Share, Preserve, Adapt, Rethink – a focused framework for circular economy

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Abstract. The concept of circular economy has peaked in both popular and scientific discussion in the past few years. Notwithstanding, no specific definition for circularity in the context of existing buildings is available. This research details a framework of circular economy in the built environment, focusing on existing buildings. The paper employs a systematic literature review on circular economy within built environment. The majority of the reviewed articles date from 2016-2019, confirming the novelty of the research area. Based on the literature review, research on circular economy in the built environment has to date largely focused on designing to facilitate circularity in the future, or salvaging and recycling building materials for new construction. This paper suggests a literature-based framework comprising three complementary approaches to implementing circularity in the context of existing buildings: 1) Share; 2) Preserve; 3) Adapt, and; 4) Rethink. The transition toward a circular economy in the built environment requires structured approaches, like the one presented here. The presented framework allows researchers to expand their thinking on circularity in the built environment, while providing practitioners a selection of potential managerial approaches. The suggested circular approaches may be particularly useful for the longer-term strategy work of real estate owners and managers.

Keywords: adaptive reuse, co-location, circular economy, maintenance, sharing economy

Introduction
Circular Economy (CE) is gaining popularity in public debate and policy, but there is still a need for theoretical refinement. Simply put, CE seeks to keep resources in use indefinitely, decoupling economic development from resource use [1]. The key CE elements comprise issues relate to resource efficiency, preserving and extending what is already made, and designing for the future. Furthermore, issues like the collaboration between stakeholders, use of novel technologies, and consequent new business models are also included in the elements [2]. Regardless of these outlined elements, the focus of CE policy has been on the recycling of material for new uses. CE policy measures have received criticism for promoting recycling rather than reuse [3].

Perhaps the most commonly used CE framework, the Regenerate, Share, Optimize, Loop, Virtualize, Exchange (RESOLVE) framework by the Elle McArthur foundation, has been adapted to the built environment by Arup in 2016 [4]. However, there is a need for theoretical refinement of CE in the built environment, specifically in the context of existing buildings. The existing building context should be of particular interest within developed nations, where the building stock renews itself slowly. Nevertheless, the real estate and construction sector has to date mostly focused on designing and
constructing new buildings to facilitate circularity in the future, or the salvaging and recycling of building materials. The New European Action Plan for CE lists measures for the sector, all focused on new construction [5]. A Nordic report likewise focuses solely on measures directed at new construction [6]. A Swedish report outlines the state of CE in the real estate and construction industry in Sweden, with a key focus on building materials [7]. A Finnish project introduces 18 measures for making the built environment circular, and only three measures relate to existing buildings [8]. Pomponi & Mancaster identified a similar bias towards building materials in research in their extensive 2017 review paper [9]. That bias is further examined here, as this study focuses on the under researched area of existing buildings. In the transition from a linear to a circular economy, a focused framework for existing buildings is much needed. This study builds on what is currently known about circularity on the individual building level. The paper engages in a systematic literature review, with database searches from the widest online scientific database, Scopus.

The paper is structured, as follows. The next section outlines the study design. The consequent section presents the findings of the systematic literature review, and the focused framework. The findings are further discussed in the following section, and the last section concludes the paper, with a future research agenda.

**Study Design**

This study employs a systematic literature review. Several consecutive Scopus database searches were carried on 6th February 2019, using different combinations of the following search terms: ‘Circular economy’ or ‘Circularity’, with either ‘Buildings’, ‘Built environment’, or ‘Real estate’ in either the Abstract, Title, or Keywords. Only English language journal articles were included, whereas conference proceedings, book chapters, foreign language articles and retracted articles were excluded. The systematic database search returned altogether 144 articles. Following the database search, Title and Source title were reviewed, and several irrelevant articles from unrelated research fields, such as linguistics or astronomy, were removed. After this second phase, 83 articles remained in the list.

The most popular source title was the Journal of Cleaner Production with 16 articles. Resources, Conservation and Recycling had hosted 10 of the articles, and MDPI’s Sustainability six articles. Other popular source titles with three articles each include the Journal of Industrial Ecology, along with MDPI’s Buildings, and Materials. The remainder of the articles were spread out, published in both journals from the environmental sciences, and from the built environment research tradition. Noticeably, only one journal specifically focusing on real estate, Emerald’s Facilities, was among the source titles. The oldest article dates back to 2007, but overall 78 out of the 83 articles date from 2016-2019, which reflects the novelty of the research area.

The third step, ‘Abstract and Keyword review’, engages in a categorization of the articles, based on Pomponi & Moncaster who divide the built environment on three scales, namely, micro (building materials), meso (buildings), and macro (city) [9]. Utilizing this division, the topic of interest for this research, the existing individual buildings, would fall on the Meso scale. It should be noted that the third step removed further five articles from the list that were from the field of built environment, but utilized the term “circularity” in a different meaning. The systematic review process is depicted in Figure 1.
As anticipated, over half of the 78 articles discuss the use of salvaged or recycled building materials in new construction, or buildings as material banks, the practice often referred to as urban mining (e.g. [10]). Moreover, almost one quarter of the articles consider circularity on the city scale, leaning towards the disciplines of urban metabolism and industrial ecology (e.g. [11; 12; 13]). This identified research bias towards the recycling of buildings materials is in line the current bias in CE policies. The existing building scale was the focus of only 11 scientific articles. An additional category, ‘All BE scales’, includes articles discussing the built environment holistically, providing insight on all three aforementioned scales. This category comprised 3 articles. The following review is based on the articles from the latter two categories.

Findings
This research focuses on the individual building scale. The reviewed 14 articles relevant to the existing building scale are listed in Table 1. The table provides basic information about the article, along with the identified approaches to CE in the built environment.

| Author(s) and title | Year | Source | Approaches to Circular Economy in the Built Environment |
|---------------------|------|--------|--------------------------------------------------------|
| Pomponi F., Moncaster A.: Circular economy for the built environment: A research framework | 2017 | J. Clean. Prod. | Propose a research framework for CE in the BE, comprising of six dimensions including governmental (e.g. planning policy and trade), economic (new ownership and business models), environmental (lowering environmental impact), behavioural (attitude towards recycling), societal (partnerships and collaboration, education), and technological (enabling circular loops). |
| Leising E., Quist J., Bocken N.: Circular Economy in the building sector: Three cases and a collaboration tool | 2018 | J. Clean. Prod. | CE is a lifecycle approach that optimizes the buildings’ useful lifetime, integrating the end-of-life phase in the design and uses new ownership models where materials are only temporarily stored in the building. |

Table 1. Summary of articles with input for the Meso scale.
| Authors | Year | Journal | Title |
|---------|------|---------|-------|
| Ness D.A., Xing K. | 2017 | J. Ind. Ecol. | Toward a Resource-Efficient Built Environment: A Literature Review and Conceptual Model |
| Sanchez & Haas | 2018a | J. Clean. Prod. | A novel selective disassembly sequence planning method for adaptive reuse of buildings |
| Sanchez & Haas | 2018b | Constr. Econ. Manag. | Capital project planning for a circular economy |
| Mulrow et al. | 2017 | J. Ind. Ecol. | Industrial Symbiosis at the Facility Scale |
| Minunno et al. | 2018 | Buildings | Strategies for Applying the Circular Economy to Prefabricated Buildings |
| Nunez-Cacho et al. | 2018 | Sustain. | What Gets Measured, Gets Done: Development of a Circular Economy Measurement Scale for Building Industry |
| Geldermans et al. | 2019 | Sustain. | Circular and Flexible Infill Concepts: Integration of the Residential User Perspective |
| Eberhardt et al. | 2019 | Build. Res. Inf. | Life cycle assessment of a Danish Office Building |
| Fregonara et al. | 2017 | Buildings | Economic-Environmental Indicators to Support Investment Decisions |

Perspective is two-fold: 1) Reuse, refurbishment, adaptation/open building, maintenance, and management of existing assets to extend their useful life, coupled with provision of replaceable building parts as a service, and; 2) Sharing, co-location and synergies among assets/facilities through cooperation and synergies among the services and programs of various actors.

Perceives adaptive reuse as an essential strategy for supporting circular economy in the construction industry. Effective adaptive reuse offers means to exploit the residual lifecycle of the current building stock. Suggests selective disassembly of building components for repair, reuse, recycle, or refurbishment.

Describes CE in the BE as long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling. Suggests developing pre-project planning for closed-loop construction and planning for the optimization of the benefits of adaptive reuse.

Proposes three approaches for a facility scale industrial symbiosis: anchor manufacturer, project organizer, and business incubator.

Proposes seven strategies towards CE in buildings: reduction of production waste, use of by-products in the production, reuse of parts, design for adaptability, design for disassembly, design for recyclability, and use of technology to track components.

Perceives CE in the BE as the management of resources and the reduction of environmental impact by the construction industry. The implementation of CE in the BE should be evaluated through seven differently weighted dimensions: the 3Rs, efficient management of energy, water and materials, emissions, waste, and transition to CE in the industry.

Circular and flexible buildings have synergistic potential, and this so-called ‘Circ-Flex’ capacity has 11 criteria, including ease of disassembly, ease of re-assembly, ease of repurposing or disposing, user willingness to invest time and money, user perceived freedom of choice, ease of maintenance, ease of redistribution, ease of remanufacturing, ease of recycling, ease of facilitating bio-cascades and east of facilitating bio-feedstock.

Design for Disassembly (DfD) to extend the service life of building materials and elements through reuse and recycling, potentially reducing future resource consumption, waste generation and environmental impacts of future construction.

Creating value from construction and demolition waste by transforming the waste into resources. CE as a self-generative system that enables decoupling economic development from environmental impact.
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| Author(s)                     | Year | Journal                          | Title                                                                 |
|-------------------------------|------|----------------------------------|----------------------------------------------------------------------|
| Kyrö et al.                   | 2019 | Facilities                       | Relocatable and leased modular buildings as the representation of     |
|                               |      |                                  | circular economy in the built environment. The buildings are         |
|                               |      |                                  | adaptable, use existing structures, minimize resource and energy     |
|                               |      |                                  | use, close material loops and introduce a novel business models.     |
| Ghani et al.                  | 2017 | Manag. of Environ. Quality. Internat. Journal | Proposes an economic input-output lifecycle assessment model          |
|                               |      |                                  | to estimate the GHG emissions from buildings, in such a way          |
|                               |      |                                  | that includes supply chain emissions as well. Views CE in the       |
|                               |      |                                  | BE as a systematic understanding considering the principles of       |
|                               |      |                                  | circular economy.                                                  |
| Hossain & Ng                  | 2018 | J. Clean. Prod                   | Suggests integrating the CE concept to building lifecycle            |
|                               |      |                                  | assessment, focusing on resource recovery and resource-efficient      |
|                               |      |                                  | construction activities. Further suggests introducing the            |
|                               |      |                                  | cradle-to-cradle approach to LCA and integrating close-looped        |
|                               |      |                                  | recycling systems and introducing recycling rates as                 |
|                               |      |                                  | sustainability performance indicators.                               |

Next, the approaches identified in the articles are categorized using the so-called RESOLVE framework by Ellen McArthur Foundation: Regenerate, Share, Optimise, Loop, Virtualise, Exchange [2]. An adaption of the RESOLVE particularly for the built environment is outlined in [4], and is utilized here.

*Regenerate* refers to the regeneration of natural habitat outside buildings. No articles discussing this aspect of the circular economy were identified. However, it should be noted that the articles discussing CE on the city scale, where this aspect is likely to be relevant, were excluded from the review.

*Share* refers to sharing of spaces and other assets. This element cements the connection between the sharing and circular economics. Out of the reviewed articles, Ness & Xing (2017), emphasizes shared space uses and co-location synergies as a way toward circular economy in the built environment [14]. The facility level industrial symbiosis “Facility-IS” concept, as presented by Mulrow, Derrible, Ashton, & Chopra (2017), also includes the element of sharing. Facility-IS entails the sharing of material, knowledge, and services such as meeting rooms or cafeterias, between co-located businesses within a single facility [15].

*Optimize* refers to building adaptation. Although not widely discussed in the reviewed articles, Sanchez & Haas [16; 17] pinpoint adaptive reuse as an important CE strategy. Furthermore, Ness & Yin (2017) include reuse and adaptation strategies as well as the management of existing assets to their extended useful life in their approach to CE in the built environment [14].

*Loop* refers to the closing of building material loops, namely, the recycling of building materials. Many articles describe CE generally as the closing of material loops. The overwhelming majority of the reviewed papers share this approach, discussing issues like storing materials temporarily in building, Design for Disassembly (DFD), integrating end-of-life to design, extending the service-life of building materials, circular flows of building materials or recycling of building materials [9; 18; 19; 20; 21]. Moreover, some articles view CE simply as an extension to LCA assessments [22; 23; 24].

*Virtualize* refers to exploiting technology in the real estate and construction industry. Minunno et al., (2018) suggest the use of tracking technologies to promote the reusing and recycling of building components [25]. Pomponi and Mancaster (2017) include technology as a sixth dimension of circular economy, and also discuss the connection between circular and sharing economies [9]. Online solutions have been identified as a key feature of the sharing economy [26].

*Exchange* in Arup’s 2016 framework refers to exchanging old, often fossil-based solutions for green alternatives. However, this study adapts a wider interpretation of the element, including all exchanges for a novel business model. Pomponi & Mancaster (2017) generally discuss the economic dimension of CE, which would entail establishing new types of value creation mechanisms for businesses [9]. Two
examples of innovative value creation were found in the literature, that of relocatable, leasable building modules [27], and that of replaceable parts as a service [14]. In summary, the most commonly identified features from the literature relate to closing the material loops and designing for the future. However, these approaches are mostly relevant for new construction, not existing buildings. The approaches identified as most relevant for existing buildings comprise Share, Optimise, Virtualize, and Exchange.

Sharing of spaces carries with it both technological and cultural prerequisites, and a paradigm shift from ownership to access. As online solutions are typically present in sharing economy solutions [26], and for the purposes of the focused framework, ‘Virtualize’ is emerged into sharing. Meanwhile, in order to emphasize the importance of optimising the useful life of buildings, the ‘Optimise’ category is further divided into two: Preserving and Adapting. The first category relates to the ongoing maintenance of buildings while the second one is related to more intrusive changes in order to maintain functionality and optimise use. These two elements are more technical, and related to a required paradigm shift from producing new to maintaining old. Finally, in order to expand the idea to better reflect the general CE principles, the ‘Exchange’ category is renamed Rethink. This category comprises all novel circular business models, which challenge the existing paradigm of ownership and new production. A focused framework for circular economy for the real estate sector is presented in Figure 2.

![Figure 2. Suggested framework for CE in the real estate sector.](image)

**Discussion**

This paper set out to define CE for the purposes of the RE sector. In order to achieve sustainable real estate, there is a need for a CE framework particularly is the context of existing buildings. As anticipated based on Pomponi & Moncaster (2017) [9] and confirmed by the literature review, so far the focus has mostly been on the design and construction of new buildings. Over half of the 78 articles discuss the use of salvaged or recycled building materials in new construction, which has also been the focus of public debate and policy. Interestingly, even the articles selected for the final review, with apparent focus on the individual building level, view existing buildings as material banks, and focus on the so-called cradle-to-cradle design practices rather than optimizing the use of existing buildings. This narrows down the CE principles to closing of material loops in future construction, and the recycling of building materials. While those principles are certainly relevant, they are only one aspect of the CE, as defined in e.g. [2]. The new construction and building material focused approach also goes against the commonly accepted waste hierarchy of ‘Reduce, Reuse, Recycle’. This misinterpretation of the CE principles is not specific to the real estate and construction industry. Elsewhere, too, CE policy has received criticism for focusing too much on the recycling activities, rather than supporting reducing and reusing (Ranta et al. 2018). Based on the review, it can be argued that the existing focus of CE within the built environment, does not comply with the basic CE principles. Moreover, focusing on new construction is ineffective, as the building stock in developed nations renews itself slowly. Much more focus should be placed on optimizing the use of existing buildings, and approaches such as sustainable adaptive reuse (e.g. [28]). In addition to reuse, the role of the sharing economy in the transition to a CE in the built environment should be emphasized, as it is said to have the most potential [4] (Arup 2016). Sharing
should include both value co-creation potential between different actors, and the use of technology in the solutions [26].

Fortunately, the viewpoint of existing buildings is not completely missing from the reviewed articles. Ness and Xin give a comprehensive view to circular economy approaches relating to existing buildings [14]. Furthermore, Sanchez and Haas implicitly make the connection between adaptive reuse and circular economy, and recognize the need for a paradigm shift away from new construction in the industry [17]. Kyro et al. likewise make the connection between adaptability and circularity [27]. Another paradigm shift, from access to ownership, which further relates to the idea of synergies and co-location [14; 15], is included in [9] and [27].

The findings contribute on the existing body of knowledge on circular economy on the one hand, and real estate management on the other. The proposed framework allows researchers to expand their thinking on circular economy, beyond building material banks for the construction industry, to alternatives focused on optimising the use of existing buildings, whether by preserving of building material, also in the context of the built environment.

Conclusions
CE, also in the context of the built environment, has peaked in both scientific and popular discourse since 2016. Nonetheless, policy, practice, and research have continuously focused on the scale of building materials, and on the design of new construction to enable circular solutions in the future. Notwithstanding, the time to act and reduce climate impact is now. The focus on new construction is contradictory to the waste hierarchy, as well as to some of the basic CE principles. This study provides an adapted, literature-based framework focused on existing buildings. The focused framework emphasizes sharing to reduce space needs and achieve synergies, optimization both in preserving what is already made and adapting to new uses, as well as rethinking the business.

Based on the findings, despite recent advancements in literature, much more research is needed about the transition to a circular economy on the scale of existing buildings. Future research by the author will test real-life cases against the developed framework. The case studies employ different strategies that align with the principles of circular economy, and the aim is to go beyond the research realm and provide managers a selection of concrete strategies to employ.

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