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Social Hotspot Analysis and Trade Policy Implications of the Use of Bioelectrochemical Systems for Resource Recovery from Wastewater

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Abstract: Bioelectrochemical systems (BESs) have been catalogued as a technological solution to three pressing global challenges: environmental pollution, resource scarcity, and freshwater scarcity. This study explores the social risks along the supply chain of requisite components of BESs for two functionalities: (i) copper recovery from spent lees and (ii) formic acid production *via* CO_2 reduction, based on the UK's trade policy. The methodology employed in this study is based on the UNEP/SETAC guidelines for social life-cycle assessment (S-LCA) of products. Relevant trade data from UN COMTRADE database and generic social data from New Earth's social hotspot database were compiled for the S-LCA. The results revealed that about 75% of the components are imported from the European Union. However, the social risks were found to vary regardless of the magnitude or country of imports. "Labour and Decent Work" was identified as the most critical impact category across all countries of imports, while the import of copper showed relatively higher risk than other components. The study concludes that BESs are a promising sustainable technology for resource recovery from wastewater. Nevertheless, it is recommended that further research efforts should concentrate on stakeholder engagement in order to fully grasp the potential social risks.

Keywords: social life cycle assessment; trade policy; resource recovery from waste; circular economy; electrochemical biorefineries

1. Introduction

Environmental pollution, resource scarcity, and freshwater shortage are critical global challenges facing humanity in this century. A growing global population, rising at 83 million per annum [1,2], exacerbate these challenges, as the demand for freshwater and resources continue to grow. For instance, in the UK, the renewable internal freshwater resources per capita has seen a decline of 10% over the last two decades [3]. Yet, a significant proportion of global freshwater supply is lost through the end-of-pipe disposal of wastewater into aquatic ecosystems. The accumulation of wastewater in these ecosystems is not only harmful to public health and biodiversity but could also result in adverse societal consequences if left unchecked. Nevertheless, wastewater can be deemed a resource that can be tapped for additional utility [4]. The potential energy resources locked within typical wastewater include organic matter (~6.4 MJ/m^3), thermal energy (~25 MJ/m^3), and nutritional elements (~2.5 MJ/m^3) [5]. Moreover, wastewater resources constitute about 50–100% of overall waste resources [6]. These valuable resources can be recovered and regenerated from wastewater and recycled into the economy for reuse towards the realisation of the circular economy concept.

In order for the potential economic, environmental and societal benefits of resource recovery from wastewater to be fully realised, a transition from the linear economy model to a circular one is essential [7,8]. Stringent surface water quality and carbon emission targets for wastewater treatment facilities are also compelling drivers for this transition. However, these goals cannot be achieved solely by existing wastewater plants, as they are capital and resource (chemicals and energy) intensive [6]. Thus, the adoption of innovative, flexible solutions for resource recovery, such as bioelectrochemical systems (BESs), could plausibly make the current wastewater infrastructure sustainable [9,10]. BESs are essentially microbial-aided electrochemical devices that receive wastewater in the anodic chamber under anaerobic conditions to produce clean water, and thereby supply electrons and protons for recovery of products in the cathodic chamber. Several experimental investigations on various configurations of BESs have been carried out, all showing potential for upscaling of the technology [11]. Nevertheless, it is essential to ascertain whether BESs, as a flexible solution for wastewater treatment and resource recovery, are 'sustainable' [8].

According to the Bruntdland report [12], sustainability comprises three aspects: environment, economic and social facets that should be assessed and weighed when designing new products or production systems. The life cycle sustainability assessment (LCSA) methodology, proposed by Kloepffer [13], combines life cycle assessment (LCA), life cycle costing (LCC), and social life cycle assessment (S-LCA). Concisely, LCA assesses environmental impacts, LCC evaluates economic costs, and S-LCA assesses social risks/impacts. The multi-dimensional approach of the LCSA methodology thus ensures that enterprise-level supply chain or country-level trade policy decisions align with sustainable development goals [14,15]. Despite the potential of LCSA to be a powerful decision-making tool, a major methodological challenge is the implementation of LCA, LCC and S-LCA in a combined way [16]. This is because, unlike LCA, and to an extent LCC, S-LCA is yet to be standardised and have consistent indicators. Consequently, various social indicators have been adopted in literature and S-LCA is still undergoing evolution [12–17]. Even so, considerable research progress has been made over the last two decades to harmonise the methodology of S-LCA, the summation of which led to the publication of the UNEP/SETAC guidelines for S-LCA of products [17]. The UNEP/SETAC guidelines provide the state-of-the-art framework for conducting S-LCA studies.

To the knowledge of the authors, sustainability studies of BESs in literature have so far focused on economic and environmental (i.e., LCC and LCA) perspectives [18–20]. Moreover, in a previous work of this group, the economic and environmental impacts of a BES for wastewater treatment and formic acid production were assessed, but the social impacts were not evaluated [21]. Therefore, the present study, for the first time, examines the potential social risks of BESs for wastewater treatment and two resource recovery functions: copper recovery and formic acid production. Herein, a social hotspot analysis of the requisite components for the construction and operation of BESs is conducted using trade import data from the United Nations Commodity Trade Statistics (UN COMTRADE) database in conjunction with the Social Hotspot database (SHDB), based on UNEP/SETAC guidelines. The study elucidates the distribution of social risks along the supply chain of BES components based on the UK's trade policy. Most importantly, this paper contributes to current understanding of the sustainability of BESs, by taking a step further from the traditional economic and environmental perspectives to a social one. Furthermore, it lays the foundation for future LCSA studies towards the triple-bottom-line sustainable development of BESs.

2. Materials and Methods

Figure 1 depicts the overall methodology employed in this study.

Firstly, inventory data, primarily metainformation of components of a BES model, are obtained from our previous work [21]. Subsequently, the inventory data are mapped to relevant commodities on the UN COMTRADE database, in order to identify the top countries of imports that constitute at least 90% of total import value of each component to the UK. The value of the imports of each commodity per country is then deflated to USD 2002 to conform to the SHDB input format. Next, the import value of each commodity is mapped to respective countries and sectors on the SHDB. Finally, social impact scores are assessed *via* the Social Life Cycle Impact Assessment (S-LCIA) method on the SHDB.

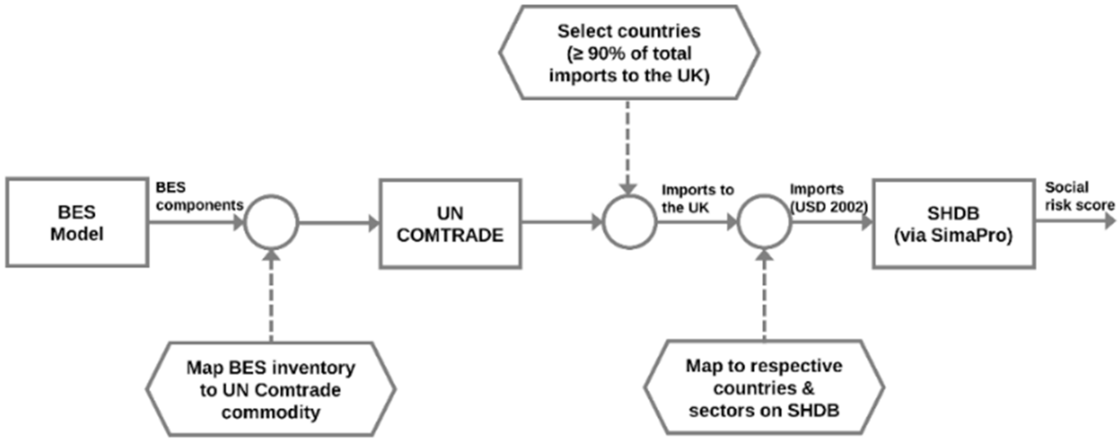

Figure 1. Flowchart of overall methodology (rectangles denote models and databases; circles denote inspection points, hexagons denote data preparation steps).

2.1. Goal and Scope of Study

The present study aims to assess the potential social hotspots in the supply chain of requisite components (commodities) for the construction and operation of BESs in the UK. The scope of this study spans the cradle (raw material extraction) to the production gate—in agreement with the scope adopted in our previous study on the environmental and economic impacts of formic acid synthesis *via* a BES [21]. It should be noted that social impacts, in contrast to environmental and economic impacts, cannot be expressed per functional unit due to the methodological challenge of linking social indicators, which are expressed as qualitative and semi-quantitative data, to the functional unit, which is based on physical output. Nevertheless, the UNEP/SETAC S-LCA guidelines [22] recommend the inclusion of a functional unit in all S-LCA studies in order to accentuate product/process utility.

In addition to treating organic wastewater at their anodes, BESs can be used for multiple functions, including metal recovery, organic acid synthesis and hydrogen production, depending on their cathodic configuration [8,23,24]. Regardless of the cathodic configuration, in most cases, BES operation and construction require the same major components: carbon-based anode and cathode, organic wastewater (anolyte), a membrane, current collectors, and an enclosure. In respect to cathodic applications, the catholyte is tailored for the resource of interest: metallic wastewater (e.g., spent lees with toxic levels of Cu^{2+}) is used for metal (e.g., Cu/Cu_2O) recovery, and potassium bicarbonate ($KHCO_3$) solution is used for organic acid (e.g., formic acid) production from CO_2 reduction. Furthermore, the aforementioned applications are catalysed either by microbes, e.g., *Shewanella oneidensis* for Cu recovery or high-efficiency metals, e.g., indium for formic acid production. Thus, in this study, 'ornamental' functional units of 1 kg Cu recovery and 1 kg formic acid production at the cathode, associated with organic wastewater treatment at the anode, are employed. Figure 2 shows the schematic of the BES under consideration.

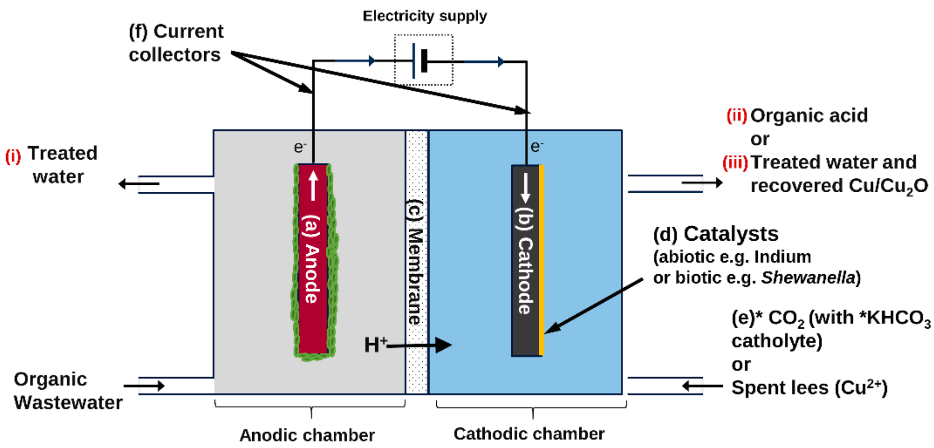

Figure 2. A BES schematic: describes the system's technical utility: (**i**) organic wastewater treatment, and (**ii**) organic acid production or (**iii**) metal recovery, and major BES components: (**a**) anode, (**b**) cathode, (**c**) membrane, (**d**) cathodic catalyst: indium or bacteria, (**e**) catholyte: $KHCO_3$ or spent lees, and (**f**) current collectors.

2.2. Inventory Analysis

The inventory data of the raw materials (components) described in Figure 2 are obtained from a previously-developed BES model [21]. Based on this model, the anode is derived from carbon fibre, which is manufactured from polyacrylonitrile. A Nafion membrane, derived from sulfonated polytetrafluoroethylene (PTFE), and current collectors, made of copper, are used. As aforesaid, the cathodic configuration depends on the function of the system. For formic acid production, a cathode, comprising indium as catalyst, carbon fibre as catalyst support and PTFE as binder, is used, and $KHCO_3$ solution (0.1M) is used as catholyte. Whereas for Cu recovery from spent lees, a carbon fibre cathode catalysed by *Shewanella oneidensis*, is employed.

These inventory data are then mapped to relevant commodities on the UN COMTRADE database in order to identify the top countries that constitute at least 90% of the imports (in USD) of the BES components to the UK. The import value of each commodity is subsequently mapped to relevant country-specific economic sectors on the SHDB. The SHDB, developed by Benoît Norris et al. [25], comprises generic social data that can be used to attribute social risks to the country-specific sectors associated with the BES commodities. The database links economic input/output (I/O) data from the Global Trade Analysis Project (GTAP) model with labour intensity factors and social indicators of country-specific sectors from reputable international organisations. The GTAP I/O model provides wage payments (USD) per economic output (USD) of product supply chains in 57 economic sectors of 113 countries. Hourly wage rates (USD/hour) for country-specific sectors are obtained from the International Labour Organisation (ILO), the Organisation for Economic Co-operation and Development (OECD), the United Nations Industrial Development Organisation (UNIDO), and the Food and Agriculture Organisation (FAO). The wage payments per economic output from the GTAP model and the hourly wage rates from various international organisations constitute the worker hours model used in the SHDB [26]. The social indicators for country-specific sectors are obtained from 200 reputable publicly-available sources, including the ILO, the World Bank (WB), and the World Health Organisation (WHO). The worker hours model is linked with the social indicators to attribute social risk (R) for the social themes within each social impact category. A single or several related social indicators are used to categorise the risk for the themes within each impact category. For example, the indicator: "percentage of population living under $2 per day" is used to attribute risk for the social theme: "Poverty" under the "Labour Rights and Decent Work" impact category. A complete list of the indicators used to attribute risks for the social themes in the SHDB can be found elsewhere [27]. Table 1 summarises the social impact categories, their respective social themes and relevant stakeholders and Figure 3 illustrates the overall SHDB methodology.

Table 1. Social impact categories, their respective social themes and stakeholders.

Social Impact Categories	Social Themes	Stakeholder
Labour Rights and Decent Work	Child labour Forced labour Excessive working time Poverty Wage assessment Migrant labour Collective bargaining Inadequate social benefits	Workers
Health and Safety	Injuries and fatalities Toxics and hazards	Workers and society
Human Rights	Indigenous rights Gender equity High conflict	Society and local community
Governance	Legal system Corruption	Society and value chain actors
Community Infrastructure	Drinking water Improved sanitation Hospital beds	Society and local community

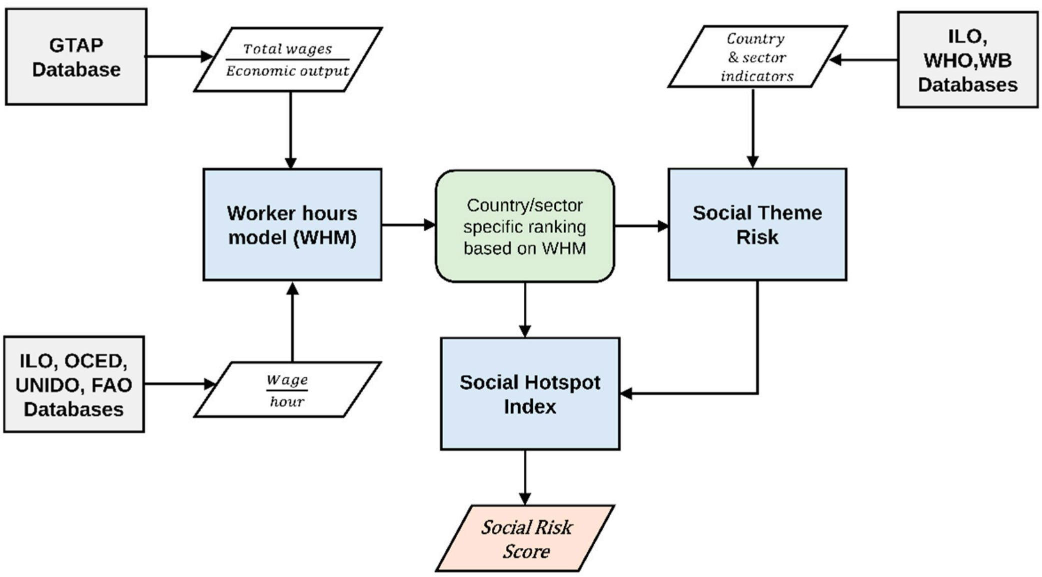

Figure 3. SHDB methodology.

2.3. Impact Assessment

The S-LCIA Method V2.00, provided in the SHDB package, is used to assess social risk levels for the BES commodities across the five social impact categories provided in Table 1. S-LCIA characterisation models, which are algorithms based on the distribution of data across the entire population of sectors and countries on the SHDB divided into quartiles, are used to assign four risk levels: low, medium, high or very high risk. In other words, the characterisation models show how the country-specific sectors compare globally. Table 2 shows the weighting factors (W) assigned to each risk level. The weighting factors essentially indicate the relative probability of an adverse situation to occur [25]. The resulting weighted risks (WR) for each social impact category, expressed in medium-risk hours-equivalent, are then aggregated into social hotspots indexes (SHIs) as described in Equation (1).

$$SHI_{cat} = \frac{\sum_{T=1}^{n} R_{avg} \cdot W_T}{\sum_{T=1}^{n} R_{max} \cdot W_T} \cdot 100\% \quad (1)$$

where n is the number of themes within a category, T is social theme, R_{avg} is the average risk across the theme, R_{max} is the maximum risk for a theme and W_T is the assigned weight.

Table 2. Weights for each risk level.

Weighting Factors	Risk Levels
10	Very high
5	High
1	Medium
0.1	Low

The SHIs are unitless, ranging from 0 to 1. As a general rule, the higher the SHI score, the higher the potential impacts in that social category for a country-specific sector.

3. Results and Discussion

3.1. Trade Value of BES Components

Table 3 shows the top countries that account for ≥90% of the import of commodities (raw materials) for the manufacture of the BES components, their respective trade values, global regions, and economic sectors on the SHDB.

Table 3. UK imports of commodities required for the BES components by country of origin, region, trade value (in $USD '000) and sectors on the SHDB.

Inventory	Country	Region	Trade Value	SHDB Sector
Polytetrafluoroethylene (PTFE)	Germany	Europe	8160	Chemicals, rubber and plastic products
	Italy	Europe	2992	
	Belgium	Europe	2863	
	USA	N. America	2723	
	India	Asia	2023	
Polyacrylonitrile	Spain	Europe	818	Chemicals, rubber and plastic products
	Belgium	Europe	729	
	Rep. of Korea	Asia	654	
	Italy	Europe	484	
	USA	N. America	155	
Potassium bicarbonate	Germany	Europe	4329	Chemicals, rubber and plastic products
	Rep. of Korea	Asia	728	
	USA	N. America	605	
	Italy	Europe	391	
	Ireland	Europe	227	
Indium	Germany	Europe	11,456	Metals nec.
	USA	N. America	10,918	
	Belgium	Europe	1532	
	Estonia	Europe	847	
	Canada	N. America	681	

Table 3. *Cont.*

Inventory	Country	Region	Trade Value	SHDB Sector
Copper	Germany	Europe	580,054	Metals nec.
	Belgium	Europe	347,562	
	Kazakhstan	Asia	279,130	
	Turkey	Europe	90,356	
	Italy	Europe	89,889	
	Spain	Europe	85,112	
	Greece	Europe	68,710	
	Russia *	Europe	66,159	
	Zambia	Africa	60,966	
	Hungary	Hungary	47,512	
	Ireland	Europe	44,317	
	USA	America	41,624	
	Sweden	Europe	39,942	

* not part of the EU.

As shown in Table 3, European Union (EU) countries constitute a significant proportion of the imports of the BES commodities to the UK. About 75% of the total imports, estimated at $USD 1.4 billion, is from the EU. This insight, while ordinarily would have been inconsequential to this study, is significant in light of the ‘Brexit’ trade negotiation between the EU and the UK. Nevertheless, it is too early to speculate on which countries will replace EU exporters to the UK, and what the potential social risks will be post-Brexit. Notwithstanding, years of research have shown that the link between commodities and supply chain actors (i.e., countries and sectors) is not always linear (one-dimensional) [28,29]. Instead, global trade is a complex interactive supply chain network and, thus, the connections and dynamics between the exporting and importing countries/sectors need to be re-assessed in subsequent research efforts.

3.2. Social Hotspot Analysis of BES Components

The SHIs, across five social categories, associated with the country-of-origin of importation of the BES components are presented in Figure 4A–E.

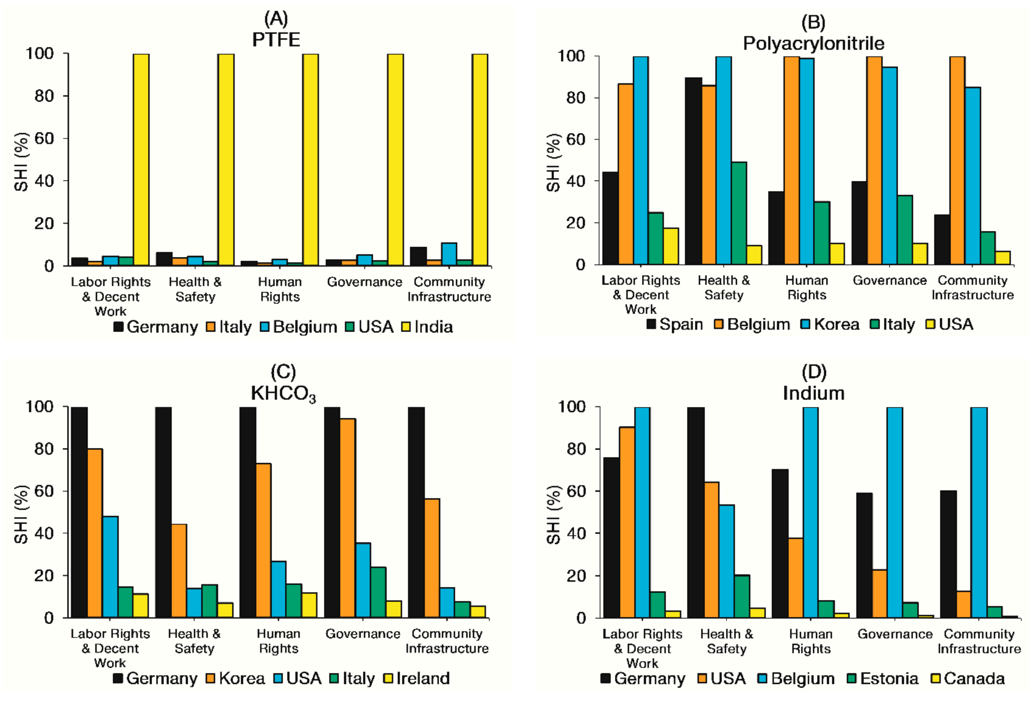

Figure 4. *Cont.*

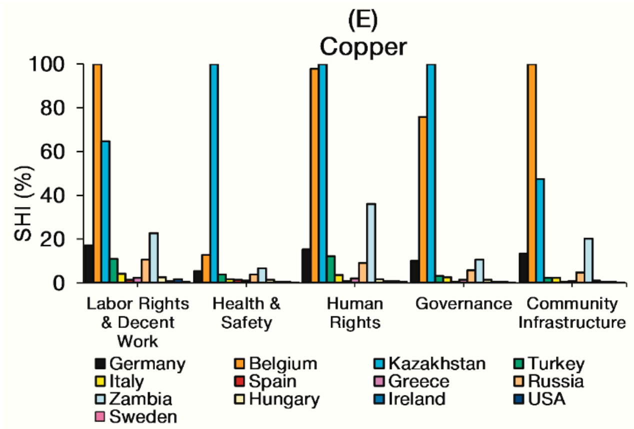

Figure 4. SHIs of the BES components per country of import across five social impact categories. (**A**) shows SHIs for PTFE, (**B**) shows SHIs for polyacrylonitrile, (**C**) shows SHIs for $KHCO_3$, (**D**) shows SHIs for indium, and (**E**) shows SHIs for copper.

The values of WR, i.e., the values used to calculate the SHIs depicted in Figure 4A–E, for the five social impact categories per commodity/country is presented in Table 4.

For PTFE, "Labour and Decent Work" shows the highest risk (i.e., WR) in all countries of imports while "Community Infrastructure" shows the lowest in all countries, except Germany and Belgium, where "Governance" and "Human Rights" exhibit the lowest risk, respectively (See Table 4). In terms of overall SHI per country, India scores the highest and the USA scores the lowest (See Figure 4A). For polyacrylonitrile, "Labour and Decent Work" exhibits the highest risk in all countries of imports, while "Community Infrastructure" shows the lowest risk in all countries, except Belgium, where "Human Rights" shows the lowest risk (Table 4). In terms of overall SHI per country, Korea has the highest score, while the USA has the lowest (Figure 4B). For $KHCO_3$, "Labour and Decent Work" records the highest risk in all countries of imports. Whereas "Community Infrastructure" records the lowest risk in all countries, except Germany, where "Governance" exhibits the lowest risk (Table 4). With respect to overall SHI per country, Germany scores the highest and Ireland the lowest (Figure 4C). For indium, "Labour and Decent Work" has the highest risk in all countries of imports, while "Community Infrastructure" shows the lowest for the USA and Canada, "Human Rights" shows the lowest for Germany and Estonia, and "Health and Safety" the lowest for Belgium. For overall SHI per country, Belgium scores the highest, and Canada scores the lowest (Figure 4D). For copper, "Labour and Decent Work" records the highest risk for Germany, Belgium, Turkey, Italy, Greece, Russia, Zambia, Hungary, Ireland, USA and Sweden and "Health and Safety" records the highest risk for Kazakhstan and Spain. Whereas "Community Infrastructure" records the lowest risk for Kazakhstan, Turkey, Spain, Greece, Russia, Ireland, USA and Sweden, "Human Rights" the lowest for Germany, Italy and Hungary, and "Health and Safety" the lowest for Belgium and "Governance" the lowest for Zambia. For overall SHI per country, Kazakhstan records highest and Sweden the lowest (Figure 4E).

From the above results, it is clear that "Labour and Decent Work" exhibits the highest risk among all social impact categories for all the commodities. Whereas "Community Infrastructure" exhibits the lowest risk among all categories for all commodities, closely followed by "Human Right"—the lowest for Indium. It is possible that the strikingly high magnitude of risk exhibited by "Labour and Decent Work" is due to the relatively large number of indicators used to attribute its risk [27]. Moreover, it appears that the magnitude of trade value does not always correspond with the extent of social risk, as the latter varies considerably due to peculiar socio-economic realities. As a case in point: India has the lowest export of PTFE to the UK among all countries of import, but shows strikingly higher risks in all categories and overall SHI than Germany, Italy, Belgium, and the USA.

Table 4. Weighted risks of the BES components. labour rights and decent work is expressed in child labour medium risk hour-equivalent (CL mhr eq), health and safety is expressed in injuries and fatalities medium risk hour-equivalent (IF mhr eq), human rights is expressed in gender equality medium risk hour-equivalent (GE mrh eq), governance is expressed in legal system medium risk hour-equivalent (LS mhr eq) and community infrastructure is expressed in drinking water medium risk hour-equivalent (DW mhr eq).

	Countries	Labour Rights and Decent Work	Health and Safety	Human Rights	Governance	Community Infrastructure
PTFE	Germany	2,577,174	2,119,651	584,900	561,975	703,444
	Italy	1,501,217	1,354,188	379,546	544,078	215,612
	Belgium	3,325,478	1,507,194	806,299	1,046,476	876,013
	USA	2,962,025	701,936	370,338	470,814	238,298
	India	73,356,715	35,550,940	27,155,486	20,484,899	8,263,333
Polyacrylonitrile	Spain	591,383	544,917	97,013	142,918	71,735
	Belgium	1,151,553	521,914	279,207	362,376	303,347
	Korea	1,332,786	608,275	276,474	342,838	257,752
	Italy	330,649	298,265	83,596	119,835	47,489
	USA	229,958	54,495	28,751	36,552	18,500
$KHCO_3$	Germany	1,860,387	1,530,115	422,223	405,673	507,796
	Korea	1,485,032	677,760	308,056	382,001	287,195
	USA	895,877	212,304	112,010	142,400	72,074
	Italy	266,690	240,570	67,426	96,655	38,303
	Ireland	208,743	109,119	49,415	32,086	28,300
Indium	Germany	12,410,936	5,482,484	2,974,947	4,726,056	4,700,009
	USA	14,726,434	3,516,719	1,599,988	1,821,052	982,496
	Belgium	16,339,111	2,933,776	4,237,613	8,003,899	7,792,364
	Estonia	2,002,089	1,106,674	349,829	570,115	400,539
	Canada	511,532	263,102	93,228	106,059	59,416
Copper	Germany	628,404,804	277,595,465	150,630,942	239,295,108	237,976,295
	Belgium	3,705,652,779	665,370,095	961,075,645	1,815,256,117	1,767,280,628
	Kazakhstan	2,404,645,460	5,179,686,690	981,873,381	2,388,544,991	841,536,953
	Turkey	399,437,194	204,898,945	118,076,683	76,136,845	37,831,224
	Italy	151,446,222	90,742,861	35,797,251	64,360,424	40,504,452
	Spain	52,804,710	65,842,137	6,664,583	11,133,944	5,445,993
	Greece	87,859,737	51,152,200	20,149,236	34,057,486	12,301,866
	Russia	392,250,069	189,972,359	88,226,634	135,381,628	82,321,925
	Zambia	839,948,514	346,915,625	355,717,051	253,052,828	355,099,991
	Hungary	93,568,774	68,144,917	15,269,800	35,691,960	20,276,281
	Ireland	32,321,689	18,454,612	7,416,720	6,915,875	6,301,878
	USA	56,141,443	13,406,755	6,099,618	6,942,381	3,745,559
	Sweden	18,594,240	16,602,542	4,164,349	5,043,023	3,944,785

In ascending order, the ranking of the combined risks (i.e., combined worker hours of the WR of the five impact categories of the countries of imports) of each BES commodity is as follows: polyacrylonitrile, $KHCO_3$, indium, PTFE, and copper. Precisely, copper ratios PTFE, indium, $KHCO_3$, and polyacrylonitrile by 145:1, 279:1, 2614:1, and 3356:1, respectively. The high combined risks exhibited by copper require particular attention, as copper recovery from metallic wastewater is paradoxically an application of BESs. Thus, from this perspective, the use of substitute metals or alloys for current collectors in BESs should be considered. The use of indium as a catalyst due to its high efficiency for formic acid production may also need reconsideration, as its modest combined risk may not justify its use. Moreover, it is a critical raw material with a low recycling rate. While the social impacts of PTFE, $KHCO_3$, and polyacrylonitrile are worth considering, they can be synthesised from different chemical pathways using other precursor raw materials or replaced with other components with similar physicochemical properties and performance.

3.3. Limitations

The lack of causal links between social indicators and the functional units in terms of quantifiable output is the major limitation of this study. Linkages between social performance indicators and the functional unit will ensure more accurate S-LCA results and help identify the trade-offs between the economic, environmental, and social implications of supply chain decisions. The use of different weighting factors could also affect the outcome of the S-LCA. Thus, it is recommended that weighting factors for the risk levels be updated as new information and evidence become available, in order to obtain up-to-date perspectives on the potential social risks. The lack of granularity in terms of commodity/sector-specific data is another limitation. For example, copper and indium are both mapped to "metals n.e.c" on the SHDB, even though the social risks associated with both metals, irrespective of country of import and trade value, may differ significantly. Furthermore, as with global trade, it is probable that the links between social risks, social indicators, and labour intensity factors are not one-dimensional. At any rate, as S-LCA is still in the nascent stage of development, research efforts in the field are ongoing to address these daunting methodological challenges.

4. Conclusions

This study provides provisional insights into the potential social risks associated with the import of requisite BES components, for copper recovery and formic acid production, to the UK. It was found that the imports of the BES components are highly skewed towards EU countries, which make up about 75% of total imports to the UK. "Labour Rights and Decent Work" exhibited the highest risk for all commodities across the countries of imports, whereas "Human Rights" and "Community Infrastructure", in equal extents, exhibited the lowest risk. Copper showed a strikingly higher social risk than other BES commodities, thus, its use as current collectors should be reconsidered. The insights gained in this study thus lays the foundation for future research for understanding the holistic sustainability of BESs. The UNEP-SETAC guidelines suggest that the results of computational S-LCA studies (such as the present study) should be verified and complemented with direct engagement with relevant stakeholders. Experimental trials of BESs have so far shown optimistic results and considerable prospects for scaling up. Moreover, previous research suggests strong environmental and economic drivers for the upscaling of the technology [21]. Therefore, it is possible that the upscaling of BESs will ultimately yield social benefits.

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

Table of Acronyms and Abbreviations:

BES	Bioelectrochemical System
EU	European Union
FAO	Food and Agriculture Organisation
GTAP	Global Trade Analysis Project
ILO	International Labour Organisation
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCSA	Life Cycle Sustainability Assessment
OECD	Organisation for Economic Co-operation and Development
PTFE	Polytetrafluoroethylene
SETAC	Society of Environmental Toxicology and Chemistry
SHDB	Social Hotspot Database
SHI	Social Hotspot Index
S-LCA	Social Life Cycle Assessment

UN COMTRADE	United Nations Commodity Trade Statistics Database
UNEP	United Nations Environment Programme
USD	United States Dollar
WB	World Bank
WHO	World Health Organisation

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