Chapter 7
Proposing a Multi-level Assessment Framework for Social LCA and Its Contribution to the Sustainable Development Goals

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Abstract In the context of sustainable product development, Life Cycle Assessment (LCA) methods are used to gain knowledge about environmental hotspots and derive options for improvement. In light of international efforts to promote sustainable development, Social LCA (SLCA) is an emerging method to assess potential socio-economic impacts of products and services. Even when available data is limited in the early stages of materials, process, and product development, the implementation of SLCA benefits target-oriented research and development to support sustainable development. This article introduces a multi-level SCLA framework for accompanying innovation processes. The multi-level framework starts by prioritizing social aspects and proceeds as more and more data becomes available with generic and primary assessments and sets the results in context to the 17 Sustainable Development Goals (SDGs). The application of the multi-level SLCA is showcased via a bio-based value chain. The study aims to identify options for social risk reduction and consequently provide recommendations for decision-makers. The results show that options to increase social sustainability can be realized by reducing chemical and fertilizer use or fostering sustainability reporting. By mapping the SLCA results to the SDGs, it could be found that the bio-based value chain at hand mostly contributes to the SDG no. 8.

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7.1 Introduction

Since around 2005, there has been a growing interest in the social dimension of sustainability assessment, and from policymakers and industry to individuals from civil society, concern regarding the social impacts of production processes, products, or services has increased. Beginning with environmental impact assessment, the call for integration of social aspects in Life Cycle Assessment (LCA) arose later and together with economic aspects form the framework of Life Cycle Sustainability Assessment (McManus and Taylor 2015; Guinée et al. 2011). The first considerations to implement socio-economic aspects into LCA started in the early 1990s (Wu et al. 2014). Since then, formal guidelines have been developed, such as the "Guidelines for Social Life Cycle Assessment of Products" in (UNEP/SETAC 2009) in 2009. With an updated version in 2020, new and more advanced guidance was created for applying SLCA in practice (UNEP 2020). Social impacts are assessed by considering relevant social issues (impact categories), which are assigned to stakeholder groups and can be quantified and measured by a combination of various quantitative and qualitative indicators (UNEP/SETAC 2009; UNEP 2020). The stakeholder groups represent human beings who may be affected by the economic activities under study. Therefore, both positive and negative impacts on affected stakeholders throughout a product's life cycle can occur (UNEP/SETAC 2009).

However, assessing the social and socio-economic dimensions still faces some challenges: one issue is the availability of characterization models for impact pathways (Chhipi-Shrestha et al. 2015; Martínez-Blanco et al. 2014). The interdependencies of social and economic factors as well as the social cause and effect chains are complex and therefore difficult to quantify (Sureau et al. 2020; Spierling et al. 2018; UNEP 2021). For instance, land use change is mainly investigated from an environmental perspective (Rutz and Janssen 2014), although the rising establishment of bio-based value chains substituting for fossil-based products, propell expectations in the creation of wealth and job opportunities particularly for the rural population (European Commission 2012a; Global Bioeconomy Summit 2015). Another issue is the availability of adequate data on the different levels of assessment (i.e., site-specific, sectoral, and regional data), especially for ex-ante assessments during the innovation process (Hesser 2015; Mair-Bauernfeind et al. 2020a). The data available in the early stages of materials, process, or product development is inherently low and increases with the progression of the development process (Hetherington et al. 2014). Though, uncertainties are high in ex-ante assessments, it provides insights into areas of concerns already at low technology readiness levels (TRL) and guides further advancements when adaptations are still relatively easily possible (for integration of LCA in research and development, see Lettner and Hesser 2020).

Following the life cycle thinking approach, the Social Life Cycle Assessment (SLCA) methodology is being developed based on the standardized method of environmental LCA (ELCA) (see ISO 14040 series). The aim of both methods is to assess the potential social or respectively environmental impacts of products or services across their entire life cycle (i.e., from resource extraction to final disposal) (ISO 2006; UNEP 2020). As life cycles are related to complex value chains and are often geographically scattered, typically involving a range of stakeholders at every stage of the value chain, a multitude of social issues may be relevant for the assessment of social impacts. Also, the geographical, sector-specific, and even the company-related contexts are important in SLCAs (Sala et al. 2015; Dreyer et al. 2010; UNEP/SETAC 2009) not to mention cultural aspects and different sustainability issues in relation to geographical context (Sutterlüty et al. 2018). Consequently, certain methodological decisions (e.g., choice of stakeholder groups, subcategories or indicators) need to be adapted to sectoral and regional specifics (Siebert et al. 2018b; Mair-Bauernfeind et al. 2020b). For instance, Fürtner et al. (2021) prioritized social issues and indicators for bio-based value chains in Slovakia in a three-step multi-methodological approach, which resulted in a set of indicators specifically for the sectoral and regional context investigated.

For a sustainable development, the different dimensions of sustainability (economy, ecology, and society) must be considered, which needs an institutional framework to integrate the different dimensions (Zimmermann 2016). The 17 Sustainable Development Goals (SDGs) are a global plan to promote sustainable peace and prosperity as well as to protect our planet, launched by the United Nations, which came into force in 2016 under Agenda 2030 (UN General Assembly 2015). A broad set of targets and indicators for each SDG form the basis for evaluating the progress made towards achieving the SDGs operationalized also on a national scale. In the context of Life Cycle Sustainability Assessment (LCSA), the SDG indicators have already been considered as a support for indicator selection (Wulf et al. 2018) and were assigned to the impact categories (Maier et al. 2016) or were used to analyze the contribution to the SDGs (Herrera Almanza and Corona 2020). However, not every global goal and indicator may be relevant in region-specific assessments (Zeug et al. 2021) and when focusing on the social dimension, it is unclear how the SDG indicators will overlap with the prioritized impact categories. Moreover, as the SDGs represent targets on a macro level, they cannot be directly implemented into the assessment of products or services (micro level) and therefore need to be downscaled for application. Another issue is that up to the revised version of the "Methodological sheets for Subcategories in Social Life Cycle Assessment" published in 2021, the SLCA method had remained isolated from the SDGs (Pollok et al. 2021). Now the methodological sheets provide subcategories assigned to SDGs and—where applicable—to SDG targets (UNEP 2021). However, an implementation of SLCA results to the SDGs and the respective targets is missing. One reason for that might be that companies struggle with how to introduce, implement, and assess the contribution of their activities to the SDGs (Herrera Almanza and Corona 2020; Weidema et al. 2018). Nonetheless, companies have already started using the SDGs for their sustainability reporting, which plays a crucial role in achieving the SDGs, as companies will

have an impact on the utilization of resources, stakeholder behavior, and innovation (Calabrese et al. 2021).

Considering this background, the aim of this study is twofold: First, a conceptual framework for a multi-level SLCA is introduced that allows accompanying the different research and development (R&D) phases with social sustainability assessment. A 2nd level assessment is showcased in this study where an SLCA is integrated into the development of a bio-based product system. Secondly, this article assigns the results of the SLCA to SDGs to depict the contribution of a product system to sustainable development. Hereby, positive impacts and the reduction of potential negative impacts to the SDGs are aimed at guiding sustainability efforts towards essential issues. Therefore, the SLCA results will be discussed based on the goals set by the SDGs. The study intends to address LCA practitioners as well as decision-makers (project managers) who are responsible for establishing bio-based product systems and developing innovations.

7.2 Methodological Approach

The multi-level SLCA and the application are showcased on the demonstration project D4EU (Dendromass4Europe), which aims to establish sustainable dendromass cultivation on marginal land in Western Slovakia valorizing the total biomass in four different bio-based value chains (D4EU 2022). Further information about the project can be found on the project's homepage (https://www.dendromass4europe.eu/). D4EU is funded by the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program. The technological development and demonstration in the project were accompanied by a set of investigations for sustainability assessment: see Perdomo et al. (2021) for LCA review on dendromass cultivation; Perdomo et al. (2022) on setting the dendromass production in context to planetary boundaries; Fürtner et al. (2021) on locating hotspots in social LCA; Ranacher et al. (2021) on willingness of farmers to engage in dendromass cultivation; Pichler et al. (submitted) on perceived fairness of dendromass production and its social license to operate; and Fürtner et al. (2022) on the costs and benefits of dendromass production.

The availability of data for products and processes at a low TRL (technology readiness level) is scarce but increases with advancing TRL. In this environment, LCA can make use of its iterative character and accompany the development progresses by co-developing the assessment models and providing preliminary assessment results and recommendations. Instead of waiting for the product to reach maturity and for accurate data to be made available, it is important to take precautions and assess the potential social impacts already at an early TRL so that unintended negative effects can be avoided (see also the European Commission's Responsible Research and Innovation framework) (European Commission 2012b). The precautions allow those managing a project to anticipate potential social hotspots already during the development process and provide the opportunity to counteract them in further development.

Fig. 7.1 Multi-level SLCA framework to accompany R&D projects/innovation processes along with their advancements

As this approach has already successfully been implemented in LCA studies (e.g., Lettner and Hesser 2020; Mair-Bauernfeind et al. 2020a), it should work for social sustainability assessments as well. Low data availability is often used as an excuse not to conduct LCA or another type of sustainability assessment. Therefore, we propose a multi-level SLCA framework from 1st level to 5th level (compare Fig. 7.1), which allows us to start assessments with open-ended process configurations and low or fragmented primary data availability.

1st level: "*Thematic Hotspotting*" presents the prioritization of social issues and indicators by indicator screening, stakeholder engagement, and risk mapping. This was done in a previous study by Fürtner et al. (2021), where a prioritization of relevant social aspects and indicators was reached by triangulating the results of several methods applied, including the following:

(a) Indicator screening (in guidelines, sustainability standards, and scientific articles);
(b) Stakeholder engagement (process experts, representatives of stakeholder groups, and affected stakeholders). This participatory approach allows to find social impacts that concern our stakeholders (Mathe 2014) and;
(c) Risk mapping (with the Social Hotspots Database Risk Mapping Tool available at http://www.socialhotspot.org/).

2nd level "*Impact Hotspotting*" includes country- and sector-specific secondary data assessment. The indicators selected in the previous level are quantified with national, regional, and statistical data. The procedure and results achieved at this level are discussed in the present article.

3rd level "*Organizational Level SLCA*" requires company-specific data, switching from a generic secondary data-based approach to a specific primary data-based approach assessing the social performance/impact of the organization.

4th level "*Process Level SLCA*" analyzes the stages of a value chain with corporate data of production processes. Cooperation of firms involved is necessary to obtain the required

information. The results help identify process hotspots and to implement targeted measures, improving the social performance.

5th level "*Consequence-based SLCA*" integrates direct stakeholder consultation. This means that the social impact data are directly gathered from the different stakeholder groups that are potentially affected by the studied processes. Level five thus allows to assess directly perceived impacts, whereas at level 1–4, potential impacts can merely be investigated.

Depending on the goal of the assessment, it is not necessary to go through all levels but rather focus on individual levels of the multi-level SLCA framework that are useful for the project development. It is also strongly dependent on time and other resources to what level the SLCA can be applied. Therefore, one should avoid omitting an SLCA due to a lack of resources but instead concentrate on single levels that can be achieved.

The application of the multi-level framework is showcased by applying the 2nd level assessment on a bio-based value chain. In principle, the 2nd level assessment is based on the reference scale approach proposed in the SLCA guidelines by UNEP (2020), where the performance of a product system is assessed in relation to predefined performance reference levels (PRPs). The PRPs are intended to compare a local situation (described by the inventory data) with an national or international threshold (Parent et al. 2010; UNEP 2020). Performing the SLCA on a generic level as is proposed in the 2nd level assessment allows for identifying the most critical societal aspects (hotspots analysis) to find levers for supporting sustainable development in the value chain during R&D. The results are used to communicate potential pathways towards decision-makers to further increase the social sustainability through the value chain under study. In the discussion, the results are then linked to the global SDGs. This helps one to focus on generally accepted and globally relevant sustainability objectives and to contribute to the development towards the defined SDGs.

7.2.1 Goal and Scope

The aim of this study is to determine potential social impacts related to the product system introduced in Fig. 7.2, by conducting the 2nd level assessment of the introduced multi-level SLCA framework (Fig. 7.1).

In the 2nd level assessment, the focus is on the foreground system of the product system (Fig. 7.2), which includes those processes that can be directly shaped by the decisions made in the project (S0–S4). The system boundaries are, therefore, "cradle to gate" and include raw material production of dendromass (S0) in Slovakia to industrial production of four bio-based products: (S1) functionally adapted lightweight board in Slovakia; (S2) eco-fungicidal molded fiber parts in Poland; (S3) bark-enriched wood plastic composite profiles in the Czech Republic; and (S4) bark-enriched wood plastic composite granulate also in the Czech Republic. These production systems differ in their production processes, sector, and geographical scope. The

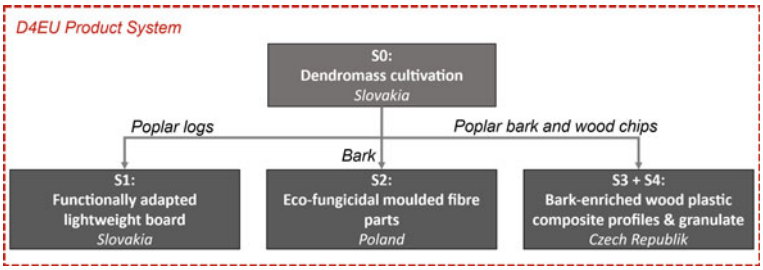

Fig. 7.2 Production system comprising the subsystems: S0 Dendromass cultivation, S1-S4 bio-based products production in different geographical contexts

UNEP (2020) guidelines propose six stakeholder groups to be investigated, in this study the central stakeholders that may be affected by the processes are as follows:

- Workers (field workers in SRC plantations and industrial workers),
- Local communities (neighboring to production systems) and
- Society (potentially affected groups of people in the region, federal state, state, etc.).

The other three stakeholder groups, namely value chain actors (people or organizations involved through a business relationship, e.g., suppliers), consumers, and children cannot be considered for this 2nd level assessment due to the challenging data situation. Likewise, the consumption and end-of-life phase is out of the scope for the 2nd level assessment.

The prioritized stakeholder groups are addressed in this 2nd level SLCA by assigning their impact categories and indicators, which have been prioritized in a pre-study (see Fürtner et al. 2021) and are used as a starting point in this study. The list of prioritized indicators and impact categories is shown in Table 7.1. The stakeholder category of value chain actors was also included in Fürtner et al. (2021) but not in this study because of data availability. The assessed impact categories and indicators have strong focus on the stakeholder groups worker and local community. This focus was also observed in other studies, like Martin et al. (2018), Siebert et al. (2018a), or Spierling et al. (2018).

7.2.2 Data Inventory

To "get a general feel for areas of social concerns in certain countries/or sectors" (Benoît-Norris et al. 2011, 687), the 2nd level assessment can be used for product systems in an early development stage. For such an assessment, modeling tools that require less accurate datasets can be used (Hesser 2015; Niero et al. 2014). In this study, the indicator results of the different production locations were compared, whereby different types of generic sectoral and country-specific data were collected.

Table 7.1 Social impact categories and indicators considered for the 2nd level assessment (based on Fürtner et al. 2021)

Stakeholder group	Impact categories	Indicators	Units	Measurement description
WORKERS	Workers health and safety	1. Occupational accident rate in Slovakia 2. Number of occupational (fatal) accidents 3. Sick-leave days per year 4. Exposure to agrochemicals	% nb nb Qual	2. Number of (fatal) accidents per year, per employee 3. Number of sick-leave days per year, per employee
	Equal opportunities	1. Country/region gender index ranking 2. Presence of formal policies on equal opportunities 3. Rate of female workers 4. Rate of workers from regional minorities	Index Yes/no % %	2. Description of potential discrimination practices
	Fair salary	1. Average Slovakian living wage (month) 2. Average payment per month, per full-time employee 3. Payment according to Slovakian living wage	€ € yes/no	3. Are all employees paid at least according to the local minimum wage?
	Working conditions	1. Job satisfaction	Index	Job satisfaction index
	Working hours	1. Contractual working hours 2. Effective working hours (average) 3. Effective used holidays 4. Overtime compensation	Hrs Hrs Days Qual	2. Hours of work per employee/day 3. Hours of consumed holidays per employee/year
	Child labor	1. Percentage of children working by country and sector 2. Absence of working children under the legal age	% Yes/no	1. Description of child labor potential 2. Stating names, birth dates of all workers

(continued)

Table 7.1 (continued)

Stakeholder group	Impact categories	Indicators	Units	Measurement description
	Forced labor	1. Evidence of forced labor in the production processes 2. Workers voluntarily agree upon employment terms	Yes/no Yes/no	2. Description of working conditions contractually regulated
LOCAL COMMUNITY	Local employment	1. Unemployment statistics for Slovakia/ Region 2. Percentage of workforce hired locally 3. Number of local full time equivalent created jobs	% % nb	
	Safe and healthy living conditions	1. Pollution levels by country 2. Management effort to minimize use of hazardous substances 3. Food security	% Qual Qual	3. Changes in national/ local food prices
	Access to material resources	1. Changes in land ownership 2. Infrastructure for community access developed	Yes/no Qual	
	Community engagement	1. Number and quality of meetings with community stakeholders	nb./ qual	1. Description of community engagement activities
	Cultural heritage	1. Strength of policies in place to protect cultural heritage 2. Landscape identity	Yes/no Qual	2. Visual attractiveness and continuity of appreciated landscape heritage
	Respect of indigenous/local communities rights	1. Prevalence of racial discrimination 2. Local land rights conflicts/land claims 3. Annual meetings held with community members	Yes/no Yes/no nb	2. Description of conflicts, land tenure structures, etc

(continued)

Table 7.1 (continued)

Stakeholder group	Impact categories	Indicators	Units	Measurement description
	Regional value creation	1. Regional Value Added 2. Regional investment, per unit input 3. Spatial proximity of investments	€ € %/qual	
	Contribution to (regional) economic development*	1. Economic situation of country/region 2. Contribution to economic progress 3. Contribution to household/farm income	€/qual €/qual €/day	1. GDP, economic growth, unemployment rates, wage level, etc 2. Revenues, paid wages, R&D costs, etc
SOCIETY	Public commitments to sustainability standards	1. Existence of public sustainability reporting 2. Publicly available documents on agreements to sustainability issues	Yes/no Yes/no	
	Corruption	1. Risk of corruption in Slovakia/the region 2. Commitment to prevent corruption 3. Anti-corruption program carried out	Index Yes/no Yes/no	
	Technology development	1. Research and development costs spent 2. Partnerships in R&D	€ Yes/no	1. On organizational, sectoral, or project level
	Respect of human rights	1. Slovakian Human Rights Index	Index	1. CIRI Human Rights Data Project

* Contribution to economic development can be considered either from the perspective of a whole society or from the perspective of a smaller local community

Secondary data was used to relate the potential social risk associated with the country or sector of production. The secondary data utilized for this study were based on various national- and sector-specific statistics and literature gathered through online research (from databases like WHO, OECD, or ILO). Information needed for the qualitative description of certain indicators was also collected through online research. Accordingly, primary data, which is company-specific information in this case was collected for those indicators, where a generic approach does not make sense. The use of a functional unit (FU) is not necessary for this 2nd level assessment because an impact on stakeholders does not depend on production volumes, but

on the principles of decision-makers in different countries, sectors, and companies (UNEP/SETAC 2009; Iofrida et al. 2018; Martínez-Blanco et al. 2014).

7.2.3 Impact Assessment

The Life Cycle Impact Assessment (LCIA) in SLCA is applying characterization methods to link the inventory data to the respective impact categories and to calculate the potential impact of the system with the help of indicators (UNEP 2020). These results are normalized in relation to reference information to bring them on a common scale for comparability (Ibáñez-Forés et al. 2019; Yıldız-Geyhan et al. 2019). This approach allows to compare the local situation (inventory data) with an international set of thresholds (e.g., EU-average of the respective data) (Parent et al. 2010). Since the data availability for the assessment of the indicators is quite inconsistent, individual reference values (e.g., EU average, national or organizational target values or, best practice targets, etc.) were used to assess each of the indicators as accurately as possible. The social risk potential is calculated following the method of Zira et al. (2020) with the Eqs. (7.1) and (7.2), introduced below.

$$SR = 1 - EXP\left(LN(0.5) \times \frac{IND}{REF}\right) \tag{7.1}$$

when a higher value than the reference point reflects a more negative impact, and

$$SR = EXP\left(LN(0.5) \times \frac{IND}{REF}\right). \tag{7.2}$$

when a lower value than the reference point reflects a more negative impact.

SR = Social Risk Potential; IND = the inventory indicator; REF = the reference point.

7.2.4 Interpretation and Discussion of the Results Based on the SDGs

The interpretation phase of SLCA facilitates identifying significant risks as well as drawing conclusions and offering recommendations on the results as well as checking for completeness, consistency, and limitations of the assessment (UNEP 2020). Considering that the SLCA is intended to provide guidance on improving the social sustainability of the evolving value chain, emphasize is given to translate the results into recommendations that support decision-making. In order to pursue

a global strategy of sustainable development, the results are interpreted in terms of the SDGs. In this regard, the frequently used technique to identify direct and indirect impacts of the evolving value chain on the achievement of the SDGs is used (Eberle et al. 2022). Whereas, a direct impact is given, when the value chain under study has an influence on the fulfillment of SDGs by its own production processes and activities. Indirect influence originates from outsourced processes in up- and downstream activities of the value chain, which are managed by external companies or parties. The recently published methodological sheets for SLCA is an updated version where the SDGs are put in relation to the respective impact categories (UNEP 2021). This document is also used as a guideline for assigning project impacts to SDGs.

For this study, it is not the goal to follow a strategy of completeness, i.e., that each SDG or SDG-indicator needs to be covered through the assessment also because not every global indicator inevitably has to be relevant for regional considerations either (Zeug et al. 2021). The approach is intended to provide guidance on pursuing proper or generally accepted goals to avoid focusing on minor social issues. To avoid judging the impact of the project on the achievement of the SDGs solely based on predetermined associations from literature and preliminary studies, project-specific impacts were elicited in a first step. Following, the relationship between global SDGs and project-specific impact categories was linked (compare Fig. 7.6).

7.3 Results of the 2nd Level SLCA

The social risk potential indicates the likelihood in how far the assessed category has a higher or a lower risk than the related PRP. The corresponding social impacts for the stakeholder groups "Workers," "Local Communities," and "Society" is presented in the Sects. 7.3.1–7.3.3. The social impact categories and indicators from Fürtner et al. (2021) were directly applied if data were available for assessing the respective indicators. The results for the product systems (S0-S4) of the bio-based value chain as well as the respective reference levels (PRP level) for all indicators are shown in Table 7.2. The numbers indicate the normalized results in relation to the PRPs and are illustrated in Figs. 7.3, 7.4 and 7.5. The results can be interpreted as follows: 0–0.35 "above compliance/better social performance"; 0.35–0.7 "around compliance/rather satisfying social performance" and 0.7–1 "non-compliance/relatively poor social performance" compared to the PRP level.

Some social aspects cannot be evaluated with quantitative data. In such cases, qualitative data is used to describe the situation even if it is not possible to include that aspect into the SLCA rating system (e.g., food security). The following results refer to the "2nd level" assessment of the introduced multi-level framework. These findings result in a country- and sector-specific hotspotting of potential social impacts.

Table 7.2 Results of the 2nd level assessment for the systems S0–S4 and their respective PRP level

Performance Indicator	S0	S1	S2	S3 + S4	PRP level
Age-standardized all-cause disability-adjusted life year (DALY) rates attributable to occupational risks (per 100,000)	0.442	0.442	0.539	0.560	EU-27
Fatal accidents at work, by sector per 100,000 inhabitants	0.922	0.498	0.477	0.401	EU-27
Non-fatal accidents at work, by sector per 100,000 inhabitants	0.243	0.261	0.268	0.391	EU-27
Percentage of unemployed people with basic education (% of total labor force)	0.771	0.771	0.317	0.408	EU
Percentage of unemployed people with advanced education (% of total labor force)	0.332	0.332	0.203	0.152	EU
Percentage of unemployed people from the Roma Communities in Slovakia	0.997	0.997	–	0.979	National
Global Gender Gap Index—Economic Participation and Opportunity	0.563	0.563	0.540	0.566	EU-27
Risk of sector average wage being lower than country's average wage	0.518	0.495	0.514	0.509	National
Risk of sector average wage being lower than country's living wage	0.287	0.264	0.135	0.208	National
Risk of sector average wage being lower than country's minimum wage	0.215	0.194	0.266	0.168	National
Fair wage potential (Neugebauer et al. 2017)	0.202	0.159	0.313	0.135	National
Global Employee Engagement Index	0.515	0.515	0.515	0.500	EU
Average usual working hours per country	0.529	0.529	0.532	0.529	EU-27
Realization of Children's Rights Index Ranking	0.546	0.546	0.537	0.534	Best practice
Realization of Children's Rights Index Ranking	0.502	0.502	0.493	0.490	EU-27
Country's risk of forced labor used to produce commodity—Global Slavery Index Ranking	0.522	0.522	0.538	0.512	EU-27
Percentage of forced labor by country	0.484	0.484	0.531	0.477	EU-27
Government response rating of legal, policy, and programmatic actions to modern slavery	0.525	0.525	0.525	0.525	EU-27
Vulnerability to modern slavery by country	0.640	0.640	0.601	0.512	EU-27
Freedom of association and collective bargaining—"ITUC Global Rights Index"	0.500	0.500	0.875	0.750	Best practice
Risk of unemployment (% of total labor force)	0.492	0.492	0.298	0.254	EU
Human development index (HDI)	0.516	0.516	0.508	0.500	EU-27
DALY rates from all causes (per 100,000)	0.541	0.541	0.535	0.508	EU-27

(continued)

Table 7.2 (continued)

Performance Indicator	S0	S1	S2	S3 + S4	PRP level
Population-weighted mean levels of fine particulate matter smaller than 2.5 microns (PM 2.5)	0.705	0.705	0.765	0.672	WHO threshold
ENAR recorded incidents of racial motivated crime, per 100,000 inhabitants	0.181	0.181	0.523	0.158	EU-27
EU Regional Competitiveness Index (RCI)	0.302	0.302	0.4516	0.530	National
EU Regional Competitiveness Index (RCI)	0.416	0.416	0.623	0.530	EU-27
Annual growth in GDP per country	0.680	0.680	0.481	0.655	EU
Sector contribution to GDP per country	0.463	0.425	0.423	0.368	EU-27
Company publishes public sustainability reporting	0.287	0.287	0.871	0.871	Best practice
Company makes documents on agreement to sustainability issues publicly available	0.287	0.287	0.871	0.871	Best practice
Corruption Perceptions Index (CPI)	0.587	0.587	0.544	0.556	EU-27
Global Corruption Index (GCI)	0.627	0.627	0.561	0.535	EU-27
Company fosters partnerships in R&D	0.435	0.435	0.435	0.435	Best practice
Human Rights Score	0.580	0.580	0.578	0.406	EU-27
Human Rights Violations	0.551	0.551	0.526	0.473	EU-27

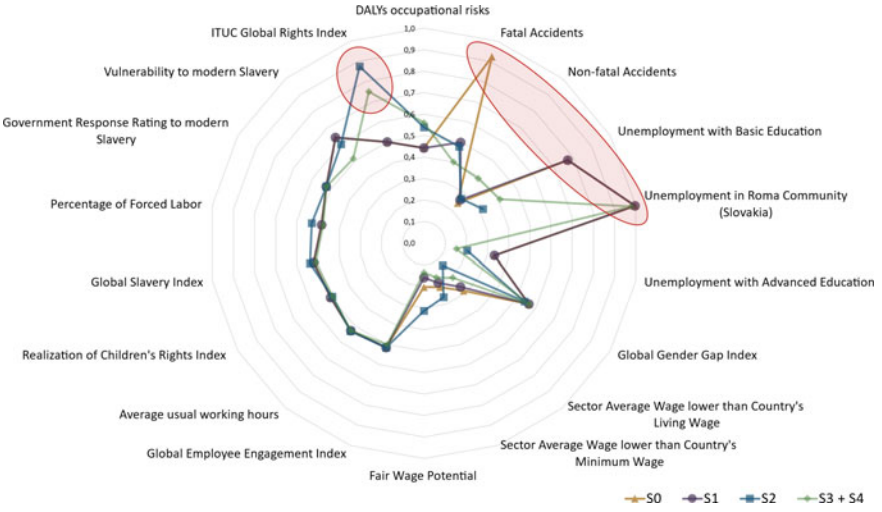

Fig. 7.3 Comparison of SLCA results among S0–S4 for the stakeholder group "Workers." Results in the respective range indicate: 0–0.35 "above compliance/better social performance" | 0.35–0.7 "around compliance/rather satisfying social performance" | 0.7–1 "non-compliance/relatively poor social performance" compared to the reference

7.3.1 *Social Risk Concerning the Stakeholder Group "Worker"*

The stakeholder group "Workers" is assessed with 20 indicators associated to eight impact categories (cf. Table 7.2). Five production systems (S0–S4) are compared to each other, whereas S3 and S4 are combined because they are produced within the same company located in the Czech Republic. The results are shown in Fig. 7.3, where 13 out of the 20 indicators for S0 (dendromass production system) have a social risk potential equal or higher than 0.5, which means that the situation is worse than the PRPs" situation and special attention should be paid to these aspects. The results are similar for S1 (bio-based product manufactured in Slovakia), S2 (bio-based product manufactured in Poland) as well as S3 and S4 (bark-enriched wood plastic composite profiles and bark-enriched wood plastic composite granulate) where 11 out of the 20 indicators yield in a value equal or higher than 0.5.

A major difference between the systems could be identified for the indicator "**fatal accidents at work**" In this area, agricultural and forestry activities impose far more risks than industrial activities. Fatal accidents in SRC production are one of the main hotspots that could be identified for dendromass production and should therefore be given special attention. Health and safety at work is a highly important topic to achieve sustainable development (Benoît-Norris et al. 2013). However, it must be mentioned that this assessment is based on statistical numbers also including timber logged in forests, which is associated with an inherently high risk. SRC specific statistics cannot be found; therefore, it is quite unsure to what extent the risk applies to dendromass production in SRC plantations. Discussions with SRC managers, harvesting experts, and planting companies, for example, indicated that the risk of accidents is significantly lower in SRC plantations than in forests due to a high degree of mechanization and controlled environment. No severe incidents were reported by them.

A rather high-risk potential could be identified regarding "**unemployed people with basic education**" for systems situated in Slovakia (S0, S1), and, for "**unemployed people from Roma communities**" for systems situated in Slovakia and Czech Republic (S0, S1 and S3, S4), which implies inequalities due to socio-demographic attributes. In this context, emphasis can be given to communicate possibilities of employment, as jobs are created with the establishment of an SRC-based value chain that could appeal to the affected groups of people. Another high-risk potential is connected with the "**global rights index**" for the systems S2–S4. This index documents violations of internationally recognized labor rights by governments and employees. The high rating for Poland and the Czech Republic indicates, that violations of collective labor rights are regularly reported (ITUC 2020).

A range of indicators were identified to be compliant with the reference level, which can be explained by relatively similar conditions among EU countries. Regarding the issue of a fair wage, the results show a relatively low risk potential, especially for the industrial activities referring to S1–S4.

7.3.2 *Social Risk Concerning the Stakeholder Group "Local Community"*

The stakeholder group "Local Communities" is assessed with eight indicators in four impact categories. The results shown in Fig. 7.4 indicate that the majority of assessed indicators result in a low or medium risk potential. A higher risk potential for "**incidents of racially motivated crime**" was detected for S2, which concerns processes located in Poland, indicating that human rights of marginalized groups are threatened by cultural mainstream. Organizations should emphasize respect to local cultural heritage as well as secure individuals" rights to preserve their cultural heritage (Benoît-Norris et al. 2013). In contrast, this threat is considered to be much lower in Slovakia and the Czech Republic, however, this does not imply that this aspect can be neglected by the companies responsible for S0, S1, S3 and S4. A major hotspot of social risks for local communities occurs in areas of high "**levels of fine particulate matter (PM 2.5)**," affecting the health of communities regarding all five systems under study. This issue should be addressed by all participating companies putting sustainable managing practices as a priority and focusing on the reduction of emissions, which contribute to the increase of PM 2.5 (e.g., caring about the reduction of vehicle use, transportation distances or emissions through incineration). Another high-risk potential could be found in the systems located in Slovakia and the Czech Republic regarding "**annual growth in GDP**," which simply means that those countries have a lower GDP growth than the EU average. According to the methodological sheets of UNEP (2021), organizations contribute to economic development by not only generating revenue but also by creating jobs, education, and training, they make investments and forward research. On a national level, this means that countries with lower GDP growth have a higher risk of contributing less to the abovementioned aspects. Note that the UNEP SETAC guidelines rate low GDP as social risk, which makes clear that the economic growth paradigm is supported.

"**Food security**" within the impact category "**safe and healthy living conditions**" cannot be described in a quantitative way as no respective data is available. However, the topic is highly discussed in the context of plantation establishment. One indicator that may illustrate this aspect is the "**Global Hunger Index**." Slovakia reached a score of 6.4 for the year 2020, which shows low severity for the risk of hunger. The "Global Hunger Index" measures and tracks the hunger situation at a global, regional, and national level from <9.9, indicating low risk to >50, indicating a severe situation (Grebmer et al. 2020). Slovakia is ranked on the 27th position out of 107 countries covered in the index. It was not possible to include the index into the generic SLCA, as reference levels were missing. For most of the EU-27 countries, the index has no value included (probably as it is no issue in the Central European context). However, it must be noted that among the included European countries (Estonia, Latvia, Lithuania, Romania, Croatia and, Bulgaria), the score for Slovakia shows the worst situation. Another indicator on that topic, which could not be included into the SLCA because of a missing reference is the number of **undernourished people in the country**. Undernourishment is measured as a caloric intake that is insufficient to meet the

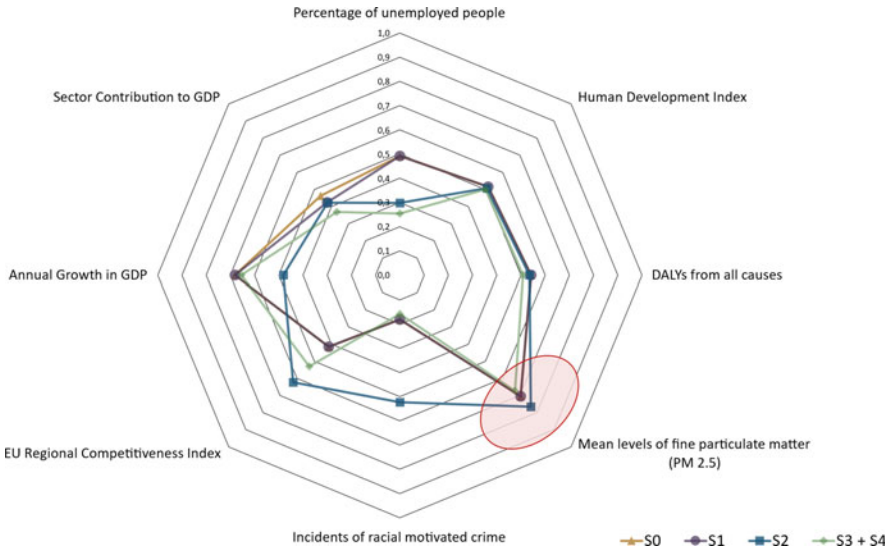

Fig. 7.4 Comparison of SLCA results among S0–S4 for the stakeholder group "Local Community." Results in the respective range indicate: 0–0.35 "above compliance/better social performance" | 0.35–0.7 "around compliance/rather satisfying social performance" | 0.7–1 "non-compliance/relatively poor social performance" compared to the reference

minimum energy requirements necessary for a given individual (Ritchie 2022). The results for this indicator are not showing rates below 2.5%, which indicates that the situation is not problematic at all. In that context, it must be mentioned that Slovakia and Bulgaria are the only two countries among EU-27 countries being included in this indicator. It was stated that in 2017, 200,000 people in Slovakia were malnourished. This risk increases the need to emphasize the selection of land for SRC plantations, using marginal land not suitable for food production to not compete with food and fodder production. This situation underlines the importance of dealing with issues in SLCA, which cannot be covered by the straight-forward quantitative assessment method but play a critical role.

7.3.3 Social Risk Concerning the Stakeholder Group "Society"

The stakeholder group "Society" is assessed with seven indicators in four impact categories. The results are shown in Fig. 7.5. The impact category "**commitment to sustainability issues**" is the only category of the 2nd level assessment, which was assessed with organization-specific information. This information could be obtained by online research, as a purely generic level would not make sense in this context. The "**existence of public sustainability reporting**" (corporate non-financial reporting

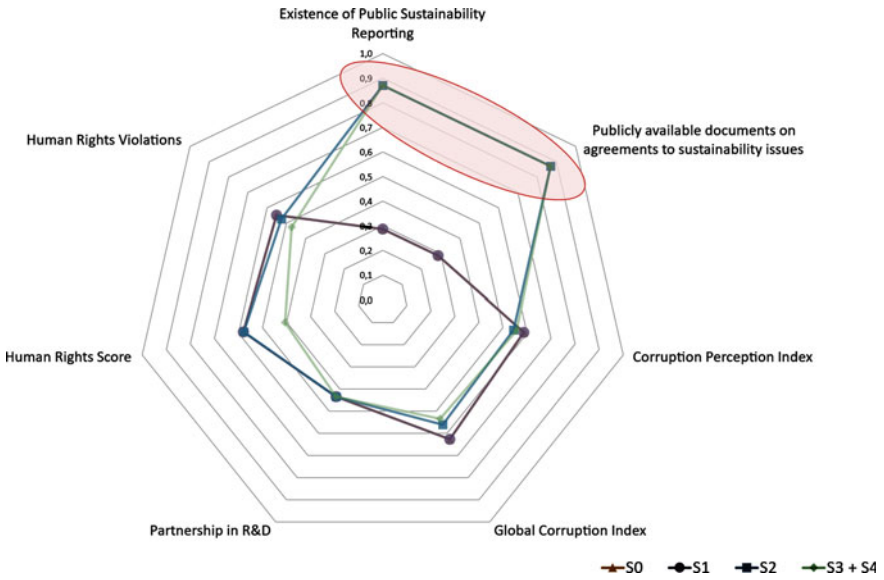

Fig. 7.5 Comparison of SLCA results among S0–S4 for the stakeholder group "Society." Results in the respective range indicate: 0–0.35 "above compliance/better social performance" | 0.35–0.7 "near compliance" | 0.7–1 "non-compliance/relatively poor social performance" compared to the reference

on environmental and social issues) and the "**availability of public documents on agreements to sustainability issues**" were assessed by publicly available sources. Only the organizations responsible for S0 and S1 publish documents on their sustainability performance; therefore, their score is relatively good in comparison to the other systems. This could be taken as an opportunity to strive for transparent documentation on the sustainability situation within the respective companies.

Not a severe, but a medium risk potential was observed for the indicators "**human rights violations**," "**human rights scores**," "**global corruption index**," and "**corruption perception index**." The **human rights scores** measure the degree to which governments protect and respect human rights, whereas the **human rights violations** indicator is an index including press freedom, civil liberties, political freedom, human trafficking, political prisoners, incarceration, religious persecution, torture, and executions (Herre and Roser 2016). The **corruption perception index** ranks countries according to the probability of corruption within the public sector of a country (Transparency International 2021). In comparison, the **global corruption index** includes the ratification status of key conventions, corruption perception, corruption experience, country characteristics, membership to FATF (Financial Action Task Force) and/or related bodies, money laundering and financing terrorism (Global Risk Profile 2020). Although, these issues just demonstrate a medium risk potential, they still should be taken seriously by all acting companies within the value chain under establishment, as the risk is still higher than the EU-average, although

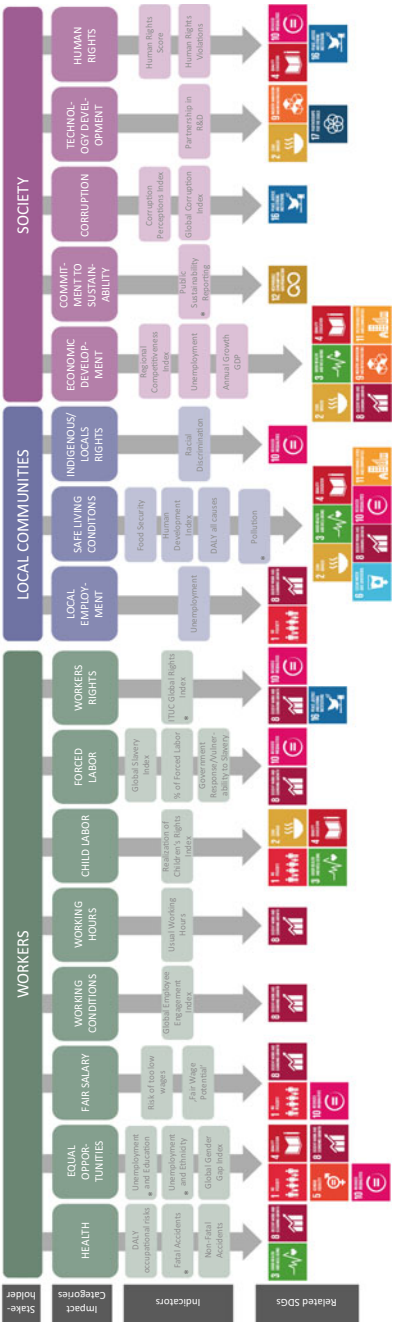

Fig. 7.6 Connecting the prioritized SLCA impact categories with the 17 SDGs. * marks the indicators with the highest risk rating

the assessment does not show a severe risk. Companies need to adopt a binding code of conduct and/or implement systems that prevent the company from getting engaged in corrupt activities (Benoît-Norris et al. 2013).

7.4 Interpretation of SLCA Based on the SDGs Framework

The 2nd level SLCA results for the bio-based production system under study shows a range of indicators with high-risk potential for the considered stakeholder groups. In this section, the social issues with the highest risk-potential will be discussed based on their respective relevance to the SDGs. Thus, the contribution of the bio-based industry to meet the goals will be discussed. The mapping of the impact categories and indicators prioritized for the bio-based value chain under study to SDGs was carried out based on UNEP (2021) and is shown in Fig. 7.6. The SDGs are global goals on a macroeconomic level, thus, comprising governmental objectives. This is probably the greatest challenge of integrating the SDGs into sustainability assessments (Wulf et al. 2018; Herrera Almanza and Corona 2020). Although there is a lack of research on SDGs-based sustainability assessment (Eberle et al. 2022), there are published approaches to integrate the SDGs into the assessment of products (e.g., Eberle et al. 2022) or the prioritization of impact categories and indicators for sustainability assessments (e.g., Wulf et al. 2018). To avoid downscaling and associated inaccuracies, the 2nd level assessment method deals with the SDGs in the interpretation phase. As the 2nd level assessment is based on country- and sector-specific data, the results are located at a similar level as the SDGs. In the following, the indicators with the highest risk rating are discussed in relation to the SGDs (marked with an * in Fig. 7.6) and per social impact category (see Table 7.1).

Workers health and safety

A relatively high-risk potential is associated to "fatal accidents" within the dendromass production system, whereas the industrial production systems (S1–S4) are associated with a lower risk. This is attributable to the different sectors, as the agricultural sector (including farming, forestry, and fishery) shows a considerably higher risk potential than the industry sector. Agriculture and forestry are one of the most dangerous sectors for workers in Europe (Jones et al. 2020). However, it is anticipated that digitalization and new technologies will help navigate the sector towards work practices with higher safety standards (Jones et al. 2020). Established harvesting options are fully mechanized and require relatively low manpower for handling the machineries that may lower the risk of occupational accidents. The prevention of work incidents contributes to ***SDG 8: promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all*** as well as ***SDG 3: ensure healthy lives and promote well-being for all***. The reduction of occupational injuries directly contributes to target 8.8., which aims to promote safe and secure working environments for all workers. The single targets of SDG 3 do not include the prevention of accidents at work or similar. This could be explained by the

fact that the SDGs focus on a broader perspective concerning political organizational units. However, target 3.9, which deals with the reduction of deaths and illnesses from hazardous chemicals as well as air, water, and soil pollution and contamination, may be influenced by the bio-based production system although low amounts of fertilizers and pesticides are needed (Ranacher et al. 2021). These aspects were not included in the SLCA, as they are assessed by ELCA (Perdomo et al. 2022). Nonetheless, a reduction of chemical and fertilizer use in plantations is also contributing to people's health.

Equal opportunities and the freedom of association and collective bargaining

Even though many workers are not needed to manage the SRC plantations (Ranacher et al. 2021), the establishment of a new bio-based value chain in rural areas is seen as an opportunity to strengthen rural areas and create job opportunities. The results of the SLCA show that unemployment rates within the Roma community in Slovakia and the Czech Republic are relatively high. People who have only basic education are also affected by higher unemployment in Slovakia, whereas the situation is much better for the system S2, S3 and S4 located in Poland and the Czech Republic. Therefore, the creation of jobs, especially for lower qualified people and for people from different cultural backgrounds, is of high importance. However, the job market in Slovakia as well as in other countries is being negatively impacted by the COVID-19 pandemic, and people from other industries (e.g., accommodation and food services) are available for employment (Svabova et al. 2020).

For the system S2 (Poland) and S3, S4 (Czech Republic), the "ITUC Global Rights Index" indicator shows a relatively high-risk potential, which indicates that companies should make sure that they are compliant with freedom of association and collective bargaining standards. In contrast, a relatively low risk could be assessed for all systems (S0–S4) regarding the wage associated indicators. These issues contribute mainly to ***SDG 8:promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all***. A contribution can be made for a range of targets within SDG 8 when the established value chain promotes sustainable economic growth and higher levels of productivity (8.1), diversification and innovation (8.2), job creation (8.3), resource efficiency (8.4) and, productive employment for all (8.5 and 8.6). Even though, the 2nd level SLCA results show severe risk potentials in the inclusion of socio-economically disadvantaged groups in the job market. It should be seen as an opportunity to create jobs for them through the establishment of a diversified and innovative value chain. Resource efficiency is again a matter of ELCA; however, it is an important goal to encourage ecological economic growth. All segments of the value chain under establishment should follow the rules to save resources (e.g., through a cascading use of the fully harvested dendromass). SDG 8 is seen as the goal with the highest potential to be positively affected by a sustainable bioeconomy (Allen et al. 2020).

Safe and healthy living conditions and the contribution to economic development

Concerning the stakeholder group local communities, most of the indicators within this group show a relatively low or equal risk potential compared to the reference levels. The highest risk-potential is shown for the fine particulate matter (PM 2.5) situation in Slovakia, Poland, and the Czech Republic, what concerns all production systems under study. PM 2.5 is a common measure for air pollution, which is described by the WHO (World Health Organization) as one of the major risks for human health in all countries of the world (WHO 2021). Air pollution is estimated to be responsible for 4.2 million premature death worldwide, causing heart, lung, and respiratory diseases (WHO 2021). Direct measurements of PM 2.5 emissions through the establishment of the bio-based value chain may be subject of ELCA calculations. However, the project management can contribute to the reduction of PM 2.5 levels by promoting the reduction of transportation distances or the reduction of incineration of wood through avoiding waste in the production processes. These effects can be mainly attributed to ***SDG 11: making cities and human settlements inclusive, safe, resilient, and sustainable*** as well as ***SDG 3***. Especially, the reduction of environmental impacts in cities with a focus on better air quality is topic of SDG 11 (target 11.6). The reduction of human death and illness incidents due to pollution is closely linked to this—and is pursued in SDG 3 (target 3.9). In Slovakia the score of annual mean concentration of PM 2.5 is moderately improving, however, is insufficient to attain the goal (Sachs et al. 2022). The situation in Poland is even rated a little worse (Sachs et al. 2022), which associates a potential to support the fulfillment of SDG 11 and 3 with the reduction of air pollution. Another aspect in this impact category is food security. Although this aspect could not be measured in quantitative terms and was not included in the assessment because of a missing reference level, it is highly discussed in the context of plantation establishment. All countries involved in the bio-based value chain show a low severity for risk in the global hunger index or undernourishment. However, among the included European countries, Slovakia performs worst and in 2017, 200,000 people in Slovakia were malnourished (Ritchie 2022). The aspects of food security contribute to **SDG 2: end hunger, achieve food security and improved nutrition, and promote sustainable agriculture**, especially target 2.2, which aims to end all forms of malnutrition. This situation underlines the importance of dealing with issues in SLCA, which cannot be covered by the straightforward quantitative assessment method but play a critical role.

Public commitments to sustainability standards

The highest risk potential, within the indicators concerning the stakeholder group society, is the non-existence of publicly available sustainability reporting and agreements on sustainability issues. The underlying cause of this result is that reporting, and agreements are missing for the systems S2–S4. However, the results are quite severe, as the indicators only allow a “yes” or “no” answer. These two aspects

regarding commitment to sustainability can be assigned to ***SDG 12: ensure sustainable consumption and production patterns***. Target 12.6 directly deals with adopting sustainable practices and integrating sustainable information into regular reporting. The reason for promoting sustainable production with sustainability reporting may be that sustainable efforts can be pushed forward through setting binding targets and KPIs. Following this path, the targets 12.2—promoting the efficient use of natural resources, 12.4—dealing with a sound management of chemicals and waste along the value chain, and 12.5—the reduction of waste through prevention, reduction, recycling, and reuse measures can be contributed to by setting targets and KPIs in the sustainability reporting.

Focusing on social sustainability in this study has shown, that mainly SDGs 3, 8, 11, and 12 can be influenced by following sustainable pathways. Compared with the study of Allen et al. (2020), our result is more restrictive than their prioritized SDGs for a bioeconomy, focusing on SDGs 2, 6, 9, 12, 13, 14, and 15, which may be due to the fact that their study focused on all dimensions of sustainability. Heimann (2019) found that a bioeconomy can have a negative impact on SDG 1 ("No Poverty") due to an increase of land demand having the same effects as industrial agriculture (land grabbing, displacements, etc.) as well as positive impacts on SDG 1 (income for farmers, higher value-added industry). This aspect could not be supported with our study or is missing within the assessed impact categories. However, Heimann (2019) found that there is the opportunity of a positive effect through a bioeconomy on SDG 8, which can be confirmed with our results.

7.5 Conclusions

The following conclusions and recommendations are derived to contribute to sustainable development of the bio-based production system/demonstration project under study:

- Promote less/no chemical and fertilizer use in plantations and fully mechanized harvesting and planting technologies to support healthy lives and well-being for all stakeholder groups (SDG 3 and SDG 8).
- Promote diversification (farms) and innovative working practices to create job opportunities especially for disadvantaged groups on the job market (SDG 8).
- Increase resource efficiency within the establishment of the bio-based value chain, to encourage the decoupling of economic growth from environmental degradation (SDG 8).
- Set measures to reduce transportation distances and incineration of wood to reduce air pollution and promote a better air quality and human health (SDG 11 and 3).
- Request sustainability reporting from companies acting within the value chain under establishment to push forward sustainable production patterns by fixed targets and KPIs (SDG 12).

Given the limited data availability, cooperation of firms, or normative underpinnings in methodologies (e.g., necessity of economic growth), the study at hand shows that already with an early stage SLCA (2nd level assessment), it is possible to generate and derive actionable knowledge to contribute, identify, and mitigate social risks. In conclusion, the knowledge of driving factors gained through the 2nd level assessment, and its results mapped to the SDGs will provide a strategy leading to increased social sustainability for decision-makers in the development of the project.

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