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SOCIETAL LCA

# Finding relevant stakeholders and related social topics for the implementation of Social Life Cycle Assessment in the multistorey timber construction sector

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## Abstract

**Purpose** This study aims to identify the most relevant stakeholder groups and related social topics for the multistorey timber construction sector and provide first insights on the potential social effects—negative (risks) and positive (benefits)—produced by the prospective increase of multistorey timber constructions in Europe considering their whole life cycle.

**Methods** The advancement of social materiality assessment was conducted to unveil the most relevant stakeholder groups and related social topics of the building sector by considering what is proposed by the UNEP Guidelines for Social Life Cycle Assessment and Handbook for Product Social Impact Assessment. To verify selected social topics and collect information on their level of relevance, we based our research approach on stakeholder engagement through a dedicated online workshop and interviews.

**Results** Seventeen social topics were selected as material for the multistorey timber construction sector according to the literature review and the stakeholder engagement activities. No significant variance in relevance level was observed according to a five-level Likert scale (from 1, not at all relevant, to 5, very relevant), all rating above level 3 (relevant); the ones perceived as very relevant being "Health and safety" (Users), "Safe and healthy living conditions" (Local Community), and "Fair salary" (Workers).

**Conclusions** This study highlights how conducting a social materiality assessment and engaging stakeholders play a crucial role in identifying an initial set of critical social topics to focus on for further evaluation of potential impacts and performance. Since there is not yet a standardized approach for the S-LCA application in the construction sector, results from this work represent an initial step towards the prioritization process of social topics. This prioritization process aims to assign priority levels to a list of social topics derived from a review process based on various sources.

**Keywords** Social life cycle assessment · Social materiality assessment · Timber buildings · Wood buildings · Relevant social topics · Stakeholders

## 1 Introduction

Today's increasing natural disaster phenomena and imminent dangers to ecosystems and human health have increased awareness at a societal level like never before (Schiermeier 2018). The construction sector (industry) is considered the principal contributor to socio-economic development in the world (UNEP 2021a); on the other side, it is the main contributor to the use of energy and natural resources (UNEP 2021a). Buildings satisfy human beings' basic needs, improve quality of life, create numerous employment opportunities, and contribute significantly to the national economy (Love and Irani 2004; Zuo and

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Zhao 2014). However, emissions related to the production of building materials and construction activities cover 36% of global final energy consumption, and in 2020, the building sector accounted for 37% of global energy-related $CO_2$ emissions (UNEP 2021a). As 10% of these emissions are due to construction materials (UNEP 2021a), their choice is crucial for reducing the embodied emissions of buildings (Pomponi et al. 2020). Moreover, it was responsible for 12% of all freshwater withdrawals in the USA alone (Amaral et al. 2020) and ultimately created up to 37.5% of annual solid waste in Europe (EU Waste Statistics—Statistics Explained 2021).

Given the high consumption of resources and energy, the construction industry is increasingly called upon to produce more sustainable buildings and building materials (Berardi 2012; Bork et al. 2015). In this regard, wood buildings are a promising solution for transforming the building sector from a carbon emitter to a net carbon sink (Churkina et al. 2020). Once used for building purposes, wood continues to store $CO_2$ during the building's life cycle, thus preventing its release into the atmosphere. This is the case if the forest is managed sustainably, i.e., if it is ensured that wood extraction is balanced with replanting a new one (Woodard and Milner 2016). Wood is part of a circular construction practice and can be reused on a large scale, partially maintaining its quality and structural integrity. In addition, wood is a natural insulator, meaning that wooden buildings require less energy to heat and cool than those made of traditional materials. This can translate into lower energy costs and reduced greenhouse gas emissions (FAO and UNECE 2023).

The EU has developed a series of standards for assessing the sustainability aspects—environmental, social, and economic—of new or existing buildings, considering their technical characteristics and functionality over their entire life cycle (CEN 2010). As for the social dimension, the governing standard is the EN 16309:2014—Sustainability of construction works—Assessment of social performance of buildings—Calculation methodology (CEN 2014), which provides the general requirements for the assessment of the social performance of a building along its life cycle; however, it does not provide provisions on the metrics and impact methods to be adopted.

The Social Life Cycle Assessment (S-LCA) is considered the most effective assessment method for the social sustainability of products and organizations (Garrido 2017). The S-LCA is a methodology able to assess the social impacts of products and services along their life cycle, and it is based on the ISO 14040 and 14,044 standards and thus includes the same four phases as the Life Cycle Assessment (LCA) (ISO 14040, 2006; ISO, 14,044, 2020). Although S-LCA practice has developed significantly, there is still no standardized approach to S-LCA in the construction sector (Backes and Traverso 2021), and a specific list of social topics to be assessed, neither in the timber sector nor in the construction sector, is absent.

According to Kayaçetin et al. (2023), the construction sector is still mainly focused on evaluating environmental and economic aspects rather than social ones. There are few studies on the S-LCA application in the construction sector, particularly on timber buildings, to the best of the authors' knowledge. This aligns with Roberts et al. (2022), who highlighted the few S-LCA case studies on wood-based products or the social impacts of timber construction more widely. Mair-Bauernfeind et al. (2020) noted that the lack of S-LCAs for bio-based products and the fact those are still in their infancy makes identifying relevant social aspects challenging. Some reasons can be referred to the complexity of the social analysis, the lack of standardized methods for quantifying social impacts, and the lack of data along the supply chain of the sector (Kayaçetin et al. 2023; Hossain et al. 2018). Also, Walker et al. (2021) mentioned several challenges, most related to the difficulty of measuring social aspects, as a defined set of indicators is not yet available (Reitinger et al. 2011; Iofrida et al. 2018). Moreover, according to Kayaçetin et al. (2023), the social assessment differs from the economic and environmental ones as it requires, besides quantitative information, qualitative ones, thus introducing new aspects to be managed at the methodological level and increasing the level of complexity.

Alongside the still open aspects from the methodological point of view, in the construction sector and wood construction, there is a growing need to assess social impacts along with environmental ones (Abowitz and Toole 2010). Especially when developing new building materials, it is essential to implement social impact assessment into the decision-making process from the beginning to create a lifecycle-based sustainable product (Backes and Traverso 2023).

Social sustainability by nature involves multi-faceted social values, which are sequentially influenced by plentiful stakeholders (Almahmoud and Doloi 2015). In particular, a socially sustainable building project should respond to the different requirements of multiple stakeholders involved in the development of the building, including the final users and construction personnel, suppliers, and local communities (Wong and Fan 2013). Backes and Traverso (2021), in a systematic literature review on the application of S-LCA in the construction sector, highlighted the complexity of the construction value chain that includes many different organizations with different sizes, roles and located worldwide, and, consequently, the variety of stakeholders present in the construction processes (i.e., Workers, Local Community, and Society). According to Dong and Ng (2015), the life cycle of buildings is influential to various stakeholders' issues, i.e., the safety of workers, noise pollution in the neighborhood, and degradation of cultural heritage, among others.

However, not all relevant stakeholders are adequately considered in S-LCA studies (Liu and Qian 2019; Montalbán-Domingo et al. 2019), as the main challenges identified were the selection and quantification of social aspects and the collection of related information. In this sense, Goedkoop et al. (2020) indicate that identifying relevant social topics is important because different value chains and products will have different impacts, and it is not always applicable to try to assess all social topics throughout the value chain. Moreover, the social inventory is a crucial phase consisting of collecting various information, both at product and organization levels, for the different actors in the construction supply chain. Collecting primary data takes a long time and is not always applicable. However, even the use of secondary data is often limited by their representativeness of the local conditions (Backes and Traverso 2023).

For all these reasons, the selection of social aspects and related stakeholders on which to focus the assessment and put efforts into collecting high-quality data is fundamental to making S-LCA a practical and helpful method for the timber building sector.

This paper aims to advance knowledge on social impact assessment of the multistorey timber construction sector by identifying the potentially most relevant stakeholder groups and associated social topics and thus laying the ground for further applications of the Reference Scale Approach (RSA) to assess the social performances of organizations operating in the sector. A reference type of multistorey timber building for both residential and commercial is used as the objective of the assessment. To do so, the materiality assessment, focused on the social dimension, was conducted following the most updated guidelines and references, considering the sector peculiarities, market trends, and the geographical context in which the sector operates. This research also provides insights into the potential negative (risks) and positive (benefits) social effects of increased multistorey timber constructions across Europe, considering the whole life cycle.

Section 2 provides a brief description of the conceptualization of the S-LCA methodology and its application to the European-funded Horizon 2020 Build-in-Wood Project,[1] from which this work derives. The project aimed to promote wood as a building material, making it a natural choice, particularly for multistorey modular buildings. In this context, S-LCA aimed to assess the social aspects connected to the proposed solutions' production, use, and maintenance. Seven European cities, including Brașov (Romania), Innsbruck (Austria), Copenhagen (Denmark), Trento (Italy), Trondheim (Norway), London (UK), and the Metropolitan Region Amsterdam (Netherlands), were selected as Early Adopter Cities, and similar buildings are considered for all cities. Moreover, stakeholders from these locations are involved in the materiality assessment. Following this, the main steps of the social materiality assessment carried out in the study are described. The social materiality development and results are presented in Section 3, while Section 4 delved into the discussion, exploring the implication of the findings, proposing recommendations for implementing a social sustainability assessment framework in the timber building sector, highlighting the possibility of future research, and acknowledging the study's limitations. Finally, Section 5 presents the conclusions drawn from the study.

## 2 Material and methods

### 2.1 Social life cycle assessment

Social Life Cycle Assessment (S-LCA) enables the assessment of social impacts, performances, and risks of products along their life cycle, including those that are at remote stages of the life cycle in which companies are involved, with the ultimate goal of improving human dignity and well-being (UNEP 2020). Developed on the foundations of the environmental LCA framework (ISO 14040, 2006), S-LCA comprises four main phases: (1) goal and scope definition, (2) social life cycle inventory, (3) social life cycle impact assessment, and (4) social life cycle interpretation (UNEP 2020). Unlike environmental LCA impact categories, the S-LCA adopts a stakeholder-centric approach to evaluate the impacts, which can be both positive and negative for different stakeholders (UNEP 2020). Its focus is more on companies than processes and less on the product life cycle processes. Social impacts are related to how companies behave towards stakeholders throughout the product life cycle. However, it is still not standardized, even if a standardization process is ongoing within the ISO/FDIS 14075 (2024).[2]

The present study utilized two primary references: the UNEP Guidelines for Social Life Cycle Assessment of Products and Organizations (UNEP 2020) and the Handbook for Product Social Impact Assessment (Goedkoop et al. 2020). The following aspects characterized the S-LCA evaluation:

- The object of the assessment is one multistorey timber building for both residential and commercial uses (Fig. 1) proposed within the project, intended to replace a concrete-based building. This building served as the functional unit of the study, and it was considered a reference for social assessment. However, impacts/effects

[1] https://www.build-in-wood.eu/.

[2] ISO/FDIS 14075 (2024) is the standard for social LCA, which was finalized and published in October 2024, so it was not yet available by the time of the present study.

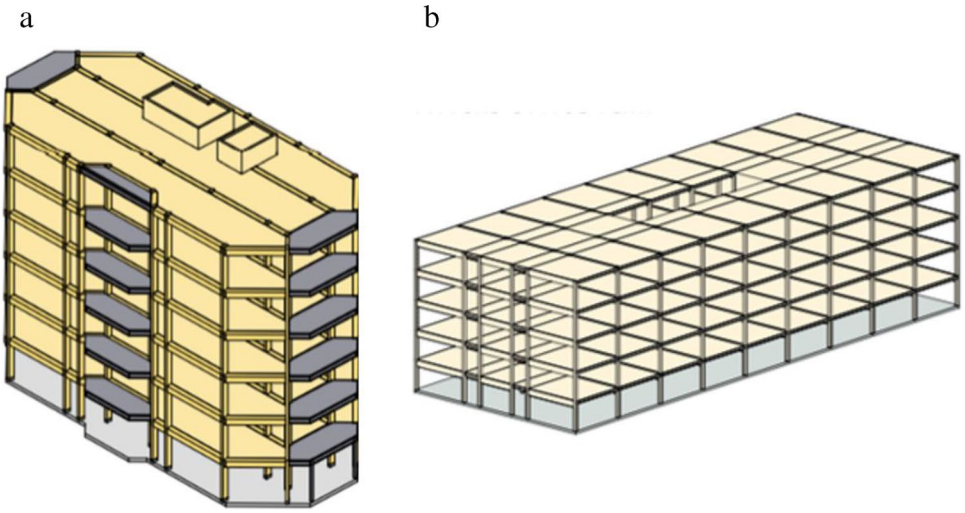



**Fig. 1** Multistorey timber buildings: designed for both residential (**a**) and commercial (**b**) uses

were not quantitatively scaled to it. In particular, the residential one has an engineered timber structure consisting of two blocks—one with 4 stories and the other with 6, each 3.25 m tall (see Fig. 1a). The total gross internal area is 2881 $m^2$. The structure uses a post-and-beam system with columns and beams in Glulam and CLT panels for the floors, roof, shafts, and stabilizing walls. The foundation is concrete. The façades are built with LVL wood skeletons, layered with gypsum, OSB, mineral wool insulation, cement-based windbreaking boards, and a tile rain shield. Steel balconies have fiber cement plates. The commercial spans 7290 $m^2$ and is 20 m tall (Fig. 1b). The primary structural components are reinforced concrete foundations and stairs, glulam beams and columns, CLT slabs, roof and core walls, LVL façade, insulation, and steel cladding. The building's composition is conservatively estimated to include about 55% concrete by weight to meet Danish acoustic standards (Danish Ministry of Economic and Business Affairs and Danish Enterprise and Construction Authority 2010).

- Although the main actors in the timber building supply chain were engaged in the assessment, the absence of an executive project and related organizations running it meant that social performances could not be evaluated at the time of the study.
- All the life cycle stages occurred in Europe, and seven different geographical contexts (Early Adopter Cities) were selected to implement the product (a multistorey timber building for residential and commercial uses). Despite being all in Europe, these cities exhibited varying socio-economic, cultural, strategic, and urban development peculiarities and needs.

As a result of the considerations mentioned above, the S-LCA methodology was applied qualitatively in this study, aiming to define the social materiality within the multistorey timber buildings sector and pave the way for future application of the Reference Scale Approach (RSA) in assessing social performances of organizations operating in the industry.

The system boundaries were defined according to EN 15804: 2012 + A2: 2019 (CEN 2019), encompassing all activities belonging to the multistorey timber construction sector system, from the raw materials production (i.e., wood, chemicals) through their processing (i.e., engineered timber panel), construction site operations, and building use and maintenance. A selected number of stakeholder groups suggested by the UNEP Guidelines (UNEP 2020) and Handbook (Goedkoop et al. 2020)—Workers, Local Community, Users, Value chain actors, and Society—are considered starting points. Figure 2 illustrates life cycle stages and stakeholders within the system boundaries.

Overall, the analysis excludes the building end-of-life phase mainly because potential positive or negative impacts will heavily depend on the specific context where the building will be fabricated and how the actors involved in the dismantling and waste management systems will operate. Such information was unavailable at the time of the study, so future studies and research focused on specific local contexts are needed.

## 2.2 Social materiality assessment

The materiality assessment selects more relevant topics because of their impact on stakeholders and/or the business. The Global Reporting Initiative (GRI) considers material issues to be the ones that reflect the organization's significant social impacts or that substantively influence the assessments and decisions of stakeholders (UNEP 2020). Currently, materiality assessment is mentioned as a key step in the S-LCA application by both UNEP Guidelines (UNEP 2020) and the Handbook (Goedkoop et al. 2020). It can be carried out as a preparation phase for the S-LCA implementation or as a step of the S-LCA interpretation phase (UNEP 2020).

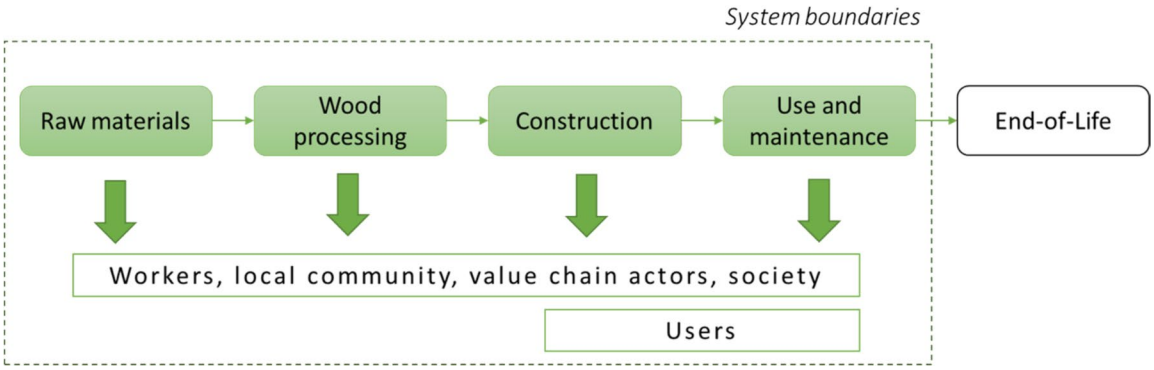



**Fig. 2** Relationship between the timber building life cycle stages and the stakeholder categories

Materiality assessment is the process by which, starting from a general list of topics, different stakeholders and actors in the product's life cycle are called to express their opinions on potential existing problems and where more attention is needed. In this sense, some expert judgment is required; however, the S-LCA Guidelines and Handbook do not practically guide how to carry out materiality assessment. The GRI scheme provides step-by-step guidance for organizations on determining material topics (GRI Standards 2023). Still, it cannot be directly applied to the Build-in-Wood project where the analysis does not concern a specific product with a real value chain but a reference product (reference type of multistorey timber building for both residential and commercial uses e designed within the project) representative of the timber buildings sector.

Consequently, the social materiality assessment steps summarized in Fig. 3 were conducted taking into consideration the key elements of the materiality assessment process described in the GRI standard (2023):

- Identification of the key actors and their activities characterizing the timber building life cycle (i.e., forest managers, wood processing, architects, builders) and the geographic locations of these activities (S-LCA reference literature and literature review).
- Definition of the sustainability context of activities and business relationships (i.e., economic, environmental, human rights, and other societal challenges at local, regional, and global levels related to the organization's sectors and geographic locations) (literature review and stakeholder engagement).
- Identification of stakeholders present across activities and life cycle stages (e.g., a complete list of individuals and groups whose interests are affected or could be

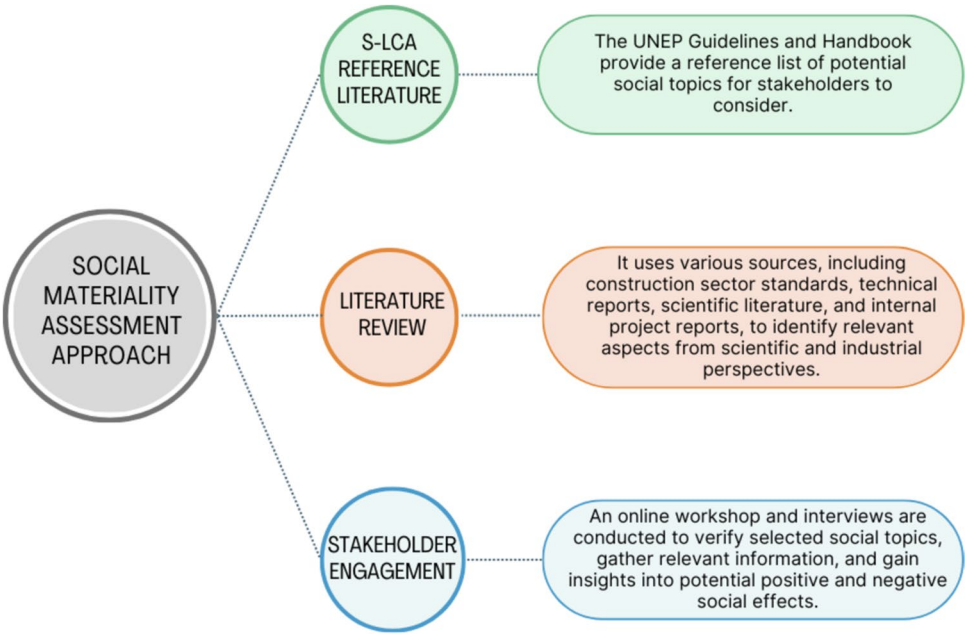



**Fig. 3** The three-step social materiality assessment approach adopted in the current study

affected by the timber building sector's activities) (literature review).
- Engagement of relevant stakeholders and experts to identify potential negative and positive social impacts the sector causes or contributes to through its activities and possible impacts directly linked to its operations, products, or services by its business relationships (stakeholder engagement).

The reference starting lists of social topics[3] are reported in Table 1. As can be observed, some social aspects are in common between the two sources—UNEP Guidelines (UNEP 2020) and Handbook (Goedkoop et al. 2020)—(with slight differences in the terminology, in some cases), while others are different. For this reason, both sources were considered. The Methodological Sheets (UNEP 2021b) and Social Topics Report (Harmens et al. 2022) comprehensively describe these topics. The stakeholder category Children, introduced in the last version of the UNEP Guidelines (2020), was considered unsuitable to the system analyzed in the Build-in-Wood project (timber buildings for both residential and commercial purposes), and for this reason, it was excluded.

## 3 Results

The following sections describe the primary outcomes of the literature review and stakeholder engagement steps within the social materiality assessment.

### 3.1 Social materiality assessment—literature review outcomes

The literature review aimed to identify the most frequently mentioned social topics relevant to the timber construction sector. This involved examining various sources related to the construction sector in general and specifically timber building with regards to (i) standards and technical reports on social sustainability and (ii) scientific literature on social assessment.

#### 3.1.1 Standards and technical reports

EN 15643–1:2010 is the EU standard that describes the methodologies for assessing the sustainability of construction works, covering the evaluation of environmental, social, and economic performances (CEN 2010). As for the social dimension, the governing standard is EN 16309:2014—Sustainability of construction works—Assessment of social performance of buildings (CEN 2014). At this moment, the standard concentrates on assessing aspects and impacts for the use stage of a building expressed using the following social performance categories: accessibility, adaptability, health, and comfort, impacts on the neighborhood, maintenance, and safety and security. It is mentioned that only the above social topics are deemed to have an agreed basis for European standardization. Two additional social performance categories are mentioned in EN 15643–3:2012 (CEN 2012), i.e., sourcing materials and services and stakeholder involvement. Overall, the standard gives requirements for describing the object of assessment and system boundary to be applied, a generic list of indicators and procedures for their application, the presentation of the results in reporting and communication, and verification. Nevertheless, this standard does not set the rules for how building assessment schemes may provide valuation methods, nor does it prescribe levels, classes, or benchmarks of performance.

To obtain a more detailed perspective on the timber building sector, technical reports focused on the social performances/impacts of the sector were detected. The search was carried out mainly via Google and Google Scholar; however, CORDIS (Community Research and Development Information Service) was also used. Overall, documents from organizations, industry associations, or agencies focused explicitly on the social performances of multistorey timber construction were not identified. The main results were derived from research projects in which industrial actors were also involved. Most of these studies deal with indoor comfort and environmental sustainability of timber buildings in comparison with traditional ones (BAMB 2019; CoNZEBs 2019; GREEN INSTRUCT 2020; HOUSEFUL Project 2023; CIRCuIT 2023). Furthermore, other research projects delve into the social assessment of specific aspects of buildings (concrete- and wood-based), such as retrofitting solutions or wood-based hybrid construction elements for different applications. The most interesting projects for this study, at the time of writing this paper, are the EU Horizon 2020-funded project INFINITE Building Renovation,[4] the CARpenTiER project,[5] and the EU Horizon 2020-funded project HYBUILD.[6]

In the INFINITE project, S-LCA is applied in different case studies located in various European countries to understand residents' socio-economic issues and needs, perception and potential impacts of novel design technologies, together

[3] In this paper, social topic and social impact categories, or subcategories, are considered synonymous and refer to social issues related to stakeholder groups that should be measured and assessed, for example, working hours, community engagement, and child labor (adapted from UNEP (2020) and Goedkoop et al. (2020)).

[4] https://infinitebuildingrenovation.eu/.

[5] https://www.carpentier.at/.

[6] https://cordis.europa.eu/project/id/768824/it.

**Table 1** Reference list of social topics and related stakeholder groups

| Stakeholders | Social topics | |
|---|---|---|
| | UNEP guidelines | Handbook |
| Worker | Freedom of association and collective bargaining | Freedom of association and collective bargaining |
| | Child labor | Child labor |
| | Fair salary | Remuneration |
| | Working hours | Work-life balance |
| | Forced labor | Forced labor |
| | Equal opportunities/discrimination | Discrimination |
| | Health and safety | Occupational health and safety |
| | Social benefits/social security | –– |
| | Employment relationship | –– |
| | Sexual harassment | –– |
| | Smallholders including farmers | –– |
| Local Community | Access to material resources | Access to material and immaterial resources |
| | Access to immaterial resources | –– |
| | Delocalization and migration | –– |
| | Cultural heritage | –– |
| | Safe and healthy living conditions | Health and safety |
| | Respect of indigenous rights | –– |
| | Community engagement | Community engagement |
| | Local employment | Contribution to economic development |
| | Secure living conditions | –– |
| | –– | Skill development |
| Value chain actors and small-scale entrepreneurs | Fair competition | Fair trading relationships |
| | Promoting social responsibility | –– |
| | Supplier relationships | –– |
| | Respect of intellectual property rights | –– |
| | Wealth distribution | –– |
| | –– | Child labor |
| | –– | Health and safety |
| | –– | Land rights |
| | –– | Meeting basic needs |
| | –– | Access to services and inputs |
| | –– | Women's empowerment |
| User | Health and safety | Health and safety |
| | Feedback mechanism | Responsible communication |
| | Consumer privacy | Privacy |
| | Transparency | –– |
| | End-of-life responsibility | –– |
| | –– | Affordability |
| | –– | Accessibility |
| | –– | Effectiveness and comfort |
| Society | Public commitments to sustainability issues | –– |
| | Contribution to economic development | –– |
| | Prevention and mitigation of armed conflicts | –– |
| | Technology development | –– |
| | Corruption | –– |
| | Ethical treatment of animals | –– |
| | Poverty alleviation | –– |

with the potential impacts on Workers, Local Community, Value chain actors, and Society produced by new industrialized buildings renovation system proposed by the project (Di Noi et al. 2022). This assessment applied both primary data on residents' views and secondary data from the PSILCA database.

In the CARpenTiER project, social analysis is carried out to develop a standardized procedure for generic sectoral-specific S-LCAs, then investigate social risks (and opportunities) in the wood processing industries in Austria to identify the best wood utilization in the construction sector and other alternative applications. Stakeholder categories such as Workers, Local Community, and Society were included in the assessment, and data collection was based on Austrian organizations (i.e., Statistics Austria, Public Employment Service, Statistics from the Chamber of Commerce, General Accident Insurance, Chamber of Labour and industry reports) (Mair-Bauernfeind 2022).

In the HYBUILD project, S-LCA is applied to compare the social impacts of two innovative compact hybrid electrical/thermal storage systems for stand-alone and district-connected buildings, namely the Mediterranean and the Continental HYBUILD systems. The evaluation included all the stakeholders and related social topics of the UNEP Guidelines (previous version: UNEP SETAC Life Cycle Initiative 2009) (Caruso and Pascale 2021).

#### 3.1.2 Scientific literature

The literature review also included scientific papers on social analysis and the S-LCA application, specifically in the timber building sector. The research was carried out through Scopus Database and ScienceDirect, using the following terms and keywords: "Social performances" + "timber buildings," "social impacts" + "timber buildings," "Social Life Cycle Assessment" + "buildings," "Social Life Cycle Assessment" + "timber buildings," and "Social Life Cycle Assessment" + "wooden buildings." Overall, 12 papers related to the building construction sector were found from the first screening phase; then, 9 studies were considered for the identification of relevant social aspects, as more detailed in the social topic analysis part (Hosseinijou et al. 2014; Dong and Ng 2015; Hossain et al. 2018; Touceda et al. 2018; Liu and Qian 2019; Balasbaneh and Sher 2021; Fauzi et al. 2022; LLatas et al. 2022; Kayaçetin et al. 2023).

The review focused on determining the stakeholder categories and social topics most mentioned across the papers, taking Table 1 as a reference. While there seems to be consensus on the most crucial stakeholder categories to consider, a wide variety of social themes are mentioned. Backes and Traverso (2021) highlighted that although the S-LCA guidelines have been published for over 10 years and were revised again in 2020, only 8% of the studies analyzed referred to the Guidelines published in 2009 by the United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC) and revised in December 2020. All other studies, analyzed by Backes and Traverso (2021), used other and individual indicators such as social cost of greenhouse gas (GHG) emissions, job creation, professional growth, contribution to growth, fair employment, and the fuel poverty gap (Touceda et al. 2018; Balasbaneh et al. 2018). Moreover, according to Roberts et al. (2022), in terms of generic social hotspot analysis or hotspot screening studies, there are few cases (Di Noi and Ciroth 2018; Hannouf and Assefa 2018; Herrera Almanza and Corona 2020) and nothing specific to any wood-based products.

Backes and Traverso (2023) also conducted a systematic literature review on applying S-LCA in the construction industry to identify relevant social indicators for carbon-reinforced concrete. The study highlighted that the social focus of the construction sector was mainly on Workers, the Local Community, and Society, while Children were not included as stakeholders. For the stakeholder group Workers, "Health and Safety," "Fair Salary," and "Hours Worked/Working hours" represent the most commonly considered social topics. For the Local Community stakeholder group, "Safe and healthy living conditions," "Local employment," "Community engagement," "Access to material resources," "Cultural heritage," and "Respect for the rights of Indigenous peoples" were the social topics assessed. The most frequently evaluated categories for the stakeholder group Society were "Contribution to Economic Development" and "Technical Progress/Technology development." Moreover, additional social topics such as "Public commitment to sustainability issues" emerged as relevant for Society. At the same time, "End-of-life responsibility" and "Transparency" appeared to be relevant to the User category, as highlighted by Backes and Traverso (2021).

Table 2 shows the most mentioned social topics of the stakeholder categories that emerged from the scientific literature review.

Based on what emerged from the various sources (standards, technical reports, scientific literature), a first list of the most frequently mentioned social topics was derived (Table 2A, in supplementary materials). This list was used for the following work step dedicated to stakeholder engagement.

### 3.2 Stakeholder engagement

The final step of the materiality assessment involved stakeholder engagement activities. Within the Build-in Wood project, two different groups of activities were conducted. The first concerned working groups directed to the seven Early Adopter Cities of the projects located in Romania, Austria,

**Table 2** Review results: scientific literature

| Stakeholders | Social topics derived from UNEP Guidelines and Handbook | N° of mentions | Source |
|---|---|---|---|
| Workers | Freedom of association and collective bargaining | 5 | Hosseinijou et al. (2014); Dong and Ng (2015); Hossain et al. (2018); Balasbaneh and Sher (2021); Fauzi et al. (2022) |
| | Child labor | 4 | Hosseinijou et al. (2014); Dong and Ng (2015); Liu and Qian (2019); Fauzi et al. (2022) |
| | Fair salary/remuneration | 5 | Hosseinijou et al. (2014); Dong and Ng (2015); Liu and Qian (2019); Hossain et al. (2018); Fauzi et al. (2022) |
| | Working hours/work-life balance | 5 | Kayaçetin et al. (2023); Liu and Qian (2019); Hossain et al. (2018); Llatas et al. (2022); Fauzi et al. (2022) |
| | Forced labor | 5 | Hosseinijou et al. (2014); Liu and Qian (2019); Hossain et al. (2018); Balasbaneh and Sher (2021); Fauzi et al. (2022) |
| | Equal opportunities/discrimination | 5 | Kayaçetin et al. (2023); Hosseinijou et al. (2014); Liu and Qian (2019); Balasbaneh and Sher (2021) (Discrimination related to the ages of workers); Fauzi et al. (2022) |
| | Health and safety | 7 | Touceda et al. (2018); Kayaçetin et al. (2023); Hosseinijou et al. (2014); Liu and Qian (2019); Hossain et al. (2018); Balasbaneh and Sher (2021) (Occupational accidents); Fauzi et al. (2022) |
| | Social benefits/social security | 1 | Fauzi et al. (2022) |
| | Employment relationship | 1 | Touceda et al. (2018) (Fair working condition) |
| Local Community | Access to material and immaterial resources | 8 | Kayaçetin et al. (2023); Hosseinijou et al. (2014); Dong and Ng (2015); Santos et al. (2017); Liu and Qian (2019); Hossain et al. (2018); Balasbaneh and Sher (2021); Fauzi et al. (2022) |
| | Cultural heritage | 4 | Hosseinijou et al. (2014); Dong and Ng (2015); Liu and Qian (2019); Balasbaneh and Sher (2021) |
| | Safe and healthy living conditions | 4 | Kayaçetin et al. (2023); Hosseinijou et al. (2014); Liu and Qian (2019); Hossain et al. (2018) |
| | Respect of indigenous rights | 1 | Fauzi et al. (2022) |
| | Community engagement | 3 | Kayaçetin et al. (2023); Hossain et al. (2018); Fauzi et al. (2022) |
| | Contribution to economic development/local employment | 7 | Touceda et al. (2018); Kayaçetin et al. (2023); Hosseinijou et al. (2014); Liu and Qian (2019); Hossain et al. (2018); Balasbaneh and Sher (2021); Fauzi et al. (2022) |
| | Secure living conditions | 2 | Dong and Ng (2015); Fauzi et al. (2022) |
| Value chain actors and small-scale entrepreneurs | Fair competition/fair trading relationships | 4 | Hosseinijou et al. (2014); Hossain et al. (2018); Balasbaneh and Sher (2021) (Monopoly and anti-competitive behavior); Fauzi et al. (2022) |
| | Promoting social responsibility | 2 | Hossain et al. (2018); Fauzi et al. (2022) |
| | Supplier relationships | 2 | Hosseinijou et al. (2014); Hossain et al. (2018) |
| | Respect of intellectual property rights | 1 | Hossain et al. (2018) |
| | Health and safety | 1 | Hossain et al. (2018) |
| | Access to services and inputs | 1 | Kayaçetin et al. (2023) |

**Table 2** (continued)

| Stakeholders | Social topics derived from UNEP Guidelines and Handbook | N° of mentions | Source |
|---|---|---|---|
| User | Health and safety | 3 | Santos et al. (2017); Liu and Qian (2019); Fauzi et al. (2022) |
| | Feedback mechanism/responsible communication | 2 | Liu and Qian (2019); Fauzi et al. (2022) |
| | Transparency | 1 | Kayaçetin et al. (2023) |
| | End-of-life responsibility | 2 | Kayaçetin et al. (2023) (for Society); Fauzi et al. (2022) |
| | Affordability | 2 | Touceda et al. (2018) (Household poverty); Kayaçetin et al. (2023) (for Local Community) |
| | Accessibility | 1 | Santos et al. (2017) |
| | Effectiveness and comfort | 3 | Touceda et al. (2018) (Indoor air quality and adequate indoor T); Santos et al. (2017); Liu and Qian (2019) |
| Society | Public commitments to sustainability issues | 2 | Dong and Ng (2015); Liu and Qian (2019) |
| | Contribution to economic development | 2 | Hosseinijou et al. (2014); Balasbaneh and Sher (2021) |
| | Technology development | 2 | Hosseinijou et al. (2014); Liu and Qian (2019) |

Denmark, Italy, Norway, the UK, and the Netherlands. At the same time, the second relied on online workshops and interviews addressed to project partners and other external experts. The objectives of these activities were threefold: (i) to validate the social topics selected from the literature review, (ii) to gather information on the level of relevance of these topics, and (iii) to gain initial insights into potential social effects, both positive and negative, associated with the identified social topics.

#### 3.2.1 Working groups with early adopter cities

The first working group aimed to support the co-creation and scenario-building workshops in pilot and Early Adopter Cities and involved stakeholders at the local level of the Early Adopter Cities. In contrast, the second working group conducted a post-occupancy evaluation (assessing technical performance and user perception) of existing multistorey wood buildings in the selected pilot locations. Particularly, the results of a post-occupancy evaluation of existing multistory wood buildings in Denmark and Norway were considered to evaluate Users' perceptions. At the same time, the primary outcomes of the specific socio-economic and regulatory context analysis of the Early Adopter Cities were beneficial to understanding the local state of the art and preconditions able to support the development of the timber building sector. Stakeholders identified from the Early Adopter Cities were compared to the reference stakeholders from the UNEP Guidelines and Handbook to validate the groups identified for the social assessment (reported in Table 1). Overall, the five categories - Workers, Local Community, Value chain actors, Users, and Society - were validated as allowed to include the most relevant stakeholders connected to the timber building system of the Build-in-Wood project. Subsequently, the leading social issues mentioned during the Early Adopter Cities involvement and the post-occupancy evaluation were linked to the reference list of social topics (Table 1) to select the most frequently mentioned ones. Notably, the social aspects of Users and Local Community were the most cited, while Value chain actors and Society were the stakeholder categories less represented. Very few mentioned Workers' issues, and the lack of qualification of the workforce related to wood construction is of the most referred. Table 3 shows an extract on the User category.

The complete list of social aspects of stakeholder categories derived from the working groups is reported in Table 1A of the supplementary materials; this list was compared to the outcomes from the literature review to further select social themes and identify an even more concise list to be submitted during the second phase of stakeholder engagement during which to determine the level of priority and possible effects (Table 2A of the supplementary materials).

#### 3.2.2 Workshop and interviews with experts

The workshop involved 40 participants, comprising project partners and external stakeholders from the Early Adopter Cities. The stakeholders were selected thanks to the project partners' contact networks. The objective was to involve diverse entities involved in or dealing with various aspects of the multistorey timber building supply chain. Notably, the majority of participants were from universities and research institutes representing sustainability and forestry fields. Representation was limited for the upstream phases

**Table 3** Social aspects from the internal Build-in-Wood deliverable (extract on the User category)

| Social topics derived from UNEP Guidelines and Handbook | Social aspects derived from the review |
|---|---|
| Health and safety | Acoustic performance (airborne and impact sound) |
| | Indoor climate (temperature, relative humidity) |
| | Risk assessment (in terms of safety, durability) |
| | Barriers related to technical components |
| | Fire safety |
| | High relative humidity encourages using breathable materials such as wood and natural thermal isolation solutions |
| | Using more wood in homes can help to improve indoor air quality due to its moisture-buffering capacity |
| Feedback mechanism/ responsible communication | Pre-conceptions about cost versus benefit |
| Transparency | Lack of knowledge from the side of the final consumers |
| | Requirements related to certifications (professionals, resources, certifications necessary for final handover of works) and regulations not set up to handle tall wood buildings |
| | Poor documentation regarding the sustainability of forests |
| | Lack of accuracy regarding data related to wood harvesting volumes |
| Affordability | Pre-conceptions about cost versus benefit |
| | Low buying possibilities for more expensive building solutions |
| | Customers often perceive wooden houses as more expensive, less durable, and easily damaged |
| Effectiveness and comfort | Enhance sustainable lifestyle |
| | Esthetic and sensory experiences |
| | Focus on durability and sustainability |
| | Customers often perceive wooden houses as more expensive, less durable, and easily damaged |

(e.g., raw material and wood processing), with only one participant from the forestry sector. In contrast, there were two participants from the manufacturing sector and one from a timber construction network for the core phase (including construction). Four representatives from the user stakeholder category also participated, focusing on the use and maintenance phase.

During the first brainstorming session of the workshop, after a brief introduction to the S-LCA methodology and the objectives of the study, participants were asked to mention the top 3 most relevant potential social risks or benefits associated with the multistorey timber construction sector according to their experience. Answers were collected through an online tool that allowed the visualization of the answers in real time. Subsequently, all responses were then elaborated to associate them with the reference list of social topics (Table 1). Overall, combining responses with the reference social topics was possible. However, some specific themes were kept separated because they suggested specific additional aspects to the general topics (i.e., durability, faster construction site work). All the answers related to environmental sustainability (i.e., carbon storage, climate change mitigation, deforestation) were grouped according to the category named "Environmental domain" (Fig. 4), which was the most mentioned, perhaps due to the project's aim (H2020 Build-in-Wood) in which the analysis took place. As shown in Fig. 4, "Health and safety" and "Effectiveness and comfort," both related to the stakeholder category Users (U), were the most remarked, followed by "Safe and healthy living conditions" for Local Communities (LC) and "Health and safety" for Users (U). "Durability" and "Faster construction site work" (additional topics from the reference list) were reported separately, as specific themes for the building construction sector.

During a second session, participants were invited to provide feedback on potential social risks and benefits on the most mentioned social topics related to the five stakeholder groups (Workers, Local Community, Users, Value chain actors, and Society). After a brief description of each social topic, participants were asked to answer a multiple-choice question on the potential effects (i.e., positive, negative, neutral, I do not know) expected by the introduction of multistorey timber construction to replace traditional construction, considering the same building, previously presented.

The elaboration of responses suggested the interpretation of results according to two groups based on the number of mentions:

- Social topics with a predominant response ($\geq 50\%$)
- Social topics without a predominant response ($< 50\%$)

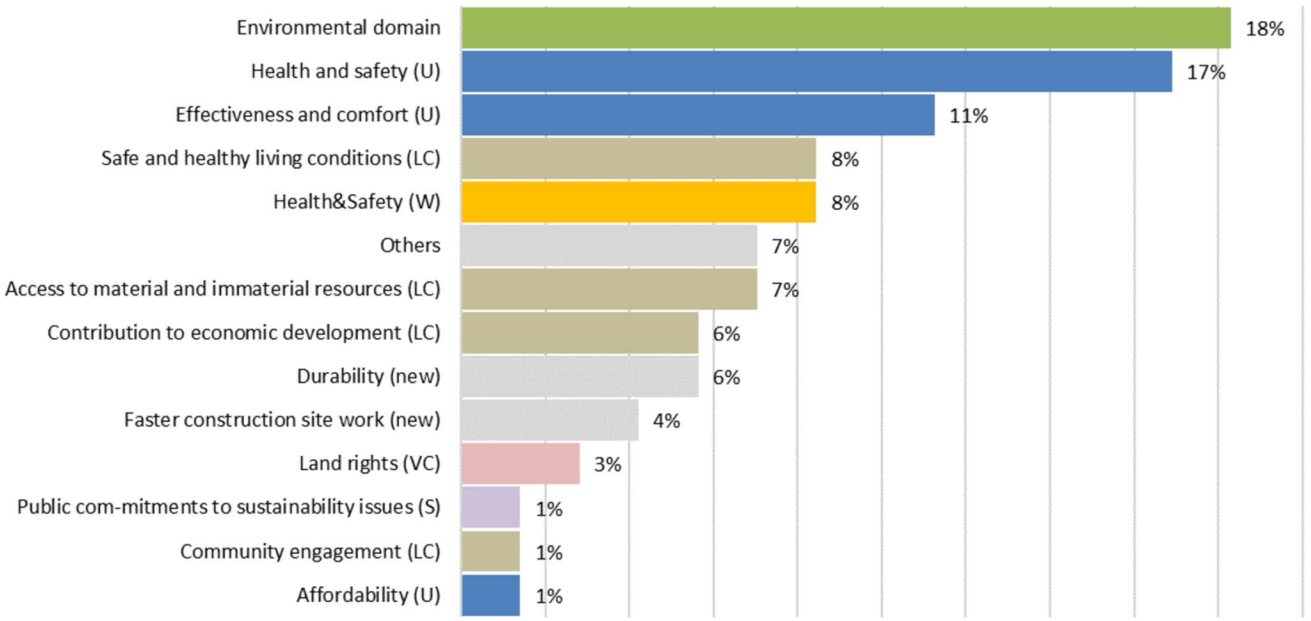



**Fig. 4** Frequency of social topics according to brainstorming outcomes. U, Users; LC, Local Community; W, Workers; VC, Value chain actors; S, Society

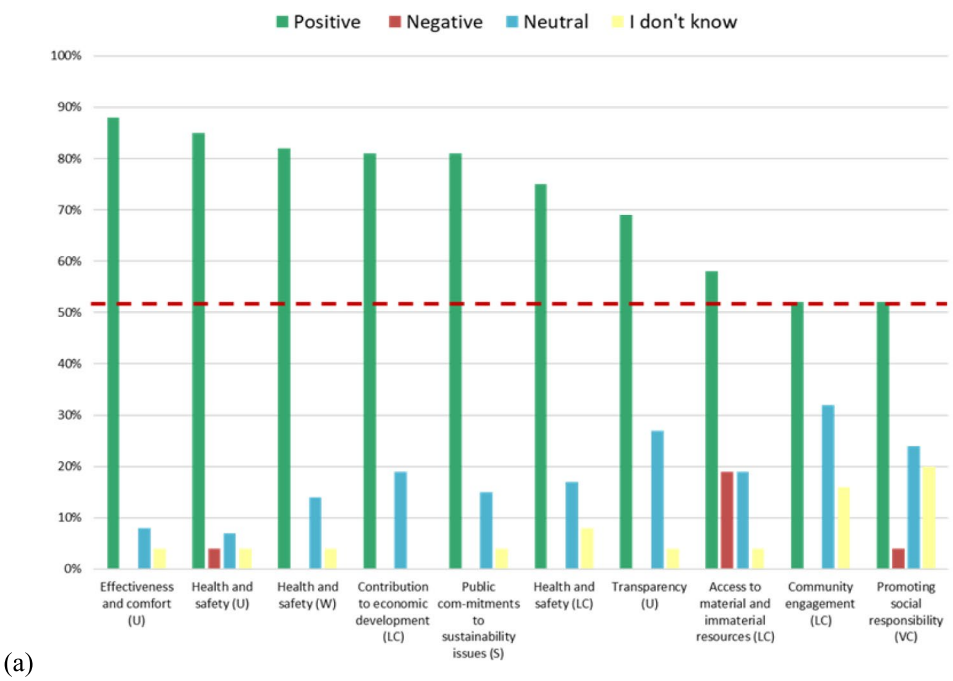
In particular, 10 out of 14 of the proposed social topics belonged to the first group, and more than 50% of the responses indicated positive effects expected from the timber buildings across all the stakeholders. In particular, these social topics mainly concern Users (U) and Local Community (LC) stakeholder categories, as reported in Fig. 5a. More uncertain answers were found for the remaining four social topics, which are "Affordability" related to the Users (U) stakeholder group and "Fair competition," "Supplier relationships," and "Land rights" concerning the Value chain actors (VC) (Fig. 5b).

All the social topics discussed and validated during the workshop were then analyzed during the interviews with respondents selected from among the workshop participants, mainly project partners with different roles inside the value chain building construction and from other European countries (Early Adopter Cities), to identify their level of relevance and so to prioritize them. During the interviews (around 30), participants were asked to indicate the relevance according to a five-level Likert scale (1: not at all relevant, 2: slightly relevant, 3: relevant, 4: fairly relevant, 5: very relevant), always considering the introduction of multistorey timber construction to replace traditional construction. Table 4A in supplementary materials shows the number of mentions for each topic. Responses were then elaborated to calculate the mode (the most frequent value), median (the middle of the distribution), and mean values for a more comprehensive view of relevance perceived across partners; results are shown in Table 4.

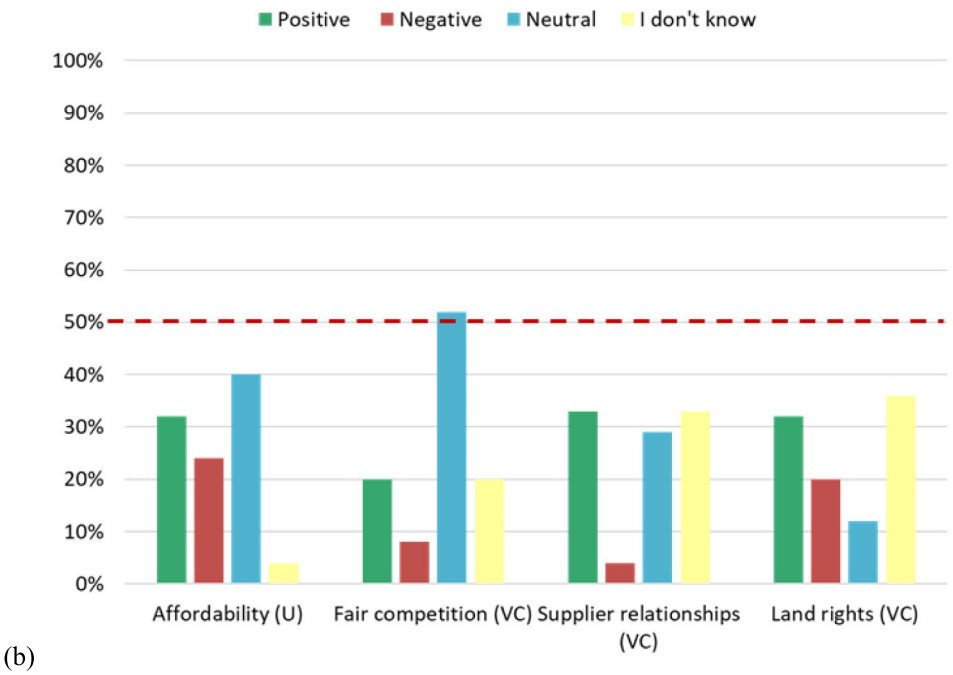
The mode, mean, and median values are similar for most social topics, indicating that responses are quite aligned. In the case of "Fair salary" (W), "Safe and healthy living conditions" (LC), and "Health and safety" (U), all three indices coincide with level 5 (very relevant), thus suggesting a complete consensus. "Land rights" resulted in the situation where mean and median match (3: relevant), while the mode is 1 (not at all relevant), thus suggesting that there is not alignment across answers. Overall, according to the mean value, a significant difference across topics was not found, and they all scored above level 3 (relevant); the ones perceived as very relevant are Fair salary" (Workers), "Safe and healthy living conditions" (Local Community) and "Health and safety" (Users).

## 4 Discussion

Overall, the social materiality assessment enabled the identification of a first list of relevant stakeholders (5) and social topics (17) where potential social risks and benefits could occur with the introduction of multistorey timber buildings. The main outcomes of the materiality assessment process highlighted how social aspects related to Workers are mentioned frequently in the scientific literature. However, their relevance did not emerge during the workshop, which focused more on new topics that could have an effect (direct or indirect) on workers due to the introduction of multistorey timber construction. In this sense, the main




(a)




(b)

**Fig. 5** Results on potential social risks and benefits: social topics with a predominant response (positive effect > 50%) (**a**) and without a predominant response (**b**). U, Users; W, Workers; LC, Local Community; S, Society; VC, Value chain actors

effects mentioned during the workshop are reduced construction time and a more comfortable working environment (i.e., safer construction sites). It can be argued that the other social topics related to Workers—i.e., fair salary and social benefits—do not depend directly on the introduction of multistorey timber buildings but mainly on the builders' companies' behaviors.

Regarding the Local Community, the most frequently mentioned aspects include "Access to material and immaterial resources," "Safe and healthy living conditions," "Contribution to economic development/Local employment," and "Skill development." Also, in this case, a faster construction time for the timber building is expected to produce benefits in terms of "Safe and healthy living conditions" for people living nearby. However, using natural resources (wood) raises the question of avoiding harmful effects on access to material resources for the local communities.

**Table 4** Mode, mean, and median of levels of relevance* calculated for each social topic selected in the analysis

| Stakeholder group | Social topics | Mode | Mean | Median |
|---|---|---|---|---|
| Workers (whole value chain) | Fair salary | 5 | 4.50 | 5 |
| | Working hours | 3 | 2.84 | 3 |
| | Health and safety | 5 | 4.26 | 5 |
| | Employment relationship | 4 | 2.75 | 3 |
| Local Community (whole value chain) | Access to material and immaterial resources | 3 | 3.42 | 3 |
| | Safe and healthy living conditions | 5 | 4.58 | 5 |
| | Community engagement | 2 | 2.90 | 3 |
| | Contribution to economic development | 4 | 3.35 | 4 |
| Society | Public commitments to sustainability issues | 5 | 4.35 | 5 |
| Users | Health and safety | 5 | 4.84 | 5 |
| | Affordability | 5 | 4.21 | 5 |
| | Effectiveness and comfort | 5 | 4.32 | 4 |
| | Transparency | 3 | 3.09 | 3 |
| Value chain actors | Fair competition | 4 | 3.14 | 3 |
| | Promoting social responsibility | 3 | 3.19 | 3 |
| | Supplier relationships | 2 | 3.10 | 3 |
| | Land rights | 1 | 3.00 | 3 |

*1: not at all relevant, 2: slightly relevant, 3: relevant, 4: fairly relevant, 5: very relevant

"Fair competition" and "Promoting social responsibility" are the most remarked topics for the Value chain actors; the increase of timber buildings passes from the rise of awareness and engagement of actors across the value chain towards common sustainability targets (i.e., to support sustainable forestry practices). Moreover, the increase in multistorey timber buildings could open up opportunities for smaller businesses to participate in the value chain and foster market diversity, even though they may face difficulties competing with the existing large companies operating in the concrete-based building sector.

Overall, social topics of Users are the most cited since the introduction and increase of timber buildings are expected to mainly produce effects in terms of "Health and safety" and "Effectiveness and comfort"; also, "Transparency" and "Affordability" issues arose during the workshop. Documentation regarding the sustainable management of forests and wood origin was remarked as a relevant aspect from the user's perspective; moreover, higher cost and durability were identified as issues of concern.

From the Society's point of view, timber buildings are seen as strategic in terms of "Public commitments to sustainability issues"; overall, municipalities consider wood-based constructions a strategic solution to decreasing city and regional GHG emissions.

Three additional aspects were identified during the workshop that need a special mention because they are specific of the sector: (1) "Durability" as an important aspect to be considered within the "Effectiveness and comfort" topic; (2) "Faster construction site work" as a possible effect produced by the timber building and which could affect both the Local Community in terms of "Safe and healthy living conditions" and the "Health and safety" of Workers positively; (3) "Preservation of local tradition," concerning specific techniques of wood construction in certain contexts (i.e., in Trondheim, there is a long tradition in building wooden houses, Build-in-Wood Project, 2023), to be considered within the "Access to material and immaterial resources."

The interviews with the key stakeholders within the Build-in-Wood project's consortium were significant in collecting opinions on the expected positive and negative effects of adopting multistorey timber buildings. The results represent the context of the project in which they are created and the case study under analysis. However, it is essential to point out that the fact that the interviewees were only a part of the workshop participants is a limitation of our study, and the lack of participation of specific Value chain actors, such as those who operate in the end-of-life stage, is another aspect affected the results obtained.

## 5 Conclusions

Despite the existence of several standards supporting the assessment of the sustainability of existing buildings, encompassing environmental, social, and economic performances (e.g., EN 15643–1:2010), there remains a scarcity of studies on the social impacts of timber buildings or construction more generally from a life cycle perspective.

The purpose of this study was twofold: (i) identify the most relevant stakeholder groups and related social topics for the multistorey timber construction sector, considering the European context, and (ii) provide first insights on the potential social effects—negative and positive—resulting from the increased adoption of multistorey timber constructions in the European countries, along the whole life cycle.

For this reason, the social materiality assessment was conducted in three steps. It resulted in 17 potential social topics relevant to the multistorey timber building sector across five stakeholder groups (Workers, Local Community, Value chain actors, Users, and Society). The social topics perceived as very relevant are "Health and safety" (Users), "Safe and healthy living conditions" (Local Community), and "Fair salary" (Workers); nevertheless, a significant difference in terms of the level of relevance was not found, and they all scored above level 3 (relevant).

The results highlighted the limited literature on the timber sector and underscored the need for further research to deepen our understanding of the associated social dynamics. To enhance the reliability of S-LCA in this sector, it is essential to expand the sample of interview participants, ensuring comprehensive representation across the entire value chain. Additionally, establishing a common knowledge base and shared terminology among participants is crucial for collecting robust and consistent responses, thereby contributing to a more thorough and accurate assessment of social sustainability in timber construction.

Overall, there is a growing need in the construction sector and in wood construction to assess social impacts along with environmental ones and, in line with recent developments in the field of S-LCA application, to develop category rules, as is happening in other areas (i.e., Product Category Rules for the assessment of the social sustainability performance of rolling stock).

The findings of this study provide valuable insights for timber construction projects, particularly within the European context. The focus on identifying social issues through literature review and stakeholder engagement highlights the influence of regional socio-economic factors, such as development levels, resource availability, and consumer perceptions. This research underscores the importance of considering socio-economic contexts in Social Life Cycle Assessments (S-LCA). While commonalities exist across European cities, regional differences emphasize the need for a generalized list of relevant social issues as a foundation for further advancing social sustainability in timber construction projects.

Although some social issues may be considered generally relevant for the sector, the level of risk or benefit, and so the level of priority, depends very much on the local context (i.e., a potential negative effect on resource accessibility was perceived more in some contexts than others).

This study underlines the critical role of social materiality assessment and stakeholder engagement in identifying potentially relevant social topics to focus attention and evaluate organizations' potential impacts and performances within the sector. This work is intended to be a proposal applicable to any timber construction project in the European context. However, it is recommended that these approaches be complemented with other methods, such as field studies and existing S-LCA databases, to investigate potential social risks, especially in the background processes. Finally, the process presented and tested in this paper can be applied to other building materials and contexts, but different literature and stakeholders might be involved.

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**Data availability** All data supporting the findings of this study are available in the paper and its Supplementary Information section.

## Declarations

**Competing Interests** The authors declare no conflict of interest.



## References

Abowitz DA, Toole TM (2010) Mixed method research: fundamental issues of design validity and reliability in construction research. J Constr Eng Manag 136:108–116. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000026

Almahmoud E, Doloi HK (2015) Assessment of social sustainability in construction projects using social network analysis. Facilities 33:152–176. https://doi.org/10.1108/F-05-2013-0042

Amaral REC, Brito J, Buckman M, Drake E, Ilatova E, Rice P, Sabbagh C, Voronkin S, Abraham YS (2020) Waste management and operational energy for sustainable buildings: a review. Sustainability 12(13), 5337. https://doi.org/10.3390/su12135337

Backes JG, Traverso M (2021) Application of life cycle sustainability assessment in the construction sector: a systematic literature review. Processes 9:1248. https://doi.org/10.3390/pr9071248

Backes JG, Traverso M (2023) Social life cycle assessment in the construction industry: systematic literature review and identification of relevant social indicators for carbon reinforced concrete. Environ Dev Sustain. https://doi.org/10.1007/s10668-023-03005-6

Balasbaneh AT, Sher W (2021) Comparative sustainability evaluation of two engineered wood-based construction materials: life cycle analysis of CLT versus GLT. Build Environ 204:108112. https://doi.org/10.1016/j.buildenv.2021.108112

Balasbaneh AT, Marsono AKB, Khaleghi SJ (2018) Sustainability choice of different hybrid timber structure for low medium cost single-story residential building: environmental economic and social assessment. J Build Eng 20:235–247. https://doi.org/10.1016/j.jobe.2018.07.006

BAMB (Buildings as Material Banks: Integrating Materials Passports with Reversible Building Design to Optimise Circular Industrial Value Chains) project (2019). https://cordis.europa.eu/project/id/642384

Berardi U (2012) Sustainability assessment in the construction sector: rating systems and rated buildings. Sustain Dev 20:411–424. https://doi.org/10.1002/sd.532

Boje C, Hahn Menacho ÁJ, Marvuglia A, Benetto E, Kubicki S, Schaubroeck T, Navarrete Gutiérrez T (2023) A framework using BIM and digital twins in facilitating LCSA for buildings. J Build Eng 76:107232. https://doi.org/10.1016/j.jobe.2023.107232

Bork CAS, Junior DJDB, Gomes J de O (2015) Social life cycle assessment of three companies of the furniture sector. Procedia CIRP, The 22nd CIRP Conference on Life Cycle Engineering 29, 150–155. https://doi.org/10.1016/j.procir.2015.02.191

Caruso MC, Pascale C (2021) D5.2 Social life cycle assessment of the HYBUILD system. HYBUILD (Innovative compact HYbrid electrical/thermal storage systems for low energy BUILDings) project

CEN (European Committee for Standardization) (2010) European Standard EN 15643–1. Sustainability of Construction Works—Sustainability Assessment of buildings—Part 1: General Framework. Brussels Belgium

CEN (European Committee for Standardization) (2012) European Standard EN 15643–3. Sustainability of construction works - Assessment of buildings - Part 3: Framework for the assessment of social performance. Brussels Belgium

CEN (European Committee for Standardisation) (2014) European Standard EN 16309. Sustainability of Construction Works - Assessment of Social Performance of Buildings - Calculation Methodology. Brussels, Belgium

CEN (European Committee for Standardization) (2019) European Standard EN 15804: 2012+ A2: 2019. Sustainability of Construction Works—Environmental Product Declarations—Core Rules for the Product Category of Construction Products. Brussels Belgium

Churkina G, Organschi A, Reyer CPO et al (2020) Buildings as a global carbon sink. Nat Sustain 3:269–276. https://doi.org/10.1038/s41893-019-0462-4

CIRCuIT (Circular Construction In Regenerative Cities) project (2023). https://cordis.europa.eu/project/id/821201

CoNZEBs (Cost reduction of new Nearly Zero-Energy Buildings) project (2019). https://cordis.europa.eu/project/id/754046

Danish Ministry of Economic and Business Affairs and Danish Enterprise and Construction Authority (2010) The building regulations 2010 (BR10)

Di Noi C, Zavratnik V, Vetršek J, Brandolini D, Gubert M, Ciroth A (2022) Social sustainability assessment for a stakeholder-centered building retrofit. In: The International Conference of Social Life Cycle Assessment 2022. – "Leave No One Behind", 5-8 September, Aachen, Germany. Available here: https://www.researchgate.net/publication/363405936_Social_sustainability_assessment_for_a_stakeholdercentered_building_retrofit

Dong YH, Ng ST (2015) A social life cycle assessment model for building construction in Hong Kong. Int J Life Cycle Assess 20:1166–1180. https://doi.org/10.1007/s11367-015-0908-5

European Financial Reporting Advisory Group (EFRAG) (2023) First Set of draft ESRS. https://www.efrag.org/lab6?AspxAutoDetectCookieSupport=1#subtitle1

EU Waste Statistics—Statistics Explained (2021). https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics#Total_waste_generation

Fauzi RT, Lavoie P, Tanguy A, Amor B (2022) On the possibilities of multilevel analysis to cover data gaps in consequential S-LCA: case of multistory residential building. J Clean Prod 355:131666. https://doi.org/10.1016/j.jclepro.2022.131666

Food and Agriculture Organization (FAO), United Nations Economic Commission for Europe (UNECE) (2023) Circularity concepts in wood construction. United Nations Publication, ECE/TIM/DP/95. Available here: https://unece.org/forests/publications/circularity-concepts-wood-construction

Garrido SR (2017) Social life-cycle assessment: an introduction, in: Abraham, M.A. (Ed.), Encyclopedia of Sustainable Technologies. Elsevier, Oxford, pp. 253–265. https://doi.org/10.1016/B978-0-12-409548-9.10089-2

Global Reporting Initiative (GRI) Standards (2023) GRI 3: Material Topics 2021. https://globalreporting.org/pdf.ashx?id=12453

Goedkoop MJ, de Beer IM, Harmens R et al (2020) Product Social Impact Assessment Handbook - 2020, Amersfoort

Gray R (2006) Social, environmental and sustainability reporting and organisational value creation? Whose value? Whose creation? Account Audit Account J 19:793–819. https://doi.org/10.1108/09513570610709872

Green Instruct (Green Integrated Structural Elements for Retrofitting and New Construction of Buildings) project (2020). https://cordis.europa.eu/project/id/723825

Hannouf M, Assefa G (2018) Subcategory assessment method for social life cycle assessment: a case study of high-density polyethylene production in Alberta. Canada Int J Life Cycle Assess 23:116–132. https://doi.org/10.1007/s11367-017-1303-1

Harmens R, Pillay S, Davis D et al (2022) Product social impact assessment- social topics report - 2022 Amersfoort

Herrera Almanza AM, Corona B (2020) Using social life cycle assessment to analyze the contribution of products to the Sustainable Development Goals: a case study in the textile sector. Int J Life Cycle Assess 25:1833–1845. https://doi.org/10.1007/s11367-020-01789-7

Hossain MdU, Poon CS, Dong YH et al (2018) Development of social sustainability assessment method and a comparative case study on assessing recycled construction materials. Int J Life Cycle Assess 23:1654–1674. https://doi.org/10.1007/s11367-017-1373-0

Hosseinijou SA, Mansour S, Shirazi MA (2014) Social life cycle assessment for material selection: a case study of building materials. Int J Life Cycle Assess 19:620

Houseful Project (2023) Innovative circular solutions and services for new business opportunities in the EU housing sector. https://cordis.europa.eu/project/id/776708

Iofrida N, De Luca AI, Silveri F et al (2018) Psychosocial risk factors' impact pathway for social life cycle assessment: an application to citrus life cycles in South Italy. Int J Life Cycle Assess 24(4):767–780

ISO/FDIS 14075 (2024). Environmental management — principles and framework for social life cycle assessment

Kayaçetin NC, Piccardo C, Versele A (2023) Social impact assessment of circular construction: case of Living Lab Ghent. Sustainability 15:721. https://doi.org/10.3390/su15010721

Liu S, Qian S (2019) Evaluation of social life-cycle performance of buildings: theoretical framework and impact assessment approach. J Clean Prod 213:792–807. https://doi.org/10.1016/j.jclepro.2018.12.200

LLatas C, Soust-Verdaguer B, Hollberg A et al (2022) BIM-based LCSA application in early design stages using IFC. Autom Constr 138:104259. https://doi.org/10.1016/j.autcon.2022.104259

Love PED, Irani Z (2004) An exploratory study of information technology evaluation and benefits management practices of SMEs in the construction industry. Inf Manage 42:227–242. https://doi.org/10.1016/j.im.2003.12.011

Mair-Bauernfeind C, Zimek M, Lettner M et al (2020) Comparing the incomparable? A review of methodical aspects in the sustainability assessment of wood in vehicles. Int J Life Cycle Assess 25:2217–2240. https://doi.org/10.1007/s11367-020-01800-1

Mair-Bauernfeind C (2022) Social risks in the wood processing industries in Austria – A generic analysis of sectoral differences. In: The International Conference of Social Life Cycle Assessment 2022 – "Leave No One Behind", 5-8 September, Aachen, Germany

Mathe S (2014) Integrating participatory approaches into social life cycle assessment: the SLCA participatory approach. Int J Life Cycle Assess 19:1506–1514. https://doi.org/10.1007/s11367-014-0758-6

Montalbán-Domingo L, García-Segura T, Amalia Sanz M, Pellicer E (2019) Social sustainability in delivery and procurement of public construction contracts. J Manag Eng 35:04018065. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000674

Pomponi F, Hart J, Arehart JH, D'Amico B (2020) Buildings as a global carbon sink? A reality check on feasibility limits. One Earth 3:157–161. https://doi.org/10.1016/j.oneear.2020.07.018

Reitinger C, Dumke M, Barosevcic M, Hillerbrand R (2011) A conceptual framework for impact assessment within SLCA. Int J Life Cycle Assess 16:380–388

Roberts G, Skinner C, Ormondroyd GA (2022) The environmental and social impacts of modified wood production: effect of timber sourcing. Int Wood Prod J 13:236–254. https://doi.org/10.1080/20426445.2022.2117923

Santos P, Pereira AC, Gervásio H, Bettencourt A, Mateus D (2017) Assessment of health and comfort criteria in a life cycle social context: application to buildings for higher education. Build Environ 123:625–648

Schiermeier Q (2018) Droughts heatwaves and floods: how to tell when climate change is to blame. Nature 560:20–22. https://doi.org/10.1038/d41586-018-05849-9

Touceda MI, Neila FJ, Degrez M (2018) Modeling socioeconomic pathways to assess sustainability: a tailored development for housing retrofit. Int J Life Cycle Assess 23:710–725. https://doi.org/10.1007/s11367-016-1194-6

UNEP SETAC Life Cycle Initiative (2009) Guidelines for social life cycle assessment of products. Management 15(2):104. Retrieved from http://www.unep.fr/shared/publications/pdf/DTIx1164xPA-guidelines_sLCA.pdf

United Nations Environment Programme (UNEP) (2020) Guidelines for social life cycle assessment of products and organizations. In: Benoît Norris C, Traverso M, Neugebauer S, Ekener E, Schaubroeck T, Russo Garrido S, Berger M, Valdivia S, Lehmann A, Finkbeiner M, Arcese G (eds). Paris, France

United Nations Environment Programme (UNEP) (2021a) Global status report for buildings and construction: towards a zero-emission, efficient and resilient buildings and construction sector. Nairobi

United Nations Environment Programme (UNEP) (2021b) Methodological sheets for subcategories in social life cycle assessment (S-LCA). In: Traverso M, Valdivia S, Luthin A, Roche L, Arcese G, Neugebauer S, Petti L, D'Eusanio M, Tragnone BM, Mankaa R, Hanafi J, Benoît Norris C, Zamagni A (eds)

Walker AM, Opferkuch K, Roos Lindgreen E et al (2021) Assessing the social sustainability of circular economy practices: industry perspectives from Italy and the Netherlands. Sustain Prod Consum 27:831–844. https://doi.org/10.1016/j.spc.2021.01.030

Wong K, Fan Q (2013) Building information modelling (BIM) for sustainable building design. Facilities 31:138–157. https://doi.org/10.1108/02632771311299412

Woodard AC, Milner HR (2016) Sustainability of timber and wood in construction. In: Sustainability of Construction Materials. Elsevier, pp 129–157

Zuo J, Zhao Z-Y (2014) Green building research–current status and future agenda: a review. Renew Sustain Energy Rev 30:271–281. https://doi.org/10.1016/j.rser.2013.10.021