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Circular economy in buildings

Ieva Andriulaitytė[1] (*orcid id: 0000-0001-8097-2982*)
Marina Valentukeviciene[1] (*orcid id: 0000-0001-8097-2982*)
[1] Vilnius Gediminas Technical University

Abstract: The circular economy is not only a system of waste management. It is a system which includes the products' design construction, recycling of raw materials and whose aim is that all components and materials bring added value in different technical and biological cycles. The construction sector is currently among the world's largest producers of waste. It is estimated that about 1.3 billion tons of construction and demolition waste is generated every year and half of it comes from the construction sector. The building industry has a significant impact on many sectors of the economy, on local jobs and quality of life. It requires vast amounts of resources and accounts for about 50% of all extracted material. According to experts, the amount of waste in the construction sector is the same or even higher than the amount of municipal waste. At the same time, the stream of construction waste makes up the biggest part of industrial waste. Currently, more than at any time before, there is a crucial need for new circular solutions, especially in the building sector. Therefore circular economy principles have a huge potential to contribute to reducing waste and to increased reuse of materials in buildings.

Keywords: circular economy, buildings, waste, constructions, built environment

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Introduction

The construction industry significantly contributes to the EU economy: the sector provides about 18 million jobs and contributes to about 9% of the EU's GDP. It also creates new jobs, promotes economic growth, provides solutions for social, climate and energy challenges. It is estimated that the construction sector is responsible for over 35% of the EU's total waste generation (Eurostat, 2016). Greenhouse gas emissions from material extraction, manufacturing of construction products, construction and renovation of buildings are estimated at 5-12% of total national GHG emissions (www.boverket.se). According the experts, greater material efficiency could save 80% of those emissions (Hertwich et al., 2020).

Currently, more than at any time before, there is a need to apply circular economy and resource efficiency principles to buildings to reduce future resource use. The Circular Economy (CE) stands out as an example that aims to reach sustainable development goals by preserving natural capital and generating economic value. Circular buildings may produce wide ranging forms of value: they impact positively on materials, energy, waste, health and wellbeing, etc. CE implementation in buildings remains a fresh approach. There are different tools available to assess sustainability in buildings. The aim of this analysis is to present and compare circularity assessment models to measure buildings' CE.

1. Circular economy in built environment

Circular economy (CE) is a systemic approach to economic development designed to benefit businesses, society, and the environment. Contrary to the 'take-make-waste' linear model, a circular economy is regenerative by design and aims also to gradually separate growth from the consumption of finite resources. In a report published by the Ellen MacArthur Foundation (*Growth Within: A Circular Economy Vision for a Competitive Europe 2015*), the concept rests on three core principles:

- Preserve and enhance natural capital.
- Optimise resource yields.
- Minimise system risks and improve its effectiveness.

In a circular economy, the aim is to maximise the utility of the existing infrastructure across the product value-chain, hence waste from one system can be used as input into another system. A circular approach can help minimise the environmental footprint of the built environment sector, potentially reducing lifecycle costs, and avoiding construction delays due to the volatility of commodity markets in procuring virgin materials. Compared with other sectors, buildings do not typically operate on a take-make-dispose system. Creating CE in the built environment is one of today's biggest social challenges. However, the main principle of CE is to make the optimal use of the inner processes such as 'maintain', 'reuse' and 'remanufacture', and in this way prevent waste.

The EU Action Plan for the circular economy, launched in December 2015, outlined a set of specific actions, and generic obstacles to support the EU's transition to a circular economy. The EU's call for all new buildings to be nearly zero-energy by the end of 2020 implies complete enforcement of the Energy Performance Building Directive as a key tool to apply the circular economy in the built environment's energy consumption. The built environment sector is very complex with multiple stakeholders, long lead times, massive investments and capital risks. A circular built environment embeds the principles of a circular economy across all its functions, establishing an urban system that is regenerative, accessible and different by design. The adaptation of the circular economy principles to the built environment would support a growing construction's sector, which is resilient to variable prices of raw materials, maintains essential natural ecosystem services and creates urban areas that are more liveable and convenient. It is the sector which also produces the largest and longer-lived products. Therefore it is important to note that the forms and constructs of buildings, infrastructure, districts and cities have the capacity to shape how the circularity in every other part of the economy has been achieved. The design principles for circular building aim to make conscious decisions regarding several aspects of circularity. They all have a focus on different areas and should be used in combination when designing a building. However there is still a lack of research on the implementation of the CE into the construction industry.

2. Circular buildings

What is a circular building? „It is a building that is developed, used and reused without unnecessary resource depletion, environmental pollution or ecosystem degradation. It is constructed in an economically responsible way and contributes to the wellbeing of people and the biosphere" (urbact.eu).

Buildings consist of many components which can be replaced by circular components during maintenance and renovation, leading to a bottom-up implementation of a circular economy in the built environment. New developments and innovations take place at a rapid pace and there are more and more conceivable options in the field of circularity.

Given the limitations of green and sustainable buildings, which mainly focus on design, use of life-stages of the buildings and concentrate on end-of-life scenarios, Circular Buildings have arisen and been put forth as a more holistic approach to CE in the built environment. Academia and non-governmental institutions promote the reliability and efficiency of Circular Buildings to ensure a better transition towards CE. Six factors were described as relevant to Circular Buildings: Environment, Technology, Economics, Society, Government, and Behaviour.

3. How to measure circularity?

For the circular economy to become a success, a simple measure of achievement is necessary as a first step towards fully integrated reporting. Seeking to summarise different aspects of the application of circular economy at a building level it is necessary to set the indicators to measure building circularity. CE indicators are classified into three measurement types (www.sciencedirect.com):

– Direct CE with Specific Strategies: indicators can focus on one or more identifiable CE strategies, e.g. Recycling Rate.

- Direct CE with Non-specific Strategies: indicators always focus on more than one strategy, and it is not possible to recognise the explicit strategies, e.g. water withdrawal.
- Indirect CE: indicators may evaluate aspects of CE strategies but with the use of additional approaches to assess CE, e.g. the indicator 'Eco-innovation index.

A couple studies have been conducted towards measuring circularity in the building sector. The Ellen MacArthur Foundation developed an approach to measure material circularity (Ellen MacArthur Foundation & Granta Design, 2015). This measurement tool is focused on all material usage in the world. The circular measurement method should incorporate the principles for a circular economy to guide the circular economy concept (Ellen MacArthur Foundation, 2013). The Building Circularity Indicator assessment model is developed specifically for the construction sector and identified the KPI's for circular economy in the built environment (Verberne, 2016). This model has been developed at the University of Technology Eindhoven. The Building Circularity Indicator is a step towards being able to measure how well the principles of the circular economy are implemented in a building project. It is important to note that this model limits itself to technical factors and not the underlying process.

The Building Circularity Indicator (BCI) is an assessment model that aims to capture the circularity potential of building developments. It provides guidance during the decision making process to make concrete the circular ambitions of different stakeholders (Verberne, 2016). The BCI is based on Key Performance Indicators (KPI's). These KPI's are structured as technical requirements, preconditions and Drivers (Verberne, 2016). Disassembly is one of the two major KPI's in the BCI assessment model and is an important factor to enable material reutilization.

The Building Circularity Indicator (BCI) assessment model aims to measure the circular potential of a building in which disassembly potentials plays a big role. This research aims to redevelop the method for assessing disassembly potential in the BCI assessment model. The BCI is calculated in four steps starting by calculating the Material Circularity Indicator (MCI), then the Product Circularity Indicator (PCI), then the System Circularity Indicator (SCI) and lastly the Building Circularity Indicator (BCI):

- **The Material Circularity Indicator (MCI)** is calculated with the percentage of material input (virgin/non-virgin), the material output (energy recovery/landfill) and the technical lifecycle. This represents the theoretical circular potential of each product. A Bill of Materials (BOM) is used as input to calculate the MCI of every product (Verberne, 2016). The MCI represents fifty percent of the circular potential of products.
- **The Product Circularity Indicator (PCI)** is calculated with the MCI and the disassembly possibilities of each product. The disassembly possibilities of products are assessed with seven Disassembly Determining Factors (DDF's) adopted from the Transformation Capacity model (van Vliet, 2018). Seven DDF's are selected to keep the BCI model evident to assess the disassembly possibilities (Verberne, 2016). All disassembly factors are weighted equally im-

portant in the assessment model. The BOM is used to determine the disassembly score for each factor (Verberne, 2016). The score of each disassembly factor for each product is estimated. The disassembly possibility represents the other fifty percent of the circular potential of products.

- **The System Circularity Indicator (SCI)** is an aggregation of all MCIp (theoretical) and PCIp (practical) towards a systematic value (Verberne, 2016). The PCI's are categorized according to the different layers of Brand (van Vliet, 2018) resulting in a value for the System Circularity Indicators (SCI) for each layer.
- Normalized factors are used to determine a weighted average of each product towards the SCI. The factor mass is chosen. This factor is disputable and other proposals are also arguable like sales revenue, number of materials, volume, etc. (Verberne, 2016). Alba Concepts disregarded the SCI and adopted the Element Circularity Indicator (ECI).
- **The Building Circularity Indicator (BCI)** functions to aggregate all results into one score corrected by the level of importance. The level of importance is based on the layers of Brand (Brand, 1994) because products with a shorter lifetime are considered more important to be circular than products with a longer lifetime (Verberne, 2016). The BCI determines the overall performance of a building according to circular potential and can be used to compare the circular potential of buildings with each other.

The general importance of the Building Circularity Assessment was evaluated according to all important indicators of a 5 years evolution process in the EU construction sector (Fig. 1).

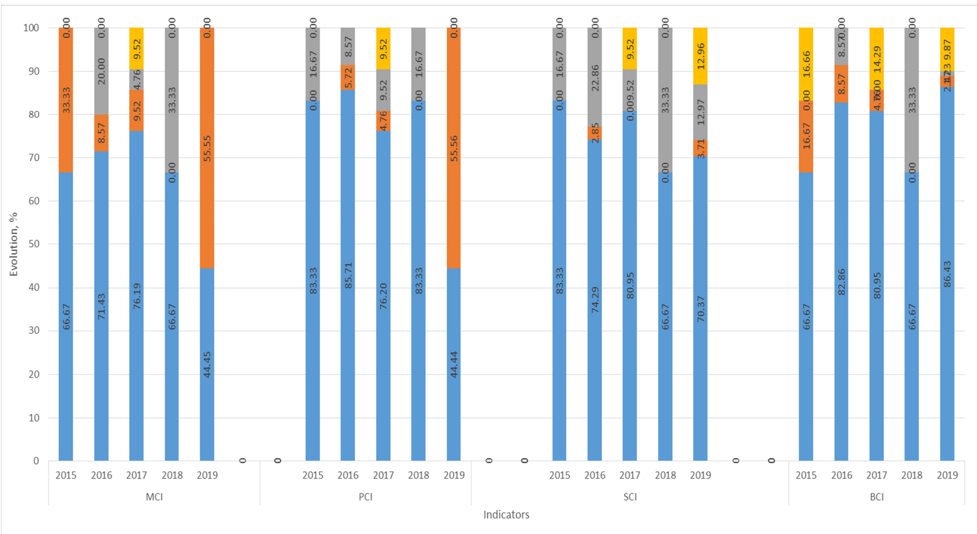

Fig. 1. The Building Circularity Assessment according to MCI, PCI, SCI, BCI indicators of 5 years evolution process on EU construction sector (Verberne, 2016)

The highest importance for the circularity indicators are presented in blue colours; the partial importance assessment is in greyscale; yellow represents neutral positions of circularity assessment and orange shows the negative assessments.

Conclusions

The circular economy is not only a system of waste management. It is a system which includes product design production, recycling of raw materials and whose aim is that all components and materials would bring added value in different technical and biological cycles.

The circular economy consists of three aspects: the ecological cycle, the economy model and the technological cycle. The goal of the technological cycle is to iterate (building) materials through the economy with different feedback elements. Because buildings are nowadays complex entities of interconnected materials, the ability to disassemble materials plays an important role in enabling material reutilization and as well as the circular economy.

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The EU Action Plan for the circular economy, launched in December 2015, outlined a set of specific actions, and generic obstacles to support the EU's transition to a circular economy. The EU's call for all new buildings to be nearly zero-energy by the end of 2020 implies complete enforcement of the Energy Performance Building Directive as a key tool to apply circular economy in the built environment's energy consumption.

For the circular economy to become a success, a simple measure of achievement is necessary as a first step towards fully integrated reporting. Seeking to summarise different aspects of the application circular economy at a building level it is necessary to set the indicators to measure building circularity.

Bibliography

Ellen MacArthur Foundation https://www.ellenmacarthurfoundation.org/

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0098

Eurostat data for 2016.

Hertwich, E., Lifset, R., Pauliuk, S., Heeren, N., IRP, (2020), *Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future*.

https://www.boverket.se/sv/byggande/hallbart-byggande-och-forvaltning/miljoindikatorer---aktuell status/vaxthusgaser/

https://urbact.eu/transition-circular-economy-%E2%80%98%E2%80%99power%E2%80%99%E2%80%99-building-sector-towards-better-cities

https://www.sciencedirect.com/science/article/pii/S092134491930151X

Verberne, J.J.H. (2016) *Building Circularity Indicators*. Eindhoven University of Technology.

van Vliet M. (2018) *Disassembling the Steps Towards Building Circularity Redeveloping the Building Disassembly Assessment Method in the Building Circularity Indicator.*