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Transitioning towards the bio-economy: Assessing the social dimension through a stakeholder lens

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Abstract

International institutions are calling for a transition towards more sustainable systems of production and consumption. In this transition, sustainable innovations are expected to play an ever-increasing role. In particular, the production of innovative bio-based products—products wholly or partly derived from biological materials or from innovative production processes and/or innovative biomass such as food waste or forest residuals—will be part of this process. However, the sustainability of such products must be assured along their entire life cycle and across the three dimensions mentioned above. Against this background, our study aimed at identifying a social impact framework tailored to bio-based products. It employed a two-step methodological framework encompassing (a) identification of the relevant social impact categories, subcategories, and indicators and (b) validation of these factors, according to participatory stakeholder involvement. The validation exercise enabled us to consider a restricted number of social indicators so as to reduce the amount of data needed for assessing and decreasing related costs.

KEYWORDS

bio-based products, SLCA, social impacts, social innovation, stakeholder analysis

1 | INTRODUCTION

The dominant approach to the sustainable development debate concerns the dynamics that affect firms' innovation—with particular reference to technological and institutional conditions—and sustainability. To be effectively sustainable, development must embrace three distinct but interrelated pillars: the environment, the economy, and society. Current societal challenges (e.g., climate change, depletion of natural resources, and food security) could foster innovative trajectories that increase firms' competitiveness and contribute to bettering society (Wagner, 2009). Therefore, the development and diffusion of successful sustainable innovations,[1] understood as new business models that are economically affordable, environmentally respectful, and socially responsible (Clark & Charter, 2007), are crucial for stimulating firms' social and environmental responsiveness while enhancing their economic performance (Dibrell, Craig, Kim, & Johnson, 2015). Recently, the European Union and some member states launched strategies aimed at promoting the development of a renewable resource-based bio-economy (e.g., European Commission, 2012; Italian Agency for Territorial Cohesion, 2016). Under their auspices, the bio-economy

[1] See Carrillo-Hermosilla, del Río, and Könnölä (2010) for a list of "eco-innovation" and "sustainable innovation" definitions.

is expected to reduce dependence on natural resources, transform productive models, and promote the sustainable use of renewable resources. However, by increasing demand for bio-based resources, bio-economy concepts impose additional pressures on ecosystems. For example, they may increase the use of forests and agricultural land, potentially beyond planetary boundaries, producing erosion and contamination (Purkus, Hagemann, Bedtke, & Gawel, 2018). In restraining such pressures, a transition towards innovative and sustainable technologies should be sensitive to the utilization of renewable resources (Falcone & Sica, 2019). Thus, sustainable innovation for the bio-economy should ensure: overall competitiveness with respect to traditional fossil-based resources, low environmental impacts, and adequate social acceptability. However, analysis of the overall impacts of sustainable innovations is not straightforward, and a clear perspective on the methods by which such analysis should be conducted has yet to be defined (Ardito, Carrillo-Hermosilla, del Río, & Pontrandolfo, 2018).

A significant body of literature on the performance outcomes of sustainable innovations includes empirical contributions by social scientists with regard to, among other topics: (a) economic, social, and environmental development goals (Montiel & Delgado-Ceballos, 2014); (b) tensions between short-term and long-term returns (Slawinski & Bansal, 2015); and (c) societal effects (Longoni & Cagliano, 2018). However, there remains significant uncertainty as to whether sustainable innovations actually generate a more sustainable society (Hall & Wagner, 2012). Sustainable innovation processes can concentrate on developing new procedures and technologies that meet current market demand, or they may create new market demand for innovative, environmentally friendly products (Iles & Martin, 2013). In particular, they may generate bio-based products with the potential for additional functionality, less resource intensive production, and efficient use of natural resources.[2] The utilization of bio-based products can stimulate a larger transition towards sustainability with socioeconomic benefits (i.e., job creation and economic growth; EuropaBio, 2011). However, although the European Commission strongly supports the production of renewable biological resources and their conversion into value added products and bio-energy (see, e.g., the Bioeconomy Strategy), concerns abound with respect to the sustainability of bio-based products along the entire life cycle, from the provision of feedstock to the end of life (InnProBio, 2018). Therefore, it is of the upmost importance to evaluate the performance of bio-based products in a manner that acknowledges and encompasses different stakeholders' perceptions and impacts; without such an evaluation, it will be difficult to understand and accurately assess the strengths and weaknesses of various sustainability options (Martin, Røyne, Ekvall, & Moberg, 2018).

Life cycle assessment (LCA) methodologies are widely considered the most suitable approaches to measuring the effects of bio-based products (see Canals et al., 2011; Hottle, Bilec, & Landis, 2013). In fact, according to the European Union, the standards and labels—as well as the public procurement—of bio-based products should strongly rely on LCAs (European Union, 2007). The life cycle sustainability assessment (LCSA) framework considers the three pillars of sustainability (economic, environmental, and social sustainability) throughout the entire life cycle of a product (see Zamagni, 2012). Specifically, the LCSA consists of (a) environmental LCA, (b) life cycle costing, and (c) social life cycle assessment (SLCA; Kloepffer, 2008). However, the framework is currently in development and subsequently lacks the required empirical evidence to validate it as an effective measure of the social performance of a bio-based product (Falcone & Imbert, 2018).

Recently, along with emerging comprehensive LCSA studies (see Jungmeier et al., 2016; Keller, Rettenmaier, & Reinhardt, 2015) and research on environmental impacts, there has been an increase in SLCA studies focused on bio-based products (see, e.g., Macombe, Leskinen, Feschet, & Antikainen, 2013; Rafiaani et al., 2018; Siebert, Bezama, O'Keeffe, & Thrän, 2018a). The use of adequate measures could support policy makers in designing a fit-for-purpose social sustainability scheme (with respect to, e.g., standards, labels, and certifications) that effectively addresses product-related impacts on different stakeholders (Jørgensen, Dreyer, & Wangel, 2012). In this vein, an understanding of stakeholder involvement and perception should help to identify the main life cycle social impact categories and indicators worth including in a social sustainability assessment of bio-based products and to operationalize new processes, strategies, and outcomes according to these criteria. SLCA studies on the bio-economy (Ekener-Petersen, Höglund, & Finnveden, 2014; Matos & Silvestre, 2013; Siebert, Bezama, O'Keeffe, & Thrän, 2018b) have recommended a stakeholder participatory approach to the development of measures. However, the use of participatory approaches for the purpose of developing a standardized methodology for SLCA has been insufficiently explored in the literature (De Luca, Iofrida, Strano, Falcone, & Gulisano, 2015). Therefore, in an attempt to acquire new knowledge in this area, research should work towards a new methodological framework of social sustainability that encompasses the viewpoints of different interest groups (i.e., stakeholders).

The United Nations Environment Programme and the Society of Environmental Toxicology and Chemistry (UNEP-SETAC, 2009) guidelines describe social impacts as consequences of positive or negative pressures on social endpoints (i.e., stakeholder well-being). It is widely recognized in the SLCA literature that the identification of social impacts arises from an analysis of the stakeholder categories that represent all social groups of actors affected by production and consumption processes. Grießhammer et al. (2006) identified four main groups of stakeholders: workforce, local community, society, and consumers. Adding to this, the UNEP-SETAC guidelines proposed an additional group of stakeholders—value chain actors. In order to conduct SLCA, it is necessary to identify and understand the most important social domains, in order to determine where social issues most frequently arise. To this aim, SLCA identifies social impact categories in order to group the ways in which stakeholders may be impacted within a particular context (Reitinger, Dumke, Barosevcic, & Hillerbrand, 2011); these categories are related to corresponding stakeholder

[2]According to the European Standard (EN 16575:2014), bio-based products are wholly or partly derived from materials of biological origin, excluding materials embedded in geological formations and/or fossilized. These might include chemicals, lubricants, surfactants, enzymes, pharmaceuticals, cosmetics, and food additives.

groups. At a more fine-grained level of analysis, subcategories aim at representing particular impacts within social impact categories. A further deepening of the analysis is achieved through the identification of social indicators, which act as the bridge between subcategories and impact categories. In this regard, well-defined indicators are extremely important in guiding the data collection process for effective social sustainability assessment (Wu, Yang, & Chen, 2014).

This paper attempts to identify and understand the most relevant social impact categories, subcategories, and indicators that should be included in an SLCA of bio-based products. The objective is to contribute to the development of an appropriate framework for sustainability that ensures that innovative bio-based products effectively contribute to the transition towards a sustainable, bio-based economy. In our research, we first performed a literature review to gather the most common social topics and indicators. Second, by means of a participatory approach involving multiple stakeholder categories (i.e., workers, consumers, local community, value chain actors, and general society), we held two context-related interactive workshops in two European cities (Rome and Santiago de Compostela), with the aim of validating and/or integrating the list of social impact categories, subcategories, and indicators for the social assessment of bio-based products. We believed that this approach might (a) contribute to filling the gap concerning the limited scientific interest in SLCA involving a broad spectrum of stakeholders (see Kühnen & Hahn, 2017) and (b) define a social impact framework tailored to bio-based products.

The remainder of the paper is organized as follows: Section 2 provides a brief overview of the stakeholder analysis applied in SLCA, Section 3 clarifies the methodological approach, Section 4 deals with the research findings, and Section 5 ends with concluding remarks.

2 | THEORETICAL BACKGROUND OF STAKEHOLDER ANALYSIS IN SLCA STUDIES

The relationship between sustainable innovation and stakeholder participation is receiving increased scholarly attention (see, e.g., Ayuso, Ángel Rodríguez, García-Castro, & Ángel Ariño, 2011; De Chiara, 2017; Jorna, 2017). In particular, several studies have utilized stakeholder engagement to define the most relevant aspects for inclusion in the assessment of sustainable innovation (see Gillund, Myhr, Utskarpen, & Hilbeck, 2016; Popper, Popper, & Velasco, 2017). It is worth noting that social assessment, relative to environmental assessment (which is based on highly technical criteria), may involve a broader spectrum of aspects that directly affect stakeholders, ranging from human rights, working conditions, health and safety issues, equity, social responsibility, job creation, and social participation to social capital, access to basic resources, and happiness (Colantonio & Lane, 2007). Therefore, it is central to consider stakeholder perspectives when formulating the most relevant aspects for inclusion in a social sustainability assessment for bio-based products (Morone, 2018).

It is clear that the sustainability assessment of products should include multidisciplinary information incorporating different perspectives on economic, environmental, and social challenges (Cucchiella, D'Adamo, & Gastaldi, 2017). Particular attention should be paid to the social dimension, in order to ensure the enhancement of social capital and the collective capacity to respond positively to sustainability challenges (Lelea, Roba, Christinck, & Kaufmann, 2014). It is therefore necessary to take a broad approach, integrating not only multiple scientific disciplines but also nonacademic perspectives (Lelea et al., 2014). Sustainability assessment should promote a participatory and collaborative approach, considering the knowledge, interests, participation, and values of all categories of stakeholders (e.g., workers, consumers, general society, local community, and value chain actors). According to Blackstock, Kelly, and Horsey (2007), the active involvement of stakeholders in these activities is motivated by many reasons, including (a) the promotion of social learning, (b) the inclusion of multiple perspectives to improve our understanding of problems and solutions, and (c) the prevention or reduction of potential social issues.

Stakeholders should be capable of impacting policy development, as policy implementation is difficult when a participatory approach has not been systematically applied. In the SLCA literature, stakeholders generally appear as actors who are affected by the impacts of a specific product's value chain. However, stakeholders can play other roles in the assessment—for example, defining relevant impact categories or other stages of the LCA methodology and feeding back information on their use of LCA outcomes (Mathe, 2014). Researchers and policy makers should become more sensitive to the role that stakeholders can play in their analyses and make a greater effort to engage stakeholders in this process (Sisto, van Vliet, & Prosperi, 2016).

The identification of stakeholders is an essential step in the participatory approach (Lelea et al., 2014). Stakeholder analysis, which aims at identifying the actors who can most efficiently cooperate with researchers, supports this process. Once identified, stakeholders may be brought together to discuss specific issues. Because social indicators are context dependent, participation adapts indicators to the real context more effectively than expert consultation, alone (Mathe, 2014), and ensures a final set of indicators that more accurately reflects stakeholder values. However, the choice of stakeholders and methodologies always determines the value of the results. Methodologies should include structured techniques capable of supporting participation and interaction and should provide coherent support for public decision makers (Sisto et al., 2016). Specific steps of stakeholder analysis should include (a) defining the supply chains involved in manufacturing the specific bio-based product, (b) identifying the actors involved in that supply chain, (c) formulating the research objectives, (d) identifying the related stakeholders, and (e) selecting stakeholders for the participatory methodology (Lelea et al., 2014).

Bryson (2004) claimed that stakeholder analysis is not only a useful methodology for identifying real problems in the development of a specific industry or policy but also fundamental for providing rational and appropriate solutions. He reviewed several techniques of stakeholder identification and analysis, including organizing participation, creating ideas for strategic interventions, reviewing and adopting proposal developments, and implementing policy. He concluded that important research, education, and practices are needed in all stakeholder analysis techniques.

Sisto et al. (2016) developed a methodology for stakeholder participation, combining both puzzling and powering. As a result of their methodology, the authors observed a positive effect on the democratization of policy making. In particular, puzzling was applied through email surveys and workshops, with the latter enabling stakeholders to share knowledge and visions with experts and to draw possible policy actions. Powering was accomplished through strategy validation questionnaires, which allotted power to each stage of the process. The traditional structure of stakeholder participation includes two workshops; however, it does not guarantee the attendance of the same participants in both. The methodology proposed by Sisto et al. (2016) modified this structure to enable stakeholders to contribute to the entire process. To this end, a questionnaire was sent to a group of stakeholders prior to a workshop. The workshop lasted only half a day, and at the end, participants were asked to complete a short questionnaire about their perceptions of the workshop. One month later, a second questionnaire was sent, asking them to reflect on the procedure and results of the workshop. The authors concluded that this approach was a practical first step for involving stakeholders in areas in which stakeholder participation is not an established practice.

Mathe (2014) suggested a participatory approach based on the "principle, criteria, and indicator" method. This approach uses a hierarchical and embedded framework to relate indicators to contextualized impacts and the general principles of sustainable development. It includes five steps: (a) stakeholder selection; (b) literature review; (c) working groups of social LCA professionals; (d) selection of social principles and impact categories, as ranked and validated by stakeholders; and (e) quantification of social indicators. The authors determined that this methodology has some technical and methodological drawbacks, because it relies on stakeholder commitment throughout the process, follows a multidisciplinary approach, and requires social LCA practitioners to integrate new knowledge and skills.

3 | METHODOLOGY

Our study aimed at contributing to the social dimension of the transition towards bio-based products by identifying and validating the main social impact categories and related indicators pertaining to the bio-based products realm. We employed a robust two-step methodological framework encompassing (a) identification of the relevant social impact categories and stakeholders and (b) validation of the identified categories and related indicators. In the following sections, these steps are outlined in more detail.

3.1 | Social impact categories and stakeholder identification

In the first step, we performed an in-depth literature review focusing on social sustainability and SLCA, as applied to bio-based products. In this endeavor, we consulted two academic databases with wide-ranging coverage of English language scientific journals in the social sciences: Scopus and Web of Science. A broad keyword search was conducted in order to retrieve relevant papers within the publication timeframe of 2002–2018. We paired certain anchor keywords (i.e., "bio*," "soci*," and "sustainab*") with search strings (i.e., "life cycle," "supply chain," "indicators," and "impacts"). Additionally, by means of an iterative method of search and discussion between the authors, additional search words were used with the aim of focusing the analysis mainly on social aspects in the context of bio-based products: "bio-based products," "bio-based products life cycle," "social assessment of bio-based products," and "social indicators of bio-based products." This exercise allowed us to select studies pertaining specifically to the social dimension of bio-based products. Furthermore, in order to also consider studies and reports outside of peer-reviewed academic journals (i.e., gray literature), we used the Google search engine.

Our in-depth literature review uncovered more than 500 papers pertaining to the social performance assessment of products and more than 100 concerning bio-based products. In a subsequent stage, we refined this pool of articles by carefully examining the text of each article in order to ascertain the presence of a well-defined idea or value judgment with regard to the area of investigation. We extended this exercise by also looking at socioeconomic criteria and indicators in existing certifications and standards, as well as indicators proposed by initiatives and research projects (i.e., UNEP-SETAC, Prosuite, Global Bioenergy Partnership, and Global-Bio-Pact). This process enabled us to identify a preliminary list of social impact categories and potentially affected stakeholders to consider in our appraisal of case studies from a social viewpoint.

3.2 | Validation of the social impact categories and related indicators

The second methodological step took the form of two interactive workshops held in July 2018. These workshops were conducted with representatives of the stakeholder categories identified in the previous step: workers, consumers, local community members, value chain actors, and members of the general society. Each workshop lasted between 2 and 2.5 hr and followed the same protocol of action. Specifically, the workshops were introduced by two facilitators, whose aim was to help participants focus on the topic under investigation. The role of the facilitators was crucial for ensuring a well-structured meeting, focus on a common goal and process, a neutral attitude throughout, record of the group's discussion, overall consensus, and productive outcomes (Steinert, Boillat, Meterissian, Liben, & McLeod, 2008). In order to ensure the smooth elicitation of knowledge, a workshop information overview was sent in advance to all participants (see Appendix A).

The interactive workshops were divided into two parts:

- Validation of the social impact categories: Participants were asked to discuss (with peers) the social impact categories and subcategories provided by the facilitator(s) in terms of their relevance for evaluating the sustainability performance of bio-based products.

Unitelma Sapienza, University of Rome *University of Santiago de Compostela*

Source: *authors.*

FIGURE 1 The two workshops [Colour figure can be viewed at wileyonlinelibrary.com]

- Brainstorming on the relevant social indicators: Participants were asked to select the relevant social indicators associated with the previously identified impact categories for the social assessment of bio-based products.

Participants had the opportunity to signal if any impact categories and/or social indicators were missing from the preliminary list proposed by the facilitator(s). After sharing their opinions at the workshops, participants were asked to reach a consensus about the most important social topics for the social assessment of bio-based products.

4 | RESULTS

The review of sustainability assessment analysis for bio-based products identified 21 studies containing information on a cradle-to-gate level and six pertaining to the social impact assessment of bio-based products.[3] The overview identified a total of nine social impact categories that appeared pertinent for the social sustainability assessment of bio-based products: labor rights and decent work, human rights, health and safety, social benefits/social security, social acceptability, economic contribution, food security, fair competition in the market, and migration. Although each of these impact categories can transversally affect different stakeholders (e.g., "health and safety" can be assessed with reference to workers, consumers or the local community), in our research, social impacts were related to a specific stakeholder category by means of impact subcategories—namely, workers (e.g., freedom of association, child labor, and health and safety), the local community (e.g., delocalization and migration, and healthy living conditions), consumers (e.g., feedback mechanisms and end-of-life responsibility), general society (e.g., public commitment to sustainability issues and contribution to economic development), and value chain actors (e.g., fair competition and social responsibility). For each subcategory, one or more social indicators tailored to bio-based products were proposed with the aim of providing participants a comprehensive list from which to select (see Appendix C).

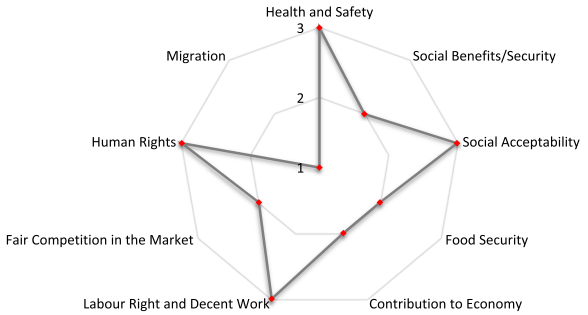
[3]In Appendix B are reported the identified SLCA case studies on bio-based products.

4.1 | Validation of social impact categories, subcategories, and indicators: Stakeholder perspective

To analyze the extent to which the most relevant aspects of social sustainability should be considered in an SLCA of bio-based products, we aimed at establishing which of these aspects and related measurement indicators stakeholders deemed most important. To this end, we combined different processes of stakeholder participation with the aim of identifying a bundle of "standardized social indicators." Specifically, two interactive workshops were carried out at Unitelma Sapienza—University of Rome and University of Santiago de Compostela, within the Horizon 2020-funded project STAR-ProBio (Sustainability Transition Assessment and Research of Bio-Based Products; see Figure 1). Invitations to these workshops were directed to researchers, generally, and to industry practitioners in Italy and Spain.

Each of the 21 workshop participants came from one of 13 different organizations and belonged to one or more of the stakeholder categories. In more detail, processors and producers of bio-based products (e.g., boards, bio-adhesives, and bioplastics) were invited, in order for both workers and value chain actors to participate. A consumer association also participated in one workshop, representing the stakeholder category of consumers. On behalf of the local community, representatives of the local government and other local associations joined the sessions. The general society was represented by a research and innovation company, as well as research groups (from universities as well as public and private institutions). Figure 2 shows the different levels of importance assigned by participants to the previously identified impact categories.

Specifically, according to the stakeholders, the most relevant categories for an SLCA of bio-based products were as follows: health and safety, social acceptability, labor rights and decent work, and human rights. Participants recognized the strict relationships that existed among these impact categories and their transversal relevance to different stakeholder categories. For instance, the health and safety impact category was commonly perceived as very relevant, because it enabled the appraisal of different stakeholders' well-being, which in turn was thought to depend on adequate labor rights and respect of human rights. Indeed, such positive conditions have been found



Legend: 1 = can be removed; 2 = can be considered; 3 = should be considered.

FIGURE 2 Impact categories tailored to bio-based products [Colour figure can be viewed at wileyonlinelibrary.com]

to impact on social acceptability, which facilitates the transition towards a bio-based economy (McCormick & Kautto, 2013). In contrast, the impact category of migration was deemed only slightly relevant and could thus be removed from the assessment. As emphasized by a representative of the value chain actor stakeholder group, migration issues (i.e., the delocalization of firms and integration of migrant workers) were less related to bio-based product value chains, given that, for example, the necessary biomass (e.g., waste streams) is dispensed in a uniform manner worldwide.

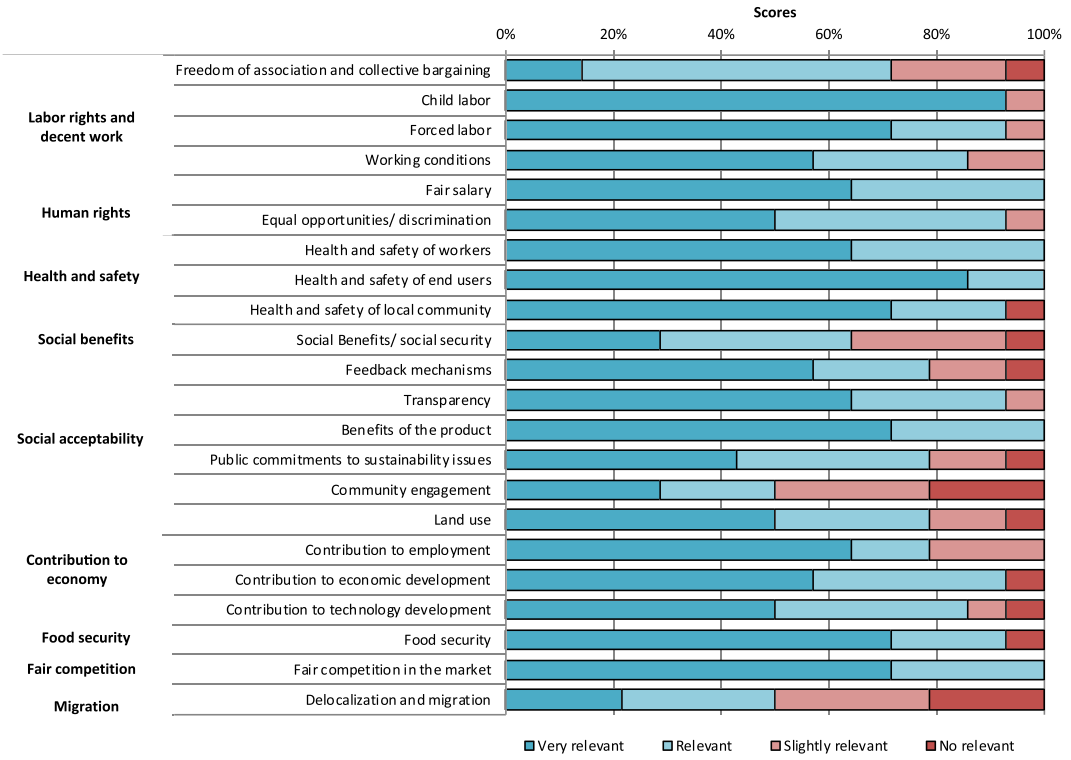
In a subsequent stage, participants were asked to provide their opinions about the relevance of each impact subcategory and related indicators with the aim of looking at the social impacts on stakeholder categories. Specifically, a structured questionnaire[4] was individually administrated during the second phase of the workshop. After filling in the questionnaire, participants were solicited to discuss and justify their answers. The main findings of the evaluation of the relevance of social impact subcategories are shown in Figure 3.

Overall, participants found the majority of the proposed impact subcategories adequate for assessing the social sustainability of bio-based products, because they effectively captured the social impacts that characterized the research context. More specifically, five impact subcategories, referring to a variety of stakeholders along the product value chain, were unanimously deemed "very relevant" or "relevant": fair salaries, the health and safety of workers, the health and safety of end users, benefits of the product, and fair competition in the market. Stakeholders agreed on the importance for workers to earn, during the development phase of the bio-based market, a fair salary capable of providing for their needs, in compliance with established standards (i.e., the "prevailing industry wage" or a "living wage"). Interest in the workers category was also considered in light of their physical, mental, and social well-being. The health and safety of workers was explicitly viewed a crucial aspect, because, in this type of industry, workers may deal with dangerous substances and management practices must be in place to guarantee a safe and healthy workplace. Moreover, all participants acknowledged that the health and safety of end users was "very relevant." It emerged from the discussion that there is no adequate public information on the impacts of bio-products (e.g., bio-based food packaging and bio-based diapers) on human health, and this could negatively affect consumers' willingness to pay for such products. Moreover, the appropriate communication of the reduced environmental impact of bio-based products relative to their conventional and fossil-based substitutes (i.e., the benefits of the product) was thought to possibly increase consumer demand for such products. In this perspective, structural changes will be needed along the whole supply chain as well as in consumers' attitudes and behaviors (Falcone & Imbert, 2017). Finally, fair competition in the market was also considered as "very relevant." According to the stakeholders, bio-products should not have more market restrictions than fossil-based products. Rather, they should be incentivized and regulated in order to guarantee equal opportunities for small- and medium-sized enterprises to enter bio-based markets and to avoid market concentration.

Conversely, some impact subcategories were considered only "slightly relevant" or "not relevant" by stakeholders and were thus excluded from the social sustainability assessment of bio-based products. In more detail, community engagement and delocalization and migration were considered negligible by 50% of participants, whereas social benefits and freedom of association and collective bargaining were considered negligible by 30% of participants. Although an organization may feel that engaging with the local community represents an important aspect of sustainable development, involving local community stakeholders in relevant decision-making processes could represent an obstacle in terms of managing and organizing activities. Moreover, far from dismissing the important role of organizations in providing opportunities for migrant workers, the concepts of migration and firm delocalization were perceived as irrelevant for bio-based industries, given that the provision of feedstock (second generation) was relatively equally distributed throughout the globe. Furthermore, social benefits (e.g., medical insurance, nurseries, education, and training) were considered only slightly or not relevant in the social sustainability assessment of bio-based products, because the applicability of such subcategories depends largely on the geographical area under consideration (e.g., developing vs. developed counties). Likewise, freedom of association and collective bargaining is referenced in several human rights instruments, and, as such, it can be taken for granted. In this regard, one representative of the "general society" category raised the issue of the relevance of some social impact categories, stressing that some are more tailored to bio-based products and some are more transversal (e.g., human rights, and health and safety). Health and safety concerns have become a central issue also in the rise of grassroots movements against the illegal disposal of waste pointing at the relevance of end-of-life responsibility (D'Alisa, Germani, Falcone, & Morone, 2017).

In gathering data for the SLCA of a bio-based product, it is paramount that the proposed social indicators provide significant and adequate information about the social impacts on relevant subcategories, impact categories, and stakeholders. To this end, the validation and

[4]See Appendix D.

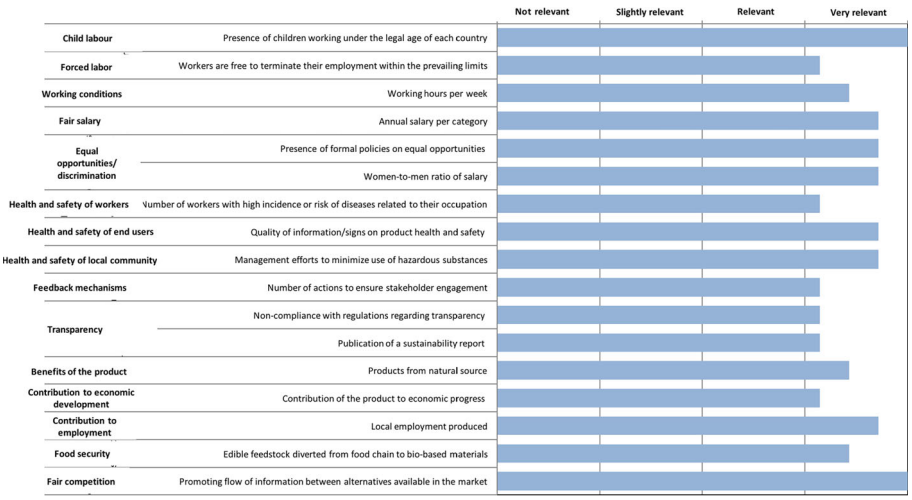


Source: authors.

FIGURE 3 Validation of social impact subcategories [Colour figure can be viewed at wileyonlinelibrary.com]

selection of the most relevant social indicators is indispensable to effectively weigh the social impacts relating to human well-being. Figure 4 presents the stakeholders' perspectives on the most appropriate social indicators for measuring the social impact of the relevant subcategories.

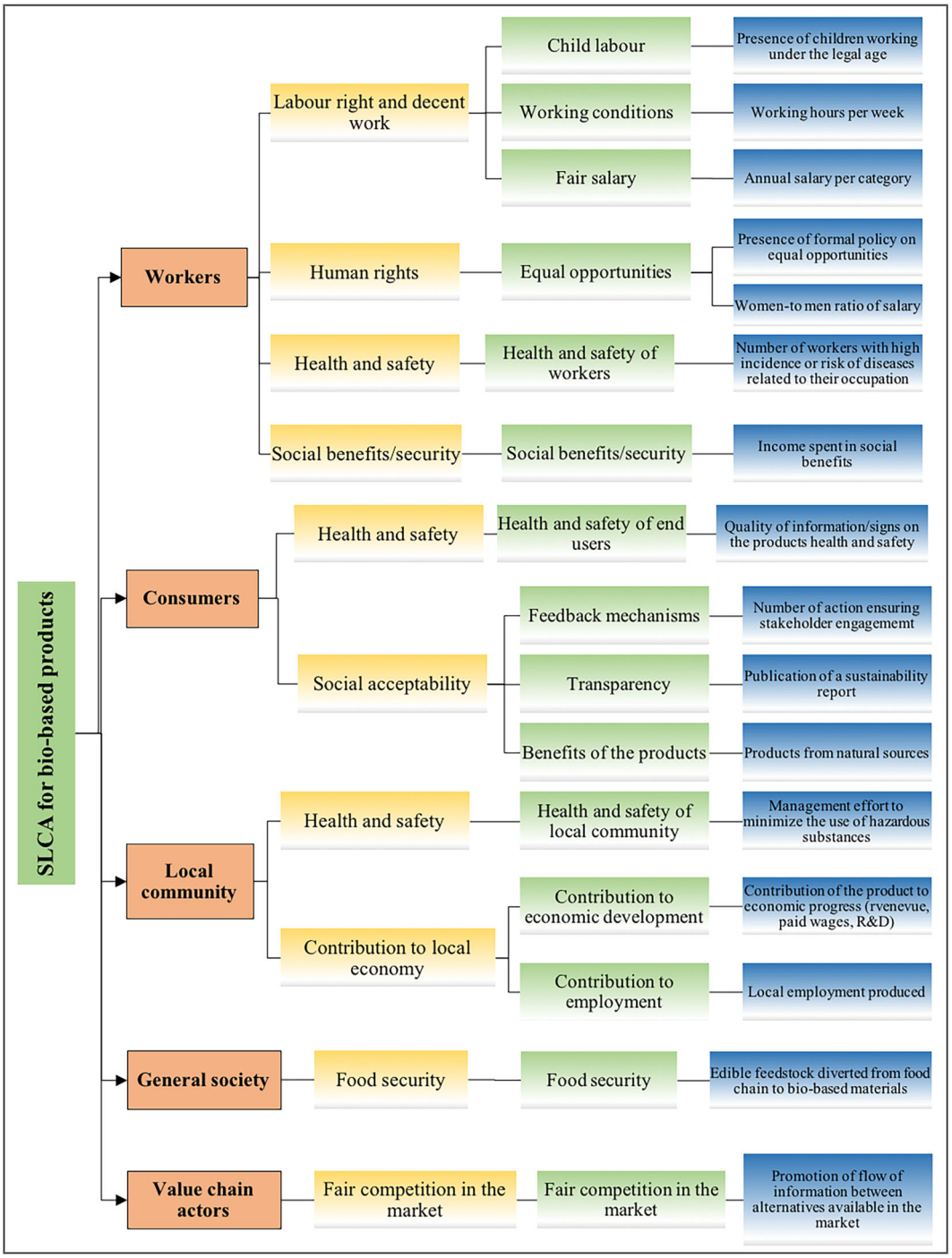
As evidenced in Figure 4, two social indicators—namely, the presence of children working under the legal age of each country and promoting the flow of information between available market alternatives—were unanimously deemed very relevant for determining the presence of labor rights (e.g., with respect to child labor) and fair market competition. In the discussion, the presence of child labor emerged as a critical issue, because raw materials (and biomass in general) might come from developing countries, where the poverty in rural areas and poor access to schools may give rise to a



Source: authors.

FIGURE 4 Selection of social indicators for the social life cycle assessment of bio-based products [Colour figure can be viewed at wileyonlinelibrary.com]

situation in which children work. Another noteworthy aspect concerns the presence of market initiatives to unlock innovative markets. Such initiatives should be conducted in a fair way and in compliance with legislations preventing anticompetitive behavior, antitrust, or monopoly practices. In this context, the European Commission is pushing on established knowledge and leading technological and industrial positions to encourage the fast adoption of bio-based products. However, this process seems to be slowed by the perceived uncertainty around the properties of bio-products and weak market transparency. Therefore, it is crucial to have timely information about the health and safety of end users (quality of information on the health and safety of the product), the benefits of the products (product derived from natural resource), transparency (publication of sustainability reports), and food security (edible feedstock diverted from food chain to bio-based materials). Moreover, nondiscrimination in employment opportunities (i.e., presence of formal policies on equal opportunities) and equal



Source: authors.

FIGURE 5 Social impact matrix for bio-based products. R&D, research and development; SLCA, social life cycle assessment [Colour figure can be viewed at wileyonlinelibrary.com]

remuneration for men and women for work of equal value (i.e., women-to-men ratio of salary) were generally considered relevant social indicators.

4.2 | Social impact framework for bio-based products

At the end of this validation exercise of social impact categories, subcategories, and indicators tailored to bio-based products, a social impact matrix was proposed. Figure 5 shows, in taxonomic order, each group of stakeholders associated with one or more important impact categories and subcategories that, in turn, can be assessed by means of social indicators. In short, the matrix identifies eight impact categories (i.e., labor rights and decent work, human rights, health and safety, social benefits/social security, social acceptability, economic contribution, food security, fair market competition, and migration) encompassing all stakeholder groups (i.e., workers, consumers, local community, general society, and value chain actors), 15 subcategories, and 16 social indicators that, according to the workshop participants, are worthy of consideration for an effective SLCA of bio-based products.

Due to the relative novelty of SLCA, the identification of what is worthy of being measured has, to date, been relatively unfocused on methodical approaches. Although the several studies that exist have differed in their scope and assessment techniques (De Luca et al., 2015; Ekener-Petersen et al., 2014; Stamford & Azapagic, 2014), they have mainly drawn on UNEP-SETAC guidelines (Benoît & Mazijn, 2009) for their choice of social indicators. Other studies have defined their own social impact categories and indicators on the basis of an examination of different stakeholder categories involved along the product value chain. German, Schoneveld, and Pacheco (2011) examined the scientific literature on the environmental, social, and economic impacts of biofuels at a global scale, focusing on indicators associated with social issues (e.g., poverty, rural development, and job creation) to provide policy implications for relevant social issues and governmental policies. Manik et al. (2013), using the case of palm oil biodiesel in Indonesia, identified unequal working conditions, alienation, and negative impacts on liveability and communities as the most important social topics within the product assessment. Other important social aspects, such as labor issues, human rights, health and safety, food security, and social benefits, have been considered in sustainability studies about bioplastic (Álvarez-Chávez et al., 2012) and biodiesel production in China (Ren et al., 2015).

Although tackling these issues would require the involvement of all relevant stakeholders, balancing environmental and social costs, Kühnen and Hahn (2017) presented a systematic review of indicators in the global scientific SLCA literature across all sectors, finding that social aspects were most commonly related to the workers category. This could be due to the fact that data for social indicators for categories such as consumers are more problematic to gather, whereas generic data on labor issues are publicly available (Spierling et al., 2018).

5 | CONCLUSIONS

Sustainable innovation has played a central role in directing production towards new models of sustainable development, embracing its distinct but interrelated pillars of the environment, the economy and society. The production of innovative bio-based products—that is, products that are wholly or partly derived from biological materials or from innovative production processes and/or innovative biomass such as food waste or forest residuals—is part of this process. However, the sustainability of such products must be assured along their entire life cycle and across the three dimensions mentioned above. In recent years, alongside more established environmental assessments, social and economic assessments have entered LCSA, even though a number of challenging issues have been pointed out by the emerging SLCA literature related to bio-based products. In this paper, we contribute to this strand of literature by proposing a social impact framework encompassing a set of social impact categories, subcategories, and indicators that should be assessed when considering bio-based products. Specifically, we link all of these to potentially affected categories of stakeholders, thereby expanding the current body of research, which is mainly focused on a limited number of stakeholders (e.g., workers and end consumers).

In particular, given that a triple bottom line life cycle assessment (concurrently considering the three sustainability pillars) represents a costly process, in terms of both time and money, for organizations involved in innovation, we employed a participatory approach. After generating a list of social topics and related indicators from a review of the academic literature, international conventions, policy documents, standards, and assessment tools, we engaged stakeholders to validate and select the main social topics and related indicators from this list. This validation exercise enabled us to consider a restricted number of social indicators and subsequently reduce the amount of data needed for assessment, thus decreasing related costs. Additionally, the participatory method of investigation enabled us to gather different sustainability viewpoints; this approach made the proposed framework more shared and robust, given that stakeholders' interests were often misaligned.

Although important work has been done to determine a general SLCA framework for bio-based products, much more effort is required to make this approach more rigorous. Future research should therefore compare the comprehensiveness of the proposed framework across different products and countries, testing the relevance of the proposed set of categories and related indicators. Thereby, a more consolidated framework should be built, considering the different case studies, with the aim of ascertaining the presence of possible methodological weaknesses. This could pave the way for an efficient choice of social indicators and their possible application as a standardized framework of analysis. In this vein, data collection could benefit from increased standardization and integration with social science methods, especially frameworks for surveys and interviews (Grubert, 2018).

Finally, a more standardized framework could provide important managerial and policy implications. Indeed, such a framework could be used by innovating companies as a valuable instrument to

understand the social impacts of their innovative products, improving their competitive advantage while also revealing risks and possible improvements (Spierling et al., 2018). In this respect, it could encourage effective dialogue between firms and various stakeholders (i.e., public authorities, local community, suppliers, and financial intermediaries; Gasbarro, Annunziata, Rizzi, & Frey, 2017) about corporate social responsibility and green finance practices (Falcone, Morone, & Sica, 2017).

At the same time, a more standardized framework could also represent a viable and flexible tool for policy makers to overcome the lack of knowledge about the socioeconomic effects of innovative bio-based products. Policy makers should consider these effects alongside environmental effects when designing interventions to support innovating organizations.

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APPENDIX A

WORKSHOP: ASSESSMENT OF BIO-BASED PRODUCTS: EXPLORING THE SOCIAL DIMENSION

A.1 | Goal of the workshop

The goal of the workshop is twofold: (a) validation of the social and socioeconomic impact categories list pertaining to the bio-based products realm that has been selected by an extensive literature review (i.e., scientific papers, gray literature, and bio-based product-related European projects) and (b) brainstorming on the relevant social indicators.

A.2 | Targeted audience

Stakeholders belonging to the following categories: value chain actors, consumers, local community, general society, and workers.

A.3 | Workshop format: Interactive

Workshop title	Assessment of bio-based products: Exploring the social dimension		
Length	120 min (including 15-min break)		
Workshop format description	Time (min)	Activity	Objectives
	15	Welcome	Briefly explain the agenda and other practicalities (5 min)
		Go round exercise	Get to know each other (10 min)
	35	Small task groups	Validate the social and socioeconomic impact categories list pertaining to bio-based products
	15	Break	Networking
	45	Ranking, rating, and sorting exercise; VIPP discussion	Brainstorm on the relevant social indicators
	10	Harvesting	Gather feedback from the participants; summarize the main results of the workshop

Abbreviation: VIPP, Visualization in Participatory Program.

APPENDIX B

SLCA STUDIES ON BIO-BASED PRODUCTS

Author(s), year	Aim	Approach	Impact categories	Social indicators	Geographical context or scope
Ren, Manzardo, Mazzi, Zuliani, and Scipioni (2015)	Assessing the most sustainable scenario for bioethanol production according to the preferences of decision makers and stakeholders, by studying three alternative pathways for production	Test the combination of an MCDM methodology and LCSA for sustainability decision making	A. Human rights B. Working conditions C. Cultural heritage D. Socioeconomic repercussions E. Governance	A → Child labor; equal opportunities, etc. B → Freedom of association and collective bargaining; fair salaries C → Land acquisition, delocalization, and migration D → Contribution to local employment, food security, etc. E → Public commitment to sustainability; fair competition	China
Ekener-Petersen et al. (2014)	Comparing potential social and socioeconomic impacts of four types of vehicle fuel—two bio based (biodiesel and bioethanol) and two fossil based (diesel and petrol)—utilized in the EU, especially in Northern Europe and Sweden; identifying potential social hotspots	Use the Social Hotspots Database, focusing on mostly risky aspects (screening SLCA)	A. Human rights B. Labor C. Health and safety D. Community E. Governance	A → Indigenous rights, high conflicts, gender equity, and health issues B → Child labor, forced labor, excessive working time, poverty, migrant labor, freedom of association, and unemployment C → Injuries and fatalities; toxics and hazards D → Hospital beds, drinking water, sanitation, children out of school, smallholder, or conventional farms E → Legal systems; corruption	Country- and/or sector-level data on fuel within the EU, especially in Northern Europe and Sweden
Manik, Leahy, and Halog (2013)	Identifying the social and socioeconomic impacts of palm oil biodiesel in an Indonesian province	Ground impact categories and criteria on UNEP-SETAC (2009), preliminary survey, and literature review; weigh criteria via expert evaluation (by questionnaire) to ensure further applicability to MCDA	A. Human rights B. Working conditions C. Cultural heritage D. Socioeconomic repercussions E. Governance	A → No child labor, no forced labor, equal opportunities, and no discrimination B → Freedom of association and collective bargaining, fair salaries, decent working hours, occupational health and safety, and social benefits	Indonesia

(Continues)

(Continued)

Author(s), year	Aim	Approach	Impact categories	Social indicators	Geographical context or scope
				C → Land acquisition, delocalization, and migration; respect of cultural heritage and local wisdom; community engagement; and safe and healthy living conditions D → Contributions to local employment, contributions to economic development, food security, and technology and knowledge E → Public commitment to sustainability; fair competition	
Macombe et al. (2013)	Pointing out the differences between performances, effects, and impacts in conducting an SLCA; investigating social impacts/effects; performing a scenario analysis on biodiesel; and comparing different raw materials (i.e., palm oil, forest biomass, and algae)	Base approach on Weidema (2006), E-LCA	A. Health B. Well-being	A → Company level: health of the population, health of workers, and health in foreign countries Regional level: health of regional workers; health of regional population State level: health of the national population; occupational health B → Regional level: well-being of the regional population (no tool available) State level: welfare (e.g., changes in poverty) of national population (no tool available); welfare of foreign populations	General company, region and state levels
Aparcana and Salhofer (2013)	Assessing the social impacts of three Peruvian recycling systems	Ground impact categories and subcategories on UNEP-SETAC (2009) and context-specific topics	A. Human rights B. Working conditions C. Socioeconomic repercussions	A → Child labor, discrimination, freedom of association, and collective bargaining B → Working hours; minimum income and fair income; recognized employment relationships and fulfillment of legal social benefits; physical working conditions; and psychological working conditions C → Education	Regional level

(Continues)

(Continued)

Author(s), year	Aim	Approach	Impact categories	Social indicators	Geographical context or scope
Álvarez-Chávez, Edwards, Moure-Eraso, and Geiser (2012)	Evaluating the general sustainability of different bio-based plastics, considering environmental, health, and safety impacts throughout their life cycles	Conduct systematic literature review	A. Environmental hazards B. Occupational health and safety	A → Feedstock grown using industrial agricultural production methods (which has relatively high energy and water requirements) B → Exposure to pesticides; exposure to elevated temperatures and pressure	General level

Source: Authors.

Abbreviations: EU, European Union; E-LCA, environmental life cycle assessment; LCSA, life cycle sustainability assessment; MCDM, multicriteria decision making; SLCA, social life cycle assessment.

APPENDIX C

LIST OF IDENTIFIED IMPACT CATEGORIES, SUBCATEGORIES, AND SOCIAL INDICATORS TAILORED TO BIO-BASED PRODUCTS

Stakeholder category	Impact category	Impact subcategory	No.	Social indicator
Workers	Labor rights and decent work	Freedom of association and collective bargaining	1	Employment conditioned by any restrictions on the right to collective bargaining
			2	Presence of measures that support the rights to exercise freedom of association and collective bargaining
			3	Number of workers enrolled in trade unions
			4	Number of trade unions at value chain or enterprise level
			5	Presence of unions within the organization
		Child labor	6	Presence of children working under the legal age of each country
		Forced labor	7	Workers free to terminate their employment within the prevailing limits
		Working conditions	8	Working hours per week
		Fair salaries	9	Annual salary per category
	Human rights	Equal opportunity/ discrimination	10	Women-to-men ratio of labor force
			11	Presence of formal policies on equal opportunity
			12	Total number of female employees that took parental leave
			13	Total number of male employees that took parental leave
			14	Women-to-men ratio of salary
	Health and safety	Health and safety	15	Number of accidents
			16	Presence of a formal policy concerning health and safety
			17	Hours of employee injuries
			18	Adequate general occupational safety measures taken
			19	Number of workers with high incidence or high risk of disease related to their occupation
			20	Preventive measures and emergency protocols exist
			21	Education, training, counseling, prevention, and risk control programs in place to assist workforce members
	Social benefits/social security	Social benefits/social security	22	Income spent on social benefits
Consumers	Health and safety	Health and safety of end users	23	Tests performed to check safety
			24	Quality of information/signs on product health and safety
	Social acceptability	Feedback mechanisms	25	Number of actions to ensure stakeholder engagement
		Transparency	26	Noncompliance with regulations regarding transparency
			27	Publication of a sustainability report
			28	Consumer complaints regarding transparency
			29	Communication of the results of social and environmental life cycle impact assessments
		Product benefits	30	Products from natural source
Local community	Migration	Delocalization and migration	31	Number of individuals who resettle (voluntarily and involuntarily) that can be attributed to an organization
			32	Strength of organizational policies related to resettlement

(Continues)

(Continued)

Stakeholder category	Impact category	Impact subcategory	No.	Social indicator
			33	Strength of organizational procedures for integrating migrant workers into the community
	Health and safety	Safe and healthy living conditions	34	Organizational efforts to strengthen community health
			35	Management efforts to minimize use of hazardous substances
	Social acceptability	Community engagement	36	Number of meetings with community stakeholders
			37	Organizational support (volunteer hours or financial support) for community initiatives
			38	Diversity of community stakeholder groups that interact with the organization
		Land use	39	Land grabbing
			40	Land use change
	Economic contribution	Contribution to employment	41	Local employment produced
General society	Social acceptability	Public commitment to sustainability issues	42	Available certification or documentation about sustainability issues
			43	Signed principles or codes of conduct related to sustainability
	Economic contribution	Contribution to economic development	44	Contribution of the product/service/organization to economic progress (revenue, gain, paid wages, R&D costs in relation to revenue, etc.)
			45	Potential market share of the company
		Technology development	46	Patents granted
	Food security	Food security	47	Land that has been converted from stable crops
			48	Edible feedstock diverted from the food chain to bio-based materials
Value chain actors	Fair competition in the market	Fair competition in the market	49	Promotion of the flow of information between available market alternatives

Abbreviation: R&D, research and development.

APPENDIX D

RANKING, RATING, AND SORTING EXERCISE

Objective: Brainstorm the relevant impact subcategories and social indicators.

Activity in brief: In the first round, participants are asked to rank the impact subcategories and social indicators provided according to their relevance for evaluating the sustainability performance of the bio-economy, considering the score scale below. In the second round, they are asked to collectively discuss their relevance.

Score scale: 1 = *not relevant*; 2 = *slightly relevant*; 3 = *relevant*; and 4 = *very relevant*.

D.1 | Social indicators list

Stakeholder category	Impact category	Impact subcategory	Score	Social indicator	Score
Workers	Labor rights and decent work	Freedom of association and collective bargaining		Employment conditioned by any restrictions on the right to collective bargaining	
				Presence of measures that support the rights to exercise freedom of association and collective bargaining	
				Number of workers enrolled in trade unions	
				Number of trade unions at value chain or enterprise level	
				Presence of unions within the organization	
		Child labor		Presence of children working under the legal age of each country	
		Forced labor		Workers free to terminate their employment within the prevailing limits	
		Working conditions		Working hours per week	
		Fair salaries		Annual salary per category	
	Human rights	Equal opportunity/ discrimination		Women-to-men ratio of labor force	
				Presence of formal policies on equal opportunity	
				Total number of female employees that took parental leave	
				Total number of male employees that took parental leave	
				Women-to-men ratio of salary	
	Health and safety	Health and safety		Number of accidents	
				Presence of a formal policy concerning health and safety	
				Hours of employee injuries	
				Adequate general occupational safety measures taken	
				Number of workers with high incidence or high risk of disease related to their occupation	
				Preventive measures and emergency protocols exist	
				Education, training, counseling, prevention, and risk control programs in place to assist workforce members	
	Social benefits/social security	Social benefits/social security		Income spent on social benefits	

(Continues)

(Continued)

Stakeholder category	Impact category	Impact subcategory	Score	Social indicator	Score
Consumers	Health and safety	Health and safety of end users		Tests performed to check safety	
				Quality of information/signs on product health and safety	
	Social acceptability	Feedback mechanisms		Number of actions to ensure stakeholder engagement	
		Transparency		Noncompliance with regulations regarding transparency	
				Publication of a sustainability report	
				Consumer complaints regarding transparency	
				Communication of the results of social and environmental life cycle impact assessments	
		Product benefits		Products from natural source	
Local community	Migration	Delocalization and migration		Number of individuals who resettle (voluntarily and involuntarily) that can be attributed to an organization	
				Strength of organizational policies related to resettlement	
				Strength of organizational procedures for integrating migrant workers into the community	
	Health and safety	Safe and healthy living conditions		Organizational efforts to strengthen community health	
				Management efforts to minimize use of hazardous substances	
	Social acceptability	Community engagement		Number of meetings with community stakeholders	
				Organizational support (volunteer hours or financial support) for community initiatives	
				Diversity of community stakeholder groups that interact with the organization	
		Land use		Land grabbing	
				Land use change	
	Economic contribution	Contribution to employment		Local employment produced	
General society	Social acceptability	Public commitment to sustainability issues		Available certification or documentation about sustainability issues	
				Signed principles or codes of conduct related to sustainability	
	Economic contribution	Contribution to economic development		Contribution of the product/service/organization to economic progress (revenue, gain, paid wages, R&D costs in relation to revenue, etc.)	
				Potential market share of the company	
		Technology development		Patents granted	
	Food security	Food security		Land that has been converted from stable crops	
				Edible feedstock diverted from the food chain to bio-based materials	
Value chain actors	Fair competition in the market	Fair competition in the market		Promotion of the flow of information between available market alternatives	

Abbreviation: R&D, research and development.