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Article — Published Version Circular Economy Strategies in Densification and Refurbishment of Residential Buildings – State of Application and Future Directions

Circular Economy and Sustainability

*Suggested Citation:* de Souza Rocha, Fernanda Andreia; Reitberger, Roland; Staudt, Johannes; Lang, Werner (2024) : Circular Economy Strategies in Densification and Refurbishment of Residential Buildings – State of Application and Future Directions, Circular Economy and Sustainability, ISSN 2730-5988, Springer International Publishing, Cham, Vol. 4, Iss. 3, pp. 1899-1912, https://doi.org/10.1007/s43615-024-00365-7

This Version is available at: https://hdl.handle.net/10419/316980

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**ORIGINAL PAPER** 



# Circular Economy Strategies in Densification and Refurbishment of Residential Buildings – State of Application and Future Directions

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Received: 12 April 2023 / Accepted: 21 March 2024 / Published online: 3 April 2024 © The Author(s) 2024

#### Abstract

The fast population and economic growth put tremendous pressure on the planet's resources. In this context, the building sector is recognized as one of the most significant contributors to greenhouse gas emissions and the use of raw materials. The Circular Economy (CE) is expected to contribute to a reduction of waste landfills, extraction of raw materials, and greenhouse gas emissions. This study aims to understand to what degree and how CE strategies can be applied to the refurbishment and densification of residential buildings. Using a qualitative approach, this study examines the application of CE strategies in the building sector through five semi-structured expert interviews. The literature identifies five CE principles for buildings: building in layers, designing-out waste, designing for adaptability and flexibility, designing for disassembly, and selecting materials. From the interviews, designing-out waste was the most common approach for refurbishment and densification of residential buildings. Nevertheless, the implementation of CE strategies within the building sector is still limited and challenging due to various barriers and little encouragement. More stimuli from governments through regulations and guidelines, increased collaboration between stakeholders, and technological advancements are expected to reduce the obstacles to implementing CE strategies in refurbishment and densification.

**Keywords** Circularity · Urban Densification · Refurbishment · Expert Interviews · Circular Economy

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### Introduction

Exponential economic growth cannot proceed perpetually in a finite world [1], necessitating a change in the current economic and environmental relationship. Projections indicate a 130% increase in cumulative global gross domestic product from 2016 to 2050 [2], with the world's population expected to soar from 7.8 billion in 2020 to 9.9 billion in 2050, a rise of over 25% [3]. Additionally, almost 70% of the world's population is projected to reside in urbanized areas by 2050, exerting immense pressure on natural resources [4]. Consequently, all economic sectors are striving to decouple economic progress from its environmental impact [5], with the European Union leading efforts by promoting policies such as reuse and recycling since 2014. These policies aim for transition to a Circular Economy (CE), reducing raw material extraction and waste generation [6, 7]. Due to its substantial environmental footprint, the construction industry stands out as a priority sector for transitioning from a linear to a CE. Buildings account for 38% of greenhouse gas emissions, 40% of raw materials consumption, and 40% of waste generation globally [8, 9]. Specifically, they consume 1.6 billion tons of materials annually, resulting in a  $CO_2$  footprint of 250 million tons [10]. Moreover, the European Union acknowledges the imperative of renovating existing buildings to achieve the goal of a net-zero economy by 2050, which means a nearcomplete decarbonization of the building sector [11]. With 76% of the European building stock predating energy efficiency regulations and over 85% of buildings expected to remain in use by 2050 already constructed [12–14], refurbishment and densification of residential areas become paramount. Further legislation, such as the EU's focus on land use strategies that aim to prevent urban sprawl and soil degradation by reducing building on green-field areas, even more emphasizes the necessity for refurbishment and densification of existing residential areas [6, 15].

In this context, the CE concept can be introduced as an approach to reduce waste landfills, extraction of raw materials [16], and associated greenhouse gas emissions. By using CE strategies during the refurbishment and densification process, materials can gain added value after the building's end of life by being reused, repaired, refurbished, recycled, and recovered. Additionally, the usability of the building itself can be extended [17]. Studies conducted by Lee et al. and Aljaber et al. identified the current situation of CE strategies in the construction industry and the feasibility of CE adoption in the building sector [18, 19]. These papers shed light on construction companies' attitudes towards the importance of CE strategies and highlighted the barriers and enablers to the adoption of the CE concept in the building sector. Their findings provide valuable insights that inform our understanding of the landscape and challenges associated with implementing CE principles in construction practices.

Building on these insights, this study aims to deeply understand to what degree and how existing CE strategies could be applied to the refurbishment and densification of residential buildings. The investigation seeks to bridge the gap between theoretical understanding and practical implementation of CE principles within the building sector, particularly focusing on the challenges associated with refurbishment and densification projects. Ultimately, the study suggests future research directions for the advancement of CE initiatives and the realization of environmentally responsible building practices.

In the context of circular strategies for the building sector, it is essential to understand the CE concept. This study considers the CE as defined by the Ellen MacArthur Foundation: "The Circular Economy is a system where materials never become waste, and nature is regenerated. In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling, and composting. The circular economy tackles climate change and other global challenges, like biodiversity loss, waste, and pollution, by decoupling economic activity from the consumption of finite resources." [17].

In line with the principles of the CE, buildings' life cycle can be extended by designing them to be more adaptable and by guaranteeing that materials and components can be recovered and reused at their end of life. Understanding the different types of materials and components of a building ensures that biological materials can return to the biosphere and technical materials can be recovered and reused [20]. Figure 1 illustrates the five principles of CE when applied to buildings. The nested circles demonstrate the hierarchical structure, with the first three internal circles being the most preferable. The most resource-efficient strategy is to retain the already existing building stock and refit and refurbish existing buildings. For the other three circles, the most important strategies are reclaiming or remanufacturing materials and components, with the last option being to recycle [20]. The five sections superimposed on the circles are the design principles applied to buildings to reduce waste and extend their life cycle. From the literature review, it becomes clear that the concept of circularity in the building sector is still diffuse since CE strategies were applied in various ways during building design and construction. Eberhardt et al. identified 16 different CE strategy definitions in the literature [21]. Nevertheless, the authors also named design for disassembly, material selection, and design for adaptability & flexibility as the most applied CE strategies.



Fig. 1 Circular economy principles applied to the building sector adapted from [20]

## Building in layers (shearing layers model)

The building-in-layers concept defines several layers in a building, each with a different life cycle duration. The shearing layers model includes site, structure, skin, services, space plan, and stuff [22]. The first layer is the site, the geographical location of the building. The site does not have a determined lifespan since it is 'eternal'. The second layer is the structure of a building, which includes the foundation and the load-bearing elements. Its lifespan ranges from 30 to 200 years. The third layer is the skin of a building, which contains the façade and roof and lasts around 50 years. The fourth layer consists of the services of a building, such as pipes, wires, energy, and heating systems. The life span of such systems varies between 7 and 25 years. The fifth layer consists of the space plan, which represents the internal layout, including walls and floors and the average lifespan is 15 years. Finally, the sixth layer consists of the stuff, including furniture, pictures, lighting, etc. The life cycle of this last layer ranges from 1 day to 7 years. These time spans are estimates and further research is required to better understand this concept in practice [22].

### Designing-out Waste (DoW)

Designing-out waste means making efficient use of resources during the design phase of the construction project. The main concept is to implement available materials as efficiently as possible to decrease the demand for resources used in the construction sector [23]. For existing buildings, DoW demands to refit and refurbish existing buildings instead of demolishing and building new ones. Refitting and refurbishing existing buildings means using as much of the original building as possible to decrease the need for virgin materials and save time on site.

# **Design for Adaptability & Flexibility**

Designing for adaptability is a crucial strategy for developing sustainable buildings since it decreases the likelihood of the building becoming obsolete [24]. By designing for adaptability, buildings can be easily modified to accommodate the needs of new users as well as to integrate new technologies [20]. There is a difference between flexible and adaptable building designs [13]. Flexible building designs enable an easy reorganization of the building's internal fit-out to match the changing requirements of occupants. In contrast, adaptable building designs refer to buildings that can be easily modified to the extent of their life and suit new uses. Nevertheless, these terminologies are occasionally neglected or interchanged in the literature [25].

# **Design for Disassembly**

Being able to assemble and disassemble building materials to enable an economic recovery of structural components and their associated value is an important part of implementing the CE [26]. Planning for deconstruction involves the development of a detailed deconstruction plan, which should include instructions on how to disassemble elements and a complete inventory of the building components and materials and how they can be reused, recycled, or reclaimed [27].

Materials play a vital role in circular building design. Hence, the right choice of materials from a CE perspective during the designing process significantly reduces the environmental impacts of buildings [10]. To achieve a CE, materials and components of a building need to be declared and defined in an inventory. Materials should be selected according to their lifespan and material type (biological or technical). Additionally, materials should retain their purity by preventing the mixture of biological and technical substances so that biological materials can return to the biosphere and the technical ones can be kept in a closed loop.

# Methodology

This study adopts a qualitative approach to explore the implementation of CE strategies in refurbishment and densification projects in the building sector. The methodology comprises semi-structured interviews with experts. The questionnaire was composed of open questions. Additional questions were asked to achieve a deeper insight into the respondents' knowledge regarding the application of CE in the refurbishment and densification of residential buildings. Concerning the sample selection, five architecture companies were chosen. Table 1 shows all participating companies and their respective locations. The first selection criterion was to elect architecture companies with experience in applying circular strategies in project development. Hence, during the search, the companies' websites and project publications were carefully examined to ensure that the company had knowledge about at least one CE strategy. This step guaranteed that they could provide sufficient data. Regarding the five interviewees' roles, four are architects responsible for project design and development, and one is the head of engineering responsible for product development. The second selection criterion was to choose companies located in Europe. This is related to the fact that many European countries have a similar climate and, therefore, similar building features and requirements [28], as well as similar CE-related regulations and incentives. The collected information was about the usage of CE strategies during project design of buildings and the main challenges and barriers. Furthermore, data was gathered about the difference in implementing CE strategies between new and existing buildings. Additionally, perspectives from the respondents regarding the effectiveness and how easy it is to implement each CE strategy were obtained.

Table 1         Interviewed companies           and locations	Participating companies	Locations
	The New Makers	Netherlands
	FRANTZEN et al. architects	Netherlands
	Architekten Cie	Netherlands
	3XN/GXN	Copenhagen, Stockholm, New York, and Sydney
	Zirkular	Switzerland

# Results

### **CE Strategies for Buildings**

The interviews show that all five cited CE principles can be applied during project design. Moreover, it is evident that the respondents have different methods of applying CE strategies in their projects, i.e., each interviewee has their preferred CE strategies. In this regard, the respondent from FRANTZEN et al. architects said: 'Firstly, we try to design buildings that can be reused as a whole over and over again. Secondly, if the first approach is not possible, we make sure that buildings can be disassembled and reused elsewhere. Thirdly, we try to use as many renewable materials as possible.' In addition, the respondents from Zirkular and from The New Makers stated, respectively: 'Our strategy is to reuse single elements or the building itself. First, we look at what is there and what the client wants to do. Then we try to match both. The best is to keep the same use. When the building is deconstructed, we try to implement the materials from the deconstruction process.' and 'Our focus is the flexibility of use and the possibility for disassembly. The development phase can be flexible to make it easy to variate, it helps to change the usability of the buildings, and at the end of life, you can disassemble them. Additionally, we make use of renewable, bio-based, and recycled products.' Moreover, the respondents from Architekten Cie and 3XN/GXN argued, respectively: 'Our CE strategies lay on selecting materials, building in layers, and using the Dutch checklist called the 10Rs.' and 'We maintain a strong geometrical blueprint of our building parts throughout our development process. This allows us to apply a variety of assembly, modular, and sustainable methods to each part and layer of the building design. Our process is digitally controlled, but physical mock-ups are being built to ensure that all parts and materials are carefully selected and joined together in the way we intended.' From the interviews it became clear that most of the participants use more than one CE strategy. Figure 2 shows the frequency that the interviewees mentioned the five CE strategies. The main CE strategies cited by the interviewees are design for disassembly with 26%, selecting materials and designing-out waste, both with 22%, followed by design for adaptability & flexibility with 17%.



Fig. 2 Frequency that the interviewees mentioned the five CE strategies

#### CE Strategies Applied to Refurbishment and Densification of Residential Buildings

Regarding the application of CE strategies in existing buildings, most interviewees implement a common basic approach: to use as much of the original building as possible to avoid demolition and save natural resources. Considering this, the following statements can be highlighted:

- 'First, we look at what is there and what the client wants to do. We try to match both.'
- 'We try to reuse as much as possible of the existing buildings.'
- 'Each project is different and offers new opportunities and challenges, but our method and principles are the same. We thoroughly scan the existing buildings on the site and evaluate if the best and most feasible method is to reuse, recycle, or refurb. A lot of the old buildings still have a strong structural system, but the spaces and floor heights need to be redesigned and reconfigured.'
- 'We keep the structural part of the building by analyzing what can be used, then go for design criteria depending on the project.'

However, some interviewees argued that refurbishment and densification projects are more complex and costly. On this matter, one respondent stated: 'You never know what you find (in the existing building), which makes it more expensive. It needs more skilled workers and therefore, taking it all away and placing a new one is easier'.

Additionally, two of the interviewees found it very difficult to refurbish residential buildings due to regulation barriers and a lack of awareness of the clients. One interviewee argued: 'For residential buildings, in the case of the Netherlands, circularity is almost impossible to implement due to standards and regulations for residential buildings. For instance, fire regulation.' However, it is important to highlight that this perception is directly related to the company's resources such as the number of employees with diversified know-how. The respondent from 3XN/GXN presented one of the company's densification projects as an example. The respondent showed that the designers were able to reuse 95% of the structural walls and 65% of the columns, beams, and slabs of a high-rise building. As a result, the company achieved substantial economic savings and a significant reduction of  $CO_2$  emissions. According to the respondent, the architects and innovation team were the main drivers for this success.

When it comes to the interviewees' viewpoints on the application of the CE strategies in refurbishment and densification projects, two different perspectives arose. The first perspective regards the difference in the application of CE strategies between new and existing buildings, while the second perspective concerns the degree of difficulty applying CE strategies during project design. Regarding the first perspective, for some of the respondents, there is no difference between new and refurbishment/densification projects, while for others, the lack of flexibility of the existing building is a challenge. For example, the respondent from Architekten Cie said: 'We work on new and refurbishment projects in the same way; the only difference is that for existing buildings, we first try to analyze what can be used, then we go for design criteria.', while the respondent from Zirkular said: 'It is best to keep the same use of the buildings. Otherwise, the project becomes complex to apply circularity'. Concerning the second perspective, each respondent has a unique viewpoint regarding the degree of difficulty in applying CE strategies during project development. In this context, the following statements can be highlighted:

- 'Design for adaptability is doable, but it costs sometimes. Existing materials are the most complicated because you must adapt to what you find.'
- 'The easiest to apply is the design for disassembly because you do not need a different design to do it; it is just detailing. Oppositely, design for adaptability, you need a different design that is not normal nowadays. Designing-out waste is the most difficult because the building industry is not yet used to it, and it is a perfect situation that does not exist at the moment.'
- 'Material selection is the easiest because you must do it upfront. First materials and then design; otherwise, you raise cost and complexity. (The most difficult is) building in layers (you do it) because sometimes it makes sense to integrate elements. Focus on it 5% due to its complexity.'

Moreover, when the respondents were asked to rank the five strategies from the most effective to the least effective, most of them ensured that a ranking was not possible. For instance, respondents Architekten Cie and 3XN/GXN said that all of them are effective and, therefore, it is not possible to rank them. One respondent argued further: 'Every approach is so different from project to project, and therefore, all of them are important. Additionally, I would add that because each project differs from the next, the ranking of the principles also changes and is re-evaluated depending on the project's challenges.' In this context, even though some of the respondents ranked the strategies, they clearly stated that all of them are essential for the application of circularity in the building sector.

# **Challenges of the CE Strategies**

Several challenges to implementing CE strategies in new and existing building projects were noticeable from the literature review and the interviews. These can be associated with three predominating challenges: economical, institutional, and social. Table 2 shows the identified challenges and their sub-challenges.

Most respondents argued about the difficulty of applying CE strategies in new and existing building projects due to financial aspects. For instance, one interviewee said: 'Today's investment strategies are based on financial decision systems in which future values are

Table 2 Challenges of the CE strategies	Challenges	Sub-challenges
	Economic	<ul><li>High costs</li><li>Lack of future view</li></ul>
	Institutional	<ul> <li>Lack / not clear regulations and guidelines to encourage CE</li> <li>Regulations that work as an obstacle to implementing CE</li> <li>Lack of knowledge and experience of stake- holders (architects, engineers, etc.)</li> <li>Lack of communication between stakeholders</li> </ul>
	Social	<ul> <li>Lack of awareness</li> <li>Lack of encouragement</li> <li>Lack of commitment to CE implementation</li> </ul>

estimated, and the way they are estimated is all set in a current legal contract, and circular buildings are more expensive'. Another person stated: 'Costs are a big challenge, and it is a barrier that makes circularity difficult' and 'Circularity is difficult to achieve. It was done because of the target of the government. It is very difficult for a private customer in terms of cost'. In this last statement, the interviewee said that CE strategies are more likely to be applied in public projects than in private ones. It can be reinforced by the argument of the respondent from Zirkular: '(The main challenges are) cost [...] since clients often look today and not tomorrow, they look the cheapest now.' Furthermore, as found in the literature, circular business models show high risks connected with the high prices of secondary materials, labor, and logistics [29]. As a result, circularity becomes more expensive and, therefore, more difficult to be applied.

Moreover, the interviewees mentioned challenges related to the current regulatory framework. Some of the respondents said there is a lack and/or unclear regulations or guidelines that harm the implementation of CE strategies in the building sector. Others mentioned that many regulations work as barriers to applying CE strategies. For example, the interviewee from Architekten Cie said: 'There is a lack of regulations to encourage circularity, and at the same time, there are many regulations that work as a barrier for circularity, making the introduction of circularity difficult.' Another example is from the respondent from The New Makers: 'Guidelines would help to standardize, for instance, regulations that make an obligation to re-use parts of the buildings. Additionally, regulations nowadays are not clear enough, and it is difficult to check them.'. Furthermore, the respondents elaborated on the lack of knowledge and communication between stakeholders. According to one respondent: 'There is a lack of knowledge and experience to design in a circular way. We are learning by doing,' he also argued 'Lack of knowledge and communication between stakeholders make it (circularity) more difficult.' To complete this, the interviewee from Architekten Cie stated: 'The communication between stakeholders is a challenge (architects, engineering, etc.), so we brought stakeholders together during the design process'.

When it comes to the application of CE strategies in refurbishment and densification projects, the main challenges mentioned by literature and interviewees are the lack of material inventory of the existing buildings, the lack of knowledge regarding the condition of the existing buildings, the difficulty in changing the building's serviceability and the lack of flexibility of the floor height. In many cases, the possibility to reuse or recycle materials from an existing building is not considered due to the deficit of knowledge about the value of the materials stored in the building in question [6]. 3XN/GXN confirms this statement: 'I think one of many challenges is not knowing what is inside the walls in an existing building. Unfortunately, today's existing buildings do not have a digital model but only exist in 2D drawings. To map and scan an existing building is time-consuming, but depending on the scale, you can save a lot of the existing core building. We don't know what is inside the building before we start dismantling it. Suppose we discover that walls and structures are in good condition. In that case, we still need to analyze their performance and quality to ensure that they can continue their story in the next building as well'. He further argues: 'People's behavior, what they expect from spaces and how they interact with spaces is always in flux. One parameter that is coherent in all buildings is the floor-to-ceiling height. In new buildings, you set the height for enough room height for different room programs. Still, in existing buildings, we often experience floor-to-ceiling height not being within acceptable requirements and what is considered a good spatial experience. Today requirements for fire and acoustics have caused the slab-built-up to increase. This is okay in new buildings but very difficult to fit in existing buildings. In those projects, we spent a lot of time in spaceplanning to ensure that we offer the best conditions by introducing double-height spaces and arranging different functions depending on their needs and qualities together'.

#### **Companies' Perceptions and New Opportunities for CE**

The respondents outlined some new opportunities that the concept of CE brings to the building industry. Most respondents said that implementing CE strategies has some advantages for the company itself, such as recognition and longevity of the business. For instance, respondents won awards for sustainability. The person from The New Makers stated, '(The introduction of CE strategies supports) the long-term approach of the products. With the constant development of the product for durability, you make sure that you can keep making your products anyway. The product can integrate other services.' Moreover, the interviewee from Architekten Cie argued that the company can help its customers achieve their sustainability goals. Oppositely, there was also one to argue that the introduction of CE strategies did not bring any commercial advantage to the company. However, when he was asked about the main factor that encouraged the company to introduce circularity for the first time, he stated: 'In 2009, the company won a sustainability tender in which the criteria were only energy efficiency, but we thought that it was not enough because the real problem of the world is resource scarcity. Therefore, we implemented the cradle-to-cradle approach in the project.' Hence, even though the primary success was based on energy efficiency, the introduction of circular approaches led to a widespread appreciation of the company.

The new opportunities CE brings to the building sector can be stimulated by new regulations. According to the interviewees, the regulation framework plays a vital role in encouraging the implementation of CE strategies as well as in making them more affordable. In this context, the respondent from Architekten Cie said: 'The government can change building regulations and make circularity obligatory – you have to build in a circular way'. The respondent from FRANTZEN et al. architects also added: 'We must look at it not just from the technological perspective. Focus on economic and legal situations to make it possible is also needed'. Moreover, new opportunities are emerging with the concept of CE. For instance, companies are working in partnerships instead of competing and they create new business models and design methods that make circularity a focus area. The following statements can be emphasized: 'We see that clients are expecting more from their buildings, and the requirements are increasing from project to project. We team up with other companies and experts in the field to ensure that we deliver a building in the best possible condition to the client by using a joint knowledge approach.' and 'The difference in the business plan, make a building as a product and then a service. Trying to gain knowledge regarding materials and new ways of building – companies are still learning.'

#### Discussion

The literature review showed that the CE concept is broad, with various definitions, terminologies, and design strategies. Within the building sector, five main CE strategies are distinguished: designing-out waste, building in layers, design for disassembly, design for adaptability & flexibility, and selecting materials. According to the circular hierarchy, designing-out waste is the most resource-efficient strategy within the building sector since retaining, refitting, and refurbishing existing buildings can significantly decrease the demand for virgin materials and avoid waste in the construction sector [23]. However, the literature reveals that the use of all five strategies in a mixed way can support buildings to extend their life cycle and reduce waste and material demand. The literature frequently mentions a dependence among the five CE strategies. This dependence is suggested especially for the design for disassembly, design for adaptability & flexibility, and selecting materials. Moreover, the main challenges cited in the literature are the high costs of applying such CE strategies, lack of knowledge, and lack of communication between stakeholders.

Even though there are many debates about CE applications, the actual implementation is lacking. This can be attributed to several reasons. First, there was a divergent understanding of CE strategies among interviewees although all of them affirmed its importance for reaching sustainable development. Second, no consensus exists among interviewees about ranking the importance of each CE strategy and how they are applied. Third, the choice and degree of difficulty to apply each CE strategy depend on the project and the experience of the professional. Fourth, there is still a considerable lack of knowledge and many barriers to applying CE strategies in the building sector. Finally, there are few guidelines and no clear regulations to encourage CE strategies.

Economic, institutional, and social obstacles greatly influence the application of CE strategies within the building sector. For instance, high cost was mentioned to be the greatest barrier to implementing CE strategies (economic), followed by the lack of knowledge and communication between stakeholders (social). Additionally, the absence of non-clear regulations to encourage CE and the regulations that work as an obstacle may lead to an avoidance of the application of CE strategies in projects (institutional).

When it comes to the refurbishment and densification of buildings, the challenges become even more significant due to the lack of material inventory of the existing buildings, the lack of knowledge regarding the condition of the existing buildings, the difficulty in changing the building's serviceability, and the lack of flexibility of the floor high. For refurbishment, the designing-out waste strategy was the main strategy mentioned since it aims to save as much as possible from the existing building. Nevertheless, the respondents showed difficulties in applying the remaining strategies to refurbishment and densification projects. In this context, it can be assumed that the application of circular strategies is more challenging for existing buildings. Still, new buildings can already be projected to accommodate such changes and avoid barriers by design. As a result, future refurbishments will not face these obstacles.

Therefore, implementing CE strategies within the building sector requires increasing awareness among stakeholders, especially companies and investors. Additionally, incentives and the establishment of market demand for circular or reused products can be encouraged by regulations, which in turn would decrease the prices for secondary materials and promote CE strategies within the building sector. It is essential to highlight that the communication between stakeholders and the change in business model is vital to the pursuit of a CE. According to Abma, close cooperation between companies and other actors in the market can increase the application of CE strategies [30]. The author also suggests that this change can result in a more significant commitment of the supply chain partners to collaborate and work towards a CE. Finally, enhancing professionals' knowledge can support introducing CE strategies in projects more easily.

#### **Limitations and Future Research**

While this study offers insights into applying CE principles within the refurbishment and densification of residential buildings, it is important to acknowledge its limitations. Firstly, the literature review revealed instances where CE strategies were conceptually conflated, making it challenging to clearly identify and separate each strategy for refurbishment and densification. Secondly, during the interviews, there was inconsistency in how interviewees articulated CE strategies, resulting in variations in the interview data and hindering quantitative analysis. The small number of five interviewees is another aspect of this study that limits generalizability.

Despite these limitations, this research shows possibilities for further exploration in the CE domain. Specifically, it organizes the main CE strategies within the built sector, laying a foundation for deeper analysis. It would be beneficial to conduct a quantitative analysis by developing a questionnaire that meticulously evaluates the definitions and assesses the importance and impact of each CE strategy in refurbishment and densification. Such an approach could provide valuable insights for experts, facilitating the development of CE definitions and understanding their impact within the building sector.

# Conclusion

Utilizing a qualitative methodology centered on semi-structured interviews with industry experts, this research explores the application of CE strategies within the refurbishment and densification of residential buildings. The study aims to elucidate the existing implementation status of CE principles while also identifying the barriers and drivers inherent in their practical adoption.

The literature review delineated five primary CE strategies applicable to the building sector: designing-out waste, building in layers, design for disassembly, design for adaptability & flexibility, and selecting materials. It underscored the synergistic benefits of employing multiple CE strategies in densification and refurbishment, leading to waste reduction, minimized material demand, and extended building life cycles. However, the integration of these strategies often comes with a significant cost implication, posing a deterrent to widespread adoption.

The ambiguity surrounding CE strategy definitions and concepts, as revealed in the interviews, reflects industry professionals' diverse perspectives and experiences. The choice and complexity of implementing CE strategies are heavily influenced by project requirements and individual expertise. Despite inherent challenges, this study highlights the potential for incentivizing CE strategy adoption through regulatory frameworks and innovative business models. Regulatory support and market-driven incentives can play a pivotal role in overcoming barriers and fostering a conducive environment for sustainable construction practices. Challenges intensify when applying CE strategies to refurbishment and densification projects, primarily due to existing buildings' inherent constraints and limitations. The lack of flexibility and knowledge regarding building structures presents obstacles that necessitate creative solutions and enhanced collaboration among stakeholders.

In conclusion, the successful integration of CE strategies in residential refurbishment and densification projects requires a concerted effort to address barriers, promote regulatory alignment, and foster knowledge sharing within the industry. By leveraging regulatory support and adopting collaborative approaches, the construction sector can navigate challenges and embrace sustainable practices that prioritize resource efficiency and environmental stewardship.

Acknowledgements This work was carried out within the research project 'Densification in the Context of Climate Change', funded by the Bavarian State Ministry of the Environment and Consumer Protection (StMUV) and the research training group Urban Green Infrastructure (German Research Foundation, 437788427 - RTG 2679).

Authors Contributions F.R.: Conceptualization, interviews, analysis, interpretation of results, first draft, writing, editing. R.R.: Conceptualization, interpretation of results, writing, review. J.S.: Conceptualization, interpretation of results, writing, review. W.L.: Supervision, review, acquisition.

**Funding** Open Access funding provided by the Technical University of Munich (TUM). Authors were funded by the Bavarian State Ministry of the Environment and Consumer Protection (StMUV) and the research training group Urban Green Infrastructure (German Research Foundation, 437788427 - RTG 2679). Open Access funding enabled and organized by Projekt DEAL.

Data Availability On request.

#### Declarations

Ethics Approval and Consent to Participate Not applicable.

Consent for Publication Not applicable.

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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