Integrating social aspects into sustainability assessment of biobased industries: Towards a systemic approach

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Abstract

Considering its potential impacts on development, biobased industries require to be assessed according to the positive and negative effects they can bring to the society. Typically, the implications of biobased industries are considered in terms of economic, environmental and technical indices while social factors are usually neglected in the majority of impact assessments. This is mainly due to the fact that social issues are not easy to be quantitatively analyzed, measured and monitored. Indeed, the following issues need to be addressed: (i) how the social dimension is understood from different stakeholders' perspective; (ii) how the social pillar can be properly integrated into sustainability evaluation methodologies which are mainly focused on environmental performance and (techno)-economic assessments of biobased industries. This review paper aims to answer these questions firstly through identifying the main social impacts and indicators of the biobased industries at local level in order to find an answer for the second question by analyzing and comparing the current methodologies for assessing social impacts in bio-industries. These methods mainly include Social Impact Assessment (SIA), Socio-economic Impacts Assessment (SEIA) and Social Life Cycle Analysis (SLCA). The latter, although is in its early steps of development, has been considered to have substantially promising methodological attributes for bio-industries' social sustainability assessment. Although ongoing research tackles the incorporation of the environmental dimension into extended techno-economic assessments, no integration of the social pillar into such assessments has been made. Given that, this review focuses on the social dimension for integrated sustainability assessments of biobased industries to assess the main social impacts resulting from each operation or from the bioenergy sector. The current review focuses on the importance of social sustainability indicators and evaluation techniques. By discussing the methodologies for evaluating social impacts, a systemic methodology for assessing and integrating the social dimension into the sustainability assessments of bio-industries is developed, considering the four main iterative steps of an SLCA framework and three useful SLCA-based approaches including Product Social Impact Assessment; Prosuite and the UNEP SETAC Guidelines for SLCA of Products. It is concluded that the term systemic analysis implies that the whole approach needs the capacity to understand different subsystems and relations between them. Accordingly, the systemic assessment of biobased technologies should simultaneously include technological, economic, social and environmental dimensions. The result of this study identifies social impacts in the bio-economy and particularly highlight the importance of considering social issues in biobased industries' design and innovation.

1 Introduction

Biobased products are products that are entirely or in some parts extracted from biomass which may have been converted to a biobased product through some chemical, physical or biological processes[1]. Biobased industry has assisted Europe to meet the target of an actual sustainable economy considering its contribution in a total employment of 520,000 direct and indirect jobs and a yearly turnover of around €78 billion[2]. Therefore, biobased product supply chains (Fig. 1), can play a critical role in turning the economy of Europe into a biobased economy. Given that, sustainability evaluation approaches that examine economic, environmental, and social impacts are required for the biobased industries[3] as there are numerous concerns with regard to the environmental (such as biodiversity, soil, water and air quality), social (such as labour and human rights, health issues, food safety) and economic (such as local welfare, job creation) impacts of producing biomass at large scales.

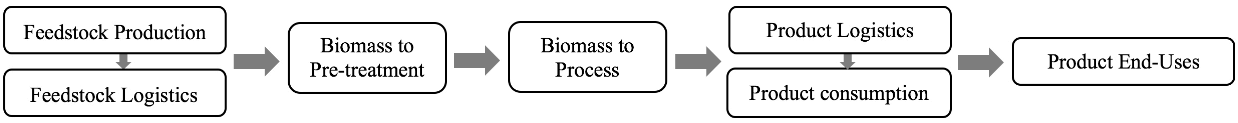

Fig 1. Schematic overview of a general biobased product value chain.

The majority of the existing models assess the economic impacts of biomass supply chains[4,5,6] and environmental aspect of bio-industry[7,8,9,10]. In contrast to the environmental and economic pillars of sustainability evaluations of the bio-industry, the social assessment yet lacks a comprehensive agreement on sufficient indicators or a consistent methodology[11]. Since the clear distinction between social and economic impacts of a biobased project is not possible and such an analysis would present an incomplete result[12,13], socio-economic indicators are considered in this study to be applied on a supply chain of bio-industry. Accordingly, there is a lack of social(economic) data regarding the use of biomass for bioproducts that mainly considers environmental dimensions[14,15]. Although some efforts have been made to integrate social dimensions into sustainability assessment of bio-industries[16,17,18,19], there is no consensus on a standardized methodology to evaluate the impact of a process or a product on local and regional levels. Moreover, most of the social elements that are utilized so far are qualitative and thus not so easy to embed in the sustainability assessment's tools. Therefore, there is a need for developing an approach to integrate social aspect into sustainability assessment of biobased industries to be sure that the technology development is sustainable and can contribute to the consistency of the industry and society. This study provides a review study on the existing methods and tools for assessing the social impacts of the biobased industries. Moreover, based on the current methodologies, this study aims to come up with a systemic approach for social impact assessment of the biobased industries in order to incorporate it into sustainability assessments.

2 Currently available approaches and methodologies for social impact assessment of bio-industry supply chains

Various evaluation methods have been developed to measure the social impacts of projects, programs and policies. As Valente[20] et al. stated, it is quite challenging to define social sustainability since its meaning is not obvious. In general, according to Black[21], social sustainability is "the extent to which social values, social identities, social relationships and social institutions can continue into the future". According to the literature, the main approaches related to the social sustainability assessment of bio-industries include *Social Impact Assessment (SIA), Socio-economic Impacts Assessment (SEIA)* and *Social Life Cycle Analysis (SLCA).* SIA provides knowledge regarding the social aspects of an implement, into the designing, decision-making and management procedure related to that implementation[22]. It is worth to mention that SIA is a principally qualitative approach which is not easy to be completely precise or predictive, particularly because it depends on the fairness of the practitioner and the experience and knowledge or commitment of the involved stakeholders in telling the truth[23]. Besides, the definitions of the SIA and those of SEIA can be compared as both approaches have a lot in common in a way that both assessment types are mixed at some points. However, a clear difference is that in a suitable SEIA both economic and social impacts are investigated. According to Mackenzie[24], the SEIA is the systematic analysis to identify and evaluate the potential socio-economic and cultural impacts of a proposed development of biofuel/bioproduct conversion chains on the local well-being, their families' lives and their communities as a whole. In comparison with the other two mentioned approaches, SLCA provides a more comprehensive picture of the product life cycle, encompassing multiple value chains in its evaluation. Nowadays, there is a growing interest to expand SLCA approaches in bio-industry researches[25,26,27]. An important 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 and process levels through considering the entire product life cycle[28]. Thus, SLCA provides the possibility to evaluate a wide range of socio(economic) effects in a systematic context within the life cycle of bio-industries, however, enhancements in methodological approaches are needed[29].

The same four main iterative stages of the life cycle assessment (LCA) procedure is followed in SLCA based on which various evaluation tools have been developed in order to quantify the socio(economic) impacts of bioprojects. Two important tools include: **Prospective Sustainability Assessment of Technologies** (Prosuite[30]) aimed to introduce a large LCA framework, considering the three aspects of sustainability: environmental, economic, and social and the **Product Social Impact Assessment**[31] which is a quantitative methodology designed to evaluate the social impacts of a product on stakeholder groups involved throughout the life cycle of the product. In the following section, this review utilizes a common assessment SLCA framework and the two mentioned SLCA methodologies for identifying indicators and assessment of social impacts through the whole life cycle in order to develop a new comprehensive tool that can be used to estimate socio-economic impacts of bio systems for the production of bioenergy and bioproducts and to integrate them into sustainability framework for bio-industries.

3 Towards the development of a systemic assessment approach for social impacts and its integration into sustainability assessment of biobased industries

Figure 2 shows the proposed Socio(economic) impact assessment framework developed based on the four general phases of SLCA taking three SLCA-based approaches including Product Social Impact Assessment[31]; Prosuite[30] and the UNEP SETAC Guidelines for SLCA of Products[32] into consideration. At the end, the integration of social aspects into overall sustainability assessment was proposed via Multi Criteria Analysis (MCA). Recommendations provided by corporate level standards[33, 34] for life cycle assessment were also considered for the development of different steps of the proposed framework.

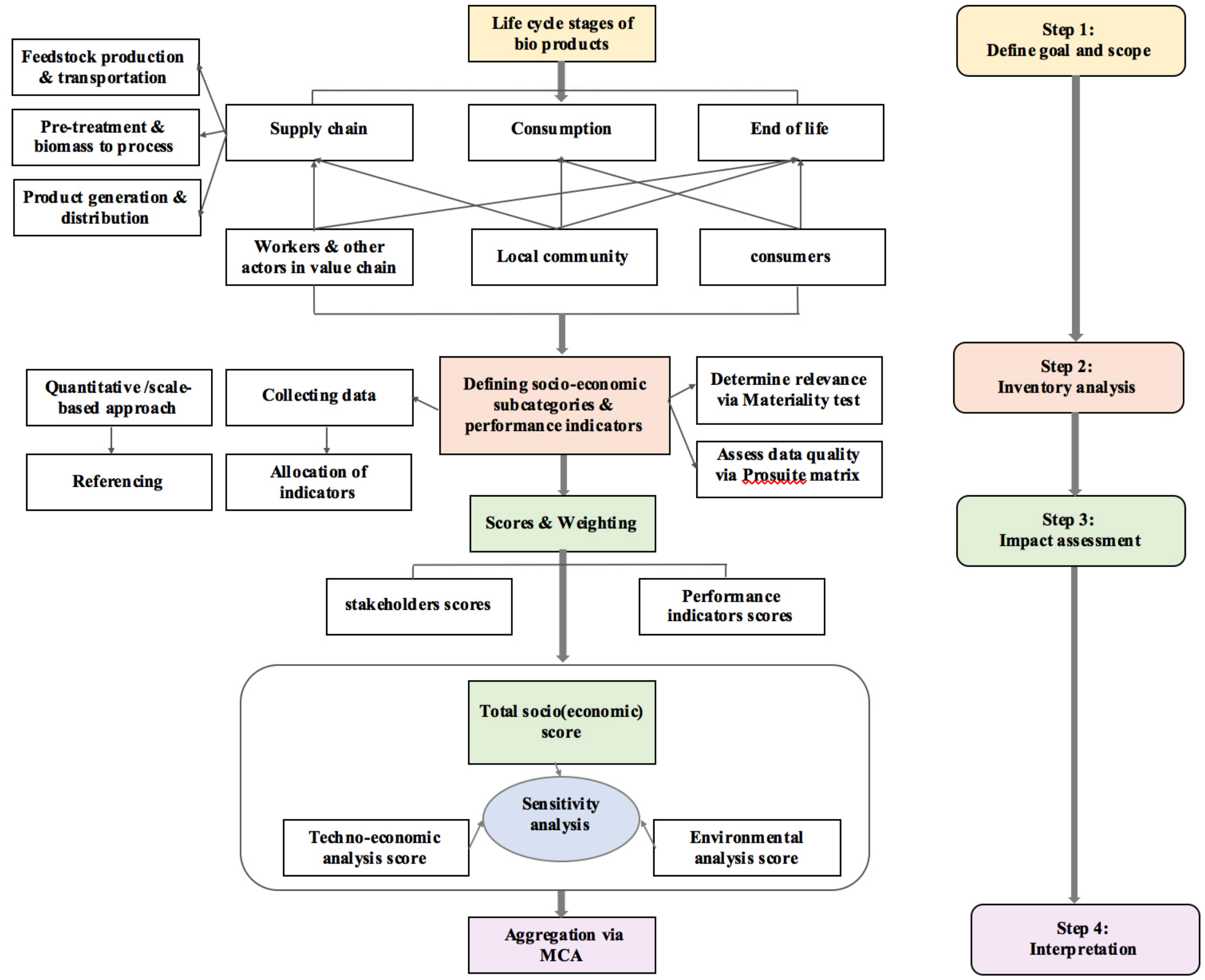

Fig 2. The proposed socio(economic) impact assessment framework & its integration into overall sustainability assessment

As the figure shows, the main part of SLCA approach are the impact categories which in our case comprise social and socio-economic impacts of bio industry supply chains, and are associated to particular stakeholder groups[35], throughout the life cycle of the bio-industry. After the first stage, for inventory analysis, in order to effectively quantify and evaluate the socioeconomic attributes of bio-industry options, the proposed framework in this study uses Materiality test[33] for identifying the relevant impact categories and performance indicators through presenting a comprehensive and universal set of indicators already existing in literature to the stakeholders identified to be involved in the bio-industry under consideration (see ESMAP[36] et al.) for the potential stakeholder groups for biofuel projects). Among the available frameworks, the Global Bioenergy Partnership (GBEP)[37], the EU funded Global-Bio-Pact project[38] and Oak Ridge National Laboratory (ORNL) by Dale[39] et al (2013) specifically focused on the biobased and bioenergy sectors. These frameworks along with other international references and case studies (e.g., Carrera and Mack[40] who reviewed literature from the last twenty years and looked for proper parameters for the assessment of social impacts of energy systems and van Dam[41] (2010) who introduced a list of socio-economic impacts related to biomass production), offer a set of socio-economic sustainability criteria and indicators for biomass production chains to cover the entire biofuel/biomass/bioproduct life cycle**.**

The materiality analysis is conducted via four main steps including (i) identification of social topics and respective performance indicators; (ii) their prioritization; (iii) their alignment with available time and resources and (iv) checking their validation to see whether the social (economic) topics and indicators selections made in the prior steps are stable and reliable, and if not, modify (Fontes, 2016). Afterwards, data will be collected either through quantitative or scale-based approaches proposed by the Product Social Impact Assessment methodology and the quality of data will be examined using Prosuite matrix[30]. In the third stage, the impact assessment will be conducted through weighting the impacts via stakeholder scores and performance indicators scores to finally come up with the overall socio(economic) impacts score of the bio product. Sensitivity analysis also can be performed during the evaluation process and at the end of the sustainability assessment to provide a better insight about the significance of the impact of the assumptions for a specific case study.

Finally, the socio(economic) score needs to be integrated into the sustainability approach for bio-industries. Nowadays, there is a wide range of various methodologies conducted to integrate socio-economic impacts in the overall assessment framework of bio-industry use. A commonly applied methodology is the MCA, which has been broadly utilized in the bioenergy associated fields over the past 15 years[42]. For example, Elghali[43] et al conducted a case study on UK bioenergy systems using the Multi-attribute utility (MAU) method as an Multi Criteria Decision Analysis (MCDA) tool. Furthermore, several studies present technology assessment of clean energy technologies applying the Analytic Hierarchy Process (AHP)[44,45]. AHP is also combined with other methods, for example Antunes[46] et al used AHP in combination with Social Multi-criteria Analysis principles to make a comparison between irrigation technologies in Portugal. Moreover, Halog and Manik[47] suggested a comprehensive framework applying life cycle thinking methods including LCA, LCC, and SLCA; AHP and dynamic system modelling for sustainable assessment of biofuels supply chain. In this regards, Prosuite[48] provides a comprehensive review on the application of MCA-tools for the sustainability assessment of technologies for environmental, economic, and social indicators. Accordingly, in the suggested framework here, aggregation for the total sustainability assessment can be done through the appropriate MCA-tools considering the scopes and goals of the impact assessment for the case under consideration.

4 Conclusions

By supporting the assessment of social(economic) performance of bio-industries, this review can assist these industries to achieve more clarity on the social impacts of their products. We believe that the proposed social impact assessment framework and its integration to sustainability assessment can become the basis for innovation technologies management to consider social(economic) life cycle sustainability assessment of bio-systems at various organization levels.

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