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Regeneration of the Built Environment from a Circular Economy Perspective

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Circular Economy and Regeneration of Building Stock: Policy Improvements, Stakeholder Networking and Life Cycle Tools

Serena Giorgi, Monica Lavagna and Andrea Campioli

Abstract This chapter shows the results of a study carried out on the application of circular economy principles throughout the building stock regeneration process, highlighting the challenges, the opportunities and several key themes for future research. The methodology of research is based on a literature review and on-field investigation through direct interviews with operators and stakeholders of the building value chain, on a European level. At first, the chapter shows the importance of applying the circular economy concept to the built environment and the crucial role of the building level. After that, the chapter looks into the parallel issue of the current necessity to renovate a large part of existing buildings. Consequently, the opportunities and the challenges in linking the circular economy to building stock regeneration are discussed. Secondly, the chapter identifies the strategies to support the transition towards a sustainable circular building regeneration process, identifying the policy improvements necessary to promote circular strategies during the building process, the strategic partnership useful to activate profitable and sustainable circular business, and the environmental and economic life-cycle assessment tools for supporting decisions and for verifying that the implementation of circular strategies is actually sustainable from an economic and environmental life cycle point of view.

Keywords Life cycle sustainability · Stakeholders · Building process · CDW management · Business models

1 Introduction

«*Anyone who believes that exponential growth can go on forever in a finite world is either a madman or an economist*» said K. Boulding in 1966 (Boulding 1966), in order to introduce a necessary change in the relationship between economy and

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environment. After Boulding, many others (Georgescu-Roegen; Costanza; Daly; Commoner) have discussed this connection, gradually influencing the policy framework. The argument is still open and all economic sectors are still working to find a solution to decouple economic growth from its environmental impacts (UNEP 2011). Since 2014, European policies have promoted, as part of green economy objectives, the transition towards a circular economy, which focuses on the importance of activating virtuous strategies such as reuse and recycling in order to reduce the quantity of raw materials extracted, and reduce the quantity of waste (European Commission 2014, 2015).

The construction sector is identified as a 'priority area' to transform the current linear economy towards a circular economy. In fact, the construction sector is the main sector that produces waste, representing 33.5% of the total waste generated by all economic activities (Eurostat 2016), and one of the main causes of resource consumption. Moreover, the construction sector is crucial because it provides 18 million direct jobs and contributes to about 9% of the EU's GDP (European Commission 2018). Thus, current studies are looking for solutions to apply the circular economy concept to the built environment.

At the same time, the necessary regeneration of European building stock represents a challenge that can also be an important opportunity to apply circular economy to the built environment. The renovation of buildings could be a favourable circumstance to change the decision-making process, promoting the maintenance and life prolongation of existing buildings, and to change the material/waste flows, promoting the conservation of resources through reuse and recycling. In order to activate an actually sustainable circular economy, it is fundamental to assess the sustainability of the new practices towards circularity, within a life cycle perspective. Therefore, the introduction of life cycle tools to verify the level of sustainability during the building process is, now more than ever, crucial: if the building process has to change to achieve a circular process, it is important to change it in an effective and sustainable way.

There are a lot of challenges, especially because buildings are complex systems in a continuous state of change: they are constituted by various elements, with different lifespan and functions, and the building process involves a lot of stakeholders (Fig. 1).

2 The Circular Economy in the Built Environment

The holistic concept of circular economy in the built environment can be declined at three levels. According to Pomponi and Moncaster (2017): on a macro-level, regarding a system of cities or urban agglomerates, on a meso-level, which considers the buildings' scale, and on a micro-level, focusing on the material dimension.

The *macro-level* is discussed by many studies (e.g. Prendeville et al. 2018) which apply the circular economy principle on an urban level through the 'urban mining approach', considering the systemic management of anthropogenic resources stocked

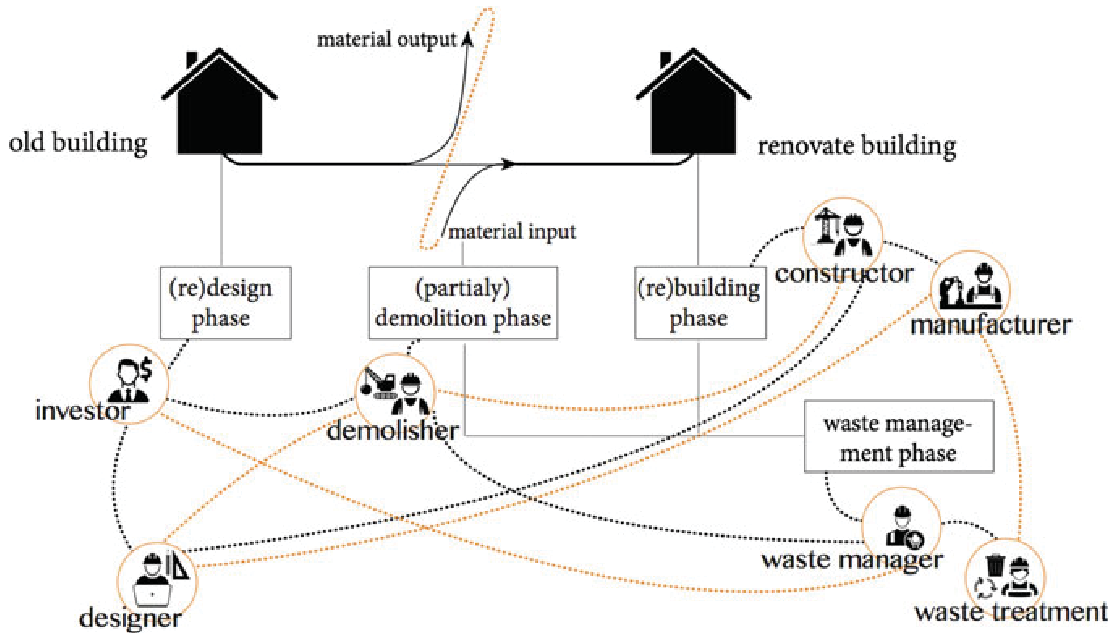

Fig. 1 Changing the building renovation process and stakeholders' relationships towards a circular building renovation process. The orange lines represent the links that have to be enabled in a circular building process

in the urban site, such as materials, waste, water and energy flows. The micro-level is also discussed in a significant number of studies (e.g. Smol et al. 2015), particularly when it comes to considering the exchange of by-products and waste between different industrial sectors (industrial symbiosis) in order to produce new products with recycled components (e.g. to use ash and sludge from purification processes for producing construction products). Hence, the *micro-level* is linked with an intersectoral approach based on the concept of the eco-industrial park and industrial ecology developed in the early Nineties.

The application of the circular economy on a *meso-level* (Pomponi and Moncaster 2017) is yet to be investigated in depth. There are studies (e.g. Cheshire 2016; Geldermans 2016) that give an impulse to the application of circular economy principles at the building level, considering 'buildings as material banks'. In general, there are a number of principles which strongly characterize the circular economy at the building level. These principles are classifiable in three main groups: design process aimed at adaptability and reversibility; resource/waste management aimed at reuse and recycling; business models aimed at extending life and value of products while also changing the concept of ownership. Waste prevention through the extension of the building life, product durability, maintenance, repair, reuse, must be the first goal for an efficient and effective use of resources.

Therefore, research about the circular economy at the building level is fundamental because of the lack of studies in comparison to the micro and macro levels, and because it is a link between these other two levels: circular requirements (e.g. exchange and use of reused/recycled materials) at building level can activate circular practices on an urban level and with regards to materials' composition. To do this, it is important to understand how the entire current building process (the design process, the construction process, the management process and the demolition process) has to change, within practices and relationships, towards a circular building process. It is necessary to involve all stakeholders in the research, in order to understand their relationships, their needs, their requirements and the decision-making steps. It is necessity to rethink the building according to a life cycle approach, considering the environmental impact at every stage of the life cycle: extraction of raw materials, manufacturing, transportation, construction, use, maintenance, recycling and disposal at the end of life.

The prospect requires an improvement in knowledge, skills and relationships between the member of the supply chain, and the inclusion, from the early design stage, of new operators (Campioli et al. 2018).

3 Opportunities and Challenges in Building Stock Regeneration

The European Commission proposed, in 2012, an action plan called 'Construction 2020', in order to assign a number of challenges to the construction sector to be completed by 2020. This action plan (European Commission 2012) highlights the great potential of the renovation of existing buildings and infrastructure maintenance to achieve the later objectives for 2050, with regards to decarbonization and resource conservation. In fact, the European building stock is in particular need of renovation: 50% of residential building stock (which represents 76% of the entire building stock) was built before the 1970 when the energy efficiency regulation did not exist. Only 19% of residential buildings were built after 1990, hence, after the EPBD 2002/91 and the following EPBD 2010/31 (Lavagna et al. 2018).

European policies have introduced more attention on land use, identifying soil sealing as one of the main causes of soil degradation (European Commission 2006). Over the last decade, attention on soil conservation led to the avoidance of the urban sprawl phenomenon, and to the possibility of building on green-field decreased. Consequently, the regeneration intervention of brown-field increased, in order to preserve the soil. In Italy, in 2015, CRESME shows the increase of renovation of existing buildings (+3.5%) in comparison with the new construction buildings (+1.6%).

This context proposes an interesting trial field for the application of circular economy principles. The circular economy approach can limit waste landfills and avoid extraction of raw materials, giving more value to the existing building and avoiding demolition waste increasing the longevity of buildings' subsystems and elements. It is possible to open a new cycle for the unavoidable waste generated by demolition parts of buildings as secondary resources within the construction sector to produce new materials aiming at upcycling. During the renovation process, the construction of new parts for the existing building can be designed and completed with disassembly solutions, using materials that are reusable and recyclable, without toxic or hazardous materials. Moreover, in this perspective construction techniques can also be improved, avoiding the construction waste caused by incorrect operation (e.g. design error, site operation, materials scraps) which can be avoided with a BIM design, which enhances communication, increases efficiency and reduces errors (Osmani 2011).

Despite these opportunities, there are also a number of challenges to address, because in the building process the circular strategies are hardly applied on heterogeneous and long processes with dynamic relationships of different operators related to each other in a discontinuous manner.

Currently, the transition towards a sustainable circular renovation of building stock is still thwarted by political and economic barriers along with a lack of awareness. In the next paragraph, the study illustrates the main obstacles to overcome and provides strategies to support the transition towards a sustainable circular regeneration, through the identification of: (i) policy improvement, (ii) strategic partnerships for circular networks, (iii) environmental and economic life-cycle assessment tools to support the decision-making process.

4 Strategies Towards a Sustainable Circular Building Regeneration Process

In order to identify the obstacles and strategies for the transition towards a circular economy, the study carried out an in-depth analysis, through interviews with stakeholders regarding the building renovation process: the current material and information flows, the relationships among the operators and stakeholders and the tools used during the process. This analysis is useful to understand the current practices, design and management choices when a building has to be regenerated, in order to identify the critical points and necessary changes.

4.1 Policy Improvements

After the publication of the 'European Construction 2020 strategy' and the other European communication which promotes circular economy in the construction sector (European Commission 2014, 2015), it is possible to say that the policies regarding circular economy at European and National levels, are mainly promoting actions that deal with the management of CDW, recycling activities and waste logistics. The other aspects of circular economy on a building level, such as design approach and circular business models, are not yet promoted by policies.

The ‘EU Construction and Demolition Waste Management Protocol’ (2016), and the ‘Guidelines for the waste audits before demolition and renovation works of buildings’ (2018) are the primary actions which are part of the Circular Economy Package presented by the European Commission in 2015. These initiatives act on the improvement of waste identification, through a better separation and collection, waste logistics, through better traceability of the waste stream, waste processing, through an efficient recycling process, and quality management, through the introduction of quality labelling and certification.

Analysing the current CDW management of European countries (Giorgi et al. 2018), the first obstacle to a sustainable waste flow management is the lack of a database for monitoring CDW quantities and the confusion regarding who should control and monitor waste management. In Italy, for example, the legislation (d.lgs.152/2006) provides several exemptions from the obligation to declare the quantity of waste generated by the construction and demolition process, as in the case of a medium-size building process. Consequently, the real-waste flow remains unknown. The lack of monitoring also concerns the extraction of materials: there is no official data available on the extraction of construction minerals (such as sand and gravel), even if the extraction of construction minerals represents a large share of total material extraction (UNEP 2016). Moreover, if the materials flow does not change, becoming more efficient and effective, the material consumption in the construction sector is expected to further increase in future (Fishman et al. 2016).

The Member States that present the highest level of CDW recovery, show the introduction of laws banning landfills (such as in Belgium and Netherlands) or high taxes on landfills (such as in the UK) (Resource Efficient Use of Mixed Wastes 2017). These measures have increased the recycling process, mainly through downcycling. Instead, within circular economy, it is important to activate upcycling and reuse processes; however, there are still barriers for the activation of such effective circular practices.

Through direct interviews with stakeholders of the building value chain (Giorgi et al. 2019) the obstacles of upcycling and reuse were successfully identified. The reason that thwarts the activation of a sustainable circular practice at the building level is the lack of expert operators able to disassemble, and of space to store the materials to be reused. These gaps lead to high costs in human labour and difficulties in logistics. However, the main obstacle concerns the legislative framework and responsibility. Nowadays, the legislative framework does not enable the certification of the quality and durability of a reused material, because there is a lack of data and knowledge of the history of the material itself. Consequently, even if it is possible to use reused/recycled materials, designers and constructor companies prefer to use new ones only, because they are responsible for the material quality used to build a building.

More ambitious legislation is necessary to promote the reuse/upcycling of materials. First of all, it is important to improve market demand for secondary materials, also for the construction industry, through the application of laws which ban the extraction of raw materials (e.g. to forbid the opening of new quarries). Secondly, public building renovation should be the exemplary intervention for introducing circular practices throughout the entire process; hence, the development of green public procurement with ambitious requirements (e.g. with regards to the reuse of building parts and elements, the reversible design approach and the use of recycled/recyclable materials) is necessary.

The introduction of economic incentives is fundamental to overcome the economic barriers: for instance, for building renovations that use reused/reusable materials or recycled/recyclable materials; which base the design phase on strategies for disassembly, using BIM tools and off-site construction technics to avoid construction waste; which use life cycle tools to assess the sustainability of the project solutions chosen. Finally, it is important to upgrade the sustainability rating system with new criteria useful for assessing the potential of the project with respect to the themes of a circular economy.

4.2 Relationships Throughout the Building Renovation Value Chain and Circular Business Models

Building renovation is accomplished via a long and complex process, conducted by a lot of operators with different roles and relationships. Sometimes operators are not in contact with one another and the information flow is interrupted during the process. Also, crucial decisions are made by different operators in different moments of the process: for example, the investor decides the type of intervention and the sustainability target to achieve; the designer can decide how to obtain the target, the materials and technical solution; the demolisher decides the demolition techniques (selective demolition or deconstruction); the demolition-yard organization and the management and destination of material/waste. This fragmentary process is one of the obstacles to an easy application of circular economy at the building level.

The analysis of relationships along the value chain shows that the value of materials stocked in the building is completely unknown by the investors; consequently, they are not interested to know the destination (landfill or recovery) of the materials deriving from a renovation process. Also, the designer, most of the time, during the building renovation design process, does not take into account the material quantity output in order to consider the possibility of reusing or recycling it. The pre-demolition audit could be an existing instrument useful to improve the cooperation and communication among designers, demolition companies and waste managers; however, this instrument is not commonly used. Improvement and specificity during the procedure are necessary in order to boost the instrument as a decision-making process and avoid demolition waste. Moreover, designers tie the difficulties in designing a reversible building to a lack of available easily disassembled products on the market. It is necessary to open up a dialogue between designers and producers in order to develop technological solutions to build a building based on a design for disassembly and adaptability.

In order to activate circular strategies, a change in relationships among the stakeholders of the building value chain, is necessary.

Consequently, it is very important to support the operators' network, in activating circularity during the building process, also by using BIM software, to improve the cooperation from the early stage of the process. Moreover, it is important to identify competences and new operators, in order to accomplish the disassembly and remanufacturing phase, to trace the material flows, to improve the collection and to exchange second-life materials, towards a reuse/remanufacturing materials value chain. At the same time, it is important to define the space to store and collect all material quantities (big or small) destined to a second-life.

The promotion of circular business models that shift ownership from user to producer can be useful to overcome the difficulties of relationships among the stakeholders and the problems concerning responsibility and adding new professional figures in the product/service value chain, for example, introducing warranties or third-party figures that play an "insurance" role for the reused material.

4.3 Life Cycle Tools as a Decision-Making Support

The analysis of the state of the art (Giorgi et al. 2017; Geissdoerfer et al. 2017) concerning the application of the life cycle tools within scientific articles, shows that, at the moment, the combination of the circular economy and life cycle tools is still very lacking. Moreover, the link between circular economy and sustainability is not yet clear in the literature (Blomsma and Brennan 2017). Circular economy strategies should aim at safeguarding resources in all life stages of a product/service, encouraging reuse and upcycling with sustainability verification, through the application of life cycle tools for an environmental and economic benefit assessment.

It is, therefore, necessary to evaluate the sustainability of circularity strategies through instruments that are recognized, such as the methodologies involving life-cycle assessment and life cycle cost, which are the ISO-standardized methodologies used to quantify the real benefit, avoiding burden-shifting among different life-cycle phases.

These fundamental assessments must be introduced during the decision-making phases of the regeneration process, from the end of life management of the existing building to the renovation planning phase. Specifically, the design phase is crucial for assessing the environmental impact and market opportunities with the life-cycle approach. The use of life cycle tools, for example, can highlight the benefits of renovation rather than total demolition, and of a reversible building instead of a traditional one. In this way, it is possible to avoid unnecessary upstream waste and maximize the value and sustainable use of materials. Another important phase during the entire process is the waste management phase when, thanks to a previous environmental and economic life-cycle assessment, it is possible to decide the more effective choice when it comes to material waste destination, which can, for example, involve reuse, recycling or landfill disposal.

In this perspective, it is essential to disseminate the environmental sustainability information of the product, promoting, for example, the use of existing certification, such as EPD, or defining a certification that indicates the sustainability of a specific circular strategy (such as reuse, remanufacturing and recycling) considering the entire process (e.g. including the impacts due to transport and the entire logistics required for the circular strategy). However, in this case, not only are policies necessary in order to favour the use of life cycle tools in the building renovation process, but also awareness and knowledge among the stakeholders regarding the sustainability must be encouraged.

5 Conclusion

The chapter discusses the opportunities to link circular economy and the process of building stock regeneration, in order to activate sustainable strategies which can avoid the generation of construction and demolition waste and the consumption of raw materials. In order to achieve the transition towards a sustainable circular renovation building process, a change in policies, relationships and tools is necessary. Regarding policies, future research needs to identify the reasonable differences in price between landfill, raw materials and secondary materials in order to encourage reuse and upcycling process; the achievable but ambitious targets to add to green public procurement to encourage circular practices, and future increasing targets; the economic incentives to promote the design for disassembly and the use of secondary materials. Regarding the relationships, future research needs to identify the best network process among operators in order to activate circular strategies, such as reuse and remanufacturing; what type of agreement or win-win solution can be activated among clients and material producers/suppliers in order to activate take-back strategies or circular business models based on leasing; moreover, the research needs to identify how to train and educate expert operators/advisers on monitoring and optimizing material flows, and accomplishing disassemble projects (in parallel, the mechanics technologies needed to aid human labour should be developed). Finally, regarding the tools, the research needs to define specific tools (while also implementing the existing ones, such as the pre-demolition audit) which can help the decision-making process to shift towards circular strategies with the support of LCA and LCC, in order to achieve only sustainable strategies, identifying the specific decision-step and operators which need the support of sustainable tools.

The application of circular economy through the building renovation process opens operators up to the necessity to identify and train specific expert operators/advisors who can help current operators directly involved during the building renovation process in deciding upon circularity and sustainability.

The challenges are many, however, just by working on all three prospects it can be possible to activate a sustainable circular economy in the built environment, and definitely contribute to sustainability goals.

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