positive light. This may also inspire governments of other countries like India for instance, which is highly dependent on phosphate imports to sustain its agricultural sector and feed its ever-increasing population.

In an LCSA conducted in Kuwait, Aleisa and Al-Jarallah (2017) found out that among six different solid waste management (SWM) alternatives—different combinations of incineration, landfilling, recycling and composting—100% incineration turned out to be the most socially acceptable (although economically unfavourable), contrary to 100% landfilling which was ranked lowest in this regard. The authors conclude with the caveat that the uncertainties associated with S-LCA results of SWM vary widely across cultures, ideologies and degrees of socio-economic development. This is not unusual as it is often the choice of the system boundaries which determines the final results of a life cycle analysis, be that environmental or social. After all, cultures and ideologies form an integral part of the social aspect of sustainability.

Mirdar Harijani et al. (2017) carried out an analysis similar to the Kuwaiti one in Aleisa and Al-Jarallah (2017), for Iran. They compared different combinations of material recycling, anaerobic digestion, composting, landfill with methane gas recovery and advanced thermal treatment, and showed that an improvement in the social sustainability comes at a cost—profits decrease and the environmental impacts tend to increase. This is in stark contrast to the complementary nature of the socio-economic and environmental benefits in the Ugandan case study of Musaazi et al. (2015), as discussed earlier. However, when one of the aspects of sustainability improves at the cost of the other two, prioritising and weighting are often needed in order to determine whether the measures undertaken to improve social sustainability are holistically sustainable. For a developing country like Iran, which also needs to guard against environmental degradation to sustain its socio-economic development, one can assign equal importance to the three aspects and proceed to determine whether the measures analysed are holistically sustainable.

Discussions

A SWOT analysis of S-LCA can be conducted on the basis of affirmations made by researchers in S-LCA publications read (213) and reviewed (41) in this particular paper. The **SWOT** here includes **Strengths** of S-LCA which are being utilised currently, **Weaknesses** which are known and need to be overcome, **Opportunities** which can be availed of once the weaknesses are overcome, and **Threats** to the entrenchment

of S-LCA as a sustainability analysis tool along with E-LCA and LCC, if the **Opportunities** which can be availed of, are not, owing to persistent **Weaknesses**. Here, it is apt to note that **Strengths** and **Weaknesses** are inherent to the tool, and the development of the tool over time will serve to magnify the former and diminish the latter. However, **Opportunities** and **Threats** are external factors—**Strengths** enabling S-LCA to avail of the former, and **Weaknesses** undermining it, in the wake of the latter. This section therefore clubs together strengths and opportunities on the one hand, and weaknesses and threats on the other.

Strengths and opportunities

As Aleisa and Al-Jarallah (2017) and Cardoso et al. (2018) have observed, E-LCA needs to be compounded with S-LCA and LCC as the financial and social aspects of any system cannot be overlooked if an analyst wishes to prove feasibility and credibility at a strategic level to decision-makers. In other words, S-LCA helps to set up what could be labelled as an ‘inclusive business model’ (Thomas et al. 2014) which would assume responsibility for the health, safety and well-being of workers, the local community, society, the environment and economic development. In Lenzo et al. (2017), for instance, the Mongolian player in the supply chain accounted for the largest share in the social footprint of the product sold by the Italian firm. When such facts are uncovered courtesy an S-LCA, the final producer can assume the responsibility to induce its suppliers to enforce corporate social responsibility and contribute to truncating the social footprint of the product/s sold eventually in the global marketplace (Dewulf et al. 2015).

A detailed evaluation of all the risk levels—from low to very high—is necessary to get a complete picture of the hot spots in the supply chain of a product. S-LCA is a tool which is capable of such an evaluation, given the availability of reliable and comprehensive data. Often, one would like to focus on the high-risk nodes of the supply chain only, at the expense of the low-risk ones. But an understanding of the dynamic nature of the social impacts needs to be imbibed, so that any possibility of a low-risk node deteriorating to a high-risk one is not overlooked. This is where the periodically updated SHDB (Benoit Norris 2014) serves as a pillar supporting S-LCA analyses.

S-LCA uncovers not just the adverse social impacts a process may cause, but also credits it for the positive ones (analogous to the avoided impacts for which a process is given credit for, by expanding the system boundaries in an E-LCA). If an S-LCA includes positive social impacts, the contexts in which they materialise are very important when it comes to interpreting the results. In other words, the starting point with respect to which the changes (or positive impacts) are measured determines the context. In order to

elucidate this, we may think of ‘not so good’ to ‘good’ being a significant change, vis-à-vis ‘good’ to a ‘little better’.

As depicted in Fig. 4 earlier, S-LCA is slowly and surely gaining in popularity as more and more journals are accepting methodological and application papers for publication. This is also an indication of a gradual mushrooming of the S-LCA community and if the history of E-LCA (Baumann and Tillman 2004) is anything to go by, maturation of the tool and its firm entrenchment in LCSA as a harmonised tool is not very far away in the future.

If S-LCA can also be used to study the use phase in life cycles in greater detail than it has been done in analyses thus far, the effectiveness and comprehensiveness of the tool can be demonstrated and this would work in its favour. Just as one finds eco-labels on products in the supermarket for instance, the emergence of socio-labels (Nikolaou and Tsalis 2018) is not far away if concerted efforts are made to refine the methodologies and facilitate a globally standard interpretation of the data on the socio-labels. Products which are able to acquire both the labels can be sold at a premium, the reason being transparently communicated to the prospective buyer—the labels, by virtue of their credibility, representing all the data and analyses.

Weaknesses and threats

Researchers are yet to arrive at a consensus regarding the choice of impact indicators, as Bocoum et al. (2015) have observed. Brent and Labuschagne (2007) had pointed out that quantitative approaches to S-LCA were impaired by the absence of global standards in this field of research, and recommended that the use of indicators must be introduced in the analysis of any project in the chemical industry, only when information would be readily available. It must be mentioned that this impasse still exists a decade down the line. However, one must note at this juncture that even E-LCA which is better entrenched now in the field of sustainability research can be carried out using different methods and different sets of indicators (Baumann and Tillman 2004). That begs the question—cannot one likewise think of different methods and therefore different sets of indicators in S-LCA? If E-LCA analysts can use CML, EcoIndicator99, ReCiPe, EPS or EDIP without creating any confusion in the minds of readers and end-users of such results, why must the diversity of S-LCA methods be confusing for S-LCA researchers, as Chhipi-Shrestha et al. (2015) for instance, has stated? Jørgensen et al. (2009) have, however, advocated that as long as one learns to differentiate among usable S-LCA methods, valid S-LCA methods and methods that are likely to yield beneficial results, any element of confusion that may exist can be thwarted easily.

Results in the form of quantitative and semi-quantitative indicators are more effectively communicated vis-à-vis

qualitative ones, as stated in Arcese et al. (2013), though an inability to define quantitative or semi-quantitative indicators for the analysis must not be a reason for not carrying out an S-LCA. This is one of the observations made in Zortea et al. (2018), who found it challenging to integrate qualitative results from an S-LCA with quantitative ones from the E-LCA and LCC in an LCSA done for soybean cultivation in Brazil. Of course, if one would perform just a uni-dimensional analysis, like Teah and Onuki (2017), then qualitative S-LCA indicators will still enable the analyst to communicate the end results effectively. It is not just about whether an indicator is quantitative or qualitative, but also about what exactly is a social impact indicator, how it must be defined and measured, as Babashamsi et al. (2016) have stated in their paper. Even if there would be a large family of indicators to select from, it is essential to know precisely what each one stands for, in the larger scheme of things and standardise the methods of measurement to a certain extent.

Singh and Gupta (2018) encountered challenges with non-availability of site-specific data when they performed an S-LCA of the Indian steel sector. This is a hurdle which needs to be overcome, and it is necessary to differentiate among company-level, sector-level and national-level SAM, as Hannouf and Assefa (2018) have done and recommended, to highlight the errors that may creep in if one resorts to generalisation. Data availability (in order to eliminate the need for proxies) has been and will continue to be the cornerstone of both environmental and Social LCA.

The tediousness which the iterative nature of S-LCA introduces into the analysis often (Smith and Barling 2014) is a perceptible drawback which may temper the advancement of this field of research and application. This can be overcome if one can accept the fact that the complexity is simply a mirror of the reality around us, which the tool it helps us to measure and understand.

Aggregating results to a single social impact score will make communication of the results to non-specialists clearer and easier, but many researchers have advocated caution here, especially when there are conspicuous data gaps and uncertainties (or subjectivity regarding the weighting factors) to be accounted for. It is here that do Carmo et al. (2017) recommend an uncertainty analysis before proceeding with the aggregation based on the weighting factors. The ‘story behind the aggregated score’ tends to become suspect, if there is no clear communication about the possible uncertainties. The weighting factors needed for the aggregation have to be derived through the entire gamut of focus groups—workers, local community, society and value chain actors—for a set of chosen social impact categories. This diversity will confer greater legitimacy on S-LCA as a decision-making tool.

It is also necessary to be aware of the fact that the uncertainties associated with S-LCA results vary widely across

ideologies, cultures and degrees of socio-economic development (Aleisa and Al-Jarallah 2017), and this is quite obvious, as just like E-LCA, the results obtained are dependent on the system boundaries one chooses for oneself. This is not a threat as such, but failure to appreciate this may distort one's understanding of comparative S-LCA results.

Conclusions

In this paper, a literature search was carried out on Scopus for peer-reviewed journal publications with 'S-LCA' or 'SLCA' or 'Social LCA' or 'social life cycle assessment' in title and/or abstract and/or keywords. Overall, 213 publications, over a 22-year period, were unearthed. Well over 50% of the publications were applications of S-LCA to a variety of sectors of the global economy—primary (mining, agriculture, forestry, etc.), secondary (processing and manufacturing) and tertiary (a range of service sectors).

A detailed review and analysis of applied S-LCA publications originating in the developing and transitional economies in the world (41 of the 121) were subsequently done. These 41 papers encompassed 12 industry sectors as defined in Table 2. Some 'talking points' centred around the present and the future of S-LCA were raised. Emergent knowledge was discussed using a SWOT analysis. There are still challenges to be overcome, en route to a consensus regarding standardisation of methodologies and indicator sets, which many researchers have recommended over the last 4–5 years, as indispensable for the maturation and establishment of S-LCA as a reliable tool. It must be noted, however, that applications of S-LCA can lead to different types of deliverables like the Social Water Scarcity Index introduced and calculated by Pastor et al. (2018), for instance, or the offshoot Work Environment LCA (WELCA) developed and applied by Arvidsson et al. (2018), or the opportunity to use companion methods like VIKOR (Ren et al. 2015), or set up new models which could be used by researchers in the future, like the social impact model for construction (Arcese et al. 2013). In this article, the segmentation of the studies on the basis of the economic sectors throws light on the drawbacks associated with generalising the challenges associated with the social aspect of sustainable production and manufacturing. Decision-makers ought to devise tailor-made policies for different sectors of the economy, based on more nuanced knowledge of conditions.

In conclusion, one may state that there is a consensus among many researchers that while LCC and E-LCA have matured a lot over time, S-LCA is evolving slowly to become a harmonised tool which can serve as an effective complement to the aforesaid two, in LCSAs of products and processes in industry. Talking of consensus, however, researchers are yet to arrive at one regarding the choice of indicators,

and the difficulty in defining what a social impact actually is, and how it must be measured, tends to persist. While the use phase figures prominently in an LCC and an E-LCA, it needs to be studied in much greater detail than it has been till date, in an S-LCA, and further development of this methodology must take this into account. From a developing world perspective, a detailed evaluation of all the risk levels—from low to very high—is necessary to get a complete picture of all the hot spots in the supply chain of a product. This article narrowed down its focus to the developing world. Unlike the developed world where ideologies, cultures and levels of socio-economic development are fairly similar (though there are nuances for those who wish to investigate), one finds a veritable palette of ideologies, cultures and levels of socio-economic development in the developing countries and transition economies that understanding the uncertainties associated with the results of S-LCA studies in different regions of the world is an interesting area of research in itself.

S-LCA as a standalone tool is effective in itself, but in combination with E-LCA and LCC, it provides richer insights from the point of view of sustainability, as some publications based on LCSA have shown.

Harking back to the name of this journal, the adjective 'clean' which appears in front of technologies when one talks of 'clean technologies' needs to be interpreted holistically. Environmental policy-making cannot isolate itself from the socio-economic aspects of production and manufacturing systems in the world.

Acknowledgements Sincerest thanks to the reviewers for their highly constructive comments, which enabled the author to revise the manuscript and improve its quality, readability and relevance.

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