Sustainable Built Environment and Urban Transition
October 12-13, 2023, Linnaeus University, Växjö

CIRCULAR ECONOMY IN WOOD MULTI-STOREY BUILDING CONSTRUCTION: A SYSTEMATIC LITERATURE REVIEW

Nastaran Khalili [1*] and Ambrose Dodoo [1]

[1] Building Technology, Faculty of Technology, Linnaeus University, Sweden,
Nk222re@student.lnu.se, ambrose.dodoo@lnu.se

([*]Main presenter and corresponding author)

Abstract

There has been a growing interest in wood-based buildings in Europe in recent years. A reason for this is that sustainability issues are becoming increasingly important in the building and construction sector, which is responsible for around 40% of the total CO_2 emissions and between 25-30% of the total waste discarded in landfills, worldwide. Previous studies have shown that linear economic practices regarding used wood in construction and discarding it with minimal reuse or recycling after the demolition of the building results in significant environmental impacts. Therefore, applying circular economy concepts and criteria in wood building construction seems vital. This article provides state-of-the-art literature review of circular economy and its implementation in wood multi-storey building construction. A systematic literature review is conducted in which relevant peer reviewed articles were retrieved and explored to identify the state-of-the-art and current knowledge gaps that require further research. From an initial set of 157 scientific papers, a set of 15 highly relevant papers were selected for in-depth examination. The visualization tool VOSViewer is used to identify and gather the relevant data and information from the following academic databases: Web of science, ScienceDirect and Google Scholar. This systematic review provides concepts, indicators and tools for circular economy and circular construction solutions for multi-storey wood building construction. It also highlights the key knowledge gaps that require further research. By addressing these issues, this study aims to contribute to promoting circularity in design, construction, use, and post-use phases of wood multi-storey buildings, which are urgently needed in the construction sector to mitigate climate change.

Keywords: Circular economy, Wood building construction, Sustainability, Systematic literature review, Circularity indicators

1 Introduction

The need to address critical sustainability issues in the built environment is becoming increasingly urgent in the face of growing environmental challenges driven by human activities. Among these challenges are global climate change, primary raw materials depletion and excessive waste generation [1], [2]. A recent World Bank report showed that 2.01 billion tonnes of municipal solid waste were generated in 2016 [3]. It is projected that under a business-as-usual scenario, waste generation will reach 3.40 billion tonnes by 2050 [3].

euni well European University for Well-Being

Co-funded by the Erasmus+ Programme of the European Union

The building and construction sector can play a key role in achieving the sustainable development goals (SDGs). The sector poses significant environmental challenges and is estimated to be responsible for 30% to 40% of the urban waste in the world [4], around 40% of the total CO_2 emissions [5], 30% of raw materials consumption [6], and 35% of the total energy consumption [7]. Therefore, it is vital to focus on the building and construction sector to make the attainment of the SDGs possible. One strategy to do this is to use wood-based materials instead of alternative concrete and steel materials in new urban buildings. A recent study suggests that using wood in 50% of new urban buildings could deliver 9% of global emissions reduction required to encounter 2030 targets for keeping global warming below 1.5 °C [8]. Another strategy is to adopt a circular economy approach, which contrasts with the linear economy ("take, make, dispose") approach to address the environmental issues in the building sector [9]. In the European Union, the building and construction sector is identified as a priority area for circularity [10]. A circular economy ensures that material resources are retained as far as possible in the economy, and the so-called 'wastes' are either minimized or become economic resources. This facilitates achieving the SDGs, e.g., climate action, affordable and clean energy, responsible consumption and production, and sustainable cities and communities.

The purpose of this paper is to provide a state-of-the-art literature review on circular economy (CE) and its application in wood multi-story building construction. This study aims to contribute to the promotion of circularity in the design, construction, use, and post-use phases of wood buildings by highlighting key knowledge gaps that require research for circularity in wood multi-storey building construction.

2 Methodology

This study follows the approach employed by Norouzi et al. [11], who was inspired by the methods of Aria and Cuccurullo [12] and Zupic and Cater [13], to perform the systematic literature review. A schematic representation of the study's approach is presented in Figure 1. The first step is study design, where the research issues, keywords and the appropriate bibliometrics are defined and primary search is performed [11]. The second step is data collection, which involves three sub-stages: (i) retrieving data from online bibliographic databases, (ii) loading and converting the data to make it compatible with the selected bibliometric tools, (iii) cleaning the data by removing duplicates and misspellings [12]. The next step is data analysis and visualization, which requires extracting networks from different parameters of analysis, using bibliometric tools or statistical software [11], [12], and subsequent visualization of data, entailing choosing the suitable mapping tool and method. The last stage is interpretation, entailing explanation of the data analysis and results [11].

2.1 Study Design

In the study design stage, primary literature search was performed using keywords which characterize and describe the research issues of the paper. The keywords are: "circular economy in wood building", "circular economy in wooden building", "circular economy in timber construction", and "circularity in wood buildings". These keywords reflect the main topic of this paper and were chosen to capture relevant publications in the field. To ensure a comprehensive coverage of the literature, three online bibliographic databases were used: Web of Science (WoS), Science Direct, and Google Scholar. These databases provide access to different scientific journals and publications across various disciplines [12]. The geographical scope of this study was not restricted to any specific region and included publications from all over the world. The time frame was set from 2010 to 2023, as this period represents the most recent developments and trends in circular economy of wood construction.

2.2 Data Collection

The data collection step involved querying and retrieving relevant literature from the WoS database, based on the defined keywords and terms. The same search keywords were also applied to Science Direct and Google Scholar to identify and include papers that were not indexed in WoS. The next step was to prepare the data for further analysis by creating, merging and cleaning the text files for each search query. This involved removing duplicate papers and standardizing different terms, e.g., replacing variations of "LCA" with "life cycle assessment".

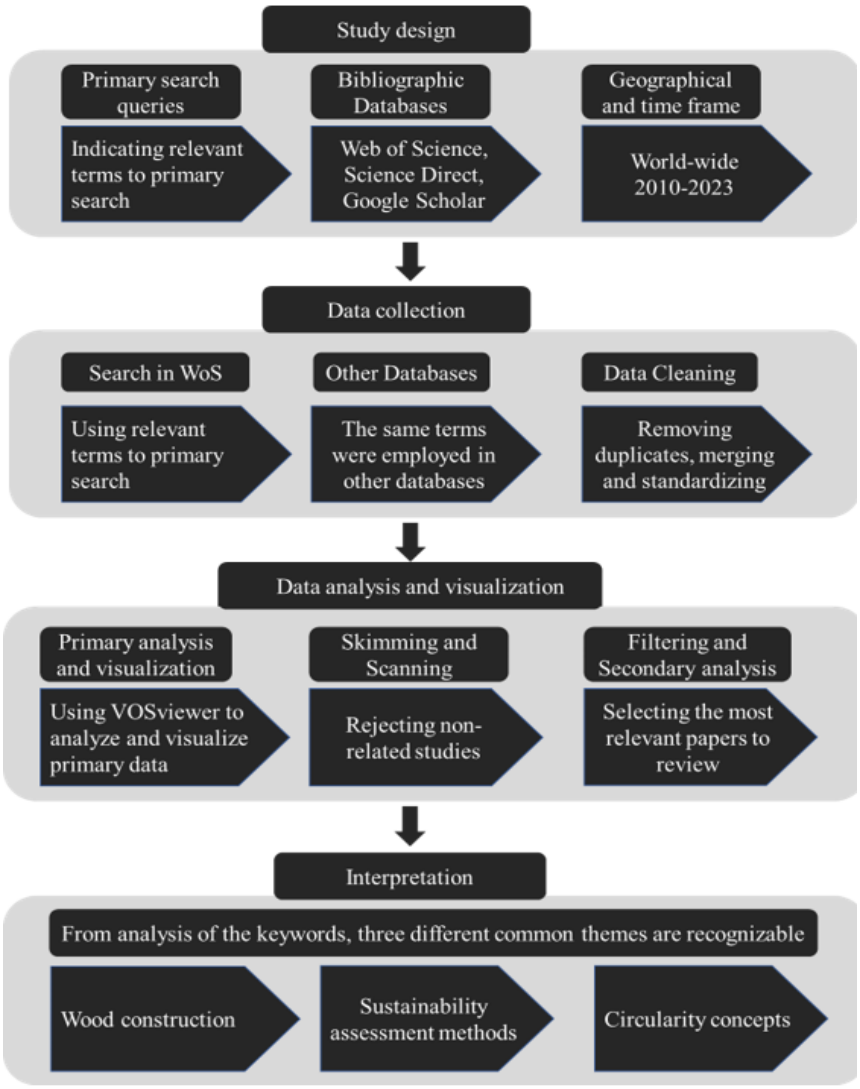

Figure 1. Outlines of systematic literature review process

2.3 Analysis and Visualization

For the primary analysis, VOSviewer software was used to examine keyword co-occurrences and co-authorship associations, employing various units of analysis, including author keywords and countries.

A thorough skimming process ensued, during which all collected papers were evaluated based on titles, types, and relevancy to the topic. Subsequently, a comprehensive scan involving keyword analysis, abstract assessment, and conclusion review was conducted to select pertinent papers. To augment this selection, additional relevant publications were manually added. The VOSviewer software was employed to analyze and visualize the data extracted from the selected articles.

2.4 Interpretation

Through the analysis of the extracted keywords, evident thematic clusters were identified, illustrating various aspects and features regarding the issue of circularity in wood-based multi-story building construction.

3 Analysis and Results

3.1 General Bibliometric Analysis

The literature searches in the WoS resulted in 91 articles for "circular economy in wood building," 22 articles for "circular economy in wooden building," 47 articles for "circular economy in timber construction," and 17 papers for "circularity in wood buildings." Collectively, the search in WoS yielded a total of 147 peer reviewed scientific articles when duplicate entries are removed. Additionally, 10 more articles were found and added to the dataset when the same search terms were applied to Science Direct and Google Scholar, expanding the initial set of papers to a total of 157 papers.

3.2 Analysis of Relevant Documents

Perusal of the documents, involving scanning of the titles, types, and a further analysis of keywords, abstracts, and conclusions led to the exclusion of articles that do not align with the research's scope, and subsequent selection of 14 highly relevant papers for in-depth review. Additionally, a newly published paper [14] (accepted in July 2023) which is not yet indexed in the chosen bibliometric databases added to the selected papers, resulting in a final set of 15 articles for examination. Table 1 provides titles and summary of the research aims and scope of the selected papers while Table 2 gives their key findings, recommendations and literature gaps, encompassing challenges, and issues for future research.

Table 1. Summary of aims and scope of the reviewed papers

Paper ID	Title and reference	Aim and scope of study
P1	Circular economy development in the wood construction sector in Finland [15]	This study aims to fill a research gap in the development of CE in the Finnish wood construction sector by using a qualitative research approach and questionnaire surveys.

P2	A market inventory of construction wood for residential building in Europe – in the light of the Green Deal and new circular economy ambitions [16]	The study aimed to address the challenge of accurately quantifying wood usage in new residential construction in thirty European nations by calculating wood-use intensity as the ratio of wood use to useful floor area.
P3	Circular economy in mass timber construction: State-of-the-art, gaps and pressing research needs [17]	This study categorizes CE-based governing principles in construction and explores circular approaches in mass timber research, focusing at post end-of-life (EOL) stages.
P4	Circular economy in the building and construction sector: A scientific evolution analysis [11]	This research summarizes the current state of global CE research in the building industry.
P5	Circular economy in wood construction – Additive manufacturing of fully recyclable walls made from renewables: Proof of concept and preliminary data [18]	The paper introduces a novel 3D printing strategy for building walls and highlights the need for more efficient material utilization in the wood market.
P6	Circular economy practices on wood panels: A bibliographic analysis [19]	This study reviews CE procedures in wood panel production waste management, emphasizing the need for integration of CE in production processes to minimize waste.
P7	Circular economy strategies in modern timber construction as a potential response to climate change [14]	The study reviews CE strategies in the mass timber and timber construction sector, covering commonly used strategies, their impact on climate change, and obstacles and benefits of CE in timber construction.
P8	Circular economy of construction and demolition wood waste—A theoretical framework approach [20]	The research explores CE for wood waste at all life cycle stages, including end-of-life materials management strategies and the development of secondary markets for recycled materials.
P9	Complete circularity in cross-laminated timber production [21]	It investigates the possibility of achieving full circularity in cross-laminated timber (CLT) production by using production residue and recycling, addressing a lack of research in this area.
P10	Cross-laminated timber for building construction: A life-cycle-assessment overview [7]	This article evaluates the life cycle implications of CLT buildings, focusing on carbon footprint, and identifies gaps in the literature, such as EOL impacts and management strategies.
P11	Design strategies to increase the reuse of wood materials in buildings: Lessons from architectural practice [22]	The study examines the role of architectural measures in wood product circularity, highlighting the lack of material efficiency regulation and consensus on circular techniques in new wood buildings.
P12	Life cycle assessment as a guide for designing circular business models in the wood panel industry: A critical review [23]	The study focuses on developing circular business models for the wood panel sector to reduce environmental impact, emphasizing the challenge of tracking wood panels' use and EOL.
P13	Prolonging life cycles of construction materials and combating climate change by cascading: The case of reusing timber in Finland [24]	This research assesses cascading construction and demolition timber in Finland and its economic and environmental potential, addressing concerns, feasibility, and benefits for mitigating climate change.

P14	Planning reclamation, diagnosis and reuse in Norwegian timber construction with circular economy investment and operating costs for information [25]	The study examines the challenges, viewpoints, and attitudes of value chain players in the Norwegian timber construction industry, emphasizing the scarcity of case studies on wood recovery and reuse.
P15	Reusing timber formwork in building construction: testing, redesign, and socio-economic reflection [5]	This study investigates the viability of plywood formwork reuse, this study explores structural applications for discarded formwork elements due to their strength and stiffness.

Table 2: Key findings and issues for future research in the literature.

Paper ID	Main findings	Issues and suggestions for future research
P1	This study found that CE and sustainability concepts are gaining attention in the Finnish construction industry. Tools and practices such as BIM, product certification, chemical reduction, education, training, and effective communication are noted as vital for CE advancement.	Future studies should explore the environmental performance of various design and construction strategies related to CE concepts. This research can help in understanding the ecological and sustainability impacts of different approaches.
P2	This study reported that the market development for wood use in new buildings varies across European countries. It also points out a gap in the literature regarding EOL approaches for mass timber buildings.	Research should explore the development of a non-biogenic material comparator to quantify the average greenhouse gas substitution effect of wood use in construction.
P3	This study presents categorization of governing principles for CE in mass timber construction, encompassing assessment, material, planning and design, integrating technology, economics, and frameworks.	-
P4	This study notes that a growing body of literature regarding CE in buildings, with 21% yearly growth rate in publications between 2005 and 2020.	It suggests for further studies include investigation of innovative business models that promote circularity and sustainability, and studies on how smart cities and industries can contribute to and align with CE concepts.
P5	Automating the design and construction process could improve the production process, leading to the reduction of waste and thereby promoting circular economy.	-
P6	This study suggests measures to increase circularity in the wood panel industry, including recovering various parts as fertilizer, fuel, and raw materials.	Future studies could emphasize CE applications in the EOL phase, where materials and products reach the end of their useful life and are managed in a sustainable manner.
P7	Key CE strategies in timber construction are identified, with positive benefits including waste reduction, lower carbon emissions, and resource efficiency. Barriers to circularity are also discussed.	Research can involve conducting comprehensive case studies to explore innovative design techniques and strategies in prefabricated and modular buildings.
P8	Recommendations for waste reduction and CE implementation are proffered, including waste prevention, BIM and prefabrication, pre-demolition audits, selective deconstruction, and source separation of wood waste.	More research is needed to investigate the practical aspects of managing construction and demolition wood waste, including collection, sorting, and separation processes.

P9	CE approaches are vital in the CLT production process as the production generates approximately 20% waste as off-cuts. Effective reprocessing technology can reuse about 70% of these cuttings for new panels and products.	Future research could focus on developing effective reprocessing technologies for effective use of CLT off-cuts.
P10	This study reports that CLT buildings can give significant GHG benefits but data concerning the EOL benefits of CLT are not available.	Accurate characterization of the benefits associated with the EOL stage of CLT products and systems, which is a vital aspect of CE of such product and systems.
P11	The study's results suggest that a combination of upstream and downstream techniques can ensure wood product longevity and easier disassembly for reuse in timber construction, to facilitate CE.	Research can focus on quantifying the frequency of single patterns in existing structures and assessing the potential for wood cascading based on these patterns.
P12	The initial obstacles to CE application are identified and attributed to hazardous and non-renewable materials in products. Circular business models are suggested, focusing on circular materials, resource recovery, and product life extension.	Future research should focus on conducting comparative LCAs to identify the relationship between circularity and environmental impacts of composites. This is instrumental in determining the trade-offs between current practices and potential circular strategies.
P13	Interviews conducted in the study indicate eagerness for use of novel remedies for construction and demolition timber reuse and recycling. Challenges related to deconstruction techniques, effects of aging, standardization, and the role of biogenic carbon is pointed.	-
P14	The study proposes a process framework for planning reuse in the building industry, emphasizing the importance of collaboration with various stakeholders and local governments to regulate resources and promote circular practices in timber construction.	-
P15	This study indicates that material reuse and circular construction require a flexible and comprehensive strategy. It emphasizes involving key stakeholders such as contractors and engineers early in the design process to support and facilitate CE in such efforts.	Further research should focus on establishment of more consistent definitions, guidelines, and codes to create a clear framework for CE implementation in the construction industry.

3.2.1 Gaps in Current Knowledge

Figure 2 shows the density of co-occurring keywords, which is essential in identifying thematic themes and knowledge gaps regarding circular economy in wood-based multi-storey building construction. The significant thematic themes on the topic include wood construction, engineered wood, climate change, life cycle assessment, waste, recycling and reuse. The areas with lower density in the visual representation indicate limited research attention in the area. These areas include circular timber construction, cascading, reutilization, disassembly, and deconstruction practices. As such, these represent critical research needs to address knowledge gaps and facilitate efforts to promote circular economy in wood-based multi-storey building construction.

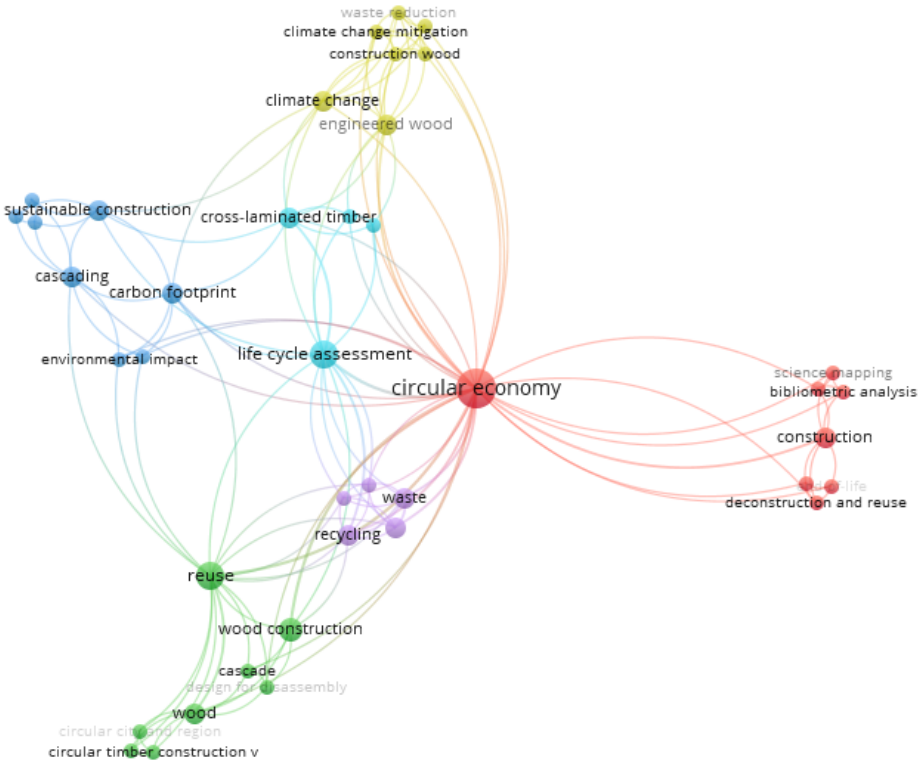

Figure 2. Network visualization of analysis of **c**o-occurrence in unit of author keywords in reviewed papers

3.2.2 Wood Construction and Climate Change

The literature emphasized the urgent need for mitigating climate change, stressing the need for significant changes in human actions and choices, including the greater use of wood-based materials [18, 15]. The selected papers point to wood-based materials and products holding considerable promise for circular construction of multi-storey building with research exploring different aspects [27, 16]. Engineered wood products such as cross-laminated timber, glued-laminated timber and laminated veneer lumber [19], [24] are highlighted for their potential for large-scale modern buildings and circular construction, leading to improved wood use and environmental benefits [17].

3.2.3 Indicators for Circularity in Multi-Storey Wood Building Construction

The papers emphasized the need for acceleration towards circular economy, to reach sustainability goals in the built environment [23]. Some key terms, concepts and indicators emphasized in relation to circularity of wood-based multi-storey construction are as follows:

- Construction and demolition wood waste generation: The substantial volume of wood waste arising from construction and demolition is highlighted, with timber waste suggested as constituting a significant portion of this waste [20].
- Wood residue utilization:: The potential of repurposing wood residues like sawdust and woodchips as raw materials for new products is emphasized and discussed with the aim to reduce the demand for virgin natural raw materials and resources [21].

- Waste reduction strategies: Strategies and efforts to reduce waste are discussed in the papers and include the adoption of modular prefabricated construction methods which facilitate disassembly during the end-of-life stage [27].
- End of Life (EOL) management: Effective management of EOL wood-based materials and buildings are suggested to minimize lifecycle impacts. Resource-efficient choices at the EOL stage are reported to give potential for substantial reductions of environmental impacts [17].
- Reuse and recycling practices: Strategies of reusing [5] and recycling materials are suggested as vital for achieving resource efficiency and sustainable practices [26], [28].
- Cascading utilization: The significance of cascading, an approach maximizing the utilization of wood products for both material and energy purposes, is emphasized [22, 25].

3.2.4 Sustainability Assessment Methods and Tools

The literature review highlighted that understanding the environmental impacts and benefits of wood construction relies on assessing sustainability through different methods. In this regard, Environmental Product Declaration (EPD) can play an important role when assessing the environmental performance of wood-based construction and choosing solutions to enable circular wood-based construction. The approaches and tools pointed out in the literature review for sustainability assessment to facilitate circular economy in wood-based construction include:

- Life Cycle Assessment (LCA), a well-established method which is commonly used to analyze and optimize the environmental performance of buildings' considering the complete lifecycle [7].
- Carbon Footprint Analysis, which focuses on the total net CO_2 and other GHGs emitted to the atmosphere during the lifecycle of a product or material, akin to the global warming potential impact category of LCA [14, 29].

4 Conclusions

Considering the growing interest in wood multi-storey building construction in Europe, linear economic practices regarding using wood in construction and discarding it with minimal reuse or recycling need to be rethought. Circular economy concepts can be applied in wood multi-storey building construction. The present paper presents a systematic literature review conducted in four main steps: study design, data collection, data analysis and visualization (using VOSviewer tool), and interpretation. The titles and summaries of the research objectives and scope of the chosen publications are included in Table 1, while Table 2 presents their important conclusions, literature gaps, comprehensive difficulties, and topics for further research. The synthesis of findings shows that there are three main themes in the reviewed articles: wood construction, sustainability assessment methods, and circularity concepts. This indicates that areas that have received limited research attention include circular timber construction, cascading utilization, deconstruction practices and reutilization. Therefore, new research is needed in these areas to address knowledge gaps, to facilitate circular economy in wood multi-storey building construction.

References

[1] Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I, "A review of the global climate change impacts, adaptation, and sustainable mitigation measures.," *Environmental Science and Pollution Research,* 2022.

[2] S. Kirsch, "Running out? Rethinking resource depletion," *The Extractive Industries and Society,* 2020.

[3] Kaza, Silpa; Yao, Lisa C.; Bhada-Tata, Perinaz; Van Woerden, Frank, "What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050.," Urban Development;. © Washington, DC: World Bank, Washington, DC, 2018.

[4] Huanyu Wu, Jian Zuo, Hongping Yuan, George Zillante, Jiayuan Wang, "A review of performance assessment methods for construction and demolition waste management," *Resources, Conservation and Recycling,* 2019.

[5] Arno Pronk, Stijn Brancart, Fred Sanders, "Reusing Timber Formwork in Building Construction: Testing, Redesign,and Socio-Economic Reflection," *Urban Planning (ISSN: 2183–7635),* vol. 7, no. 2, pp. 81-96, 2022.

[6] Leonora Charlotte Malabi Eberhardt,Julie Rønholt ,Morten Birkved, Harpa Birgisdottir a, "Circular Economy potential within the building stock - Mapping the embodied greenhouse gas emissions of four Danish examples," *Journal of Building Engineering,* 2021.

[7] Adel Younis, Ambrose Dodoo, "Cross-laminated timber for building construction: A life-cycle-assessment overview," *Journal of Building Engineering,* 2022.

[8] Austin Himes, Gwen Busby,, "Wood buildings as a climate solution," *Developments in the Built Environment,* vol. 4, 2020.

[9] Benjamin I. Oluleye, Daniel W.M. Chan, Abdullahi B. Saka, Timothy O. Olawumi,, "Circular economy research on building construction and demolition waste: A review of current trends and future research directions," *Journal of Cleaner Production,* vol. 357, p. 2022.

[10] E. commission, "An EU action plan for the Circular Economy," 2015. [Online]. Available: https://www.eea.europa.eu/policy-documents/com-2015-0614-final.

[11] Masoud Norouzi, Marta Chafer, Lusia F Cabeza, Laureano Jimenez, Dieter Boer, "Circular economy in the building and construction sector: A scientific evolution analysis," *Journal of Building Engineering,* 2021.

[12] Massimo Aria , Corrado Cuccurullo, "bibliometrix: An R-tool for comprehensive science mapping analysis," *Journal of Informetrics,* 2015.

[13] Zupic, I., & Čater, T, "Bibliometric Methods in Management and Organization," *Organizational Research Methods,* 2015.

[14] Mohsen Ghobadi, Samad M.E. Sepasgozar, "Circular economy strategies in modern timber construction as a potential response to climate change," *Journal of Building Engineering,* 2023.

[15] Roope Husgafvel , Daishi Sakaguchi, "Circular Economy Development in the Wood Construction Sector in Finland," *Sustainability,* 2023.

[16] R. Sikkema, D. Styles, R. Jonsson, B.Tobin, K.A. Byrne, "A market inventory of construction wood for residential building in Europe in the light of the Green Deal and new circular economy ambitions," *Sustainable Cities and Society,* 2023.

[17] Namhyuck Ahn, Ambrose Dodoo, Mariapaola Riggio, Lech Muszynski, Laurence Schimleck, Maureen Puettmann, "Circular economy in mass timber construction: State-of-the-art, gaps and pressing research needs," *Journal of Building Engineering,* 2022.

[18] B. Kromoser, S. Reichenbach, R. Hellmayr, R. Myna, R. Wimmer, "Circular economy in wood construction – Additive manufacturing of fully recyclable walls made from renewables: Proof of concept and preliminary data," *Construction and Building Materials,* 2022.

[19] Cristiane Karyn de Carvalho Araújo, Rodrigo Salvador, Cassiano Moro Piekarski , Carla Cristiane Sokulski, Antonio Carlos de Francisco, Sâmique Kyene de Carvalho Araújo Camargo, "Circular Economy Practices on Wood Panels: A Bibliographic Analysis," *sustainability,* 2019.

[20] Israt Jahan, Guomin Zhang, Muhammed Bhuiyan and Satheeskumar Navaratnam, "Circular Economy of Construction and Demolition Wood Waste — A Theoretical Framework Approach," *sustainability,* 2022.

[21] Ilze VAMZA, Karlis VALTERS, Ilze LUKSTA, Peteris RESNAIS, Dagnija BLUMBERGA, "Complete Circularity in Cross-Laminated Timber production," *Environmental and Climate Technologies, sciendo,* 2021.

[22] Chiara Piccardo, Mark Hughes, "Design strategies to increase the reuse of wood materials in buildings: Lessons from architectural practice," *Journal of Cleaner Production,* 2022.

[23] Ali Tighnavard Balasbaneh, Willy Sher, "Economic and environmental life cycle assessment of alternative mass timber walls to evaluate circular economy in building: MCDM method," *Environment, Development and Sustainability,* 2022.

[24] Cristiane Karyn de Carvalho Araújo, Mariane Bigarelli Ferreira, Rodrigo Salvador, Camilla Kawane Ceciliano de Carvalho Araújo, Bruno Silva Camargo, Samique Kyene de Carvalho Araújo Camargo, Cristiane Inacio ´ de Campos, Cassiano Moro Piekarski, "Life cycle assessment as a guide for designing circular business models in the wood panel industry: A critical review," *Journal of Cleaner Production,* 2022.

[25] Yishu Niu, Kaarle Rasi, Mark Houghes, Minna Halme, Gehard Fink, "Prolonging life cycles of construction materials and combating climate change by cascading: The case of reusing timber in Finland," 2021.

[26] Sondre Litleskare and Wendy Wuyts, "Planning Reclamation, Diagnosis and Reuse in Norwegian Timber Construction with Circular Economy Investment and Operating Costs for Information," *sustainability,* 2023.

[27] Jim Bowyer, Katie Fernholz, Alicja Kacprzak, "CIRCULARITY CONCEPTS IN WOOD CONSTRUCTION," United Nations and the Food and Agriculture Organization of the United Nations, Geneva, 2023.

[28] Carme n Cristescu , Daniel Honfi , Karin Sandberg , Ylva Sandin, Elizabeth Shotton , St John Walsh , Marlene Cramer , Daniel Ridley-Ellis , Michael Risse , RaphaelaIvanica , Annete Harte, Caitríona Uí, Chúláin , Marina De Arana -Fernández , Daniel F. Llan, "Design for deconstruction and reuse of timber structures – state of the art review," In future wood, 2020.

[29] Mukherji A.P. et al., "Synthesis Report of the IPCC Sixth Assessment Report (AR6)," IPCC, 2023.