Social Life Cycle Assessment in Biobased Industries: Identifying Main Indicators and Impacts

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1 Abstract

Assessing social impacts of various products, services and human activities has achieved an increasing interest worldwide. The nature of sustainability of biobased industries from a social point of view is how and to what extent they are perceived by society, and how various societies take advantages from such activities. However, an important issue is that social factors are not usually easy to be quantitatively analyzed and although the social impacts might be very remarkable, especially at the local scale, they have been not possible to be investigated in the majority of impact evaluations in the past. Despite the existence of many different methodologies towards Social Life Cycle Assessment (SLCA) to address social impacts of various businesses and industries, most of them impartially address social performances of an industry. The aim of this paper is to highlight the main criteria that need to be taken into account in SLCA approaches for identifying the social indicators and impacts of biobased industries that is a timely topic worldwide toward climate change mitigation goals. Accordingly, considering the general approach of SLCA and particularly its inventory analysis phase for impact categories and indicator determinations, the paper provides an overview of the existing guidelines and frameworks for identifying social indicators and impact categories associated with bio-industries. In conclusion, main impact categories and indicators formulated in the existing frameworks applied to biobased industries are demonstrated as a basic set of applicable elements of social dimensions in evaluating bio-industries' sustainability when conducting SLCAs. The state of the art for this study mainly includes leading journal articles, international reports and conference papers up to and including 2016 on SLCA in biobased industries. According to the reviewed frameworks in this study, quantitative, midpoint and site-specific data are the main elements taken into account when collecting the data for biobased product social impact assessment. This study also reveals that although SLCA is in its early steps of development and despite in numerous cases, conducting a comprehensive SLCA is not yet feasible, it has been considered to have substantially promising methodological attributes that can help policymakers and other stakeholders to quantify and assess sustainability of bio-industries from the social perspective. Recommendations for further research work concerning SLCA in bio-industries are also presented.

2 Main text

2.1 Introduction

With about 57 billion € annual turnover and 300,000 direct and indirect job creations, the biobased industries sector is currently providing lots of benefits for the EU[1]. Given that policy developments support the bioenergy and biobased products generation, it is important to be sure about the sustainability of the industry[2,3]. Hence, sustainability evaluation approaches that measure environmental, economic and social impacts are required for biobased industries[4]. With regard to bio-industry, the production and usage of bioproducts and biofuels might have positive and negative social impacts, however, existing research on the social aspects of bio-industry is limited[5,6]. Thus, for assessing the impacts of producing biomass and its processing for biofuels and bioproducts valid data and in depth research is required[7]. Given the entire value chain, there are a large number of social impacts over the whole biobased product chain. Therefore, it is vital to have an effective tool for determining the impacts throughout the complete chain in order to ensure that any positive and negative change in social effects will be captured[8]. Nowadays, there is a growing interest between researchers and industrial experts to expand Social Life Cycle Assessment (SLCA) approaches [(3,9,10)] which are considered as the usual and effective methodology for evaluating the possible positive/negative socioeconomic impacts of products along the life cycle[11]. Compared to the majority of social impact assessment tools working with social aspects in the supply chain, the main reason of such growing interest for applying SLCA is related to the difference in scope and level of the social impact addressed by SLCA since it uses data collected at company, manufacture and process levels for the entire product life cycle[12] while for example Social Impact Assessment (SIA) "only cover a glimpse of some phases of a product's life cycle at a particular time"[(11, p.32)]. The SLCA approach has been carried out in different case studies from various industries (e.g. Bork[13] et al. in the furniture sector; Kruse[4] et al. and Flysjö[14] in salmon production systems) but limited case studies from bio-industries (e.g., Ekener-Petersen[15] et al.; Aparcana and Salhofer[16]; Foolmaun and Ramjeeawon[17]; Prosuite[18]; Manik[19] et al.;

Macombe[20] et al.; German and Schoneveld[21]). The Literature review, thus, shows that SLCA provides the possibility to evaluate a wide range of social effects in a systematic context with a life cycle approach in bio-industries, but also that enhancements in methodological approaches (e.g., development in access to data on social impacts, selecting and measuring the social impacts) are needed[15]. According to a recent review conducted by IUCN[22], more in depth information of social impacts are needed to understand the rights of different groups with regard to the production of biofuel, especially workers, local communities, and women. Given that, the following section provides an overview of the available frameworks and guidelines for the impact categories and indicators identification stage which is directly related to the inventory analysis stage of SLCA for data collection. As a result, a set of applicable elements of social dimensions is highlighted which can be particularly carried out for identifying the social indicators and impacts through SLCA approaches for biobased industries' sustainability assessments.

2.2 Recently developed frameworks and guidelines for impact categories and indicators identification for future SLCA practitioners in biobased industries

In order to efficiently measure and assess the social impacts of bio-industry alternatives when evaluating sustainability of an industry, first indicators that are usable along the entire biobased production supply chain are needed to be determined. This makes it easier for policy makers and planners to judge comprehensively and unbiased in relation to the situation of particular social issues regarding to a range of values and objectives[23]. However, recognizing social aspects and the most suitable method for assessing them differ between supply chains. Since the explicit separation among social and economic impacts of a biobased project is not feasible and such an evaluation would give an incomplete result[24,25], socio-economic indicators are usually considered to be applied on a supply chain of bio-industry[26]. Some social concerns reason behind the fact that stakeholder involved are more interested in making the maximum economic benefit[24]. For example, the smaller scale bio-industry operations usually have higher cost. Nevertheless, the social sustainability policy goals for biofuels encompass improvement of rural development and involving smallholders[27]. Thus as Dale[28] et al suggested, socio-economic indicators such as profitability, social well being need to be considered when evaluating the sustainability of bioenergy systems. A completely critical challenge here for SLCA to work perfectly is to find ways for determining the social impact categories and providing existing data regarding social impacts of (bio)product life cycle stages[29]. The need for the establishment of indicators shows that some critical themes are more important or that needs to be protected more for the industry involved, as a result interpreted as "areas of protection". Weidema[30], Dreyer[31] et al and Fan[32] et al suggest "human well being" as the area of protection in SLCA and fundamental part for all existing SLCA approaches. Furthermore, identifying all stakeholders associated with the product life cycle is a basic matter when conducting an SLCA[33]. These two main concerns are directly related to the second step of the SLCA approach i.e., the inventory analysis where the goal is to gather related data, determined over the scope definition (Fig.1). However, "what type of information is needed to be collected" is still a question that has different answers among the practitioners of various SLCA approaches. In other words, the development of impact categories and indicators, is not the only challenge related to SLCA but data collection also is one of the most challenging issues[3]. Thus, the available frameworks need to be considered regarding the impact categories and indicators and therefore, to be a basis for inventory analysis stage of SLCA to be carried out for identifying the social indicators and impacts of biobased industries.

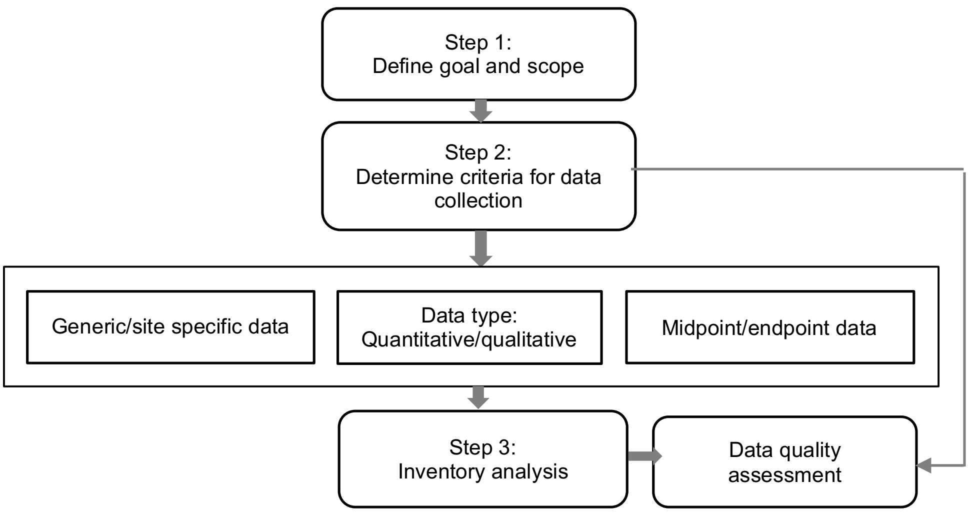

Fig.1. Main steps for identifying indicators of bio-industry SLCA towards inventory analysis step.

SLCA follows the similar four main iterative phases as those applied in Environmental Life Cycle Assessment (ELCA). These include: 1. Definition of the goal and scope; 2. Life cycle inventory analysis; 3. Impact assessment; 4. Interpretation. As the figure shows, following the scope and goal, geographic location and system boundaries are defined. Afterwards, the inventory phase encompasses the data collection, which will make the evaluation of the social impacts of the product's life cycle possible[34]. Accordingly, depending on the scope of the study, the following main criteria are considered before starting the inventory analysis phase (Fig. 1), in a way that the difference between the life cycle inventory analysis stage of various SLCA approaches would depend on these criteria:

i) **Data type**
The social indicator can be either quantitative or qualitative. There is a common discussion on whether to utilize mainly quantitative inventory information for SLCA or to concentrate more on qualitative indicators and data[35]. Quantitative indicators can be based on calculation in physical units, semi-quantitative scores, or yes/no scales whereas there is no limitation on the type of data to incorporate in the assessment when using the qualitative indicators and, therefore, they can be applied in a more exploratory context comparing to the quantitative and/or semi-quantitative elements[3]. However, it has been suggested that quantitative and qualitative data, indicators and measurements should be combined as quantitative data alone are not enough to represent all dimensions of social impacts[35]. On the other hand, there is a possibility to convert qualitative outcomes into (semi-)quantitative results as proposed by Benoit[12] et al and Dreyer[31] et al.

ii) **Midpoint data vs. endpoint data**
Several SLCA approaches utilize midpoint indicators while others take endpoint indicators into consideration. This difference is related to the indicators location along the impact pathway[3]. The two types of indicators are in essence connected by an impact pathway defining the cause-effect relationship among midpoint and endpoint, however, this relationship is usually not easy to reveal. Since midpoint indicators are very close to the source of impact and also more comprehensible for stakeholders involved and decision makers, Dreyer[31] and Flysjö[14] cited that these are the preferable ones[35]. The midpoint impact is taken to be a spot in the cause-and-effect chain of the impact pathway before the endpoint[36]. Anyhow, the midpoint indicator can be an indicator for a specific subject under a social impact whereas the endpoint indicator is an indicator for a social impact itself which might be more desirable for the decision makers.

iii) **Generic data and site specific data**
Inventory data for SLCA are collected across various scales (i.e., generic or site specific), depending on the availability of time, information and the scope of the research. For a generic study, international, national and/or sector information are usually gathered while the main data source for a specific study would be interviews and data collection at site level though general data might also be gathered[37]. Although generic data can present a general comprehension of the system under study, this does not consider the social variations between regions or the social implementation of a particular organization[8]. As stated by Dreyer[31] et al, what is preferable for the workers may differ, indicating that incorporating the site specific impact categories may be more desirable. Considering site specific data implies, at least, one major issue that instead of considering a unit process dimension, which is the case in ELCA, SLCA should consider a company dimension. Indeed, SLCA calculate the social effects on people, which are associated with the companies' activities in the product chain instead of a solely unit process[32]. Therefore, with regard to bio-industry, the focus would be on the company level as a potential major user group and considering the site specific data is important. Nonetheless, as Dreyer[31] et al pointed out, a combination of top-down and bottom-up approach needs to be applied in order to establish a supportable set of indicators. A top-down approach, in this manner chooses those indicators that represent a picture of widely identified societal values from literature comprising international sustainability standards (e.g., ISO 26000, SA 8000 and Global Reporting Initiative (GRI)). In contrast, the bottom–up approach integrates the preferences and priorities of the stakeholders involved. Such integration should be used in a way that both develop social elements that are desirable for the stakeholders, as suggested by Mathe[38] and also represent the regional condition.
According to these three main criteria, Table 1 provides an overview of the list of recommended indicators in existing frameworks that addresses socioeconomic aspects of sustainability of biosystems. Among the available frameworks, the Global Bioenergy Partnership[39], the EU funded Global-Bio-Pact project[40], Oak Ridge National Laboratory (ORNL) by Dale[28] et al and BioSTEP[41] (2016) specifically focused on the biobased and bio-energy sectors. Some recent references that applied these frameworks for identifying impact categories and indicators in bio-industries are also presented. As the table shows, according to the reviewed frameworks here, quantitative, midpoint and site specific data are the main elements taken into account when collecting the data for biobased product social impact assessment.

Table 1. Overview of the list of recommended indicators in existing frameworks based on the three main criteria of Data type, Impact pathway and scale for identifying socioeconomic aspects of bio-system

guidelines and frameworks	Social impacts categories	Potential indicators	Data type	Impact pathway	Recent References for using Generic/site specific data
Social Life Cycle Assessment of Products ((UNEP-SETAC, 2009)	Stakeholder "worker"	Freedom of Association and Collective Bargaining; Child Labour; Fair Salary; Working Hours; Forced Labour; Equal opportunities/Discrimination; Health and Safety; Social Benefits/Social Security	Qualitative & Quantitative	Midpoint & endpoint	**Generic data:** *Siebert[8] et al.:* Social life cycle assessment of wood-based products from bioeconomy regions in Germany. *Blom Madeleine and Solmar[42]:* How to socially assess biofuels: a case study from Stockholm, Sweden using the UNEP/SETAC code of practice for social- economical LCA **Site specific data:** *Mbohwa and Myaka[43]:* Social Life Cycle Assessment of Biodiesel in South Africa *Chingono and Mbohwa[44]:* Social Impacts of Biofuels Production in the Kwa-Zulu Natal and Western Cape Regions of South Africa *Valente[45] et al.:* Social Life Cycle Sustainability Assessment (LCSA) of New Norwegian Biorefinery
	Stakeholder "consumer"	Health & Safety; Feedback Mechanism; Consumer Privacy; Transparency; End of life responsibility			
	Stakeholder "local community"	Access to material resources; Access to immaterial resources; Delocalization and Migration; Cultural Heritage; Safe & healthy living conditions; Respect of indigenous rights; Community engagement; Local employment; Secure living conditions			
	Stakeholder "society"	Public commitments to sustainability issues; Contribution to economic development; Prevention & mitigation of armed conflicts; Technology development; Corruption			
	Value chain actors	Fair competition; Promoting social responsibility; Supplier relationships; Respect of intellectual property rights			
The GBEP sustainability indicators for bioenergy (2011)		Allocation of land	Quantitative	Midpoint	**Generic data:** *Köppen[46] et al.:* Implementing the GBEP Indicators for Sustainable Bioenergy in Germany *van Dam[47] et al.:* Using the GBEP indicators in the Netherlands bioenergy sector **Site specific data:** *Hayashi[48] et al.:* site-specific data from case study of Kyoto *FAO[49]:* A Pilot Testing of GBEP Sustainability Indicators for Bioenergy in Colombia
		price and supply of a national food basket			
		change in income			
		Jobs in the bioenergy sector			
		Unpaid time spent by women and children collecting biomass			
		Access to modern energy services Mortality and disease due to indoor smoke			
		Occupational injury			
Global-Bio-Pact (2012)	Economics		Quantitative	Midpoint & endpoint	**Using both generic and site specific data:** Seven in-depth case studies in the framework of Global-Bio-Pact: - Biodiesel from soy in Argentina[50] - Palm oil and biodiesel in Indonesia[51] - Bioethanol from sugarcane in Brazil[52] - Bioethanol from sugarcane in Costa Rica[53] - Jatropha oil and biodiesel in Tanzania[54] - Jatropha oil and biodiesel in Mali[55] - 2[nd] generation biofuels and products from lignocellulosic material in Europe - North- America[56]
	Employment generation	Employee income, Employment benefits Income spent in basic needs			
	Working conditions	Hours of work, Freedom of association			
	Health issues	Work related accidents and diseases, Personal protective equipment, OSH training			
	Food issues	Land that is converted from staple crops, Edible feedstock diverted from food chain to bioenergy, Availability of food, Time spent in subsistence agriculture			
	Land use competition and conflicts	Legal title of land right, Communal/ public land, Land conflicts			
	Gender issues	Benefits created for women			
Oak Ridge National Laboratory (ORNL): Dale et al (2013)	Social well- being	Employment; Household income; Work days lost due to injury; Food security	Quantitative	Midpoint	**Site specific data:** *Efroymson[57] et al.:* Socioeconomic indicators of sustainability of algal biofuels *Dale[28] et al.:* Socioeconomic Indicators for Bioenergy Sustainability as Applied to Eucalyptus
	Energy security	Energy security premium; Fuel price volatility			
	External trade	Terms of trade; Trade volume			
	Profitability	Return on investment (ROI); Net present value (NPV)			
	Resource conservation	Depletion of non-renewable energy resources; Fossil energy return on investment (fossil EROI)			
	Social acceptability	Public opinion; Transparency; Effective stakeholder participation; Risk of catastrophe			
BioSTEP (2016)		Food security (including GMO crops); Land access (incl. gender issues & tenure); Employment; Household income; Workdays lost due to injury; Quality of life; Health; Numbers of multi-resistant organisms; Exposure to agrochemicals; Toxicity of 'green' vs. 'grey' industrial products	Qualitative & Quantitative	Midpoint & endpoint	**Generic data:** Hasenheit[41] et al.: Social, economic and environmental impacts of bio-economy

Furthermore, these recent studies revealed that due to the lack of a comprehensive and reliable theoretical framework from which to establish new social indicators, most researchers have to pick up a suite of indicators from available indicators via existing frameworks and desk research. For example, Carrera and Mack[23] investigated literature from the last twenty years and searched for suitable indicators for the assessment of social effects of energy systems. Accordingly, common social indices applied in the reviewed frameworks and study examples include social well being, working conditions, energy security, forced labour, child labour, income, and health and safety[28,31,47]. However, SLCA approaches apply different social indices and a broad range and types of social indicators. Therefore, the suitable choice and development of such elements and indicators continue to stay as one of the critical challenges in SLCA. Thus, which data collection approach to carry and who should be taken into account when identifying stakeholder preferences substantially relies on the scope of the study and the capacities and competency of the SLCA practitioner.

2.3 Conclusions and recommendations

No worldwide suite of indicators is available which can be applied in all cases in the same way[58]. The value of an indicator depends on the data quality it comprises. Therefore, the indicator must be sharply chosen. According to our review, so far there is no one best approach which covers all social dimensions as it really depends on the scope of the study and the priorities of the stakeholders involved in the bio-industry under consideration. Therefore, additional research is required to enhance the partially new and restricted body of knowledge on the social aspects of bioenergy and bio-products. Studies will require to adjust according to the difficulties and complications of sustainability challenges, and the availability of data and tools to identify the main indicators and impact categories. This review provides useful information for future researchers in bio-industry sector in order to help them to identify the social issues based on the main identified criteria for determining the social issues before starting the inventory analysis phase of SLCA for sustainability assessment of biobased industries.

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