



## Review

# Social sustainability in a good bioeconomy paradigm: A systematic review of social life cycle assessment (S-LCA)

Irene Zarauz<sup>a,\*</sup>, Alexia Sanz-Hernández<sup>a</sup>, Juana M. Rivera-Lirio<sup>b</sup>

<sup>a</sup> Department of Psychology and Sociology, University of Zaragoza, C/ Atarazanas, 4, Teruel, 44003, Spain

<sup>b</sup> Department of Finance and Accounting, University Jaume I, Av. Vicent Sos Baynat, s/n 12071 Castelló de la Plana, Spain



## ARTICLE INFO

Handling Editor: Yutao Wang

## Keywords:

Good bioeconomy  
Social sustainability  
S-LCA  
Social transformation  
Social assessment

## ABSTRACT

The bioeconomy is prominent in global political agendas and is expected to drive sustainable development. However, its potential to achieve transformative sustainability outcomes has been questioned. Life Cycle Sustainability Assessment (LCSA) evaluates bioeconomic models across the three dimensions of sustainability; however, social aspects are largely ignored. This study sought to comprehensively analyse all existing publications on Social Life Cycle Assessment (S-LCA) within the bioeconomy. The main aim was to determine whether these assessments consider social transformations and align with the concept of a 'good' bioeconomy, where sustainability across all dimensions is achieved. A systematic literature review was conducted using the Preferred Reporting Items of Systematic reviews and Meta-Analyses method (PRISMA) and 51 relevant documents were identified. A mixed deductive-inductive method and thematic analysis were used to define the scope and methodologies of S-LCA research in the bioeconomy and explore the dominant research themes, key social aspects and indicators, and the actual extent of social transformations. These findings indicated that studies primarily on S-LCA development often neglect the evaluation of social transformations, and instead focus on regional development, green job creation, and supply chain management. Moreover, research that integrates the social dimension into LCSA often regards these aspects as requirements for conducting comprehensive sustainability assessments. However, an in-depth exploration is generally lacking. Consequently, this study found that S-LCA does not assess whether the bioeconomy fosters a transition towards social sustainability. This gap may be attributed to the predominantly Eurocentric and highly technical nature of the reviewed literature. This study contributes to existing knowledge by providing a theoretical exploration of the implications of social sustainability within the context of a good bioeconomy. Additionally, it offers recommendations for future research and outlines policy implications that may promote social responsibility in the paradigm of a good bioeconomy.

## 1. Introduction

The bioeconomy as a sustainable paradigm is referred to as the current political vision worldwide (Asada et al., 2020). In fact, numerous countries have adopted various bioeconomic strategies (Dietz et al., 2018). However, bioeconomy is not sustainable (Bracco et al., 2019). On the one hand, the bioeconomy has aroused high expectations; on the other hand, it has sparked debate on the credibility of its sustainability impacts, as industrial bio-resource production involves challenges in environmental conservation and social welfare (Starke et al., 2022). Hence, academic discussion on the transformative potential of this bioeconomic transition for sustainable development is ongoing and regards political debate as promising (Eversberg et al.,

2023; Többen et al., 2024). This academic discussion centres on the environmental controversies surrounding ecological and economic transition (Starke et al., 2022); however, studies on the social dimension of the bioeconomy are beginning to emerge (Ramcilovic-Suominen, 2023). This social dimension of sustainability has not been directly addressed from a critical perspective (Sanz-Hernández et al., 2019), and the social implications of the bioeconomy are currently being considered as transformative practices, such as inclusive innovation (Bryden et al., 2017) or gender equality (Sanz-Hernández et al., 2022), rather than social global justice policies (Eversberg and Fritz, 2022; Ramcilovic-Suominen et al., 2022).

Thus, there is an urgent need to reassess the principles underlying socio-ecological transformation within bioeconomic strategies

\* Corresponding author.

E-mail address: [izarauz@unizar.es](mailto:izarauz@unizar.es) (I. Zarauz).

<https://doi.org/10.1016/j.jclepro.2024.144570>

Received 10 October 2023; Received in revised form 9 December 2024; Accepted 22 December 2024

Available online 24 December 2024

0959-6526/© 2024 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

(Ramcilovic-Suominen, 2023). Consequently, this review adopted a new paradigm, called a 'good' bioeconomy, where achieving social sustainability is possible. Kurki and Ahola-Launonen (2021) have envisioned a 'good' bioeconomy, which describes a utopian scenario that prioritises socio-political action and diminishes the centrality of technoscience as the primary solution to current socio-ecological crises. This study aimed to reformulate this concept under a 'strong' sustainability scenario, where environmental and social dimensions predominate over economic decisions (Dietz and Neumayer, 2007).

To gain a better grasp of a good bioeconomy, all three dimensions of sustainability should undergo significant transformations to enable a fair, inclusive, and environmentally sustainable transition (Temper et al., 2018). However, there is still no clear agreement on the transformative characteristics that specifically define changes in socio-ecological systems (Feola, 2015). Therefore, in this study, the term 'transformation' was used to denote the fundamental and complex challenges associated with drastic, uncertain, and contested changes in three sustainability dimensions: environment, society, and economy. In this regard, ecological transformation may pave the way for enhanced protection of the environment with a circular system that minimises resource inputs and outputs through increased innovation (Salvador et al., 2021) while also advocating the establishment of global environmental justice (Temper et al., 2018). Economic transformation implies diminishing the dominance of economic growth, which supports fresh initiatives such as degrowth (Escobar, 2015) or a regenerative economy (Andreucci et al., 2021).

Finally, from a social perspective, social transformations involve challenging established structures and several policy orientations through social innovations aimed at ensuring justice and equality on a global level (Eversberg and Fritz, 2022; Ramcilovic-Suominen, 2023). Further research on the social dimension towards a good bioeconomy is needed (Sanz-Hernández et al., 2019). Therefore, this study based its critical and analytical perspective on theoretical debates that promote social sustainability within the bioeconomy (Eversberg and Fritz, 2022; Ramcilovic-Suominen, 2023; Sanz-Hernández et al., 2022). To understand the extent to which progress is being made towards a good bioeconomy, it is imperative to conduct sustainability assessments. Nevertheless, most of these analyses focus on environmental and economic dimensions within the bioeconomy (Alidoosti et al., 2021). Therefore, research should be conducted in the context of the transition towards social sustainability within the bioeconomy to address the existing knowledge gap (Ramos-Huarachi et al., 2020). This study aimed to emphasise the social aspects of the transformation process towards a good bioeconomy by exploring the current understanding and measurements of social sustainability in this emerging bio-based economy. To perform a more comprehensive analysis, this study examined the most common tool for quantifying social sustainability: Social Life Cycle Assessment (S-LCA). S-LCA offers the possibility of systematically assessing a wide range of social impacts throughout product and/or service life cycles (Ekener-Petersen et al., 2014; UNEP, 2020) and complementing their results with the other two sustainability dimensions (Ferreira et al., 2022), thus completing the three pillars of sustainability along with Environmental Life Cycle Assessment (E-LCA) and Life Cycle Costing (LCC) tools. The Life Cycle Sustainability Assessment (LCSA) framework is gaining acceptance (Zeug et al., 2021), and S-LCA is a relatively recent area of research compared to the other two life cycle approaches (Spierling et al., 2018). However, the increasing academic interest in the S-LCA methodology has resulted in significant updates to both the primary S-LCA Guidelines (UNEP, 2020) and the 'Methodological Sheets for subcategories in Social Life Cycle Assessment' (UNEP, 2021); henceforth, Methodological Sheets.

S-LCA remains under development and discussion, especially regarding methodological issues, which make its consistent application more difficult (Rebolledo-Leiva et al., 2023). A possible explanation for this might be that the concept of social sustainability is vague and controversial (Ly and Cope, 2023) and therefore requires a thorough and

clearer analysis and a more precise delineation of the principles encompassing social sustainability (Littig and Griessler, 2005). One reason for this complexity is the interdisciplinary nature of social science, which is influenced by regional socioeconomic and technological conditions (Siebert et al., 2018a), sociopolitical and cultural contexts (Mair-Bauernfeind et al., 2020), and researchers' perspectives on measurement methods (Sanz-Hernández et al., 2022). Therefore, S-LCA in the bioeconomy presents significant methodological challenges related to the standardisation of impact categories and social themes, uneven representation among stakeholders, lack of correlation between functional units and results, assessment methods and inclusion of positive aspects, need for social databases, and increased transparency of results to address common uncertainties in the methodology (Rebolledo-Leiva et al., 2023).

Recently, there has been an increasing body of literature on S-LCA (Huertas-Valdivia et al., 2020; Petti et al., 2018; Pollok et al., 2021; Ramos-Huarachi et al., 2020). These studies demonstrate a growing interest in social sustainability research through S-LCA in initiatives such as the bioeconomy (Ramos-Huarachi et al., 2020). Indeed, in recent years, research has focused on specific sectors such as municipal solid waste management systems (Costa et al., 2022b), the agri-food sector (Tragnone et al., 2022), bio-based products (Falcone and Imbert, 2018; Spierling et al., 2018), and broader areas such as the circular economy (Luthin et al., 2023). Although some research has been conducted on S-LCA, only Rebolledo-Leiva et al. (2023) studied S-LCA within the bioeconomy framework. In their study, they described the state of the art of S-LCA methodological aspects and highlighted the main procedural and practical issues, alongside the specificities of the bioeconomy within this tool. Finally, they underlined the need to explore whether S-LCA adequately supports the social transition to a bioeconomy, which is critical and requires further academic scrutiny. For instance, Sanz-Hernández et al. (2022) concluded that the bioeconomy is inadequately addressing social issues such as gender equality, and further research is needed to develop social sustainability indicators using appropriate evaluation methods, including life cycle assessment tools.

This study attempted to conduct a more in-depth review. No previous studies have analytically considered the implications of both S-LCA and social sustainability in the bioeconomy (Silva et al., 2024). Therefore, this study emphasised the need for transformative sustainable development and sought to obtain data that will help address the current knowledge gap. Due to the growing interest in this research field, this study makes two noteworthy contributions: first, it makes an original and theoretical presentation of the concept of a good bioeconomy, and second, it provides recommendations for improving the operationalisation and measurement of transformative social aspects within S-LCA and the bioeconomy. Therefore, the present study complements and expands current reviews from an innovative perspective and offers insights into social assessments in the bioeconomy. This review considered the aspects of social sustainability in a good bioeconomy as elements of social transformations. Social transformation is brought about when there is a debate over the implications of social sustainability. It incorporates approaches aimed at diagnosing the sources of present socioeconomic and ecological crises and offers solutions to address these issues. Thus, this review explored the extent to which social aspects are being examined and whether previous studies have included social transformation movements such as decolonisation, capitalist transitions, degrowth and post-development, non-anthropocentric societies, the defense of cultural differences, and social and environmental justice (Escobar, 2015). Consequently, this study sought to answer the following research questions.

- Where is research on S-LCA conducted under the bioeconomy framework? How, or in what way, are studies measured through S-LCA? What social aspects did they consider?
- What are the main lines of research on S-LCA and the bioeconomy? Do they incorporate the elements of social transformation?

- Is the current research on S-LCA and the bioeconomy measuring elements of social transformation in the paradigm of a good bioeconomy? What implications and recommendations have emerged from this study for advancing research on social sustainability through S-LCA within the context of a bioeconomy?

Hence, the purpose of this study was to understand and characterise the current state of research in this field and to identify and suggest three main lines of research. Moreover, it explored the degree of attention devoted to appraising the elements of social transformation towards a good bioeconomy and proposed recommendations to address current knowledge gaps. The remainder of the paper proceeds as follows: In the Methods section, the methodological approach is defined; the Results section presents the findings of the research; the Discussion section shares an innovative perspective on social sustainability in a good bioeconomy; the Research section includes a discussion of the implications of the findings for future research in this area; and finally, the Conclusion provides a brief summary and frame policy.

## 2. Methods

We conducted a systematic literature review to answer these questions. The methodology was based on a review of all published articles on S-LCA and bioeconomy research to collect a representative sample of studies from the literature. This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology (2009) (Fig. 1). The PRISMA statement is designed to improve systematic reviews and meta-analyses. It is intended to define selections more precisely and increase the scope and quality of the selected studies (Moher et al., 2009; Desiderio et al., 2022). Several reviews have applied PRISMA statements to the bioeconomy field (Papadopoulou et al., 2022; Sanz-Hernández et al., 2022), S-LCA framework (Petti et al., 2018; Tragnone et al., 2022), and social sustainability (Desiderio et al., 2022; D'Eusanio et al., 2019).

### 2.1. The literature selection process

The literature selection process involved sequential decisions based on the identification, screening, and eligibility of relevant studies, primarily focusing on bioeconomy academics and social dimensions within

the S-LCA framework. As shown in Fig. 1, keywords were initially identified and searched for in databases such as Scopus and Web of Science. The search conducted in October 2022 dealt with two main queries: the first query focused on the 'article title, abstract, keywords' (Scopus) and on 'topic' (Web of Science) with the keywords 'Social Life Cycle Assessment' OR 'S-LCA' OR 'SLCA' AND 'bioeconomy' OR 'bio-based' OR 'bioproduct' OR 'bio\*'; and the second query had the keyword 'bioeconomy' in all the fields and 'social' in the title. Because similar search terms can deliver a similar or even the same result (e.g. bio-based economy or bio-product), the search was broadened to avoid losing articles that are not framed explicitly in the bioeconomy. Additionally, a second search with the term 'social' identified articles that assessed social aspects within the S-LCA framework, which were ignored in the initial search. Finally, similar searches were conducted on Google Scholar and an interesting article for this study that did not appear in the previously used databases was obtained.

A total of 515 articles, limited to English-language journals and peer-reviewed literature (research articles and reviews), were retrieved and reduced to 363 studies after removing duplicate references. The next stage involved screening the search results by abstract, focusing on S-LCA articles and reviews related to the bioeconomy. If the term 'bioeconomy' was absent but there was inference towards activities within this framework, the full-text reading was screened. Consequently, a discussion among the authors was held to determine whether the articles met the inclusion/exclusion criteria, as exemplified by the circular economy and innovation derived from biological resources. Articles in line with the S-LCA methodology, which usually adhered to the S-LCA Guidelines (UNEP, 2020) and undertook a social impact assessment or literature review, were included. As a result, a large number of papers were excluded because they were not employing an S-LCA, despite the fact that research in the social field of bioeconomy was produced or because the term 'bioeconomy' appeared in other sections such as bibliography, acknowledgements, or author affiliations.

After eligibility checks, 65 studies were obtained and subsequently reviewed based on the number of existing social indicators in the studies. Hence, the screening was scaled up to the full text to detect the number of social indicators (at least three). This requirement was particularly relevant since the present study sought to fully explore the social aspects and address one of the research questions, which centred on which social aspects are covered and what type of indicators are

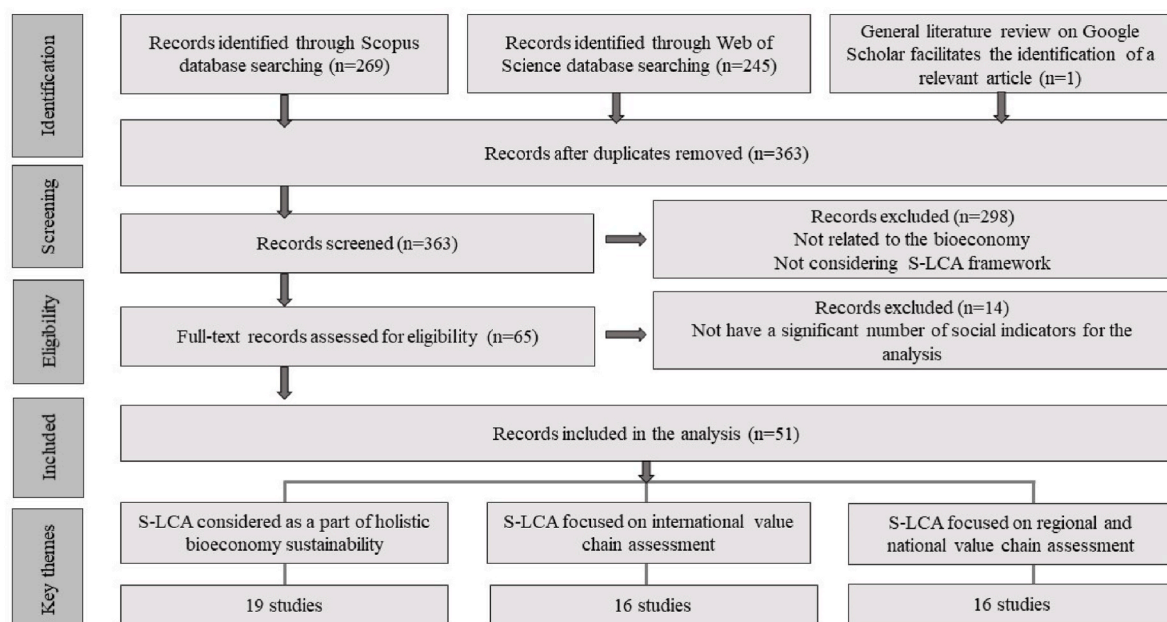


Fig. 1. PRISMA flow diagram. Adapted from Moher et al. (2009).

employed for their measurement.

A sample of 51 publications (Table 1) were retrieved for a suitable literature review. The limitations of the literature search were related to the restrictions of articles and reviews in English, excluding grey literature, which often included closely related research topics. Furthermore, these limitations extended to studies that did not undertake comprehensive S-LCA, which may lead to a constrained number of social indicators.

## 2.2. Data and thematic analysis

A mixed deductive-inductive method, in line with the methodology proposed by Sanz-Hernández et al. (2022), was adopted after reviewing the literature. Prior to the analysis, a database with several descriptive variables was created to meet the research objectives (Table 2). First, this database was set up to characterise where research is being conducted, to show how S-LCA is being applied, and to establish what social sustainability aspects and indicators are being assessed through S-LCA within the context of the bioeconomy; second, the database determined the main lines of research in this field of knowledge and the centrality in the elements of social transformation. Given the context-dependent nature of social sustainability (Ekener et al., 2018), the variables related to the location and authorship of the studies were defined. Moreover, owing to the importance of methodological proposals in S-LCA (Macombe et al., 2018), variables concerning the measurement tool itself, including scope, subject, type of assessment (Reference Scale Social Life Cycle Impact Assessment -RS S-LCIA- or Impact Pathway -IP S-LCIA-), and databases (Social Hotspots Database -SHDB- or Product Social Impact Life Cycle Assessment -PSILCA-) were delineated. Additionally, to analyse social sustainability aspects thoroughly, an open variable of social indicators was defined based on Methodological Sheets. Finally, a variable to show centrality in social sustainability was established in each article and classified based on its implications for the elements of social transformation and the achievement of social sustainability transition measurement.

Once this analysis was performed, a full-text review and thematic analysis were conducted using the methodology proposed by Nowell et al. (2017). This qualitative research method is useful for identifying, analysing, describing, and reporting several key features found in a dataset and arriving at a clear and organised final report (Nowell et al., 2017). The authors discussed and compared the coding of each article to examine the key themes necessary to respond to the research question. After exploring aspects such as similarities, interactions, (in)congruences, and differences, three central themes emerged: (1) S-LCA as part of holistic bioeconomy sustainability; (2) S-LCA focused on international value chain assessment; and (3) S-LCA focused on regional and national value chain assessment.

## 3. Results

To address each research question, the variables listed in Table 2 were carefully analysed. This section summarises the main findings and provides a methodically structured response to the aforementioned research questions.

### 3.1. Where is research on S-LCA under the bioeconomy framework being conducted? How or in what way are the studies measuring through S-LCA?

To answer the first research question, a bibliometric analysis was conducted to identify variables such as publication year, journal, study location, country of the first author, and disciplinary area. First, it revealed that S-LCA is a recent and growing field of research (Fig. 2). There has been an increasing interest in S-LCA since 2013, and especially since 2018. Three journals, namely the International Journal of Life Cycle Assessment (25%), Journal of Cleaner Production (22%), and Sustainability (12%), representing a total of 30 articles (59%),

**Table 1**

List of studies selected from the literature review.

N°	Reference	Year	Typology	Bioeconomic sector	Country of study
1	Alidoosti et al.	2021	Methodological	Waste resource	Asia
2	Andrade et al.	2022	Empirical	Agriculture	Europe
3	Barrio et al.	2021	Empirical	Forest	Europe
4	Cadena et al.	2019	Methodological	Waste resource	Europe
5	Cardoso et al.	2019	Empirical	Agriculture	Latin America
6	Contreras-Lisperguer et al.	2018	Empirical	Energy	North America
7	Corona and San Miguel	2019	Empirical	Energy	Europe
8	Costa et al.	2022a	Empirical	Forest	Europe
9	Costa and Oliveira	2022	Empirical	Energy	Latin America
10	Do Carmo et al.	2017	Methodological	Energy	North America
11	Ekener et al.	2018	Methodological	Energy	Europe
12	Ekener-Petersen et al.	2014	Empirical	Energy	Europe
13	Falcone et al.	2019	Empirical	General	Europe
14	Falcone and Imbert	2018	Empirical	General	Europe
15	Fürtner et al.	2021	Methodological	Agriculture	Europe
16	Ghaderi et al.	2018	Methodological	Energy	Asia
17	Jarosch et al.	2020	Empirical	Forest	Europe
18	Keller et al.	2015	Methodological	Energy	Europe
19	Macombe et al.	2013	Empirical	Energy	Various
20	Mair-Bauernfeind et al.	2020	Empirical	General	Various
21	Manik et al.	2013	Empirical	Energy	Asia
22	Martin et al.	2018	Theoretical	General	Europe
23	Martinez-Hernandez et al.	2022	Empirical	Energy	North America
24	Martín-Gamboa et al.	2021	Empirical	Energy	Europe
25	Martín-Gamboa et al.	2020	Empirical	Energy	Europe
26	Martín-Gamboa et al.	2022	Empirical	Energy	Europe
27	Marting Vidaurre et al.	2022	Methodological	Energy	Europe
28	Masilela and Pradhan	2021	Empirical	Energy	Africa
29	Mattila et al.	2018	Methodological	Forest	Europe
30	Messmann et al.	2022	Methodological	Energy	Europe
31	Muhammad et al.	2019	Empirical	Agriculture	Asia
32	Omrán et al.	2021	Empirical	Agriculture	Asia
33	Panoutsou et al.	2022	Empirical	Agriculture	Europe
34	Portner et al.	2021	Empirical	Energy	Europe
35	Prasara-A and Gheewala	2021	Empirical	Agriculture	Asia
36	Prasara-A et al.	2019	Empirical	Agriculture	Asia
37	Rafiaani et al.	2020	Empirical	Blue bioeconomy	Europe
38	Ren et al.	2015	Methodological	Energy	Asia
39	Sajid and Lynch	2018	Methodological	Energy	North America
40	Sawaengsak et al.	2019	Methodological	Agriculture	Asia
41	Siebert et al.	2018a	Methodological	Forest	Europe
42	Siebert et al.	2018b	Methodological	Forest	Europe
43	Souza et al.	2021	Methodological	Agriculture	Latin America
44	Souza et al.	2018	Methodological	Agriculture	Latin America
45	Spierling et al.	2018	Theoretical	General	Various
46	Takeda et al.	2019	Empirical	Energy	Asia

(continued on next page)

**Table 1** (continued)

N°	Reference	Year	Typology	Bioeconomic sector	Country of study
47	Tavakoli and Barkdoll	2020	Methodological	Energy	North America
48	Valente et al.	2018	Empirical	Forest	Various
49	Weldegiorgis and Franks	2014	Empirical	Energy	Oceania
50	Zeug et al.	2021	Methodological	Energy	Various
51	Zhang et al.	2021	Empirical	Energy	Asia

substantially contributed to the search.

Determining the first author's country and study location is important for identifying the regions actively involved in understanding and measuring social sustainability. The reviewed articles were led by authors located in the Global North, especially from European institutions, which implies that the conceptualisation of social sustainability in the bioeconomy is defined by Eurocentric values and perspectives. Thirty (59%) articles were authored by European institutions; Germany, Portugal and Sweden were represented by 15 articles, followed by Italy, Austria, and Spain. Regarding articles written outside the European scope, Asia was the second leading continent, with nine articles from research institutions (17%) and Thailand and Malaysia being the driving forces. Finally, the last geographic locations considered were Latin America and North America, with five articles each and Brazil standing out. Therefore, although bioeconomic policies have been highly prioritised and presented as an opportunity in developing countries with high natural capital, such as those in Latin America and Asia (Rodríguez et al., 2018), they remain a minority in the academic world. Finally, it is worth highlighting the importance of the first author's affiliation, because the geographical location where the research was conducted largely corresponded to the author's research institutions (95%).

In addition, the impact of disciplinary authorship on current social bioeconomic research is worth exploring. Hence, the first author's department/research centre was categorised according to the disciplinary area to which it belonged. In more multidisciplinary cases, the first author's academic background and qualifications were included for a more detailed classification (Fig. 3). The International Standard Classification of Education (UNESCO, 2012), was used to facilitate the analysis. Surprisingly, the results showed that the area of knowledge focusing on bioeconomic S-LCA research rarely comes from social scientists and professionals from more technical disciplines, such as engineering (51%) or life sciences (29%), who are carrying out extensive research in that area of knowledge. Therefore, measuring social sustainability using S-LCA is more common among scientists in technical fields than in the social sciences.

To address the second research question, which focused on methodological aspects, the variables of the object of study, impact assessment, scope, and social databases were examined to analyse the trends within S-LCA development. Indeed, several studies made a methodological contribution (18 articles), mainly because S-LCA remains a work in progress (UNEP, 2020).

In this review, 45 papers (88%) used a product as the object of study. Many evaluations have been conducted with the aim of supplementing prior environmental outcomes for bio-based products. The implementation of an S-LCA, which involves the integration of social aspects into a functional unit (UNEP, 2020), presents a significant challenge. Therefore, using this focal point makes the definition of the functional unit and the elaboration of the social impact assessment more complex, which may lead to potentially suboptimal results. The impact assessment process in S-LCA is even more demanding because social impacts do not have a causal relationship with production processes as in E-LCA, and further research and development of suitable methods for impact assessment are vital (UNEP, 2020). In this sense, in Social Life Cycle Impact Assessment (S-LCIA) approaches, there are two main families: Type I (also known as Reference Scale S-LCIA) and Type II (also known

**Table 2**

Descriptive variables analysed in the literature review.

Variable Code	Typology	Description	Codes
<b>Title</b>	Continuous text variable	Full headline	Open
<b>Publication year</b>	Continuous text variable	Publication date	Open
<b>Journal</b>	Continuous text variable	Journal that publishes the article	Open
<b>Authorship</b>	Continuous text variable	Authors' names articles	Open
<b>First author's corresponding country</b>	Discrete variable	Identify the country of the author's university; the location determines what regions prioritise and conceptualise social sustainability	Africa Asia Europe Latin America North America Oceania
<b>First author's disciplinary area</b>	Discrete variable	Identify the first author's scientific field (department/research centre)	Agriculture, forestry and fishery Engineering and engineering trades Life sciences Physical sciences Social and behavioural science Blue bioeconomy Energy Forest Health and biomedicine Industry Waste resources General
<b>Bioeconomic sector</b>	Discrete variable	Define bioeconomic sectors to establish connection with social sustainability	Africa Asia Europe Latin America North America Oceania Various
<b>Location of study</b>	Discrete variable	Determine the geographical location of studies to correlate social sustainability with specific territories of the bioeconomy	Cradle-to-grave Cradle-to-gate Gate-to-gate Gate-to-grave
<b>Scope of assessment</b>	Discrete variable	Decide if the scope of assessment is in line with the aim of the study. Determine whether articles cover full life cycles (cradle-to-grave), supply chains (cradle-to-gate), or other phases (gate-to-gate or gate-to-grave)	Product Organization Territory Various
<b>Object of the study</b>	Discrete variable	Analyse the perspective from which the social impacts of the bioeconomy are measured to define the most common objects of study	Product Organization Territory Various
<b>Impact assessment</b>	Discrete variable	Social Life Cycle Impact Assessment (S-LCIA) provides information related to the evaluating method to identify the most common bioeconomic measurement	RS S-LCIA IP S-LCIA Various
<b>Social database</b>	Discrete variable	Understand whether the utilisation of databases is common in the bioeconomy to identify	SHDB PSILCA Other

(continued on next page)

Table 2 (continued)

Variable Code	Typology	Description	Codes
Social indicators	Continuous text variable	requirements within these data sources Analyse commonly used indicators to identify key priorities and trends in social sustainability and to evaluate both positive and negative indicators	Open
Social sustainability centrality	Discrete variable	Evaluate centrality of social sustainability themes by assessing its relevance. High centrality indicates a strong focus on social transformation and low centrality if social sustainability is merely mentioned	High Medium Low

as Impact Pathways S-LCIA). Today, the Type I method is more operational and has been used in numerous case studies (UNEP, 2020). Thirty-three (65%) of the reviewed papers used a reference scale to assess the social performance of a product system. Although several Reference Scale approaches existed within Type I, gaps in the scoring system, use of a weighting scheme, and recognition of stakeholders were identified (Sawaengsak et al., 2019). The Type II approach was less commonly used (9%) as it focused on the improvement of the cause-and-effect chain concept and predicted potential social impacts (Do Carmo et al., 2017; Martín-Gamboa et al., 2020). Moreover, the challenges associated with evaluation methods opened up new possibilities for studies with other functional units of analysis within the bioeconomy, which focused on the territory (Jarosch et al., 2020; Siebert et al., 2018a, 2018b) or organisation (Rafiaani et al., 2020). The latest publication of the S-LCA Guidelines (UNEP, 2020) used the organisational approach as the unit of analysis.

Finally, most studies had a cradle-to-gate (45%) or cradle-to-grave (37%) scope and 35% of the reviewed papers used a social database for their assessments. The use of this database largely corresponded to studies conducted in the Global North (95%). In these studies, different social databases (SHDB or PSILCA) were used to assess their

international impact. Consequently, a strong correlation between the Northern view and social databases was observed.

### 3.2. What social aspects are considered a priority in the S-LCA bioeconomy research?

This study intended to determine whether the analysed articles used social indicators to explore the social aspects that S-LCA is currently measuring in the bioeconomy. For this purpose, the open variables of social indicators were considered (Table 2). In this respect, there was no common social measurement tool in S-LCA owing to the lack of standardised indicators (Falcone and Imbert, 2018) and the lack of harmonisation and limited comparability caused by a plethora of impact categories across studies and methods (Costa et al., 2019).

Furthermore, the selection process of these social indicators was one of the most important steps in carrying out an S-LCA (Cadena et al., 2019) and remained challenging (Costa et al., 2022b). For instance, in several studies, a large number of indicators created bottlenecks during the crucial step of defining the results (Fürtner et al., 2021; Valente et al., 2018). Other studies suggested experience-based approaches to select indicators that validate stakeholders (Falcone and Imbert, 2018; Mattila et al., 2018). However, similar to the indicator selection process, clear standards for identifying stakeholders did not exist or were complex because many impacts were interrelated or overlapping (Fürtner et al., 2021). Stakeholder perspectives also depend on the values and priorities to be measured. In this regard, Ekener et al. (2018) stated that

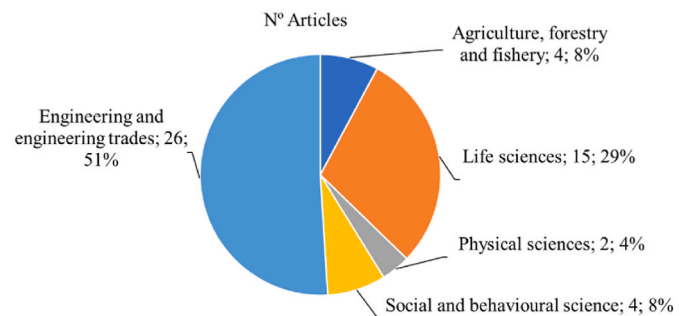


Fig. 3. The first author's field of knowledge.

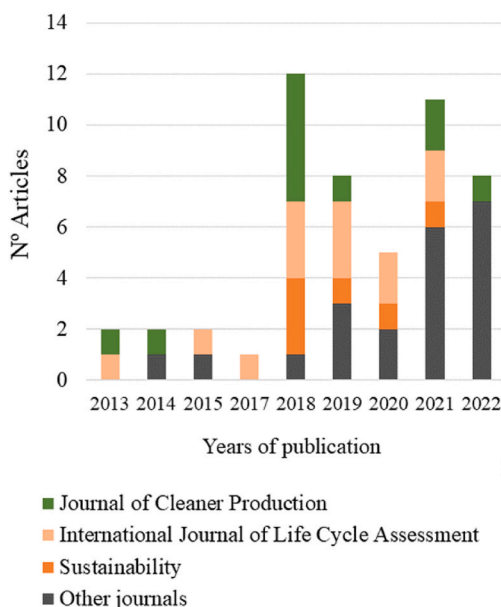
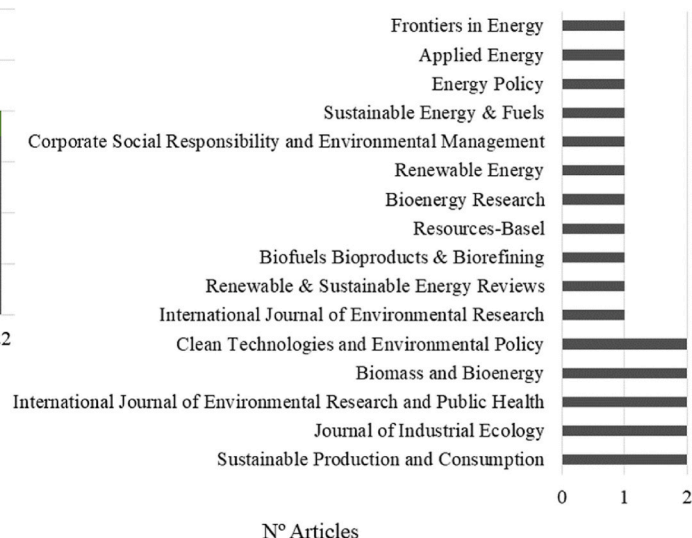


Fig. 2. Number of publications by year and type of journal.

#### Publications in other journals



although human needs are the same across all cultures, satisfying those needs depends on the context. Thus, stakeholder views on human dignity and its preservation are constrained by their environments and cultures. These constraints showed that the bioeconomy has a heavy regional dependency, especially in social terms. On a global scale, national indicators rarely showed information on specific social performance, while local indicators encountered more difficulty in collecting social data associated with specific value chains. However, this meant that the latter are more difficult to replicate (Siebert et al., 2018b). Consequently, it is highly complex to evaluate a global production system using context-specific approaches that rely on a massive amount of detail (Martínez-Blanco et al., 2014).

This study sought to analyse the most frequently used social indicators within the S-LCA framework in the bioeconomy. Methodological Sheets, which are globally recognised and reliable tools for categorising social indicators in the S-LCA framework (Tragnone et al., 2022), were used. During the entire revision process, the sheets were used to analyse and categorise all the indicators shown in the reviewed papers. Nevertheless, a small number of papers (20%) did not have a direct correlation with the subcategories of the Methodological Sheets; therefore, they had to be categorised by the authors. In this sense, as an open application of the Methodological Sheets is encouraged, this study established fresh definitions and criteria for each social subcategory to facilitate the categorisation process (see Table A.1 of the Appendix). Subsequently, in situations of uncertainty, the methodology devised by Roman et al. (1999) was employed, which suggested that two researchers should conduct an individual evaluation; in case of any discrepancies in the classification, a third researcher would also review the information. After applying this method, all social indicators were

classified into appropriate subcategories on the Methodological Sheets.

Fig. 4 summarises the main social subcategories developed after reviewing the main indicators and sorting them into subcategories of the Methodological Sheets. This revision analysed and classified 1114 social indicators (see Table A.2 in the Appendix). Consequently, *Worker* was presented as the stakeholder with the highest percentage of indicators found in the literature (48%), followed by *Local Community* (34%), *Society* (9%), *Consumer* (5%), *Value Chain Actors* (3%), and *Children* (1%).

This increased prevalence of indicators among stakeholders such as workers or the local community is primarily attributable to the strong connection between predominant social aspects, socioeconomic issues, and labour concerns (Ferreira et al., 2022). Therefore, the regional dependence of the bioeconomy on these stakeholders has become more evident. In S-LCA studies, these stakeholders are often prioritised because they have easier access to information (Huertas-Valdivia et al., 2020), demonstrating a significant correlation between the bioeconomy and local indicators associated with these stakeholders. Consequently, considering a larger number of stakeholders such as consumers, value chain actors, and society in general, tackling social issues that have so far been insufficiently addressed is crucial (Rebolledo-Leiva et al., 2023). The subcategories commonly used in this literature review are as follows:

*Worker stakeholder* (11%) was by far the most developed, which diverted the attention away from the rest of the value chain actors in the literature; and, in turn, implied that researchers have not appreciated important upstream and downstream impacts of organisational conduct (Kühnen and Hahn, 2017). Traditionally, the study of labour relationships and conditions has played a critical role in the field of social sciences because of the close connection between the social sphere and the

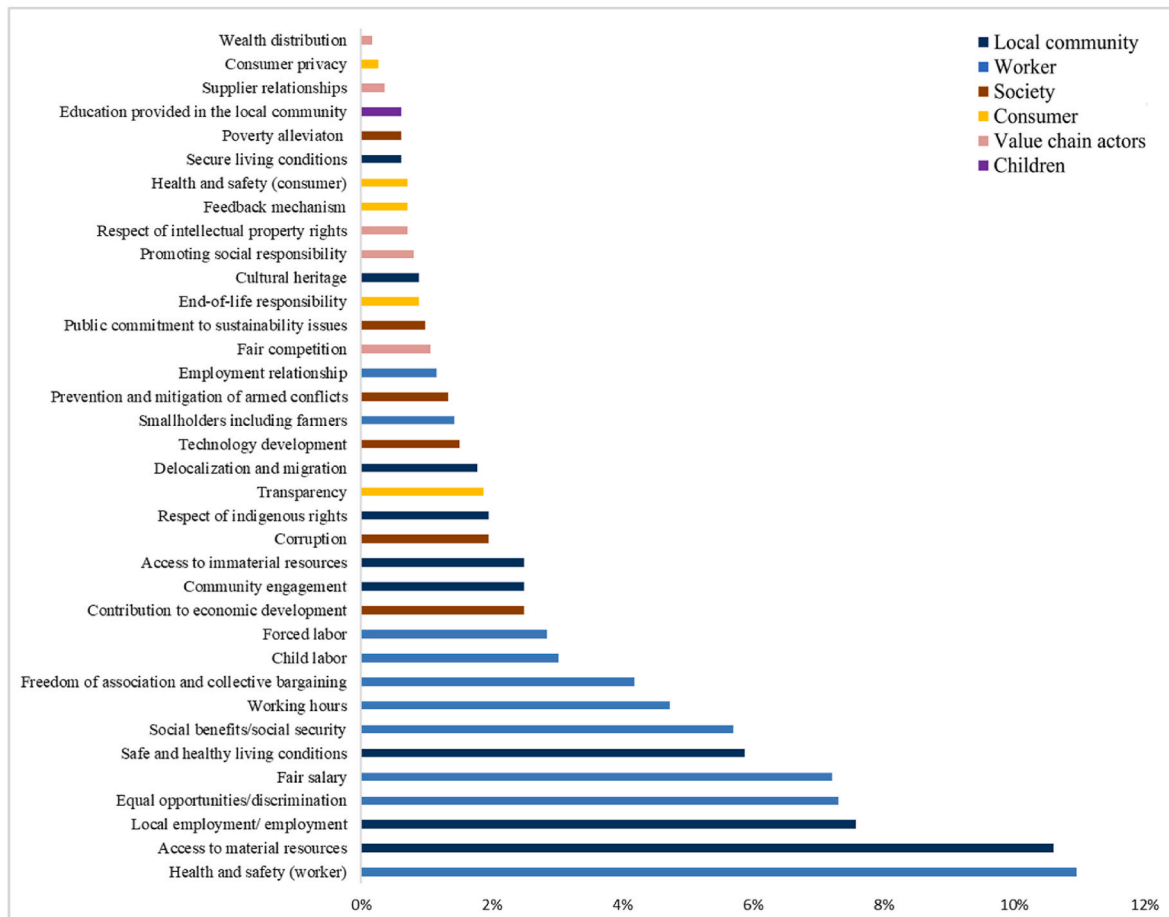


Fig. 4. Main social subcategories of the Methodological Sheets based on the number of evaluated indicators.

world of work, which accounts for the substantial impact of economic and labour factors on society. Therefore, it can be assumed that data indicators for stakeholders other than employees are more difficult to collect, whereas generic data on labour issues are publicly available (Spierling et al., 2018). Hence, *Worker Health and Safety* (11%) was the subcategory that researchers studied and agreed on the most, and health-related indicators were the most commonly conceptualised (Kühnen and Hahn, 2017).

*Access to Material Resources* (10%) was the second largest and most frequently assessed subcategory because of its importance and implications in the bioeconomic model. This subcategory was closely linked to the concept of environmental extractivism and had considerable social repercussions for *Local Community Stakeholder*. Other thematic indicators included community investments or food and energy security, mainly in the energy, agriculture, and forest sectors. In this sense, the social indicators establish the relevance of natural resource management to ensure a socially sustainable development.

*Local Employment/Employment* (8%) was the third most developed subcategory and was related to the *Local Community Stakeholder*, due to its connection to regional development. Several articles attached the significance of local employment to bioeconomic development, which showed a growing local focus in S-LCA (Mattila et al., 2018).

The subcategory *Equal Opportunities/Discrimination* (7%) explored topics such as gender equality or social inclusion and acted as a catalyst for socially inclusive growth and just societal transition (Sanz-Hernández et al., 2022).

In conclusion, the diversity of social measurement indicators within the social dimension results from the development and adaptability of the Methodological Sheets. This flexibility promotes the standardisation of topics and facilitates analysis in fields such as bioeconomy. This conceptual complexity and difficulty in defining social sustainability have generated lively discussions and gained the acceptance of various methods and proposals for social indicators.

### 3.3. What are the main lines of research in S-LCA and the bioeconomy? Do they incorporate elements of social transformation?

To explore these research questions, thematic analysis was performed to identify and discuss recurring themes in the reviewed literature. This process resulted in the creation of three categories or overarching themes in line with the main research directions in this field. In addition, the analysis incorporated a social sustainability centrality variable across each identified area. These themes were subsequently classified into two main groups according to the importance of the social dimensions.

#### 3.3.1. Social sustainability as the primary focus of assessment

This section presents two different lines of research based on the territory in which the reviewed studies exclusively assessed the social aspects of the bioeconomy.

##### - S-LCA focused on regional and national value chain assessment

The findings of this study revealed that S-LCA bioeconomic research is highly related to regional development and territorial cohesion (EC, 2018), especially in relation to the validation of novel methodological proposals. In this section, 16 articles were included with a balance between studies from developed and developing countries. Several studies addressed this regional topic in developed countries, including bioenergy alternatives in Australia (Weldegiorgis and Franks, 2014), the forestry sector in Germany (Jarosch et al., 2020; Siebert et al., 2018a, 2018b), and the forest sector in Slovakia (Fürtner et al., 2021). Tavakoli and Barkdoll (2020) developed a methodology used in a study on the algae sector in the United States, while Rafiaani et al. (2020) adopted a new perspective by focusing on the organisation as a functional unit in Belgium. In a Canadian case study, Sajid and Lynch (2018) developed an

assessment tool using currency units. Most of these studies have major methodological implications; however, their discussions and conclusions do not contribute to the debate on social sustainability.

Furthermore, some studies were based on regional and national value chains in the Global South. For instance, several studies in Brazil explored the social impact of biorefineries (Souza et al., 2018, 2021) and compared biodiesel value chains (Costa and Oliveira, 2022). Other research papers in Asia discussed the value chains of agricultural palm oil in Malaysia (Muhammad et al., 2019), sugarcane and cassava in Thailand (Prasara-A and Gheewala, 2021), and bioenergy produced from municipal waste in Iran (Alidoosti et al., 2021). Despite the urgent need for social transition in developing countries, these studies did not debate social sustainability. In this line of research, only one article showed medium centrality in the social sustainability debate and did not follow European perspectives. Manik et al. (2013) assessed the social impact of Thai palm oil biodiesel by conducting surveys and interviews, which revealed issues such as exploitative labour practices and community inequalities, offered recommendations concerning government and legislative changes, and reintegrated former smallholders into plantations.

##### - S-LCA focused on international value chain assessment

Because S-LCA was promoted owing to greater demands on the social responsibility of multiple international supply chains (UNEP, 2020), many articles dealt with global chains that could or could not apply a social database. Within this frame of reference, most articles were based in the Global North countries and made use of a database to monitor their social hotspots along their supply chains by implying operations in developing countries, for instance, to measure social impacts on Portuguese pulp and paper supply chains (Costa et al., 2022a), agricultural value chains within different European countries (Andrade et al., 2022), Finnish wood value chains (Mattila et al., 2018), biofuel value chains in Croatia (Martín-Vidaurre et al., 2022), and bioenergy supply chains in Portugal (Martín-Gamboa et al., 2020, 2021, 2022). Do Carmo et al. (2017) developed a methodological proposal to analyse the current gaps in several diverse international biodiesel supply chains.

Two studies on international value chains, primarily between European countries, analysed value chains from marginal agricultural lands (Panoutsou et al., 2022) or a process design method with a biorefinery case study based on European glycerol waste (Cadena et al., 2019). Although European countries are highly dependent on resources from non-European countries (Martín-Gamboa et al., 2020), only 38% of the studies on European regions within a cradle-to-gate/grave scope addressed international impacts in their analyses. In 2019, Takeda et al. (2019) published a paper in which they compared bioenergy scenarios in Malaysia by analysing entire supply chains; this was the only article produced in the Global South that used a database. In conclusion, the databases were primarily used in developed countries. Finally, two studies complemented social indicators within the S-LCA framework with a global perspective on the bio-based sector (Falcone and Imbert, 2018; Falcone et al., 2019).

Overall, the vast majority of studies that addressed social sustainability tended to overlook the need to adopt social transformative perspectives, even though they considered global bio-based value chains. Nevertheless, three studies promoted a debate on the effect of medium centrality on social sustainability. Macombe et al. (2013) explored the impacts of S-LCA; proposed a complementary approach at the corporate, regional, and state levels through biodiesel supply chain cases; and stressed the importance of a global theoretical framework to align researchers. They also emphasised the need to identify all affected stakeholders, as current methods often conform to Western norms and neglect vulnerable populations. Moreover, Ekener-Petersen et al. (2014) compared the social impacts of biofuels and fossil fuels, assessed S-LCA performance in northern European vehicle fuels, critiqued EU Policy for ignoring vital social sustainability aspects, and recommended S-LCA to

address social inequalities and prevent negative value chain impacts. [Ekener et al. \(2018\)](#) conducted further research on the positive impacts and regional relevance of developing countries.

### 3.3.2. Social sustainability as the secondary focus of assessment

In contrast to the previous section, another line of research was identified and proposed in this study, in which S-LCA was considered a part of the holistic sustainability of the bioeconomy.

- S-LCA considered as a part of the holistic bioeconomy sustainability

The bioeconomy, regarded as a system for achieving sustainable development, requires improvement in three dimensions: economy, society, and the environment ([Zeug et al., 2021](#)). Consequently, S-LCA appeared in several studies as an afterthought imposed by holistic sustainability analysis models. For example, 37% of the sample conducted either an LCSA with three sustainability areas or a complementary S-LCA (19 papers). This showed an encouraging increase in social concern; however, the overall consideration of S-LCA still lagged far behind the economic and environmental facets ([Ramos-Huarachi et al., 2020](#)). From the sample, only 17 studies considered the social dimension only as a 'requirement' with an important gap between environmental, economic, and social reflections and disclosures.

In this sense, most studies only presented the results of holistic assessments, such as bioproduct impacts at an organisational level ([Omran et al., 2021](#)), a comparison between biological and conventional products ([Barrio et al., 2021](#)), or between biorefineries in alternative locations ([Valente et al., 2018](#)). At the meso- and macro-levels, several studies presented scenarios with innovative processes and technologies in the energy sector in developing countries ([Contreras-Lisperguer et al., 2018](#); [Martinez-Hernandez et al., 2022](#); [Masilela and Pradhan, 2021](#)), developed countries ([Corona and San Miguel, 2019](#); [Portner et al., 2021](#)) or in agricultural sectors and developing countries ([Cardoso et al., 2019](#); [Zhang et al., 2021](#)). In this context, only [Prasara-A et al. \(2019\)](#) and [Messmann et al. \(2022\)](#) offered policy recommendations after evaluating the possibilities. Finally, other studies supported methodological proposals for designing the best decision-making scenario ([Ghaderi et al., 2018](#); [Keller et al., 2015](#); [Ren et al., 2015](#)) or conducting a review of LCSA in bio-products ([Spierling et al., 2018](#)) or LCSA indicators ([Martin et al., 2018](#)).

In conclusion, all these papers address sustainability as a whole, and surprisingly, far too little attention has been paid to the discussion of strong sustainability ([Dietz and Neumayer, 2007](#)). Furthermore, most studies present only results, occasionally provide recommendations, and often ignore social dimensions. Nevertheless, two studies have addressed the issue of social transformation in this line of research. [Zeug et al. \(2021\)](#) addressed the potential conflicts that may arise from holistically evaluating the three pillars of sustainable development using LCSA and advocated for a hierarchy to enhance environmental and social justice while questioning the dominance of economic profitability. Finally, [Mair-Bauernfeind et al. \(2020\)](#) emphasised the significance of the geographical context within the social dimension and presented the challenges of data acquisition in developing countries and prevailing Eurocentrism.

## 4. Discussion

The main purpose of this literature review was to critically analyse the extent to which social transformations within the bioeconomy towards social sustainability are being evaluated. Specifically, this study aimed to determine whether S-LCA is currently a tool for measuring a good bioeconomy. Therefore, this section discusses the findings of this research, focusing on the concept of a good bioeconomy, and seeks to tackle the issue of whether current research on S-LCA and the bioeconomy measures social transformations in line with the paradigm of a good bioeconomy.

First, providing a clear definition of social sustainability in a good bioeconomy is essential. Social sustainability in the bioeconomy can be viewed from a socially transformative perspective. Social transformation is a key element of social sustainability and is subject to location ([Ramcilovic-Suominen, 2023](#)). Therefore, the paradigm of a good bioeconomy depends on the perspective from which social sustainability is appraised. In the Global North, the concept of whether the bioeconomy implies social transformation requires a split in the satisfaction of societal needs through the unsustainable and inequitable production of goods and services ([Zeug et al., 2021](#)). Thus, transitions should be explored and more socio-political changes in Western culture and values should be introduced ([Sanz-Hernández et al., 2022](#)). Moreover, the North, the main consumer of products and services, regards consumers as active agents working towards a structured sustainable transition.

In the Global South, colonial and postcolonial contexts have influenced the capacity for social transformation. Historically, marginalised regions have experienced an increase in social movements, including environmental justice movements ([Temper et al., 2018](#)). The Global South should not stunt growth as the basis for these improvements, where other relevant social movements, such as *Buen Vivir*, challenge the 'civilisational model' of neo-liberal development and define a new paradigm that embraces different ways of living that adopt more ecological, human justice and dignified criteria ([Escobar, 2015](#)). A significant portion of the current theoretical debate on social sustainability as a pillar of a good bioeconomy revolves around the implications of the Global North as a consumer and the Global South as a producer ([Ekener et al., 2018](#)), as players in a socioeconomic and cultural context led by neoliberal movements ([Apostolopoulou et al., 2021](#)). This results from the fact that the current global socio-economic and ecological crises have disproportionately benefited and harmed different territories and segments of society and their causes have not yet been specified in a detailed diagnosis ([Kurki and Ahola-Launonen, 2021](#)). Therefore, the least responsible for socioecological crises is also the most vulnerable due to the continuous marginalisation and dispossession brought about by colonialism ([Ramcilovic-Suominen, 2023](#)). Hence, fair transformation of the material world requires decolonisation processes to begin with immaterial concepts related to knowledge and worldviews regarding social sustainability perspectives ([Apostolopoulou et al., 2021](#); [Ramcilovic-Suominen, 2023](#)).

Furthermore, the conceptualisation of social sustainability in a good bioeconomy does not depend only on location and context; it should also integrate the interconnections and interdependencies of the triple helix perspective of sustainability. The dimensions of sustainability have evolved independently and have been established without an understanding of their interrelationships or how they should be measured and evaluated within a coherent framework ([Littig and Griessler, 2005](#)). Therefore, the difficulty in finding a definition of social sustainability that adequately reconciles economic and environmental aspects persists ([Alidoosti et al., 2021](#)), even though this three-dimensional approach is internationally accepted and recognised as beneficial for sustainable development ([Lehtonen, 2004](#)).

Finally, the complexity for the conceptualisation of social sustainability is given by the fact that both terms 'social' and 'sustainability' are currently uncertain in meaning. The concept of 'sustainability' may clearly reflect the need for society inclusion in its achievement; however, the term 'social' remains complex and broad in terms of both analytical and normative meanings ([Littig and Griessler, 2005](#)), and encompasses intangible, reflective, and individual as well as collective aspects ([Lehtonen, 2004](#)). Despite the existing literature on the bibliographic review of the concept of social sustainability, the conceptualisation of social sustainability requires efforts from multiple disciplines, especially the social sciences. To date, this scattered and diverse study has led to a limited academic discussion that has contributed to the ambiguity of the concept ([Vallance et al., 2011](#)).

This review establishes a theoretical framework through the concept

of a good bioeconomy, which is considered a strong sustainability model that promotes environmental, economic, and social transformations to meet current global environmental and social challenges. Furthermore, it is crucial that the three dimensions of sustainability undergo equitable transformation and balance harmoniously to achieve objectives in all three dimensions, and to prioritise the environmental and social dimensions in case of conflict.

As explained above, conceptualising social sustainability within a good bioeconomy is complex and context-dependent. Therefore, this study attempts to establish a paradigm that should be followed by social sustainability assessment research in line with a good bioeconomy. Specifically, this study showed that research in S-LCA is aligned with a good bioeconomy when, first, it establishes a contextualised definition of social sustainability within the good bioeconomy framework to be analysed, involving stakeholder participation; second, it addresses prevalent challenges and delves into the necessary elements of social transformation to achieve global social justice; and third, it evaluates the results of social measurement, prioritising those most in need of social transformation.

Consequently, this study confirmed that research on S-LCA within the bioeconomy diverges from the paradigm of a good bioeconomy, predominantly because of the limited assessment of social transformations. Overall, the literature lacks sufficient development of arguments regarding social sustainability from a transformative perspective. However, some moderately central studies (six articles) generated theoretical discussions on social sustainability and addressed issues such as increased social justice, political challenges, anti-capitalist viewpoints, and shifts in global power dynamics. After analysing the findings of the research questions, possible reasons for the lack of discussion on social sustainability implications were detected. First, this review suggests that research should be undertaken from a fundamentally Eurocentric perspective and that it lacks contributions from researchers in social disciplines and sufficient focus on social issues. Other studies revealed the presence of Eurocentrism in S-LCA studies (Mattiola et al., 2015; Petti et al., 2018) within the bioeconomic field (Sanz-Hernández et al., 2022). This study confirmed that developed countries predominantly use social databases in their accountability assessments. Therefore, the leverage of the Global North has shaped the bioeconomy and S-LCA theory and practice and is encouraging the implementation of a supposed universality of Western knowledge by perpetuating colonialist perspectives (Ramcilovic-Suominen, 2023). Second, the limited connection between the theoretical debate on social sustainability and the S-LCA proposals in the bioeconomy can be attributed to the low involvement of social practitioners in this knowledge domain. Nowadays, academic discussions on the implications of social sustainability are not clear, because the social dimension of sustainable development is frequently recognised as the conceptually and theoretically most delicate component (Lehtonen, 2004). This review found that only 8% of the reviewed studies adopted a social science approach, which shows the predominance of technical fields, in line with the scarcity of debate on social sustainability. Given the crucial role that the social sciences play in the discussion of social sustainability in the bioeconomy and their limited prominence (Vallance et al., 2011), practitioners in this social dimension are encouraged to promote greater academic discussion in this area of research.

## 5. Research implications and future directions

The final section discusses the findings and implications for future research in this area. Therefore, this review constrained its contribution to this specific domain, aiming to establish a connection between future academic research and a social sustainability framework in a good bioeconomy, by making recommendations for its measurement through each defined line of S-LCA research.

The first line of research in S-LCA literature showed a trend towards social assessment based on regional development in the bioeconomy

because a large number of indicators have a considerable local perspective. In this regard, great importance was placed on the current EU bioeconomy policy, because most of the sample was aligned with this type of framework that focused on proposals for increased job competition and regional socioeconomic development (EC, 2018). Government rhetoric had a tangible impact on the types of research that received funding, and most studies overlooked social transformation aspects and prioritised economic growth in line with the EU bioeconomy policy, which may be seen as an indicator of potential greenwashing (Ramcilovic-Suominen and Püzl, 2018). To reverse this trend in evaluations, aspects of social transformation in the Global North should be explored more thoroughly. For instance, the use of indicators should be encouraged to evaluate the opportunities created by a bioeconomy to achieve social sustainability, such as the improvement of social welfare through the development of bioenergy self-sufficiency (Alidoosti et al., 2021) and the enhancement of land use towards food security (Panoutsou et al., 2022). Furthermore, the high capacity of the bioeconomy to generate employment at the regional level and its correlation with improvements in the social conditions of local communities and territorial equality should be examined (Siebert et al., 2018a), together with the role of consumers as active agents in changing unsustainable consumption systems (Falcone and Imbert, 2018). Additionally, there is a need to prioritise social aspects, such as the attraction and retention of a highly qualified labour force, to enhance training and employee development, ensure employee welfare and security (Andrade et al., 2022; Cadena et al., 2019), and promote equal opportunities and gender equality (Siebert et al., 2018b; Valente et al., 2018).

Nevertheless, the strong presence of Eurocentrism in the literature complicates the characterisation of social sustainability within the bioeconomy in territories such as the Global South. Therefore, further research is required to explore the social transformation involved in the context of a good bioeconomy in these territories. It would be interesting to study transformative social aspects to address the urgent need for legislative improvements that ensure environmental justice and the welfare of local communities and indigenous people (Manik et al., 2013), as well as fair working conditions, including decent wages, health and safety, freedom of association, and social benefits (Sawaengsak et al., 2019; Zhang et al., 2021). More research is needed to establish connections between theoretical concepts and social transformation movements such as *Buen Vivir*.

Overall, regardless of the location of the study, implementing S-LCA in a good bioeconomy within this line of research requires a context-specific approach due to the high relevance of social aspects and local stakeholders' opinions (Fürtner et al., 2021). Therefore, it is necessary to develop specific and detailed indicators to measure the relevant aspects of social transformation and achieve the desired scenario. Moreover, a reasonable approach to tackle this issue could be that regional assessments always incorporate a global perspective in a complementary manner, address international issues, and delineate organisational dependencies on other territories.

Finally, the utilisation of positive indicators that foster organisational behaviour is advised, which may attach significance to positive impacts to assess enhancements by bioeconomy models (Ekener et al., 2018). Although most of the literature focused on risk measurement, the novel S-LCA Guidelines prioritise positive approaches to surpass minimum legal corporate compliance and enhance the measurement of social sustainability (UNEP, 2020). Furthermore, the analysis of social indicators revealed a growing trend towards positive measurements; over 85% of the samples used one or more positive indicators in their assessments, which reveals an alignment with the concept of social transformation and proactive behaviours.

The second line of research in S-LCA literature was focused on international value chains within the bioeconomy. Although international value chains display significant disparities in their social aspects, there has been little discussion on how social sustainability in these value chains could be improved from a global perspective. A considerable

amount of literature acquired a methodological dimension inherent in S-LCA; therefore, new proposals should examine the implications of global justice in a good bioeconomy. For instance, it is recommended that the S-LCA methodology address changes in impact assessments using ‘equity weights’, which assign different weights depending on inequality aversion (Ekener et al., 2018). In addition, as previously mentioned, further work needs to be done to fully address bio-based value chains to initiate an academic discussion that centres on resolving issues of global justice (e.g. land use conflicts) within current models of production and consumption. In this research domain, the utilisation of social databases was prevalent and was often viewed as a Eurocentric tool. Although the focus on the bioeconomy may predominantly be regional, this study showed the need to adopt a global perspective to extend existing dependencies and impacts. Hence, an international perspective should be implicit to ensure that discussions on social sustainability foster the development of a sound bioeconomy.

Finally, the third line of research focused on the concept of social sustainability as part of the triple bottom line and presented complementary studies on social, economic, and environmental impacts. The variability in characteristics and rationales among sustainability dimensions, as well as the numerous interdependencies and interrelations, may generate an in-depth debate on prioritisation and resolution, especially concerning social aspects (Lehtonen, 2004). Nevertheless, most studies within the bioeconomy have prioritised economic and ecological aspects and added a social dimension without establishing greater cohesion or argumentation. Therefore, further research would be of great help in addressing the holistic measurement of sustainability with a more coherent, balanced, and equitable approach using LCSA (Zeug et al., 2021) to gain a deeper understanding of the interconnections within the dimensions of sustainability.

Fig. 5 summarises the six main recommendations for future research aligned with a good bioeconomy in the social sustainability dimension.

## 6. Conclusions and policy implications

Previous reviews have consistently highlighted that S-LCA in the bioeconomy is indeed a growing trend (Ramos-Huarachi et al., 2020), which is in line with the momentum recently gained from the bioeconomic literature written from a social science perspective (Sanz-Hernández et al., 2019). Thus far, reviews have focused on aspects

such as transparency, reliability, and relevance in social assessments (Rebolledo-Leiva et al., 2023). Most of the literature tends to focus on the accuracy of its results and the need to obtain specific and more detailed indicators (Rafiaani et al., 2020), as well as the scarcity of adequate reference data for suitable evaluation (Jarosch et al., 2020), especially in bioeconomy sectors (Alidoosti et al., 2021). Nevertheless, little attention has been paid to issues related to the implications of a social transformation towards social sustainability and its corresponding measurement and evaluation.

This review was framed within the concept of a good bioeconomy and aimed to assess whether the bioeconomy, particularly its social dimension, is being evaluated according to standards that ensure social sustainability transformation. In addition to theoretically exploring the implications of social sustainability in a good bioeconomy, this study presented the main social indicators used to measure social performance, effects, and impacts to this date (Macombe et al., 2013). Indeed, the reviewed evaluations detected a limited number of discussions on the implications of social sustainability and social transformation assessment within the bioeconomy. These findings may be attributed to the dominant forms of euro-modernity and the highly technical knowledge that feature S-LCA research within the bioeconomy today. Consequently, the S-LCA is not currently specifically applied to assess socially sustainable transitions within a bioeconomy. Thus, following the recommendations proposed throughout this review to address current knowledge gaps concerning the formulation of more interdisciplinary and transdisciplinary social assessments and to enhance the comprehension and implications of social sustainability within the specific context of a good bioeconomy is strongly recommended.

Finally, the findings indicate that the evaluation of social sustainability transitions within a bioeconomy remains limited, underscoring the need for policy implications that advocate a more comprehensive study and assessment of social transformations in this domain. Therefore, it is recommended that the design of public policies related to the bioeconomy be enhanced by defining social sustainability more precisely and establishing clear needs, objectives, and strategies for its achievement. Moreover, given the growing prominence of the S-LCA within the bioeconomy, policymakers must support its further development. This advancement should be guided by the recommendations presented in this review to ensure alignment with the principles of a good bioeconomy.

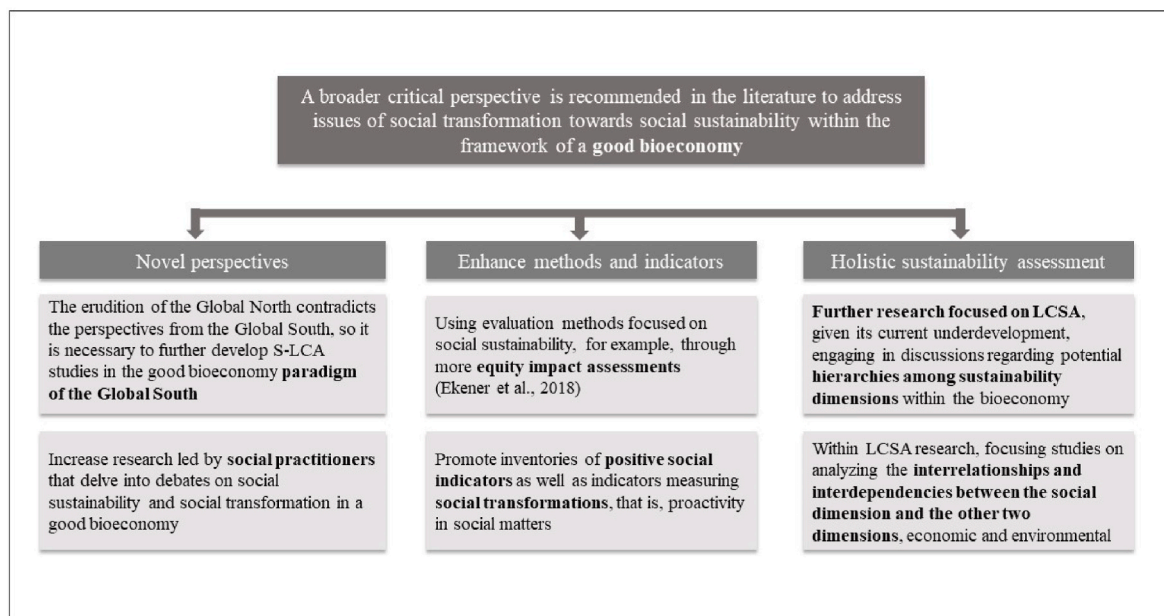


Fig. 5. Recommendations for future research towards a social sustainability in a good bioeconomy.

## CRedit authorship contribution statement

**Irene Zarauz:** Writing – review & editing, Writing – original draft, Resources, Methodology, Formal analysis, Conceptualization. **Alexia Sanz-Hernández:** Supervision, Resources, Methodology, Conceptualization. **Juana M. Rivera-Lirio:** Supervision, Resources, Methodology, Conceptualization.

## Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT in order to improve language and readability. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

This study was developed in the framework of the Cátedra Tervalis of Bioeconomy and Society (University of Zaragoza) and of the Instituto Interuniversitario de Desarrollo Social y Paz (IUDESP) (University Jaume I). This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The elaboration of the final version of the paper has been co-financed by the Regional Government of Aragón – Research Group of Socioeconomics and Sustainability. Ref.: S33\_20R (Spain), as well as by the project CIAICO/2021/090 (Generalitat Valenciana) and the ToNoWaste project (Horizon Europe Programme).

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jclepro.2024.144570>.

## Data availability

No data was used for the research described in the article.

## References

- Alidoosti, Z., Ahmad, S., Govindan, K., Pishvae, M.S., Mostafaiepour, A., Hossain, A.K., 2021. Social sustainability of treatment technologies for bioenergy generation from the municipal solid waste using best worst method. *J. Clean. Prod.* 288, 125592. <https://doi.org/10.1016/j.jclepro.2020.125592>.
- Andrade, E.P., Bonmati, A., Esteller, L.J., Vallejo, A.A., 2022. Assessment of social aspects across Europe resulting from the insertion of technologies for nutrient recovery and recycling in agriculture. *Sustain. Prod. Consum.* 31, 52–66. <https://doi.org/10.1016/j.spc.2022.01.025>.
- Andreucci, M.B., Marvuglia, A., Baltov, M., Hansen, P. (Eds.), 2021. *Rethinking Sustainability towards a Regenerative Economy*, vol. 15. Springer International Publishing. <https://doi.org/10.1007/978-3-030-71819-0>.
- Apostolopoulou, E., Chatzimentor, A., Maestre-Andrés, S., Requena-i-Mora, M., Pizarro, A., Bormpoudakis, D., 2021. Reviewing 15 years of research on neoliberal conservation: towards a decolonial, interdisciplinary, intersectional and community-engaged research agenda. *Geoforum* 124, 236–256. <https://doi.org/10.1016/j.geoforum.2021.05.006>.
- Asada, R., Cardellini, G., Mair-Bauerfeind, C., Wenger, J., Haas, V., Holzer, D., Stern, T., 2020. Effective bioeconomy? A MRIO-based socioeconomic and environmental impact assessment of generic sectoral innovations. *Technol. Forecast. Soc. Change* 153, 119946. <https://doi.org/10.1016/j.techfore.2020.119946>.
- Barrio, A., Francisco, F.B., Leoncini, A., Wietschel, L., Thorenz, A., 2021. Life cycle sustainability assessment of a novel bio-based multilayer panel for construction applications. *Resources* 10, 98. <https://doi.org/10.3390/resources10100098>.
- Bracco, S., Tani, A., Çalıcıoğlu, Ö., Gomez San Juan, M., Bogdanski, A., 2019. Indicators to monitor and evaluate the sustainability of bioeconomy. Overview and a proposed way forward. FAO, Rome. <https://openknowledge.fao.org/items/620e2572-d3fb-478b-9fde-57bfec637731>.
- Bryden, J., Gezelius, S.S., Refsgaard, K., Sutz, J., 2017. Inclusive innovation in the bioeconomy: concepts and directions for research. *Innov. Dev.* 7, 1–16. <https://doi.org/10.1080/2157930X.2017.1281209>.
- Cadena, E., Rocca, F., Gutierrez, J.A., Carvalho, A., 2019. Social life cycle assessment methodology for evaluating production process design: biorefinery case study. *J. Clean. Prod.* 238, 117718. <https://doi.org/10.1016/j.jclepro.2019.117718>.
- Cardoso, T.F., Watanabe, M.D.B., Souza, A., Chagas, M.F., Cavalett, O., Morais, E.R., Nogueira, L.A.H., Leal, M.R.L.V., Braunbeck, O.A., Cortez, L.A.B., Bonomi, A., 2019. A regional approach to determine economic, environmental and social impacts of different sugarcane production systems in Brazil. *Biomass Bioenergy* 120, 9–20. <https://doi.org/10.1016/j.biombioe.2018.10.018>.
- Contreras-Lisperguer, R., Batuecas, E., Mayo, C., Díaz, R., Pérez, F.J., Springer, C., 2018. Sustainability assessment of electricity cogeneration from sugarcane bagasse in Jamaica. *J. Clean. Prod.* 200, 390–401. <https://doi.org/10.1016/j.jclepro.2018.07.322>.
- Corona, B., San Miguel, G., 2019. Life cycle sustainability analysis applied to an innovative configuration of concentrated solar power. *Int. J. Life Cycle Assess.* 24, 1444–1460. <https://doi.org/10.1007/s11367-018-1568-z>.
- Costa, D., Quinteiro, P., Dias, A.C., 2019. A systematic review of life cycle sustainability assessment: current state, methodological challenges, and implementation issues. *Sci. Total Environ.* 686, 774–787. <https://doi.org/10.1016/j.scitotenv.2019.05.435>.
- Costa, M.W., Oliveira, A.A.M., 2022. Social life cycle assessment of feedstocks for biodiesel production in Brazil. *Renew. Sustain. Energy Rev.* 159, 112166. <https://doi.org/10.1016/j.rser.2022.112166>.
- Costa, D., Quinteiro, P., Pereira, V., Dias, A.C., 2022a. Social life cycle assessment based on input-output analysis of the Portuguese pulp and paper sector. *J. Clean. Prod.* 330, 129851. <https://doi.org/10.1016/j.jclepro.2021.129851>.
- Costa, A.M., Mancini, S.D., Paes, M.X., Ugaya, C.M.L., De Medeiros, G.A., De Souza, R.G., 2022b. Social evaluation of municipal solid waste management systems from a life cycle perspective: a systematic literature review. *Int. J. Life Cycle Assess.* 27, 719–739. <https://doi.org/10.1007/s11367-022-02057-6>.
- Desiderio, E., García-Herrero, L., Hall, D., Segre, A., Vittuari, M., 2022. Social sustainability tools and indicators for the food supply chain: a systematic literature review. *Sustain. Prod. Consum.* 30, 527–540. <https://doi.org/10.1016/j.spc.2021.12.015>.
- D'Eusanio, M., Zamagni, A., Petti, L., 2019. Social sustainability and supply chain management: methods and tools. *J. Clean. Prod.* 235, 178–189. <https://doi.org/10.1016/j.jclepro.2019.06.323>.
- Dietz, S., Neumayer, E., 2007. Weak and strong sustainability in the SEEA: concepts and measurement. *Ecol. Econ.* 61, 617–626. <https://doi.org/10.1016/j.ecolecon.2006.09.007>.
- Dietz, T., Börner, J., Förster, J., von Braun, J., 2018. Governance of the bioeconomy: a global comparative study of national bioeconomy strategies. *Sustainability* 10, 3190. <https://doi.org/10.3390/su10093190>.
- Do Carmo, B.B.T., Margni, M., Baptiste, P., 2017. Addressing uncertain scoring and weighting factors in social life cycle assessment. *Int. J. Life Cycle Assess.* 22, 1609–1617. <https://doi.org/10.1007/s11367-017-1275-1>.
- European Commission (EC), 2018. *A Sustainable Bioeconomy for Europe: Strengthening the Connection between Economy, Society and the Environment*. Updated Bioeconomy Strategy. Publications Office. <https://data.europa.eu/doi/10.2777/792130>.
- Ekener-Petersen, E., Höglund, J., Finnveden, G., 2014. Screening potential social impacts of fossil fuels and biofuels for vehicles. *Energy Pol.* 73, 416–426. <https://doi.org/10.1016/j.enpol.2014.05.034>.
- Ekener, E., Hansson, J., Gustavsson, M., 2018. Addressing positive impacts in social LCA—discussing current and new approaches exemplified by the case of vehicle fuels. *Int. J. Life Cycle Assess.* 23, 556–568. <https://doi.org/10.1007/s11367-016-1058-0>.
- Escobar, A., 2015. Degrowth, postdevelopment, and transitions: a preliminary conversation. *Sustain. Sci.* 10, 451–462. <https://doi.org/10.1007/s11625-015-0297-5>.
- Eversberg, D., Fritz, M., 2022. Bioeconomy as a societal transformation: mentalities, conflicts and social practices. *Sustain. Prod. Consum.* 30, 973–987. <https://doi.org/10.1016/j.spc.2022.01.021>.
- Eversberg, D., Holz, J., Pungas, L., 2023. The bioeconomy and its untenable growth promises: reality checks from research. *Sustain. Sci.* 18, 569–582. <https://doi.org/10.1007/s11625-022-01237-5>.
- Falcone, P.M., Imbert, E., 2018. Social life cycle approach as a tool for promoting the market uptake of bio-based products from a consumer perspective. *Sustainability* 10, 1031. <https://doi.org/10.3390/su10041031>.
- Falcone, P.M., González García, S., Imbert, E., Lijó, L., Moreira, M.T., Tani, A., Tartiu, V. E., Morone, P., 2019. Transitioning towards the bio-economy: assessing the social dimension through a stakeholder lens. *Corp. Soc. Responsib. Environ. Manag.* 26, 1135–1153. <https://doi.org/10.1002/csr.1791>.
- Feola, G., 2015. Societal transformation in response to global environmental change: a review of emerging concepts. *Ambio* 44, 376–390. <https://doi.org/10.1007/s13280-014-0582-z>.
- Ferreira, V., Fabregat-Aibar, L., Pié, L., Terceño, A., 2022. Research trends and hotspots in bioeconomy impact analysis: a study of economic, social and environmental impacts. *Environ. Impact Assess. Rev.* 96, 106842. <https://doi.org/10.1016/j.eiar.2022.106842>.
- Fürtner, D., Ranacher, L., Perdomo Echenique, E.A., Schwarzbauer, P., Hesser, F., 2021. Locating hotspots for the social life cycle assessment of bio-based products from

- short rotation coppice. *BioEnergy Res* 14, 510–533. <https://doi.org/10.1007/s12155-021-10261-9>.
- Ghaderi, H., Moini, A., Pishvae, M.S., 2018. A multi-objective robust possibilistic programming approach to sustainable switchgrass-based bioethanol supply chain network design. *J. Clean. Prod.* 179, 368–406. <https://doi.org/10.1016/j.jclepro.2017.12.218>.
- Huertas-Valdivia, I., Ferrari, A.M., Settembre-Blundo, D., García-Muñia, F.E., 2020. Social life-cycle assessment: a review by bibliometric analysis. *Sustainability* 12, 6211. <https://doi.org/10.3390/su12156211>.
- Jarosch, L., Zeug, W., Bezama, A., Finkbeiner, M., Thrän, D., 2020. A regional socio-economic life cycle assessment of a bioeconomy value chain. *Sustainability* 12, 1259. <https://doi.org/10.3390/su12031259>.
- Keller, H., Rettenmaier, N., Reinhardt, G.A., 2015. Integrated life cycle sustainability assessment – a practical approach applied to biorefineries. *Appl. Energy* 154, 1072–1081. <https://doi.org/10.1016/j.apenergy.2015.01.095>.
- Kühnen, M., Hahn, R., 2017. Indicators in social life cycle assessment: a review of frameworks, theories, and empirical experience: indicators in social life cycle assessment. *J. Ind. Ecol.* 21, 1547–1565. <https://doi.org/10.1111/jiec.12663>.
- Kurki, S., Ahola-Launonen, J., 2021. Bioeconomy in maturation: a pathway towards a “Good” bioeconomy or distorting silence on crucial matters?. In: *Bio# Futures*. Springer, Cham, pp. 165–199. [https://doi.org/10.1007/978-3-030-64969-2\\_9](https://doi.org/10.1007/978-3-030-64969-2_9).
- Lehtonen, M., 2004. The environmental–social interface of sustainable development: capabilities, social capital, institutions. *Ecol. Econ.* 49, 199–214. <https://doi.org/10.1016/j.ecolecon.2004.03.019>.
- Littig, B., Griessler, E., 2005. Social sustainability: a catchword between political pragmatism and social theory. *Int. J. Sustain. Dev.* 8, 65. <https://doi.org/10.1504/IJSD.2005.007375>.
- Luthin, A., Travieso, M., Crawford, R.H., 2023. Assessing the social life cycle impacts of circular economy. *J. Clean. Prod.* 386, 135725. <https://doi.org/10.1016/j.jclepro.2022.135725>.
- Ly, A.M., Cope, M.R., 2023. New conceptual model of social sustainability: review from past concepts and ideas. *J. Environ. Public Health* 20, 5350. <https://doi.org/10.3390/ijerph20075350>.
- Macombe, C., Leskinen, P., Feschet, P., Antikainen, R., 2013. Social life cycle assessment of biodiesel production at three levels: a literature review and development needs. *J. Clean. Prod.* 52, 205–216. <https://doi.org/10.1016/j.jclepro.2013.03.026>.
- Macombe, C., Zamagni, A., Travieso, M., 2018. Preface. *Int. J. Life Cycle Assess.* 23, 387–393. <https://doi.org/10.1007/s11367-017-1419-3>.
- Mair-Bauerfeind, C., Zimek, M., Lettner, M., Hesser, F., Baumgartner, R.J., Stern, T., 2020. Comparing the incomparable? A review of methodical aspects in the sustainability assessment of wood in vehicles. *Int. J. Life Cycle Assess.* 25, 2217–2240. <https://doi.org/10.1007/s11367-020-01800-1>.
- Manik, Y., Leahy, J., Halog, A., 2013. Social life cycle assessment of palm oil biodiesel: a case study in Jambi Province of Indonesia. *Int. J. Life Cycle Assess.* 18, 1386–1392. <https://doi.org/10.1007/s11367-013-0581-5>.
- Martin, M., Royné, F., Ekvall, T., Moberg, Å., 2018. Life cycle sustainability evaluations of bio-based value chains: reviewing the indicators from a Swedish perspective. *Sustainability* 10, 547. <https://doi.org/10.3390/su10020547>.
- Martínez-Blanco, J., Lehmann, A., Muñoz, P., Antón, A., Travieso, M., Rieradevall, J., Finkbeiner, M., 2014. Application challenges for the social Life Cycle Assessment of fertilizers within life cycle sustainability assessment. *J. Clean. Prod.* 69, 34–48. <https://doi.org/10.1016/j.jclepro.2014.01.044>.
- Martínez-Hernández, E., Sadhukhan, J., Aburto, J., Amezcua-Allieri, M.A., Morse, S., Murphy, R., 2022. Modelling to analyse the process and sustainability performance of forestry-based bioenergy systems. *Clean Technol. Environ. Policy* 24, 1709–1725. <https://doi.org/10.1007/s10098-022-02278-1>.
- Martín-Gamboa, M., Dias, A.C., Arroja, L., Iribarren, D., 2020. A protocol for the definition of supply chains in product social life cycle assessment: application to bioelectricity. *Sustain. Energy Fuels* 4, 5533–5542. <https://doi.org/10.1039/D0SE00919A>.
- Martín-Gamboa, M., Quinteiro, P., Dias, A.C., Iribarren, D., 2021. Comparative social life cycle assessment of two biomass-to-electricity systems. *Int. J. Environ. Res. Publ. Health* 18, 4918. <https://doi.org/10.3390/ijerph18094918>.
- Martín-Gamboa, M., Dias, A.C., Iribarren, D., 2022. Definition, assessment and prioritisation of strategies to mitigate social life-cycle impacts across the supply chain of bioelectricity: a case study in Portugal. *Renew. Energy* 194, 1110–1118. <https://doi.org/10.1016/j.renene.2022.06.002>.
- Marting-Vidaurre, N.A., Lewandowski, I., Lask, J., 2022. Identifying methodological challenges in the social risk assessment of cellulosic ethanol value chains. *J. Ind. Ecol.* 26, 1233–1246. <https://doi.org/10.1111/jiec.13287>.
- Masilela, P., Pradhan, A., 2021. A life cycle sustainability assessment of biomethane versus biohydrogen – for application in electricity or vehicle fuel? Case studies for African context. *J. Clean. Prod.* 328, 129567. <https://doi.org/10.1016/j.jclepro.2021.129567>.
- Mattila, T.J., Judl, J., Macombe, C., Leskinen, P., 2018. Evaluating social sustainability of bioeconomy value chains through integrated use of local and global methods. *Biomass Bioenergy* 109, 276–283. <https://doi.org/10.1016/j.biombioe.2017.12.019>.
- Mattioda, R.A., Mazzi, A., Cancigliari, O., Scipioni, A., 2015. Determining the principal references of the social life cycle assessment of products. *Int. J. Life Cycle Assess.* 20, 1155–1165. <https://doi.org/10.1007/s11367-015-0873-z>.
- Messmann, L., Wietschel, L., Thorenz, A., Tuma, A., 2022. Assessing the social dimension in strategic network optimization for a sustainable development. *J. Ind. Ecol.* 27, 760–776. <https://doi.org/10.1111/jiec.13324>.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., Group, the P., 2009. Academia and clinic annals of internal medicine preferred reporting Items for systematic reviews and meta-analyses. *Ann. Intern. Med.* 151, 264–269. <https://doi.org/10.1371/journal.pmed.1000097>.
- Muhammad, K.I., Sharaai, A.H., Ismail, M.M., Harun, R., Yien, W.S., 2019. Social implications of palm oil production through social life cycle perspectives in Johor, Malaysia. *Int. J. Life Cycle Assess.* 24, 935–944. <https://doi.org/10.1007/s11367-018-1540-y>.
- Nowell, L.S., Norris, J.M., White, D.E., Moules, N.J., 2017. Thematic analysis: striving to meet the trustworthiness criteria. *Int. J. Qual. Methods* 16, 160940691773384. <https://doi.org/10.1177/1609406917733847>.
- Omran, N., Sharaai, A.H., Hashim, A.H., 2021. Visualization of the sustainability level of crude palm oil production: a life cycle approach. *Sustainability* 13, 1607. <https://doi.org/10.3390/su13041607>.
- Panoutsou, C., Von Cossel, M., Ciria, P., Ciria, C.S., Baraniecki, P., Monti, A., Zanetti, F., Dubois, J., 2022. Social considerations for the cultivation of industrial crops on marginal agricultural land as feedstock for bioeconomy. *Biofuel. Bioprod. Biorefin.* 16, 1319–1341. <https://doi.org/10.1002/bbb.2376>.
- Papadopoulou, C.I., Loizou, E., Chatzitheodoridis, F., 2022. Priorities in bioeconomy strategies: a systematic literature review. *Energies* 15, 7258. <https://doi.org/10.3390/en15197258>.
- Petti, L., Serreli, M., Di Cesare, S., 2018. Systematic literature review in social life cycle assessment. *Int. J. Life Cycle Assess.* 23, 422–431. <https://doi.org/10.1007/s11367-016-1135-4>.
- Pollok, L., Spierling, S., Endres, H.J., Grote, U., 2021. Social life cycle assessments: a review on past development, advances and methodological challenges. *Sustainability* 13, 10286. <https://doi.org/10.3390/su131810286>.
- Portner, B., Valente, A., Guenther, S., 2021. Sustainability assessment of combined animal fodder and fuel production from microalgal biomass. *Int. J. Environ. Res. Publ. Health* 18, 11351. <https://doi.org/10.3390/ijerph182111351>.
- Prasara-A, J., Gheewala, S.H., Silalertruksa, T., Pongpat, P., Sawaengsak, W., 2019. Environmental and social life cycle assessment to enhance sustainability of sugarcane-based products in Thailand. *Clean Technol. Environ. Policy* 21, 1447–1458. <https://doi.org/10.1007/s10098-019-01715-y>.
- Prasara-A, J., Gheewala, S.H., 2021. An assessment of social sustainability of sugarcane and cassava cultivation in Thailand. *Sustain. Prod. Consum.* 27, 372–382. <https://doi.org/10.1016/j.spc.2020.11.009>.
- Rafiaani, P., Kuppens, T., Thomassen, G., Van Dael, M., Azadi, H., Lebailly, P., Van Passel, S., 2020. A critical view on social performance assessment at company level: social life cycle analysis of an algae case. *Int. J. Life Cycle Assess.* 25, 363–381. <https://doi.org/10.1007/s11367-019-01702-x>.
- Ramcilovic-Suominen, S., 2023. Envisioning just transformations in and beyond the EU bioeconomy: inspirations from decolonial environmental justice and degrowth. *Sustain. Sci.* 18, 707–722. <https://doi.org/10.1007/s11625-022-01091-5>.
- Ramcilovic-Suominen, S., Püzl, H., 2018. Sustainable development – a ‘selling point’ of the emerging EU bioeconomy policy framework? *J. Clean. Prod.* 172, 4170–4180. <https://doi.org/10.1016/j.jclepro.2016.12.157>.
- Ramcilovic-Suominen, S., Kröger, M., Dressler, W., 2022. From pro-growth and planetary limits to degrowth and decoloniality: an emerging bioeconomy policy and research agenda. *For. Policy Econ.* 144, 102819. <https://doi.org/10.1016/j.forpol.2022.102819>.
- Ramos-Huarech, D.A., Piekarski, C.M., Puglieri, F.N., de Francisco, A.C., 2020. Past and future of social life cycle assessment: historical evolution and research trends. *J. Clean. Prod.* 264, 121506. <https://doi.org/10.1016/j.jclepro.2020.121506>.
- Rebolledo-Leiva, R., Moreira, M.T., González-García, S., 2023. Progress of social assessment in the framework of bioeconomy under a life cycle perspective. *Renew. Sustain. Energy Rev.* 175, 113162. <https://doi.org/10.1016/j.rser.2023.113162>.
- Ren, J., Manzardo, A., Mazzi, A., Zulfiani, F., Scipioni, A., 2015. Prioritization of bioethanol production pathways in China based on life cycle sustainability assessment and multicriteria decision-making. *Int. J. Life Cycle Assess.* 20, 842–853. <https://doi.org/10.1007/s11367-015-0877-8>.
- Rodríguez, A.G., Aramendis, R.H., Mondaini, A.O., 2018. El financiamiento de la bioeconomía en países seleccionados de Europa, Asia y África. *Experiencias Para América Latina y el Caribe* 222, 5–59. <https://bit.ly/3r1bHcn>. (Accessed 13 January 2023).
- Roman, R.M., Hayibor, S., Agle, B.R., 1999. The relationship between social and financial performance: repainting a portrait. *Bus. Soc.* 38, 109–125. <https://doi.org/10.1177/000765039903800105>.
- Sajid, Z., Lynch, N., 2018. Financial modelling strategies for social life cycle assessment: a project appraisal of biodiesel production and sustainability in Newfoundland and Labrador, Canada. *Sustainability* 10, 3289. <https://doi.org/10.3390/su10093289>.
- Salvador, R., Puglieri, F.N., Halog, A., Andrade, F.G. de, Piekarski, C.M., De Francisco, A.C., 2021. Key aspects for designing business models for a circular bioeconomy. *J. Clean. Prod.* 278, 124341. <https://doi.org/10.1016/j.jclepro.2020.124341>.
- Sanz-Hernández, A., Esteban, E., Garrido, P., 2019. Transition to a bioeconomy: perspectives from social sciences. *J. Clean. Prod.* 224, 107–119. <https://doi.org/10.1016/j.jclepro.2019.03.168>.
- Sanz-Hernández, A., Jiménez-Caballero, P., Zarauz, I., 2022. Gender and women in scientific literature on bioeconomy: a systematic review. *For. Policy Econ.* 141, 102762. <https://doi.org/10.1016/j.forpol.2022.102762>.
- Sawaengsak, W., Olsen, S.I., Hauschild, M.Z., Gheewala, S.H., 2019. Development of a social impact assessment method and application to a case study of sugarcane, sugar, and ethanol in Thailand. *Int. J. Life Cycle Assess.* 24, 2054–2072. <https://doi.org/10.1007/s11367-019-01624-8>.
- Siebert, A., Bezama, A., O’Keeffe, S., Thrän, D., 2018a. Social life cycle assessment indices and indicators to monitor the social implications of wood-based products. *J. Clean. Prod.* 172, 4074–4084. <https://doi.org/10.1016/j.jclepro.2017.02.146>.

- Siebert, A., O'Keefe, S., Bezama, A., Zeug, W., Thrän, D., 2018b. How not to compare apples and oranges: generate context-specific performance reference points for a social life cycle assessment model. *J. Clean. Prod.* 198, 587–600. <https://doi.org/10.1016/j.jclepro.2018.06.298>.
- Silva, D.A.L., Vázquez-Ibarra, L., Farrapo Junior, A.C., Musule Lagunes, R., 2024. Comparative social hotspots analysis of biomass pellets in Brazil, Chile, and Mexico in a circular bioeconomy context. *Int. J. Life Cycle Assess.* <https://doi.org/10.1007/s11367-024-02333-7>.
- Souza, A., Watanabe, M.D.B., Cavalett, O., Ugaya, C.M.L., Bonomi, A., 2018. Social life cycle assessment of first and second-generation ethanol production technologies in Brazil. *Int. J. Life Cycle Assess.* 23, 617–628. <https://doi.org/10.1007/s11367-016-1112-y>.
- Souza, A., Watanabe, M.D.B., Cavalett, O., Cunha, M., Ugaya, C.M.L., Bonomi, A., 2021. A novel social life cycle assessment method for determining workers' human development: a case study of the sugarcane biorefineries in Brazil. *Int. J. Life Cycle Assess.* 26, 2072–2084. <https://doi.org/10.1007/s11367-021-01936-8>.
- Spierling, S., Knüpfner, E., Behnsen, H., Mudersbach, M., Krieg, H., Springer, S., Albrecht, S., Herrmann, C., Endres, H.J., 2018. Bio-based plastics—a review of environmental, social and economic impact assessments. *J. Clean. Prod.* 185, 476–491. <https://doi.org/10.1016/j.jclepro.2018.03.014>.
- Starke, J.R., Metze, T.A.P., Candel, J.J.L., Termeer, C.J.A.M., 2022. Conceptualizing controversies in the EU circular bioeconomy transition. *Ambio* 51, 2079–2090. <https://doi.org/10.1007/s13280-022-01730-2>.
- Takeda, S., Keeley, A., Sakurai, S., Managi, S., Norris, C., 2019. Are renewables as friendly to humans as to the environment?: a social life cycle assessment of renewable electricity. *Sustainability* 11, 1370. <https://doi.org/10.3390/su11051370>.
- Tavakoli, H., Barkdoll, B.D., 2020. Blended lifecycle integrated social system method. *Int. J. Environ. Res.* 14, 727–749. <https://doi.org/10.1007/s41742-020-00284-z>.
- Temper, L., Walter, M., Rodriguez, I., Kothari, A., Turhan, E., 2018. A perspective on radical transformations to sustainability: resistances, movements and alternatives. *Sustain. Sci.* 13, 747–764. <https://doi.org/10.1007/s11625-018-0543-8>.
- Többen, J., Stöver, B., Reuschel, S., Distelkamp, M., Lutz, C., 2024. Sustainability implications of the EU's bioeconomy transition along global supply chains. *J. Clean. Prod.* 461, 142565. <https://doi.org/10.1016/j.jclepro.2024.142565>.
- Tragnone, B.M., D'Eusanio, M., Petti, L., 2022. The count of what counts in the agri-food social life cycle assessment. *J. Clean. Prod.* 354, 131624. <https://doi.org/10.1016/j.jclepro.2022.131624>.
- UNEP, 2020. Guidelines for social life cycle assessment of products and organizations 2020. <https://www.lifecycleinitiative.org/wp-content/uploads/2020/12/Guidelines-for-Social-Life-Cycle-Assessment-of-Products-and-Organizations-2020-sml.pdf>.
- UNEP, 2021. Methodological sheets for subcategories in social life cycle assessment 2021. <https://www.lifecycleinitiative.org/library/methodological-sheets-for-subcategories-in-social-life-cycle-assessment-s-lca-2021/>.
- UNESCO, 2012. International standard classification of education: ISCED 2011. <http://www.uis.unesco.org/Education/Pages/international-standard-classification-of-education.aspx>. (Accessed 24 November 2022).
- Valente, C., Brekke, A., Modahl, I.S., 2018. Testing environmental and social indicators for biorefineries: bioethanol and biochemical production. *Int. J. Life Cycle Assess.* 23, 581–596. <https://doi.org/10.1007/s11367-017-1331-x>.
- Vallance, S., Perkins, H.C., Dixon, J.E., 2011. What is social sustainability? A clarification of concepts. *Geoforum* 42, 342–348. <https://doi.org/10.1016/j.geoforum.2011.01.002>.
- Weldegiorgis, F.S., Franks, D.M., 2014. Social dimensions of energy supply alternatives in steelmaking: comparison of biomass and coal production scenarios in Australia. *J. Clean. Prod.* 84, 281–288. <https://doi.org/10.1016/j.jclepro.2013.09.056>.
- Zeug, W., Bezama, A., Thrän, D., 2021. A framework for implementing holistic and integrated life cycle sustainability assessment of regional bioeconomy. *Int. J. Life Cycle Assess.* 26, 1998–2023. <https://doi.org/10.1007/s11367-021-01983-1>.
- Zhang, Y., Li, J., Liu, H., Zhao, G., Tian, Y., Xie, K., 2021. Environmental, social, and economic assessment of energy utilization of crop residue in China. *Front. Energy* 15, 308–319. <https://doi.org/10.1007/s11708-020-0696-x>.