energies

MDPI

Review

A Review Analysis of Electricity Generation Studies with Social Life Cycle Assessment

Georgios Archimidis Tsalidis [1,2,*], Maria Batsioula [3], George F. Banias [3] and Evina Katsou [2]

1 Department of Civil and Environmental Engineering, Brunel University London, Uxbridge UB8 3PH, UK
2 Department of Civil and Environmental Engineering, Imperial College London, London SW7 2AZ, UK; e.katsou@imperial.ac.uk
3 Institute for Bio-Economy and Agri-Technology (IBO), Centre for Research and Technology-Hellas, 57001 Thermi, Greece; m.batsioula@certh.gr (M.B.); g.banias@certh.gr (G.F.B.)
* Correspondence: g.tsalidis@imperial.ac.uk; Tel.: +44-7442-633-327

Abstract: This review explores the social impacts of electricity production by applying the framework of Social Life Cycle Assessment (S-LCA). The authors adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines to select studies that were published post-2010 and used S-LCA in the context of various electricity sources, including bioelectricity, solar, wind, and hydropower. The search yielded 13 eligible studies that employed both generic and site-specific assessment strategies, primarily relying on the Social Hotspot Database and Product Social Impact Life Cycle Assessment database for generic evaluations. The findings emphasize the Workers stakeholder as the most frequently examined, with significant attention also given to the Local Community, Society, Value Chain Actors, and Consumer stakeholders when social databases are employed. The studies primarily assessed socioeconomic impact subcategories related to labor practices, health and safety, and economic contributions, as well as a tailored set of self-developed social impacts and indicators specific to the energy sources and geographical contexts examined. This review demonstrates the crucial role of S-LCA in revealing the socio-economic impacts of electricity generation and the need to consider the impacts on Local Community and Society stakeholders through site-specific assessments. Such insights are crucial for guiding policy reforms and industry practices towards more socially responsible energy production.

Keywords: reference scale; PRISMA; PSILCA; SHDB; site-specific; S-LCA; SLCA

Citation: Tsalidis, G.A.; Batsioula, M.; Banias, G.F.; Katsou, E. A Review Analysis of Electricity Generation Studies with Social Life Cycle Assessment. *Energies* **2024**, *17*, 2929. https://doi.org/10.3390/en17122929

Academic Editor: Eugenio Meloni

Received: 17 April 2024
Revised: 6 June 2024
Accepted: 11 June 2024
Published: 14 June 2024

1. Introduction

Electricity is of great importance in several aspects of daily life and societal progress. Beyond being fundamental in daily life, electricity is crucial for operating appliances, enabling food preparation and preservation [1], providing lighting and powering technology, and forming the operational backbone of modern living [2]. As a result, electricity is a basic need, similar to food and water [3]. Electricity is a focal aspect of energy transition that aims for significant sustainable change in the energy system and alignment with Sustainable Development Goals (SDGs), such as affordable clean energy and reduced inequalities [4]. The socio-economic impacts of the energy transition include job creation and social equality, reinforcing the need for a balanced and fair approach that accounts for social aspects to achieve a 100% renewable energy agenda [5]. Therefore, it is crucial to identify what are the most considered social impact issues that complement the environmental and economic aspects of energy transition.

Societal dependency on electricity extends to healthcare, powering life-saving equipment, and education through digital learning tools. Furthermore, electricity is vital to industrial machinery and computing infrastructure, which are essential for economic growth. However, conventional electricity production relies mainly on fossil fuel combustion, resulting in pollution and climate change. More than 40% of energy-related carbon dioxide emissions are generated by fossil fuel combustion for electricity generation [6]. This substantial contribution demonstrates the urgent need to decarbonize energy systems, which is a critical step for many countries striving to achieve their 2030 climate goals. This process, known as the "energy transition", involves a shift from carbon-intensive energy sources, such as coal, oil, and natural gas, to renewable sources, such as solar, wind, and hydroelectric power. In addition, the energy transition must encompass environmental, economic, and societal aspects, and comprises steps to reduce the environmental footprint of modern society's production and consumption patterns. The environmental [7–9] and economic [10,11] aspects of energy transition have been heavily investigated, but the assessment of social aspects is still under-investigated [12].

Calculating the social impacts of renewable electricity types on energy transition and comparing them with fossil electricity is crucial for achieving a just and equitable shift from fossil fuels to renewable energy sources. This shift will affect employment, occupational health and safety, and socio-economic equity. For instance, transitioning to renewable energy can result in job creation in new sectors while causing job losses in the fossil energy sector [13]. For instance, Sun et al. [13] highlighted the transition's impact on the labor market, indicating significant shifts in employment structures and the need for strategies to manage workforce changes during this crucial shift towards sustainable energy practices. Therefore, researchers have focused on analyzing electricity generation using S-LCA to investigate the social issues that occur during the production stage of electricity. Moreover, certain renewable electricity sources may have higher occupational accident rates [14], but overall human health may be improved because of local pollution reduction [15]. Ultimately, consumers also affect the employment of renewable technologies due to electricity generation at the house level. For instance, Tsalidis [16] emphasized the importance of integrating individual behavior dimensions in this process, acknowledging social costs, including adjustments to consumer habits and potential price increases.

Social Life Cycle Assessment (S-LCA) uses the framework of environmental LCA to evaluate social impacts associated with organizations and products. The United Nations published comprehensive guidelines for S-LCA [17,18], which provide a structured methodology to ensure that S-LCA studies are comprehensive and address global social concerns while also identifying local specificities. S-LCA is classified into a generic or "hotspot" level, which identifies broader social issues potentially impacted by product life cycles, and a site-specific level, which offers a more detailed assessment of a product's social impacts at specific locations or facilities [18]. Benoît et al. [17] emphasize the significance of a both-level approach in S-LCA to fully understand the social impacts. In addition, S-LCA captures a wide array of social factors, ranging from labor practices, including worker rights and conditions, to community engagement, encompassing local development and societal well-being. However, S-LCA is still a developing field that lacks consensus regarding indicator and impact selection [19]. A recent review by Huertas-Valdivia et al. underscores the diversity of methodologies and challenges in standardizing approaches, particularly in defining relevant social indicators [19]. Petti et al. [20] further elaborate on this complexity, stating that both qualitative and quantitative data types are often employed by the same study, resulting in extra layers of complexity to data interpretation. Moreover, these authors observed a variety of models for impact assessment in the S-LCA, reflecting the field's dynamic nature. Therefore, this variability underscores the need for continued research and dialogue to refine and agree on standard practices in S-LCA.

Energy transition should be carefully managed to minimize the social burdens on local communities, workers, and a broader society. This is crucial because the transition can have profound impacts on employment patterns, community stability, and overall societal well-being. Recognizing these challenges, the present study delves into S-LCA research, focusing specifically on electricity generation. The basic scope is to collate and analyze studies that explore the social implications of electricity generation, from effects on workers' rights to local community impacts. This review aims to highlight current research trends and findings as well as identify gaps and areas that need further exploration. Ultimately, this study provides targeted recommendations for S-LCA practitioners, guiding future research to investigate and address social issues emerging from the shift to sustainable electricity generation. These recommendations are intended to inform policies and practices that support fair energy transition, thereby ensuring that the shift to sustainable energy sources is socially responsible and inclusive.

2. Materials and Methods

In the present review, the latest version of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [21] was employed. The latest PRISMA version was published in the form of three papers: a statement paper [21] that comprises a 27-item checklist, a development paper [22] that outlines the actions taken and provides rationale for changes to the initial PRISMA statement, and the PRISMA 2020 explanation and elaboration paper [23]. The guidelines are a set of evidence-based recommendations aimed at improving the quality of reporting in systematic reviews and meta-analyses. This way, the PRISMA methodology ensures comprehensive and transparent reporting, contributing significantly to the reliability and validity of the review.

The PRISMA Statement is based on a four-phase flow diagram (see Figure 1), which is used to illustrate the flow of information through the different phases of a review [21]. The purpose of PRISMA is to provide identification, screening, eligibility, and inclusion criteria in a transparent manner for the reader of the study.

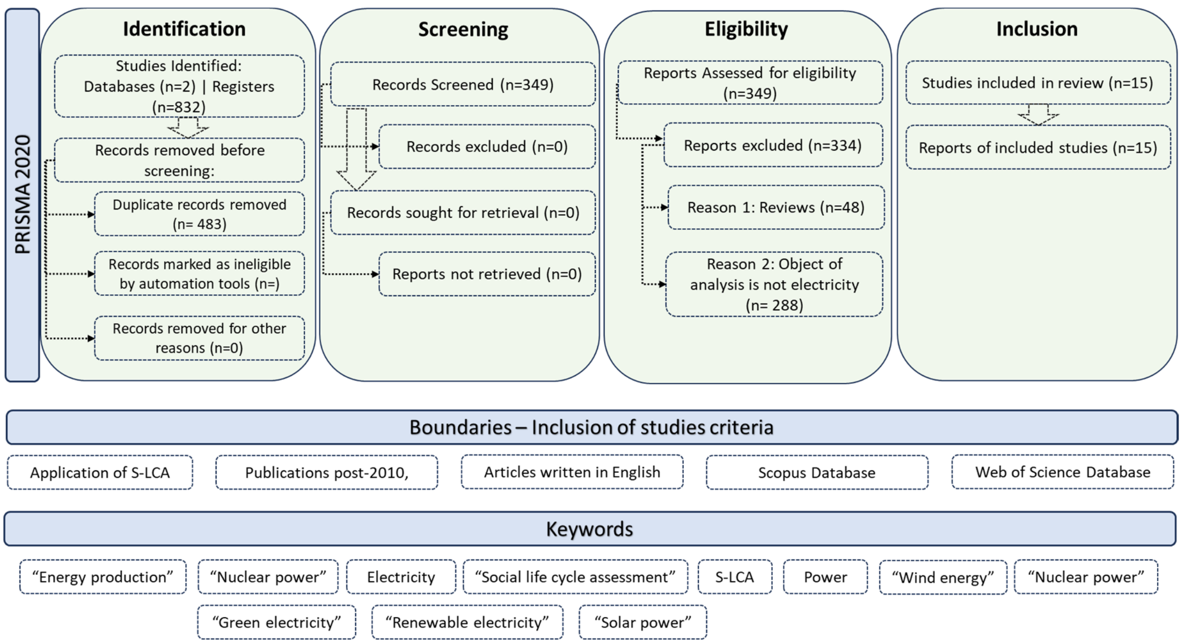

Figure 1. Study retrieval process.

First, the identification criteria for studies are defined: (i) application of Social Life Cycle Assessment (S-LCA) based on both versions of the guidelines [17,18], (ii) publications post-2010 when the first version of S-LCA guidelines were published, and (iii) articles are written in English. The Scopus and Web of Science databases served as the information source. A targeted search strategy, focusing on studies about electricity generation, was employed. Specific keywords related to "Social Life Cycle Assessment" were used in the titles, abstracts, and keywords, ensuring a comprehensive retrieval of relevant studies. The keywords were "Social Life Cycle Assessment" OR "S-LCA" OR "SLCA" AND "Solar power" OR "Wind energy" OR "Bioelectricity" OR "Nuclear power" OR "Energy production" OR "Renewable electricity" OR "Green electricity". Studies before 2010 were excluded to focus on the employment of the S-LCA guidelines and most recent findings in the field.

Second, during the screening process, no titles were used for excluding S-LCA studies. Thus, all identified studies were checked according to the eligibility criteria.

Third, upon screening, S-LCA studies focused on various industrial sectors and had various objects of analysis, such as the "Manufacturing" and "Water supply; sewerage, waste management and remediation activities" sectors, and fuels, food, and wastewater management, respectively. Therefore, the eligibility criteria regarded S-LCA studies that investigated electricity systems. The eligibility is based on the object of analysis of S-LCA studies, with an emphasis on various forms of electricity, such as wind electricity and bio-electricity. This process is essential for maintaining the specificity and relevance of the review to research objectives. The data from the selected studies were tabulated using an Excel spreadsheet (Microsoft Corporation, Redmond, WA, USA). The Excel spreadsheet (Table S1) can be found in the Supplementary Materials. Moreover, all identified S-LCA studies that were checked for eligibility can be found in Table S1 of the Supplementary Material. Descriptive statistics were applied to analyze various aspects of the studies, such as (ii) the year of publication, (ii) the location of the electricity generation plan, (iii) the level of assessment (generic or site-specific), (iv) functional unit, (v) considered impact subcategories of the guidelines [7], and (vi) self-developed social issues. This analysis offers a comprehensive overview of the current state of S-LCA in electricity generation, highlighting trends, prevalent practices, and potential areas for future research.

3. Results and Discussion

The database search yielded 325 articles. Of these, 15 were deemed eligible [24–36]. Figure 1 shows the simplified PRISMA flow diagram. No S-LCA studies have focused only on fossil-based electricity. The reviewed studies focused on specific renewable electricity sources, and one of these 12 studies considered Malaysian grid electricity that included renewable electricity to a small extent as a point of reference. Detailed information regarding the reviewed S-LCA studies is provided in Table S1 of the Supplementary Materials.

3.1. Publications Information

The selected research papers were published since 2017 and focused on (1) grid electricity, (2) bioelectricity with or without the cogeneration of heat, (3) renewable electricity, (4) solar power, (5) wind energy, (6) nuclear, or (7) hydropower (Table 1). There is a steady increase in the 2021 and 2022 in S-LCA studies of electricity. Half of the studies focused on bioelectricity generation, whereas four studies investigated solar power generation. Grid electricity, nuclear energy, combined cycle gas turbine, and coal power were analyzed once. Bioelectricity was generated from waste or biomass. In this way, the authors could include the supply chains of consumables, such as fertilizer production, in their system boundaries and account for social impacts along the supply chain. The inclusion of supply chains happened in nine of the fifteen studies with the employment of a social database, with the Social Hotspot Database (SHDB) being used more than the Product Social Impact Life Cycle Assessment (PSILCA) database. In contrast, site-specific studies either disregarded the supply chain [25], collected sector-specific data to assess the social impacts along the supply chain [24], or collected site-specific data through interviews [27].

Table 1. Reviewed publications by object of analysis and year.

Object of Analysis	2017	2018	2019	2021	2022	2023	Total Case Studies
Solar power	1		2 *		2	1 **	5 *,**
Wind energy					1	1 **	2 **
Bioelectricity		1	1 *	3	3		8
Grid electricity			1 *				1 *
Hydropower			1 *	1		1 **	3 *,**
Nuclear energy						1 **	1 **
Combined cycle gas turbine						1 **	1 **
Coal power						1 **	1 **
Total reviewed papers	1	1	2	4	6	1	15

* it includes a study that investigated four electricity sources, ** it includes a study that employed seven electricity sources.

Figure 2 shows the types of electricity assessed and the countries in which the electricity generation occurred. Two countries were assessed twice, i.e., in Nigeria and Portugal bioelectricity was investigated twice, and solar power in Spain was investigated three times. Two studies, one in Malaysia and one in Spain, investigated multiple electricity sources, such as solar power, hydropower, bioelectricity, nuclear, and grid electricity.

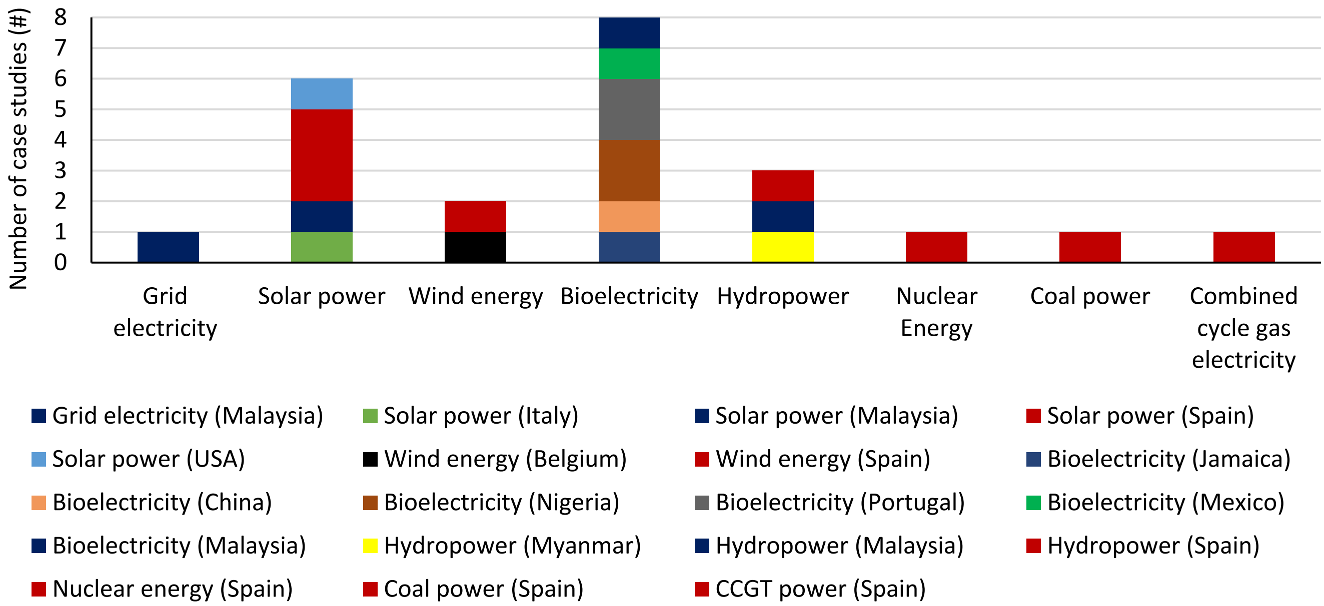

Figure 2. Studies by type of electricity and country.

3.2. Methodological Decisions

This section considers the methodological decisions that are made in the Goal and Scope Definition phase of LCA and that significantly affect the assessment results.

3.2.1. Assessment Level

Seven S-LCA studies applied a generic assessment and used SHDB or PSILCA databases. Both databases use the cost flows of materials and social information at the country and industrial sector levels to assess the potential risks of social impacts. Between the two databases, PSILCA is more aligned with the S-LCA guidelines because it includes all the impact subcategories. SHDB does not assess all impact subcategories but aggregates impact subcategory results to impact categories of "Labor rights and decent work", "Human rights", "Governance", and "Community infrastructure". However, it should be noted that the impact categories do not constitute a fixed list by the guidelines [18]. Nine studies followed a site-specific approach, and two studies [28,29] applied both assessment levels.

3.2.2. Functional Unit

The object of analysis was electricity. However, it is not always straightforward to link functional units with the considered social impacts in S-LCA studies [37]. The reviewed studies selected 1 kWh, 1 MWh, or 1 MJ as a functional unit or normalized the social impacts to one year of power-plant operation [27].

3.2.3. System Boundaries

System boundaries include the extraction of raw materials for plant construction and equipment manufacturing, supply chains of fuels and other consumables, plant operations, and demolition. However, in the case of solar power plants and wind turbines, there is no fuel supply chain. Figure 3 shows that all studies included the operational stage, but gate-to-gate studies that did not consider solar energy, wind energy, or hydropower excluded the supply chain of biofuels used for electricity generation.

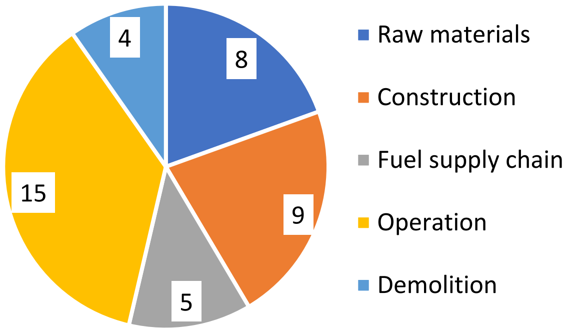

Figure 3. Life cycle stages considered by S-LCA studies in system boundaries.

In addition, power plant construction (including maintenance) in European countries arose as a relevant contributor to the indicators of women in the sectoral labor force (unfavorable impact) and contribution to economic development (favorable impact) [32].

3.2.4. Impact Assessment Type

All studies were Type I assessments, i.e., the reference scale approach was followed. No author has developed or applied an impact-pathway approach. Therefore, studies have collected generic datasets from social databases or site-specific data via questionnaires and interviews. The employment of social databases converts the input data into social impacts. For instance, the PSILCA database provides the "social impacts weighting method", which uses an ordinal scale to classify risks based on the economic sector and origin country, to calculate social impacts in medium-risk-hours. In contrast, site-specific assessments employ qualitative, quantitative, or semi-quantitative data that need to be converted to characterize social impacts. For instance, Nubi et al. [34] used a Likert scale to collect site-specific data in their case study. However, one study collected site-specific data through interviews with individuals and organizations [27] and did not mention how social impacts were characterized.

3.3. Impact Subcategories Selection

One of the criteria was that studies followed the S-LCA guidelines [17], which resulted in primarily assessing the S-LCA impact subcategories presented by the guidelines. However, a few studies have also developed social impacts, which are presented in the following subsection. The most considered impact subcategories were those belonging to the Workers stakeholder, followed by impact subcategories of the Local community, Society, Value chain actors, and Consumer stakeholders (Table 2). It should be noted that the Workers and Local community stakeholders comprise the most impact subcategories, and the use of databases results in the selection of almost all impact subcategories. For instance, five [26,28,29,33,35] of the seven studies, with more than six impact subcategories considered, used a database. The most assessed subcategories were "Child labor" which was assessed by 11 studies; "Forced labor" was assessed by 9 studies, "Health and safety" was assessed by 10 studies, and "Contribution to economic development" was assessed by 8 studies. Figure 4 shows the most assessed impact subcategories by country of the case study. In contrast, "End-of-life responsibility" and "Supplier relationships" were assessed only by one study each.

It was rarely found that the location of the power plant contributes to the "Child labor" subcategory [26,28]. One site-specific study investigated a hydropower plant in Myanmar and reported issues regarding child labor [24]. The supply chain of consumables along the supply chain caused these impacts. S-LCA studies that focused on bioelectricity reported risks of "Child labor" due to fertilizer production and natural gas that were sourced from the Algerian chemical and natural gas sectors [31,32]. S-LCA studies that focused on renewable energy linked "Child labor" with Congolese mines and Chinese electronics processing plants [26].

Table 2. Considered impact subcategories [18].

Stakeholder	Impact Subcategory	Considered by Studies
Workers	Child labor	11
	Forced labor	9
	Fair salary	5
	Working hours	7
	Health and safety	10
	Equal opportunities	5
	Social benefits	5
	Collective bargaining	8
Local community	Respect of indigenous rights	4
	Delocalization and migration	4
	Cultural heritage	3
	Employment	7
	Access to material resources	4
	Access to immaterial resources	3
	Secure living conditions	3
	Safe and healthy living conditions	4
	Community engagement	3
Society	Contribution to economic development	8
	Prevention and mitigation of armed conflicts	3
	Corruption	4
	Technology development	4
	Public commitment to sustainability	5
Consumer	End-of-life responsibility	0
Value chain actors	Fair competition	3
	Supplier relationships	1
	Promoting social responsibility	3

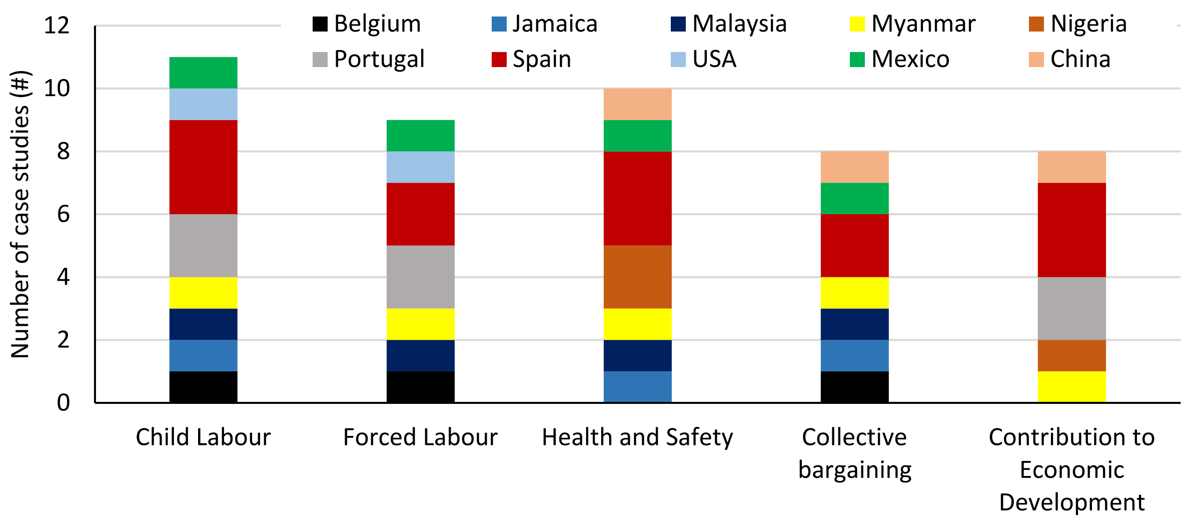

Figure 4. Number of site-specific studies that considered child labor, forced labor, health and safety, collective bargaining, and contribution to economic development.

Similarly, it was mostly the supply chain in generic studies that was contributing to the "Forced labor" impact subcategory when the power plant was operating in European countries [12,26,28]. Moreover, "Forced labor" risks were found in generic studies due to the supply of imported crude oil from Russia, Azerbaijan, Saudi Arabia, and Kazakhstan [32] or imported chemicals from Lithuania and Morocco [31]. These generic studies employed the SHDB or PSILCA databases, which comprised forced labor data at the national and sector levels collected from the Global Slavery Index [38] and US Trafficking in Persons Reports [39]. It should also be noted that petroleum products and chemicals are either both aggregated as "Petroleum, Chemical and Non-Metallic Mineral Products" for Morocco, Azerbaijan, and Saudi Arabia, or in the cases of Kazakhstan, Lithuania, and Russia the "Chemicals excluding pharmaceuticals" and "Coke, refined petroleum products and nuclear fuel" sectors were considered. However, a site-specific study [24] that investigated a hydropower plant in Myanmar reported that local citizens were forced to work on road construction and installation of transmission lines.

Power plants were found to have positive potential on a site-specific study depending on the introduction of relevant organizational policy and/or the type of acquired certifications regarding: (1) number/percentage of injuries, illness, and fatal accidents in the organization, (2) presence of formal policies on equal opportunities, and (3) lowest paid workers, compared to the country's minimum wage [27]. In contrast, a site-specific study that investigated the supply of crop residues for bioelectricity generation in China reported no organizational policies or certifications because Chinese farming is still based on household scale farming.

In addition, a site-specific study reported that the production of first-generation biomass for bioelectricity resulted in material resource conflicts because biomass is not used for food supply [27].

"Contribution to economic development" and "Public commitment to sustainability issues" were associated positively in both site-specific and generic studies due to the performance of power plants in Europe [29,30] or China [37] and supply of consumables [31], but negatively in generic studies when consumables (such as oil) were sourced from Brazil or Norway [31]. In addition, small companies are difficult to evaluate for these indicators through standard acquisition or participation in initiatives because of their size [30].

Last, "Health and safety" was also a concern in site-specific and generic studies when the power plant operated in countries with unstable labor and employment law, such as Myanmar [24,37,40], or in concentrated solar power plants in Spain [29], respectively. However, the latter was not fully justified, because the generic study reported that the Spanish "Financial services not elsewhere classified" sector presented "very high risks" for nonfatal and fatal injuries according to the SHDB. These authors explained that the "Financial services not elsewhere classified" sector was a large contributor due to the amount of money spent by this sector. In contrast, a later site-specific study by the same authors [28] for a different concentrated solar power plant in Spain resulted in benefits regarding "Health and safety" due to the companies involved in the technology supply chain. In general, Europe has better working conditions, particularly in terms of regulatory frameworks, worker rights, and safety standards [41]. For instance, a site-specific study reported that the collection of crop residues in China was not regulated with regard to occupational health and safety [37]. However, in some parts of Asia and Africa, conditions are improving due to interventions by international organizations such as the ILO, although they still lag behind Europe and the USA in many aspects [42].

3.4. Self-Developed Impacts Selection

Five studies developed social impacts that are considered relevant to the case study due to the object of analysis or location of the study, and seven studies reported social indicators (mentioned in the guidelines) with impact subcategory results. Introducing social indicators is not an uncommon approach because S-LCA is in its infancy, and practitioners develop indicators that are specialized for their case study. The self-developed indicators were (1) "Public Acceptance" [36], (2) "Government Policy" [36], (3) "Location" [36], (4) "Public awareness" [36], (5) "Improved Sanitation" [36], (6) "Improved Electricity Supply" [24,27,36], (7) "Income" [36], (8) "Strength of organizational risk assessment with regard to potential for material resource conflict" [27], (9) "Organizational efforts to reduce unpaid time spent by women and children collecting biomass" [27], (10) "Product utility" [28], and (11) "Product social utility" [29]. In this way, the authors aimed to provide a more site-specific assessment of the electricity generation system and the benefits provided to citizens because all self-developed indicators represent a social benefit except for "Strength of organizational risk assessment with regard to potential for material resource conflict".

In addition, seven studies reported social indicators with impact subcategory results because they wanted to present social benefits of electricity generation. These indicators were (1) "Lowest paid worker" [27], (2) "Safety measures" [26], (3) "Education and Training" [27,36], (4) "Legal System" [35], (5) "Population living in Poverty" [35], (6) "Unemployment" [33,35], (7) "Gender Equity" [33,35], (8) "Labor laws" [33,35], (9) "Gender wage gap" [26,31,32,35], (10) "Women in sectoral wage force" [31,32], (11) "Access to Improved Drinking Water" [33,35], (12) "Access to Improved Sanitation" [33,35], (13) "Industrial water depletion" [26], (14) "Children Out of School" [35], (15) "Risk of conflicts" [26,33,35], and (16) "Health expenditure" [31,32]. It should be noted that the "Access to Improved Drinking Water" and "Access to Improved Sanitation" indicators are not identical to those mentioned by the Methodological Sheets [43]. The latter include the "Access to Drinking Water" and "Access to Sanitation" but the authors [33,35] modified slightly to show the expected benefits. Among the self-developed indicators focus is given to the Workers with eight indicators, Society with five indicators, and Local community with three indicators. These results are well aligned with most of the selected impact subcategories (Table 2) and show that the list of impact subcategories for Society stakeholder is limited.

3.5. Results by Country

The employment of social databases accounts for all the social impact subcategories that can be analyzed using the databases' integrated impact assessment method. In contrast, site-specific assessments were conducted to investigate whether impact subcategories must be assessed when electricity is generated for certain countries. Two site-specific studies [34,36] (by the same first author) focused on electricity generation in Nigeria. These studies followed a local participatory approach to identify key social impact issues and to select impact subcategories relevant to electricity generation from waste. They considered "Health and Safety", "Employment", and the indicator "Education and Training", which are all important parameters for production systems, especially if the personnel need training to cope with new technologies (i.e., waste-derived electricity) and municipal solid waste is the energy source [44]. Another site-specific study [27] focused on bioelectricity generation in a parish with high poverty levels compared with the rest of Jamaica. They considered "Child Labor", "Health and Safety", "Equal opportunities", "Collective bargaining", "Employment", and indicators "Lowest paid worker" and "Education and Training". This study considered many impact subcategories that are typically selected (Table 2) but are also significant in Jamaica. Child labor in Jamaica affects 38,000 children [45]. High unemployment is perceived as one of Jamaica's most pressing problems [46], and several organizations focus on empowering Jamaican women for equal opportunities at work [47]. However, even though corruption is also considered a pressing problem by the BTI Transformation Index, the author did not account for "Corruption", which belongs to the Society stakeholder. A site-specific study about bioelectricity generation from crop residues in China used site surveys and literature to investigate impact subcategories of Workers, Local community, and Society stakeholders [37]. This study reported that major social issues exist in the Chinese agricultural sector, which was considered to be due to crop residue collection because workers work more than eight hours per day without a contract. The latter results in workers not having social benefits [48]. In contrast, working conditions in Chinese conversion plants that convert crop residues to biogas and power plants that convert biogas to electricity were regulated, and other social impacts were reported, such as job creation. Aung et al. [24] studied hydropower production in Myanmar on a site-specific level. These authors mentioned the great social issues that citizens in Myanmar face, which resulted in them considering the most impact subcategories (22 subcategories) among all studies. The unstable labor and employment law in Myanmar [40] resulted in these authors considering all impact subcategories belonging to the Workers stakeholder. A site-specific study [25] about solar power generation in the USA focused on Local community impact subcategories, such as "Delocalization and Migration", "Employment", "Access to Material Resources", "Access to immaterial resources", because access to rooftop solar panels is restrictive to community members with low-income. Therefore, the application of site-specific analysis was combined with the investigation of current social issues of Workers in the respective countries, but these studies avoided expanding their analysis to impact the subcategories of Local communities and Society stakeholders.

One generic study that did not use social databases but collected data from international research studies and reports explicitly for Spain should be noted. This study investigated various electricity sources in Spain, such as wind energy, solar power, hydropower, nuclear energy, coal power, and combined cycle gas electricity. As a result, reported results of various electricity types can be compared to a certain extent because all electricity types are generated within the same country, but it is not reported if generation occurs in the same region. Wind energy showed the highest occupational injuries among all electricity types. Furthermore, coal power was also not safe when compared to nuclear energy or solar power. Similarly, wind energy and coal power created more jobs than nuclear energy, hydropower, or solar power. Last, in terms of sustainability reporting, nuclear energy was evaluated the best, followed by gas electricity and hydropower.

3.6. Alterative to Social Impact Assessment with LCA End-Point Indicators

One study [26] complemented the generic social assessment with PSILCA by calculating the damage to human health caused by wind energy. The "Human health" endpoint LCA indicator of the ReCiPe method [49] overlaps with S-LCA results because human health is affected by environmental releases that affect air, water, and soil compartments and social conditions. Among the reviewed studies, only one study [26] applied environmental LCA, complementary to S-LCA, to also assess the damage to human health in Disability Adjusted Life Years. This damage assessment is performed when converting midpoint environmental impacts, such as climate change, toxicity, eutrophication, etc., to effects to human health. These authors reported that damages to human health occur mainly by manufacturing processes of the wind turbine components. PSILCA also calculated risks regarding safety measures in the manufacturing of wind turbine components and pointed out the locations where these risks occur, such as China, South Africa, and Congo. Therefore, a combination of endpoint indicators, such as Damage to human health, calculation and PSILCA application can assess the extent of damage and what is the most likely place for the damage to occur.

3.7. Limitations of Social Databases Employment

Seven of the thirteen reviewed studies employed a social database to calculate the social risks. Among these studies, three used PSILCA and four studies used the SHDB. While the application of a social database can result in social risks calculation for the electricity system under study, it also comes with biases and limitations that can affect their reliability and validity. Key challenges include representational biases, where some groups or issues are over- or under-represented owing to the geographical or demographic limitations of the source data [50]. Additionally, methodological aspects, such as data quality, data granularity, and ethical boundaries during data collection and usage, pose important issues [51]. In addition, social databases also struggle with the dynamic nature of social phenomena, where data might quickly become outdated, failing to accurately reflect current social conditions [52].

4. Conclusions and Recommendations

Energy transition should be achieved without social burdens on local communities, workers, and society. This study aimed to identify S-LCA studies that focus on electricity generation and provide recommendations to S-LCA practitioners, who will investigate social issues due to electricity generation in the future.

To date, the Workers stakeholder has been the most investigated, followed by Local community, Society, Value chain actors, and Consumer stakeholders. Furthermore, S-LCA practitioners followed three approaches to assess electricity generation at the location of the case study: (1) when employing a social database, S-LCA practitioners calculated social risks for all the impact subcategories that the social database included and considered international system boundaries due to the inclusion of technologies supply chains; (2) in site-specific assessment levels, practitioners considered the most common impact subcategories (such as "Child labor", "Health and safety", and "Contribution to economic development"), limited the system boundaries to organizations that were interviewed, and aimed to align impact subcategories selection to local social conditions, and (3) practitioners expanded social impact subcategories with self-developed indicators that focused on electricity generation systems, such as "Improved Electricity Supply" and "Product (social) utility". The latter can align electricity generation assessment with S-LCA with several SDGs, such as SDG7: Affordable and Clean Energy, SDG8: Decent Work and Economic Growth, SDG3: Good Health and Well-being, and SDG10: Reduced Inequalities.

These review findings encourage the further development and standardization of S-LCA methodologies for electricity generation studies. This includes the creation of a unified framework for selecting social impact subcategories and indicators to ensure comparability across studies. In particular, site-specific assessments need to include impacts on the Local community and Society stakeholders. If these stakeholders will not be considered with the Workers stakeholder, the incorporation of S-LCA results into broader energy policies will not facilitate a more socially responsible transition towards sustainable energy systems, aligning with global sustainability goals and promoting equitable outcomes across communities impacted by energy development.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/en17122929/s1, Table S1: Detailed information of reviewed studies.

Author Contributions: Conceptualization, G.A.T.; methodology, G.A.T.; software, G.A.T.; validation, G.A.T., G.F.B. and E.K.; formal analysis, G.A.T.; data curation, G.A.T. and M.B.; writing—original draft preparation, G.A.T. and M.B.; writing—review and editing, G.F.B. and E.K.; visualization, G.A.T. and G.F.B.; supervision, G.F.B. and E.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Soken-Huberty, E. 10 Reasons Why Electricity Is Important. Available online: https://openeducationonline.com/magazine/10-reasons-why-electricity-is-important/ (accessed on 29 November 2023).
2. Day, D. *Why Is Electricity Important*; R Turner Electric: Lewis Center, OH, USA, 2018.
3. Tanveer, J. Importance of Electricity in Our Lives. 2023. Available online: https://www.linkedin.com/pulse/importance-electricity-our-lives-tanveer-ahmed-2c/ (accessed on 29 November 2023).
4. Doukas, H.; Trachanas, G.P. Social Acceptance, Sources of Inequality, and Autonomy Issues toward Sustainable Energy Transition. *Energy Sources Part B Econ. Plan. Policy* **2022**, *17*, 2121383. [CrossRef]
5. Ma, L. Economic and Social Impacts of the Green Energy Transition: A Pathway towards 100% Renewable Energy Agenda. *Geol. J.* **2023**, *58*, 3438–3451. [CrossRef]
6. World Nuclear Association Carbon Dioxide Emissions From Electricity. Available online: https://world-nuclear.org/information-library/energy-and-the-environment/carbon-dioxide-emissions-from-electricity.aspx (accessed on 29 November 2023).
7. Bhattarai, U.; Maraseni, T.; Apan, A. Assay of Renewable Energy Transition: A Systematic Literature Review. *Sci. Total Environ.* **2022**, *833*, 155159. [CrossRef] [PubMed]
8. Yavor, K.M.; Bach, V.; Finkbeiner, M. Resource Assessment of Renewable Energy Systems—A Review. *Sustainability* **2021**, *13*, 6107. [CrossRef]
9. Cucchiella, F.; Rotilio, M.; Capannolo, L.; De Berardinis, P. Technical, Economic and Environmental Assessment towards the Sustainable Goals of Photovoltaic Systems. *Renew. Sustain. Energy Rev.* **2023**, *188*, 113879. [CrossRef]
10. Heal, G. Economic Aspects of the Energy Transition. *Environ. Resour. Econ.* **2022**, *83*, 5–21. [CrossRef]
11. Genc, T.S.; Kosempel, S. Energy Transition and the Economy: A Review Article. *Energies* **2023**, *16*, 2965. [CrossRef]
12. Hallste Pérez, T.; Rodríguez-Chueca, J.; Pérez Rodríguez, J. Inclusion of Key Social Indices for a Comparative Assessment of the Sustainability of the Life Cycle of Current and Future Electricity Generation in Spain: A Proposed Methodology. *Sci. Total Environ.* **2023**, *899*, 165541. [CrossRef] [PubMed]

13. Sun, Z.; Zhang, F.; Wang, Y.; Shao, Z. Literature Review and Analysis of the Social Impact of a Just Energy Transition. *Front. Sustain. Food Syst.* **2023**, *7*, 1119877. [CrossRef]
14. Stamford, L.; Azapagic, A. Life Cycle Sustainability Assessment of UK Electricity Scenarios to 2070. *Energy Sustain. Dev.* **2014**, *23*, 194–211. [CrossRef]
15. Chapman, A.; Shigetomi, Y.; Ohno, H.; McLellan, B.; Shinozaki, A. Evaluating the Global Impact of Low-Carbon Energy Transitions on Social Equity. *Environ. Innov. Soc. Transit.* **2021**, *40*, 332–347. [CrossRef]
16. Tsalidis, G.A. Integrating Individual Behavior Dimension in Social Life Cycle Assessment in an Energy Transition Context. *Energies* **2020**, *13*, 5984. [CrossRef]
17. Benoît, C.; Norris, G.A.; Valdivia, S.; Ciroth, A.; Moberg, A.; Bos, U.; Prakash, S.; Ugaya, C.; Beck, T. The Guidelines for Social Life Cycle Assessment of Products: Just in Time! *Int. J. Life Cycle Assess.* **2010**, *15*, 156–163. [CrossRef]
18. UNEP. *Guidelines for Social Life Cycle Assessment of Products and Organizations*; United Nations Environment Programme (UNEP): Nairobi, Kenya, 2020; p. 138.
19. Huertas-Valdivia, I.; Ferrari, A.M.; Settembre-Blundo, D.; García-Muiña, F.E. Social Life-Cycle Assessment: A Review by Bibliometric Analysis. *Sustainability* **2020**, *12*, 6211. [CrossRef]
20. Petti, L.; Serreli, M.; Di, C. Systematic Literature Review in Social Life Cycle Assessment. *Int. J. Life Cycle Assess.* **2018**, *23*, 422–431. [CrossRef]
21. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews. *BMJ* **2021**, *372*, n71. [CrossRef]
22. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Moher, D. Updating Guidance for Reporting Systematic Reviews: Development of the PRISMA 2020 Statement. *J. Clin. Epidemiol.* **2021**, *134*, 103–112. [CrossRef]
23. Page, M.J.; Moher, D.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. PRISMA 2020 Explanation and Elaboration: Updated Guidance and Exemplars for Reporting Systematic Reviews. *BMJ* **2021**, *372*, n160. [CrossRef] [PubMed]
24. Aung, T.S.; Fischer, T.B.; Azmi, A.S. Social Impacts of Large-Scale Hydropower Project in Myanmar: A Social Life Cycle Assessment of Shweli Hydropower Dam 1. *Int. J. Life Cycle Assess.* **2021**, *26*, 417–433. [CrossRef]
25. Bonilla-Alicea, R.J.; Fu, K. Social Life-Cycle Assessment (S-LCA) of Residential Rooftop Solar Panels Using Challenge-Derived Framework. *Energy Sustain. Soc.* **2022**, *12*, 7. [CrossRef]
26. Buchmayr, A.; Verhofstadt, E.; Van Ootegem, L.; Thomassen, G.; Taelman, S.E.; Dewulf, J. Exploring the Global and Local Social Sustainability of Wind Energy Technologies: An Application of a Social Impact Assessment Framework. *Appl. Energy* **2022**, *312*, 118808. [CrossRef]
27. Contreras-Lisperguer, R.; Batuecas, E.; Mayo, C.; Díaz, R.; Pérez, F.J.; Springer, C. Sustainability Assessment of Electricity Cogeneration from Sugarcane Bagasse in Jamaica. *J. Clean. Prod.* **2018**, *200*, 390–401. [CrossRef]
28. Corona, B.; San Miguel, G. Social Performance of Electricity Generation in a Solar Power Plant in Spain—A Life Cycle Perspective. In *Environmental Footprints and Eco-design of Products and Processes*; Springer: Singapore, 2019; pp. 1–57. [CrossRef]
29. Corona, B.; Bozhilova-Kisheva, K.P.; Olsen, S.I.; San Miguel, G. Social Life Cycle Assessment of a Concentrated Solar Power Plant in Spain: A Methodological Proposal. *J. Ind. Ecol.* **2017**, *21*, 1566–1577. [CrossRef]
30. Kaiser, S.; Oliveira, M.; Vassillo, C.; Orlandini, G.; Zucaro, A. Social and Environmental Assessment of a Solidarity Oriented Energy Community: A Case-Study in San Giovanni a Teduccio, Napoli (IT). *Energies* **2022**, *15*, 1557. [CrossRef]
31. Martín-Gamboa, M.; Dias, A.C.; Iribarren, D. 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* **2022**, *194*, 1110–1118. [CrossRef]
32. Martín-Gamboa, M.; Quinteiro, P.; Dias, A.C.; Iribarren, D. Comparative Social Life Cycle Assessment of Two Biomass-to-Electricity Systems. *Int. J. Environ. Res. Public Health* **2021**, *18*, 4918. [CrossRef] [PubMed]
33. Martinez-Hernandez, E.; Sadhukhan, J.; Aburto, J.; Amezcua-Allieri, M.A.; Morse, S.; Murphy, R. Modelling to Analyse the Process and Sustainability Performance of Forestry-Based Bioenergy Systems. *Clean Technol. Environ. Policy* **2022**, *24*, 1709–1725. [CrossRef]
34. Nubi, O.; Morse, S.; Murphy, R.J. Life Cycle Sustainability Assessment of Electricity Generation from Municipal Solid Waste in Nigeria: A Prospective Study. *Energies* **2022**, *15*, 9173. [CrossRef]
35. Takeda, S.; Keeley, A.R.; Sakurai, S.; Managi, S.; Norris, C.B. Are Renewables as Friendly to Humans as to the Environment?: A Social Life Cycle Assessment of Renewable Electricity. *Sustainability* **2019**, *11*, 1370. [CrossRef]
36. Nubi, O.; Morse, S.; Murphy, R.J. A Prospective Social Life Cycle Assessment (sLCA) of Electricity Generation from Municipal Solid Waste in Nigeria. *Sustainability* **2021**, *13*, 10177. [CrossRef]
37. Zhang, Y.; Li, J.; Liu, H.; Zhao, G.; Tian, Y.; Xie, K. Environmental, Social, and Economic Assessment of Energy Utilization of Crop Residue in China. *Front. Energy* **2021**, *15*, 308–319. [CrossRef]
38. Global Slavery Index. Available online: https://www.walkfree.org/global-slavery-index/ (accessed on 14 May 2024).
39. US Department of State. Trafficking in Persons Report. United States Department of State. Available online: https://www.state.gov/trafficking-in-persons-report/ (accessed on 14 May 2024).

40. International Labour Organization. *Myanmar Labour Market Remains Fragile in Challenging Conditions*; International Labour Organization: Geneva, Switzerland, 2023.
41. Vendramin, P.; Parent-Thirion, A. Redefining Working Conditions in Europe. *Int. Dev. Policy | Rev. Int. Polit. Développement* **2019**, *111*, 273–294. [CrossRef]
42. Aleksynska, M.; Berg, J.; Foden, D.; Johnston, H.; Parent-Thirion, A. *Working Conditions in a Global Perspective*; Publications Office: Luxembourg, 2019.
43. UNEP/SETAC Life Cycle Initiative. The Methodological Sheets for Subcategories in Social Life Cycle Assessment (S-LCA). 2013, pp. 1–152. Available online: https://www.lifecycleinitiative.org/updating-the-social-lca-guidelines/ (accessed on 15 May 2017).
44. Ishaq, A.; Said, M.I.M.; Azman, S.; Abdulwahab, M.F.; Alfa, M.I. Impact, Mitigation Strategies, and Future Possibilities of Nigerian Municipal Solid Waste Leachate Management Practices: A Review. *Niger. J. Technol. Dev.* **2022**, *19*, 181–194. [CrossRef]
45. International Labour Office. *Child Labour and the Youth Decent Work Deficit in Jamaica*; Fundamental Principles and Rights at Work Branch (FUNDAMENTALS): Geneva, Switzerland, 2018.
46. BTI Transformation Index. 2022 Jamaica Country Report. 2022. Available online: https://www.bertelsmann-stiftung.de/fileadmin/files/BSt/Publikationen/imported/leseprobe/1938_Leseprobe.pdf (accessed on 14 May 2024).
47. International Labour Organization. *Gender at Work in the Caribbean: Country Report for Jamaica*; International Labour Organization: Port of Spain, Trinidad and Tobago; Geneva, Switzerland, 2018.
48. Reynolds, B. China's Agricultural Policy and the Urban Labor Shortage; China-US Focus: 2016. Available online: https://www.chinabusinessreview.com/chinas-agricultural-policy-and-the-urban-labor-shortage/ (accessed on 14 May 2024).
49. Huijbregts, M.A.J.; Steinmann, Z.J.N.; Elshout, P.M.F.; Stam, G.; Verones, F.; Vieira, M.; Zijp, M.; Hollander, A.; van Zelm, R. ReCiPe2016: A Harmonised Life Cycle Impact Assessment Method at Midpoint and Endpoint Level. *Int. J. Life Cycle Assess.* **2017**, *22*, 138–147. [CrossRef]
50. Olteanu, A.; Castillo, C.; Diaz, F.; Kıcıman, E. Social Data: Biases, Methodological Pitfalls, and Ethical Boundaries. *Front. Big Data* **2019**, *2*, 13. [CrossRef]
51. Tsalidis, G.A.; Kokubo Roche, A.; Randazzo, S.; Posada, J.A. Contribution of Capital Goods Production to Social Impacts: A Life Cycle Perspective for a Circular Desalination Plant. *Sustain. Prod. Consum.* **2024**, *45*, 15–26. [CrossRef]
52. Mondal, S.; Rehena, Z. Challenges and Limitations of Social Data Analysis Approaches. In *Internet of Things Based Smart Healthcare: Intelligent and Secure Solutions Applying Machine Learning Techniques*; Biswas, S., Chowdhury, C., Acharya, B., Liu, C.-M., Eds.; Springer Nature: Singapore, 2022; pp. 307–323. ISBN 978-981-19140-8-9.