Circular-economy in the Built Environment

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The circular economy in the building sector is an approach aiming at minimizing waste and emissions, as well as closing water, energy, and material loops. Under a circular built environment, landfilling is no longer an option to handle construction and demolition waste, and design for disassembly has a central role. Design for disassembly is a concept in which buildings and products are designed intentionally for material recovery, value retention, and meaningful next use.

Keywords: circular built environment ; sustainability ; design for dissasembly ; decarbonization ; reciclability ; Construction and Demolition Waste Management ; Low environmental-impact materials ; energy efficiency ; users energy performance

1. Circular economy, decarbonization and sustainability of the built environment. European context and definitions.

The European Union (EU) is committed to establish an sustainable, competitive, secure and decarbonized energy system [1] in which buildings have a capital importance for the energy efficiency policy of the EU. The building sector is one of the most resource consuming sectors in Europe as it represents around 36% of greenhouse emissions, 40% of the final energy consumption, 50% of extracted materials, 30-50% material resource use, 21% of total water abstracted and is responsible for over 35% of the EU's total waste generation with very significant life cycle impacts, particularly associated with extraction and processing stages [1][2][3][4][5][6].

The recently approved European Green Deal [2] boosts the efficient use of resources in order to get a clean and circular economy. In the building sector, this objective implies reducing life cycle impact at the same time as providing healthy and comfortable spaces [4] by reducing whole life carbon consumption, increasing reused and recycled content and a sustainable management of construction and demolition waste, getting what is called as circular buildings. This term is used to define a building that is designed, planned, built, operated, maintained, and deconstructed in a manner consistent with circular economy principles [7].

Decarbonization means a decrease in the specific amount of carbon (or CO_2) emitted per unit of primary energy consumed. In the building sector, decarbonization can be achieved through the energy efficiency measures focused on reducing the energy demand, reducing the energy consumption and increasing the use of low-carbon technologies, such as renewable energy sources. Decarbonization in the building sector involves the materiality of the built environment throughout their whole life cycle, users' energy habits and the performance and efficiency of the building and neighbourhood systems [4].

A circular economy is one "that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value at all times'" [8]. In a circular economy waste and resource use are minimised, and when a product reaches the end of its life, it is used again to create further value [9]. In the building sector, the circular economy is applied by closing water, energy and material loops, so design for disassembly has a central role as promotes buildings and construction materials and products to be intentionally designed for material recovery, value retention and meaningful next use [7][10].

In this context, the new Circular Economy Action Plan [5] promotes circularity principles throughout the lifecycle of buildings in order to increase the material efficiency and reduce the climate impacts. These goals are aligned to the 'Renovation Wave' initiative [11] as around 60% of the current EU's buildings were built under limited or non-existent energy efficiency requirements [12][13] so they require a partial or total refurbishment in order to fulfil the EU's Energy Efficiency objectives for 2050 [12][14]. Furthermore, the current inefficient building stock is in the base of the energy poverty that suffers around 50 million of Europeans [2] which also affects to their comfort, sanitary and living conditions.

'Sustainability' and 'circular economy' have received increasing attention in the last decade, although these concepts were introduced in the mid-20th century. However, despite the several definitions or descriptions they have received, the similarities and differences between both concepts remain ambiguous [15][16]. Both concepts are based on the

environmental awareness but how they relate to each other remains unclear or not addressed at all, blurring their conceptual contours. Anastasiades et al. [16] expose a definition for they call a “Moderate sustainability”. This definition implies a combination of technological advances to solve environmental problems and of users’ habits to reduce the demand from nature. However, the circular economy also acknowledges the fact that user behaviour will need to change and the incorporation of technological advances in order to close the material, energy and water flows. Thus, as Anastasiades et al. state “sustainability is the goal, while the circular economy is a means to achieve a more sustainable economy” [16].

Under the framework of the new Circular Economy Action Plan [5] the Commission will launch a new comprehensive Strategy for a Sustainable Built Environment that will promote circularity principles throughout the lifecycle of buildings in order to increase the material efficiency and reduce the climate impacts. This strategy will promote the sustainable performance of construction products, the durability and adaptability of built assets, the decarbonisation of the materials and energy resources of the building stock, the recovery of materials and a sustainable use of excavated soils. In this context, circularity and sustainability need to be assessed over the whole life cycle of the building to optimise reduction of carbon emissions and material flows [4].

The transition to a low carbon, circular economy will have far reaching social and economic impacts. Europeans spend approximately 90% of their time in indoor spaces [17][18]. Indoor environmental quality (indoor air quality, thermal comfort, luminous comfort and acoustic comfort) plays a significant role in human health, wellbeing and productivity [17][19][20][21]; this has been specially highlighted because of the COVID-19 pandemic. The transition should eliminate energy poverty, ensuring adequate warmth, cooling, lighting and the energy to power appliances for guaranteeing health and a decent standard of living for all [22]. Furthermore, users are also participants on the sustainability of the building stock and the built environment, and they have an important role so tools are needed to transmit, in an understandable manner, how their decisions related to buildings can be sustainable. Additionally, the participatory dimension not only has an influence on the built ownership; it can go beyond and be applied to the urban regeneration actions and projects.

Closing energy loop

The final energy consumption of buildings is mainly dedicated for heating and cooling, so their decarbonisation is fundamental [1][2][12][14][23]. The energy efficiency requirements for buildings have been gradually increased towards nearly Zero Energy Buildings (nZEB) [1], expressed in the European Directives [24][25][26], for new [27] and existing buildings in order to get in 2050 a decarbonised building stock, so existing buildings must also move towards nZEB [12][14].

Nowadays, two thirds of the EU's buildings were built when energy efficiency requirements were limited or non-existent and around 70% of the buildings that we will occupy in 2050 are already built [12][13]. 97% of the existing buildings built before 2010 require a partial or total refurbishment in order to fulfil the objectives for 2050. Following the goal “Putting energy efficiency first” [3] implies to admit that the most cheap and clean energy is the energy that does not need to be produced or used [1][26][27]. Added to this is the fact that 50 million of Europeans live in energy poverty conditions, due to the effort of paying high energy bills in order to keep their inefficient homes comfortable [2].

Energy consumption during the use phase of the building is covered by various EU regulations, but looking throughout the whole life of the building, the energy used in the manufacture of construction product and during the construction process of the building has also an important role. 5-10% of total energy consumption in EU is related to the manufacture of construction products [28]. 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 [5]. Greater material efficiency could save 80% of those emissions.

Closing material loop

The construction sector has large potential for circular economy given the scale of material use, value contained in buildings, labour intensiveness and long-term effect of measures [4]. The material requirement of buildings currently represents one of the greatest resource use challenges in terms of mass of resources used [6]. It mainly consists of iron, aluminium, copper, clay, sand, gravel, limestone, wood and building stone. Minerals have the highest share of all materials in buildings. Around 65% of total aggregates (sand, gravel and crushed rock) and approximately 20% of total metals are used by the construction sector. Data and information collected on use of construction materials suggests that concrete, aggregate materials (sand, gravel and crushed stone) and bricks make up to the 90% (by weight) of all materials used [6].

Construction & Demolition Waste (CDW), when measured in volume, is the largest waste stream in the EU. Even though a vast majority of CDW is recyclable, one common hurdle to recycling and re-using C&D waste in the EU is the lack of confidence in the quality of C&D recycled materials [29].

A building and construction sector that optimises the use of resources and results in zero waste to landfill is the level of ambition the sector must achieve. This can only be achieved by keeping materials and resources in use as long as possible. The measures are based on incorporating recycled content and reducing resource waste in the manufacturing process of construction products; designing and carefully planning the interventions in order to minimise the use of new materials, select environmental-friendly construction products and choose the most energy efficient proposal; and establishing an adequate construction and demolition waste management in order to recover materials of such quality that can be reincorporated as recycled or re-used materials [28][30][31][32].

The recycling or reuse of materials or even whole products is increasingly important as a means to improve the efficient use of materials and to avoid negative impacts associated with virgin material [28]. Furthermore, the European Strategy for a Sustainable Built Environment, which will be released in 2021, will introduce requirements for recycled content and waste reduction measures in construction products and materials so it will contribute to preventing a mismatch between supply and demand of secondary raw materials and ensure the smooth expansion of the recycling sector in the EU [5] as improved recycling could reduce GHGs by 14-18% in 2050 in the G7 [32]. As part of the revision of the recovery targets for construction and demolition waste, the Commission will pay special attention to insulation materials, which generate a growing waste stream [5].

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