

**Barriers and drivers to decarbonisation and circularity of buildings:
A systematic literature review**

Danelly Gutierrez Ramirez, Luca Sabini, Leon Black

School of Civil Engineering, University of Leeds, Leeds, LS2 9JT

cnadggr@leeds.ac.uk

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Abstract

Transition to a sustainable built environment requires balancing decarbonisation and Circular Economy (CE) principles at the building level. Decarbonisation efforts primarily focus on reducing operational carbon emissions through thermal efficiency. CE aims to reduce resource consumption and extend the elements' life cycle. However, there is a lack of understanding of how to balance embodied and operational emissions in buildings while also considering CE principles. Embodied emissions are associated with the production, construction, and end of life of elements. Operational emissions arise from the energy consumed over a life cycle. Although there has been an increase of CE principles, such as deconstruction and disassembly, in the academic literature, the practical application is still limited. This study aims to address these gaps by identifying the barriers and drivers to integrating CE principles with decarbonisation efforts through a systematic literature review. This study aims to contribute to a holistic understanding of sustainable building.

Word Count: 1,837 words.

1. Introduction

Concerns over climate change and efforts to limit global warming to below 1.5°C have increased the adoption of sustainable strategies in the built environment (IPCC, 2023). The construction sector has a huge global impact on the use of natural resources, waste generation, and carbon emissions (Bellini et al., 2024). Existing literature has focused on two key areas: reducing building operational emissions and the integration of CE principles for resource management with concern for embodied emissions.

The development of the design of CE principles has increased in the academic literature, but the practical implementation is limited. Studies have identified different CE principles at the building level and explored how circularity can be integrated throughout a building's lifecycle. However, their approach does not integrate the operational emissions. Meanwhile, studies on operational efficiency focus on energy savings through design and material choices (Craft et al., 2024) but do not integrate CE principles.

This developmental paper will consider these gaps to identify the barriers and drivers for integrating resource management and carbon emissions reduction at the building level. Through a systematic literature review, we seek to identify what influences the adoption, or not, of CE principles in buildings and how different CE principles may or may not contribute to minimising carbon emissions.

The paper comprises 5 sections. Following this introduction, section 2 is reviews to the literature; section 3 describes the methodology used; section 4 aims to consider the expected findings and contributions. Finally, section 5 considers the possible conclusions.

2. Literature Review

Studies have focused on decarbonising the built environment to reduce buildings' operational emissions by the optimisation of heating, cooling, and lighting with solutions such as façade insulation, glazing, and shading (Jiménez-Pulido et al., 2022; Housh Sadat et al., 2024). Nevertheless, these solutions require increased material consumption and waste generation, increasing embodied emissions (Joensuu et al., 2022). These embodied carbon emissions are those associated with the extraction, production, construction, and demolition of each material or element (Ibn-Mohammed et al., 2014).

The material demand for construction has historically grown by about 20% per year (UNEP, 2024). Therefore, to address environmental challenges concerning resource management and waste generation in the construction sector, there is growing interest in other solutions, such as circular economy. Circular Economy (CE) is a model of production and consumption aiming to keep elements in use as long as possible (EMAF, 2013; Benachio et al., 2020). However, there is a lack of a clear CE definition, resulting in the development of various principles aimed at retaining materials and elements' value to reduce waste and natural resource uses (Geissdoerfer et al., 2017; Benachio et al., 2020). The core principle of CE is built upon the 3R's framework (Reduce, Reuse, Recycle) (EMAF, 2013). Scholars have developed other concepts based on notions of adaptability and modularity (Passoni et al., 2021). These require elements that are easy to disassemble to facilitate the process of replacement and repair to avoid generating excessive waste (Yang et al., 2024). These principles can be applied and assessed at different scales, such as material, building, industrial, and city level (Khadim et al., 2022; Ossio et al., 2023). However, the adoption of CE principles does not always lead to lower carbon emissions (Shashi et al., 2023; Seuntjens et al., 2024). For instance, extending the value of elements may promote a continual remanufacturing and reprocessing of materials or elements with low durability, leading ultimately to higher embodied emissions (Ghisellini et al., 2016).

Therefore, there is a need to balance resource management and carbon emission reductions to reduce environmental concerns.

This balancing of operational and embodied emissions has sparked debate over the timescale over which emissions are considered and appropriate resource use. Decarbonisation strategies to reduce operational emissions tend to focus on 'long-term' benefits but may increase material use (Pomponi & D'Amico, 2017). In contrast, CE principles concentrate more on reducing natural resource consumption and waste generation but can increase carbon emissions in a long-term assessment (Ghisellini et al., 2018; Seuntjens et al., 2024). Despite the increasing interest in integrating CE principles into the built environment, there is a lack of effective implementation in practice (Illankoon and Vithanage, 2023; Wuni, 2022; Ossio et al., 2023). This has prompted research to identify barriers and drivers to promote the transition from a linear (take-use-dispose) economy to a circular approach.

However, most studies have focused on the material level, increasing the material's value through recycling and remanufacturing of elements to avoid the use of new material (Gallego-Schmid et al., 2020), or at the construction industry level (Ghisellini et al., 2018; Wuni, 2022; Illankoon and Vithanage, 2023). Other studies have looked to enhance business as usual for cleaner sustainable production (Ghisellini et al., 2016) and to encourage industrial symbiosis, to upgrading waste from one user to be valorised to another (Çimen, 2021). This can be achieved through circular business models by integrating material, building, and industry levels (Ossio et al., 2023). Most research has concentrated on integrating CE principles and assessing the embodied emissions of materials for construction, demolition and waste management (Hart et al., 2019; Hossain et al., 2020; Wuni, 2022), where carbon emissions produced/ saved depend on regional supply chains and economies for the logistics, transportation, reprocessing, and storage (Ghisellini et al., 2018; Yang et al., 2024). Nevertheless, few studies have focused on identifying the barriers to integrating CE principles at the building level (Dewagoda et al., 2022).

For instance, Akhimien et al. (2021) proposed that a circular building should be designed for flexible adaptation, incorporating the 3R's to enhance resource efficiency. Illankoon and Vithanage (2023) suggest that circular buildings should be designed, constructed, operated, maintained and deconstructed in a manner that aligns with the CE principles. Munaro et al. (2022) consolidated deconstruction strategies at a building's end of life into a framework. Meanwhile, studies on operational efficiency focus on energy savings through design and material choices (Craft et al., 2024) but do not integrate CE principles. Furthermore, it has been argued that consideration of the complex systems should encompass a holistic approach and so also analyse the social, technical, environmental, economic and behavioural factors (Pomponi and D'Amico, 2017; Jiménez-Pulido et al., 2022).

3. Methodology

Growing interest in CE and the development of various CE principles have led to a proliferation of studies. This research employs a Systematic Literature Review to examine how CE principles are applied in buildings and their considerations to reduce carbon emissions throughout the whole building life cycle. By assessing the current application, the study aims to identify the barriers and drivers for integrating CE principles with decarbonisation efforts. This study has analysed the selected articles and reported the results in a thematic analysis to identify research gaps to encourage future research.

The identification of the keywords was based on using synonyms grouped into three categories: circular economy, buildings, and carbon emissions throughout buildings' lifecycle. These were,

identified through a preliminary screening literature review. The following keywords were used: *“(“CIRCULAR ECONOMY” OR “CIRCULARITY”) AND (“BUILDING” OR “CONSTRUCTION”) AND (“DECARBON*” OR “CARBON FOOTPRINT” OR “EMBODIED CARBON” OR “OPERATIONAL CARBON”)*’. The SLR was conducted in September 2024 according to the following steps:

1. The search was conducted using Web of Science (WoS) and Scopus databases, chosen for their extensive and diverse collection of peer-reviewed scientific articles. The search was made of “titles, abstracts, and keywords”, identifying 260 results in WoS and 416 results in Scopus.
2. Only already published journal articles were included to ensure no updates were missed during the review process. Conference articles, book chapters, etc., were excluded. Additionally, only articles in English were selected to avoid translation issues and because it is the common language among the authors. This resulted in 197 articles in WoS and 207 articles in Scopus.
3. To ensure relevance to construction and the built environment, subject areas were restricted to: Architecture, Business Management and Accounting, Construction Building Technology, Decision Science, Earth and Planetary Science, Energy, Engineering, Environmental Science, and Operations Research Management Science. This step reduced the selection to 187 articles in WoS and 195 articles in Scopus.
4. To maintain the study’s quality, validity, and reliability, sources were restricted to Q1 Journals, which are recognised for their rigorous peer-review processes (Tranfield et al., 2003), ranked by Scimago Journal Rank. This narrowed the selection to 81 articles in WoS and 84 articles in Scopus.
5. After removing duplicates from the two databases, 109 articles remained.
6. Titles and abstracts were analysed according to the inclusion and exclusion criteria. The selected papers had to focus on CE principles applied to buildings, other structures were excluded. Articles related to CE principles at the industrial and material level were excluded, were other sectors apart from construction, e.g. textiles, food, batteries, etc. This narrowed the research to 53 papers for a full-text reading.
7. The final review process eliminated 4 articles after reading the full text. It was identified that they did not meet the selection criteria to consider only CE principles applied to buildings. This resulted in 49 articles for analysis. The summary of these steps is shown in Fig. 1.
8. The analysis of the results is in progress.

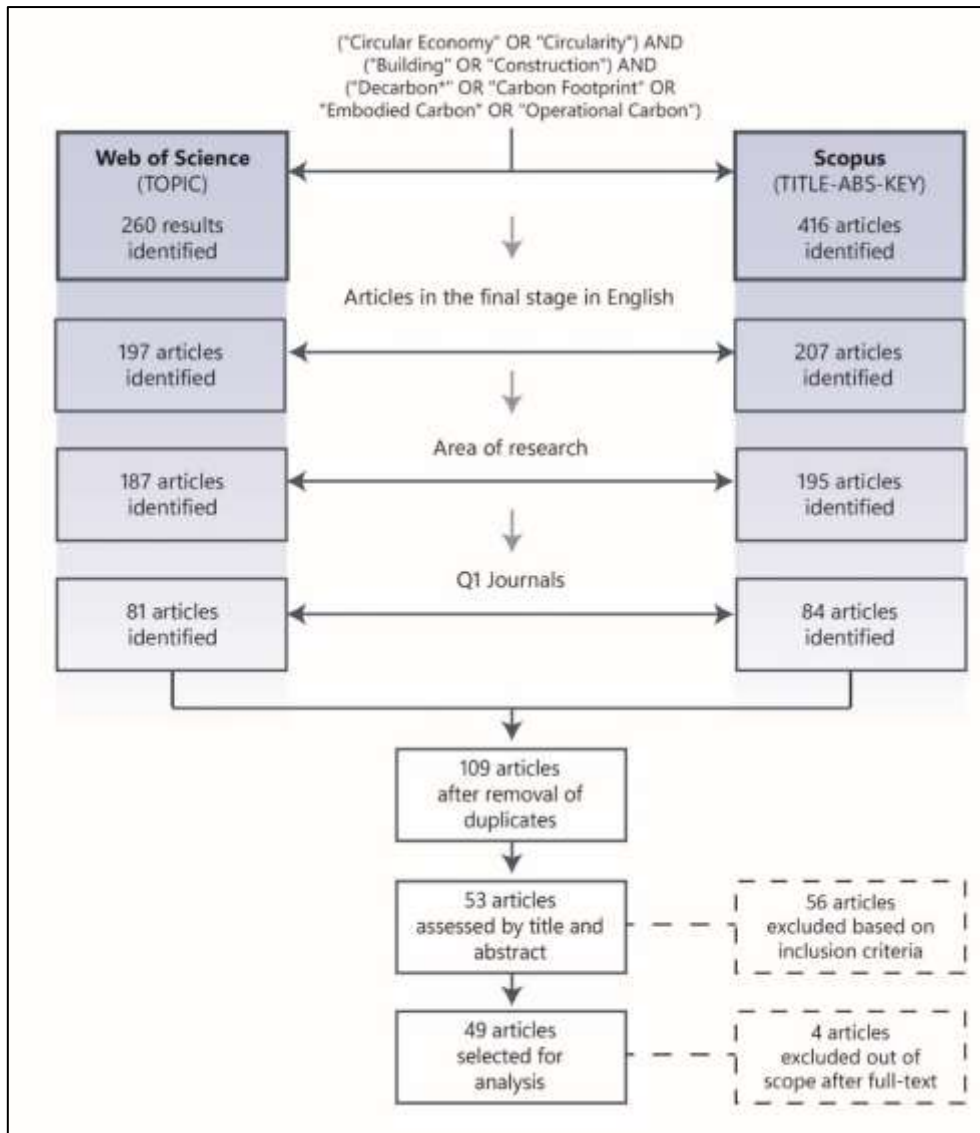


Fig. 1 Methodology of Systematic Literature Review

4. Expecting Findings and Theoretical Contributions

The research is expected to identify areas of commonality and disconnect between CE and decarbonisation of buildings, and so identify possible barriers and drivers, with a focus on balancing long- and short- term carbon and material savings. It anticipates highlighting the current fragmentation around designing for reuse or disassembly and increase the embodied carbon of an element, and how energy efficiency measures (and so long-term decarbonisation) is not always circular nor does it offer short-term decarbonisation. However, few studies consider a whole life cycle approach. Additionally, this study is expected to reveal the key driver for technical, economic, and social factors, stakeholder decision-making, plays a critical role in the transition to a more sustainable built environment.

The research will contribute to a more coherent theoretical understanding of circular construction and decarbonisation objectives at the building level. This study will advance the theoretical discourse on sustainable construction for future research to consider addressing embodied and operational emissions simultaneously. The findings aim to emphasise the need for a multi-dimensional approach to consider environmental, technical, economic, social and

behavioural factors. This study will contribute to the integration of CE within whole life cycle thinking to enhance stakeholder engagement and policy development.

5. Conclusion

This study aims to bridge the gap between CE principles and decarbonisation efforts at the building level by identifying barriers and drivers that influence their integration. The findings are expected to highlight the current disconnect between resource management focused on embodied emissions and operational efficiency measures aiming to improve energy buildings' use. By bridging this gap, the study will emphasise the need for a holistic understanding of sustainability in the built environment that integrates long-term environmental, economic and social impacts.

Furthermore, this paper aims not only to contribute to the theory but also to reinforces a whole life cycle thinking to promote the implementation in practice to maximise resource efficiency and carbon reductions across the building lifecycle.

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