The Circular City Centre – C3

A GUIDE FOR CIRCULARITY IN THE URBAN BUILT ENVIRONMENT

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98-100, boulevard Konrad Adenauer
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You can contact the C3 team at C3@eib.org.

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1 Introduction

The built environment comprises buildings and structures constructed to give people places to live, work and connect. Such structures represent a small fraction of global land use, and only 1% of the Earth can be considered "built up" in the form of cities, villages, towns or infrastructure.[1] Nevertheless, due to the increasing population and rising urbanisation rates, the built environment places increasing stress on our planet: from biodiversity loss, resource depletion and freshwater use to its emissions of greenhouse gases and pollution of aquatic and terrestrial ecosystems.[2] At the same time, the built environment is critical for maintaining societal well-being, providing shelter, safety, mobility and a sense of community.

Today, 72% of the EU population lives in cities and urban areas,[3] and the level of urbanisation is expected to increase to approximately 84% in 2050.[4] The built environment is responsible for 40% of global CO_2 emissions and more than 30% of the European carbon footprint.[5] Moreover, the built environment is one of the highest consumers of raw materials, accounting for about 63% of total material consumption globally.[6] In Europe, demand for those materials amounts to almost 6 tonnes per capita annually, but only 10.6% comes from recycled or reused sources. Although recycling building materials is a common practice in many countries, about 70% of the materials are downcycled or used for backfilling.[7] Because of the large material footprint of the construction sector and the overall environmental impact, the circular economy has gained attention as a potential solution. Circular strategies can equip the construction sector with the knowledge and tools needed to reduce the resource consumption and negative environmental impact of the built environment by taking a different approach to design, use, reuse and material choices.

This document is intended to guide cities on how to progress their circular transition in the built environment, from establishing an enabling framework to implementing circular solutions. Chapter 4 includes key recommendations and action points for cities.

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More examples and case studies on the topic of circularity in the built environment can be found in the C3 guidance document A Catalogue of Circular City Actions and Solutions and in the Circular City Funding Guide.

2 A circular urban built environment

The built environment is an intricate and multifaceted system, and a definition of a circular built environment is therefore inherently complex. The central focus is to apply the fundamental principles of the circular economy by keeping assets, components and materials in use as long as possible, through extended use, reuse and recycling, and applying new technologies and business models.[8]

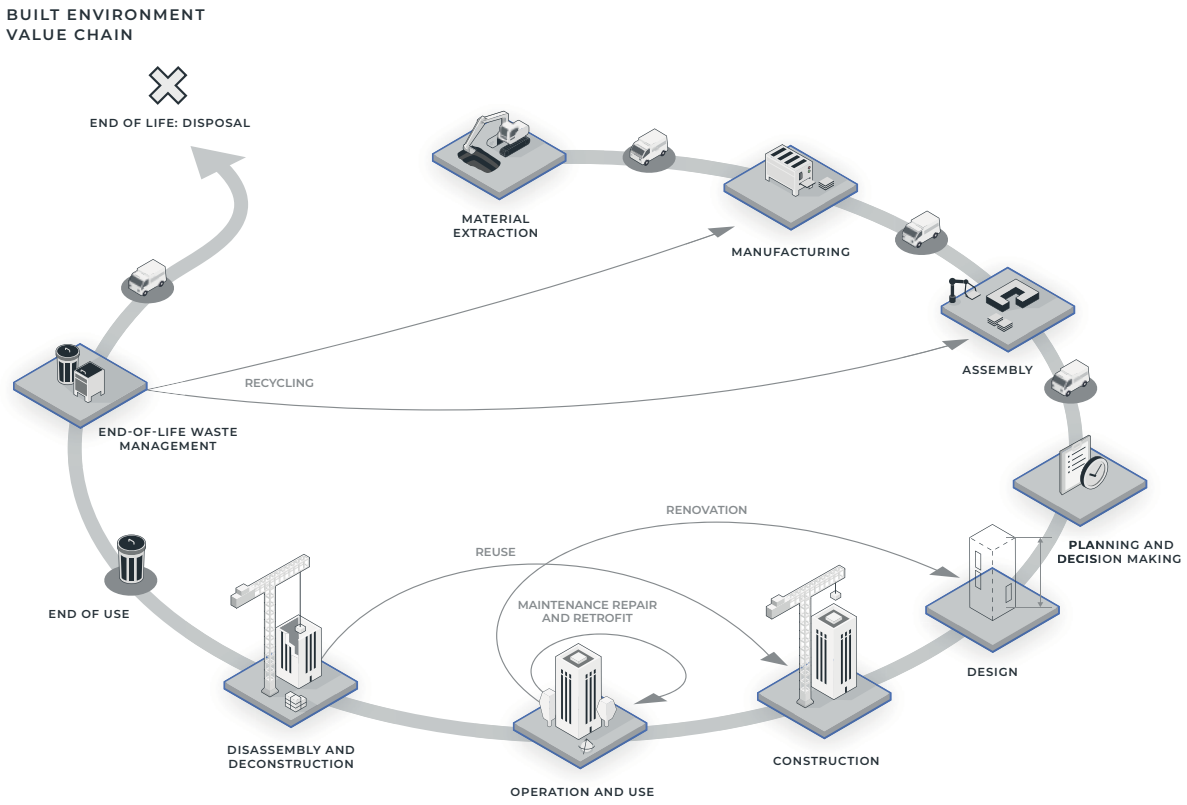
A circular built environment acts as a "living" system that operates within the boundaries of our planet, preserves the value of its resources, and ensures the well-being of its inhabitants. A circular built environment will reduce the environmental impact of the construction sector by optimising resource use and minimising wastage in all forms. The circular economy in the built environment is a promising concept and offers great opportunities for businesses, cities and governments. Numerous innovative solutions already exist in this sector, but developing scalable and replicable solutions for greater impact remains a challenge.

Cities and local governments are crucial players in the shift to a circular economy in the built environment. They hold the power to shape the future through planning, regulations, zoning and permits. Moreover, due to the far-reaching impacts of the sector, applying circular construction methods can contribute to achieving overarching urban sustainability targets and policy goals, such as those related to energy, water and climate change. This applies in terms of not only buildings but also the broader urban fabric, which can directly facilitate behaviour change among residents towards adopting more "circular" lifestyles.

While national governments set national policy and have the mandate to coordinate policy at an international level, municipal governments can better interact with local businesses and residents, encouraging them to both innovate on urban projects and facilitate a practical shift towards more circular practices. Cities can also serve as mediators to promote cooperation among the different stakeholders: from businesses to academia and individuals.[9]

Transforming the current linear urban built environment into a circular one will require several strategies at multiple levels. To fully understand these strategies, it is necessary to develop an understanding of the overall urban built environment value chain (see Figure 1). In cities, the transformation starts with planning and decision-making in municipal governments, particularly by urban planners. Private stakeholders are key in influencing how buildings are constructed, used and managed throughout their life cycle.

Figure 1. The circular built environment value chain. Source: author's own elaboration.



2.1 Planning and decision-making

Planning and decision-making are at the core of urban development. The economy, the environment, and the need for dwellings, economic activities, commerce, culture and transport must all be taken into account when a city is planned. For this, it is important not only to consider the city's current needs and structures but also to anticipate how these may change in the future. Policies, plans, permits and regulations are usually the main tools used to plan cities, aiming to avoid urban sprawl and control urban settlements in a way that is respectful of both the inhabitants and the urban environment.

In a circular economy, planning and decision-making involves not only the ambition to shape urbanisation and infrastructure development towards low-carbon pathways and urban containment, but also considerations around the whole life cycle of buildings and the overall resource efficiency of the building sector. Key actions for municipal governments, and particularly urban planners, to begin the transformation can include:

- **Urban planning and zoning.** Urban planning and zoning include details on how land can be used and can establish the characteristics that buildings can have, such as heights, widths and where they can be placed. To make planning and zoning more circular, decisions should follow the R-hierarchy framework: rethink, regenerate, reduce, reuse, recover.[10] Local governments, for example, should rethink the urban fabric as a whole. Through zoning, city planners can create self-sufficient neighbourhoods, or industrial symbiosis parks, where resource flows are closed and shared across spaces. They can also dedicate land to green and blue infrastructure, such as parks, ponds and rain gardens, to increase the climate resilience of the city and improve water management, including solutions for rainwater harvesting, nutrient recovery from wastewater or stormwater management.

- **Permitting.** Local governments should consider whether the demolition of older or underused buildings or infrastructure is necessary and, where possible, use building permits to prioritise the re-purposing and renovation of existing buildings and remediation of brownfield sites. In addition, through permits, local governments can ensure that all development plans and projects take responsibility and support the establishment of the equipment and facilities needed for the collection, sorting and reuse or recycling of secondary construction components or materials, and build awareness and capacity to properly exploit related opportunities.

- **Circular public procurement.** Municipal governments have reasons and means to invest in new buildings and infrastructure projects, and by way of procurement create signals to prioritise investments in circular construction projects. Public procurement can include circular criteria specifying the use of secondary components and materials and local material sourcing, harnessing regional resources to minimise impacts of extraction and transport from abroad while supporting local economies. Such criteria could be applied in the requirements for new buildings, renovation and maintenance work, among others. Local governments can also survey and document existing building stock and develop regulations and robust certification schemes for the reuse of secondary materials, especially where reuse of structural components is concerned. They can also stimulate secondary material markets, either by incentivising product manufacturers to build capacity in take-back and leasing schemes, coupled with awareness-raising campaigns for consumers and small businesses, or through partnerships and direct investment in storage facilities and processing equipment in key locations. These types of practice are increasingly recognised as good examples of how public bodies can set examples for the industry through procurement policies and promoting best practices.[11]

- **Plan for extended use and life.** The most circular solution to construction is not to construct, and instead repurpose and/or refurbish idle or under-utilised buildings or infrastructures. This can often be a very interesting alternative to demolition for old industrial or cultural heritage buildings. The Tate Modern Gallery in London, housed in the former Bankside Power Station, is a good example. There are also examples where office buildings have been repurposed for residential use, for example in Paris. Prioritising re-purposing and refurbishment rather than demolition and new building where possible can be highlighted as a priority in planning and policy documents.

- **Plan for the end-of-life phase.** In our current linear economic system, the end-of-life phase is not usually considered during the design or construction phases of buildings and infrastructure. In fact, the costs of demolition and redevelopment of industrial estates and office parks are not considered in the cost assessments for their financing. When the time comes to replace buildings, the community or the new investor pays the price for the end-of-life phase.[12] To carefully plan for the end-of-life phase before a project begins, local governments can introduce criteria for using material passports or building information modelling (BIM) as part of tender requirements. This will enable the recovery of components and materials through what is sometimes called urban mining by documenting the materials and components used with a view to facilitating and thereby increasing the rate of recovery and reuse. This will also reduce the need for demolition and waste generation. Local governments can also prioritise projects and proposals that design for disassembly and deconstruction to maximise the share of end-of-life buildings that can be reused or recycled (see section 2.2).

Circular procurement policy – Amsterdam, Netherlands

The municipality of Amsterdam has included circular economy criteria in tendering procedures for area developments and individual buildings. Many building projects that applied circular public procurement are influenced by the Amsterdam Circular Strategy 2020-2025, which set the ambitious target of having **all the city's invitations to tender in the built environment circular by 2032.** Although some projects started at a small scale, circular principles are now widely applied in many procurement processes.

As one example, the municipality of Amsterdam developed the Roadmap Circular Land Issue. This roadmap was successfully applied in four circular tenders, including the development strategy of the city–port area, and can now be applied in other areas as well.[13] Moreover, since January 2020, the city has adopted circular procurement for all office furnishing. Lastly, many new developments in the Zuidas area are now used as pilot projects to implement circular criteria for buildings, such as the use of bio-based materials, and a mandate that at least 30% of these new homes should be social housing.[14]

Circular public procurement: a framework for cities – Ellen MacArthur Foundation

The Ellen MacArthur Foundation's framework aims to assist local governments in implementing circular economy procurement for goods and services. This circular public procurement framework can be applied to buildings, furniture, food, packaging and other items.

Since public procurement procedures vary from city to city, this guidance cannot be used as a universal answer. Instead, it offers a broad framework that must be customised to each city's specific circumstances and conditions. The framework includes resources, questions for consideration and examples from other cities that can provide inspiration.

2.2 Design

Design is the foundational phase for any construction project. It connects multiple disciplines and professions, such as architecture, engineering, surveying and landscaping. In the current linear built environment system, the use of composite building components, toxic materials and fixed connections, etc., make it difficult to disassemble building components at the end-of-life phase. Moreover, many buildings need brute force to be demolished, making it virtually impossible to effectively separate different components or materials on site for reuse.

Circular design is a crucial precondition for enabling circularity and value creation further down the value chain. This is, for example, essential to build in flexibility and future-proof buildings for changing needs, and to unlock the potential for easier future disassembly, recycling and repair.[15] Circular design principles can be summarised into three broad categories: (1) minimising the resource consumption; (2) extending the life of existing assets; and (3) maximising the potential for reuse and resource recovery at the end-of-life phase.

- **Design to reduce.** Maximising resource efficiency and minimising material intensity, which will limit material extraction and flows, as well as the carbon footprint, are two important levers to consider throughout the design phase. A fundamental rethinking of the materials we use and how we use them is necessary. For instance, maximising the use of secondary or lightweight materials can significantly improve resource efficiency and reduce the amount of virgin materials required to construct buildings and infrastructure, such as sand, gravel and iron ore, and can minimise water use and greenhouse gas emissions. At the same time, procurement, logistics and project management are key: improved, smarter design and planning can reduce material use and waste generation during the construction phase. For instance, better planning and communication between architects, designers, engineers and contractors can allow a more precise design and calculation and procurement of the necessary building materials. When construction waste is generated, waste flows can be sorted accurately at the construction site and/or in a sorting installation to allow high-quality reuse of building materials.[16]

- **Design for longevity and optimal use.** Design plays a critical role in maximising the utility and time of the use phase and lifetime of buildings by, for instance, focusing on physical durability and adaptability to future changed needs or repair. Design for durability extends the physical longevity of buildings and facilitates future re-purposing if needed. Design is also fundamental for optimising the adaptability and flexible present and future use of buildings, so that they can be reconfigured multiple times during their life to accommodate changes in required functionality, design or appearance, ensuring that they remain useful until the end of their technical life and contribute to reducing the demand for additional resource consumption. Examples of this are multipurpose buildings that can easily be adapted to both current and future needs, flexible workspaces in office buildings and co-living spaces where residents share communal areas such as living rooms and kitchens/dining rooms.[16]

- **Design for reuse and recycling.** The advancement of reuse and high-value recycling in the built environment relies on appropriate design. A circular design approach prioritises parameters that support deconstruction and disassembly to enable the reuse of construction components and materials. For instance, design choices can favour components, materials or modes of construction and installation that facilitate subsequent deconstruction and dismantling for reassembly and use in another building or location. Standardising demountability and modularity makes disassembly simpler and more advantageous than destructive demolition. To this end, it is crucial to incorporate designing for cyclability at a very early stage in a project, starting from the architectural design and including key elements such as disassembly plans and diagrams coupled with inventories and repositories of reusable, secondary components and materials.[17]

Digitally enabled circular design

New technologies are key to enable circular design in the built environment. The development of **material passports** and **BIM** 3D design tools, which contain an extensive database of components and materials, can boost the high-quality reuse of components and materials, and even replace current municipal archives in the long run.[12] Adopting these types of digital tools to create digital twins, which means identical digital models of actual buildings, will make data available to aid decision-making for the future disassembly and reuse of components in a building when it reaches its end-of-life phase. New digital technologies, when combined with analytics, can provide critical guidance on materials and parts with high replacement rates and therefore make buildings last longer.

Arup's Circular Buildings Toolkit

Arup has developed the Circular Buildings Toolkit in partnership with the Ellen Macarthur Foundation to help designers, contractors and asset owners understand how to adopt circular economy principles in their projects. The toolkit consists of a set of strategies and measures that help identify circular design opportunities early in the planning stage and visualize their potential impact on the building's performance.

The freely accessible toolkit comprises an expanding library of project examples, technical resources and approaches that can inspire planners and other stakeholders. Workshop concepts and materials are also provided to facilitate and guide discussions around circularity in construction.

New Venlo City Hall

The Venlo City Hall is an example of the application of cradle-to-cradle (C2C) design principles on a building scale. C2C design means that all resource flows are designed in a way that allows them to be reused or recycled at the end of their life. In this way, C2C design imitates nature's cycles with everything either reused, recycled or returned to the environment, directly or indirectly. In the case of Venlo, renewable materials were also prioritised.

The **circular design principles** included designing for minimal waste generation, cyclability, durability, resource efficiency and disassembly, and prioritising non-toxic materials and inputs, as well as reusable and recyclable components, materials and inputs. During the design and building processes, a significant focus was placed on knowledge sharing among stakeholders, as well as on developing materials passports recording exactly what products were used and where.

The **procurement process** became a success, starting with five available C2C-certified products and ending up with more than 30 suppliers convinced to adopt circular processes. All products and materials were selected to be non-toxic and to be reused or recycled at the end of their life.

Financial model: The investment of €3.4 million in C2C products was calculated to have a return on investment of €16.9 million over 40 years through energy savings, product life cycle costs and an increase in employees' productivity because of indoor air quality enhancements. In addition, a take-back contract was agreed with the furniture suppliers through which they would pay €300 000 (18% of the original value) to recover the furniture after 10 years.

2.3 Construction

The construction step of the value chain involves the assembly of materials and components of different types into a building at the construction site. While most activities take place on the construction site, prefabrication of components may occur elsewhere.

During these processes, many circular approaches can improve the overall resource efficiency of the process, as outlined below.

- **Prefabrication.** Off-site manufacturing minimises the material consumption and wastage of materials on site. Prefabrication has proven to be essential for the circular economy in a number of studies, since it reduces waste and increases component reuse and material savings.[18]
- **Modular assembly.** This involves design and construction with prefabricated components that are assembled on the site. The prefabrication of building components off site, in controlled conditions, can produce superior quality. Building components are then delivered to the site and assembled quickly and efficiently. One of the main benefits of modular assembly is its accelerated timeline as opposed to traditional building projects, which in turn reduces costs. A modular building factory is also a way of reducing waste, as manufacturers can easily save and reuse scrap materials for their next project. The modular assembly of pre-fabricated components also increases the potential for disassembly at the end-of-life phase, thereby minimising the generation of demolition waste.
- **Reducing construction packaging.** Construction materials are often delivered to the site in different kinds of packaging, which can be a major source of waste generated on site. About 40% of plastic packaging used on construction sites ends up in landfills, while most of these materials can often be reused or recycled. By adopting circular practices such as reducing the amount of packaging material used or using biodegradable alternatives, such as biodegradable foam chips, construction packaging waste can be minimised.[19]

- **Bio-based materials.** Materials used in the built environment are currently dominated by non-renewable carbon-intensive minerals, such as concrete, asphalt, bricks, sand and gravel. As urbanisation increases, so does demand for these materials, resulting in negative environmental and climate impact. Substituting conventional materials with renewable bio-based materials can successfully cut demand for virgin materials, thereby decreasing the overall environmental impact of the built environment.[20] Bio-based materials have far lower levels of embodied carbon and can even act as carbon sinks, sequestering emissions from the atmosphere. They can replace hazardous materials such as asbestos and improve the health and well-being of communities. Examples of these materials include wood, bamboo, hemp and crop residues, as well as more sustainable forms of concrete (seaweed-crete, timber-crete, etc.). The market for more sustainable materials is developing fast, with a number of manufacturers having successfully launched circular and sustainable products, ranging from paving bricks and carpet tiles to "built in a day" housing projects.[12]

There are many circular innovations in construction practices that offer attractive solutions for architects and engineers to optimise resource use and minimise waste. For example, additive manufacturing and 3D printing can provide many advantages as sustainable and convenient practices for producing building components.[21] Other examples include buying materials, in particular secondary materials, locally to cut down on emissions from transport; purchasing machinery that uses renewable energy or carbon-neutral biofuels to cut the operational emissions of the industry; inventory management as a plan to reduce wastage of materials on site; and grey water reuse as an option to reduce overall water consumption.

Kongsvinger region in Norway – modular demonstration house

The O-House is a modular young person's home based on recycled wood that can be moved around in six municipalities in the Kongsvinger region to demonstrate the potential to reuse and repurpose local construction materials. It is the first building project in the region that is circular by design and that uses demolition materials as construction materials, in this case sourced from a local barn.

2.4 Operation and use

Despite having the longest duration, the use phase is probably the least discussed phase of a building's life cycle. This phase accounts for the largest energy and water consumption, and involves key decisions around maintenance and lifetime extension, which can have a direct impact on the environment.

In a circular built environment, reducing energy and water consumption in buildings, as well as waste generation, is central to improving their resource efficiency, reducing operating costs, enhancing the well-being of users, and preserving the value and functionality of buildings at the highest level. During this phase, several interventions can be applied, as discussed below.

- **Maintenance and repair.** A maintenance plan for existing assets is not only essential from an environmental point of view but also has a significant impact on the total cost of ownership. Preventive and predictive maintenance, especially when combined with data analytics, can help predict or anticipate the need for repair and thus maximise system and equipment efficiency, improve reliability and extend buildings' lifetime by preventing the failure of critical components such as facades.[22] Applying this approach is cost-efficient, and it is estimated that advanced predictive maintenance can reduce a building's maintenance and energy costs by up to 20%.[23] At the same time, circular maintenance and repair enables the introduction of new business models based on servitisation, such as product-as-a-service for lighting, elevators, air conditioning, etc., to optimise the design, use and maintenance of related equipment, thereby reducing costs, energy use and emissions. Such new business models also redistribute value and cost in the value chain by splitting ownership.

- **Renovation.** About 85% of the total buildings currently in use within the European Union will still be in use in 2050. Circular economy-based approaches to renovation could help upgrade existing EU buildings and make them more energy efficient, while also cutting 20-25% of emissions embedded in the building materials that currently make up the EU built environment. To avoid material-intensive refurbishments, the priority should be on targeted, effective renovations that also extend the lifespan of existing buildings and increase the intensity of building use.[24] This reduces the demand for new construction, which consumes more materials and has a higher carbon footprint than renovating existing buildings.[25] High-level technology plays an important role in advancing circularity in building renovations. For instance, the widespread use of BIM can help optimise the repair and substitution of materials and components with high replacement rates, such as kitchens and bathrooms, and 3D modelling can optimise renovation, which in turn can facilitate planning and logistics.

- **Retrofitting.** Circular energy retrofitting has gained traction as a strategy to improve the energy efficiency of old buildings and thereby reduce energy-related emissions. In the Netherlands, retrofitting existing residential buildings was found to prevent 7% of new residential construction per year, resulting in a significant reduction of total material consumption in the built environment sector.[16] However, it is important to note that ongoing energy efficiency renovation practices often do not prioritise secondary or (industrial) by-products, often resulting in higher material intensity for buildings than necessary and causing significant waste generation. Retrofitting should therefore always balance resource consumption and environmental impact reduction to avoid trade-offs and rebound effects, whether energy or material related. Moreover, retrofitting old buildings with smart devices combined with data analytics and artificial intelligence helps tenants to respond to real-time changes by reducing energy and water consumption.

- **Intermittent/meanwhile use.** For under-utilised buildings, looking for options to offer space for meanwhile or intermittent use is a way to increase their use and utility. This can, for example, be for short-term use and lease by startups, preferably with a circular focus or, similarly, something that can support job creation and economic development in the city. In Luxembourg, the city offers centrally located vacant commercial spaces for short-term leases as pop-up stores to startups and entrepreneurs, something that is of great value for early-stage companies and at the same time enriches the commercial offer in the city.

- **Nature-based solutions (NBSs).** NBSs are effective tools for reducing heat island effects and adapting to climate change. For example, combining retrofitting with NBSs can help reduce buildings' energy demand by providing better insulation, or harvest rainwater for flushing toilets and irrigating interior courtyards in a circular manner.[26] NBSs can also be applied to whole urban areas. Examples include permeable pavements to reduce flood risks and increase groundwater infiltration, green roofs to improve biodiversity and reduce the heat island effect, planting trees and grass along steep slopes to prevent landslides, and protecting or restoring a nearby forest or wetland that is crucial for the city's water supply and its quality.

RE:FIT buildings in London

By 2025, 40% of London's public buildings are expected to have undergone energy efficiency upgrades, thanks to the city's public building retrofit programme (RE:FIT). The city was able to streamline energy efficiency improvement initiatives throughout city departments and agencies due to economies of scale achieved through many similar projects, the availability of external funding and strong institutional capacity and experience. Energy service companies start all retrofits under guaranteed-savings contracts, which are managed by a RE:FIT Programme Delivery Unit. As a result of the model's ability to combine buildings for retrofitting, higher energy, carbon and financial savings are made possible.

2.5 Disassembly and deconstruction

After a building reaches the end of its useful life it can be dismantled, deconstructed or destroyed through demolition. Demolition is often energy intensive and results in a lot of demolition waste, and often only part of this waste can be recycled. Construction and demolition waste (CDW) accounts for more than one-third of all waste generated in the EU,[27] and it can be harmful to the environment because of its hazardous nature.[28]

In a circular economy, the aim is to steer away from demolition practices and move towards disassembly and deconstruction with high-value reuse of building components and recycling of CDW. To guarantee the availability of high-quality secondary components and materials for reuse, demolition practices need to be replaced by disassembly and deconstruction to the greatest extent possible, complemented by tools that can boost urban mining from end-of-life buildings. Useful tools and practices to put this into action are listed below.

- **Deconstruction.** Many buildings need brute force to be demolished, making it difficult to effectively separate different components on site so that they can be reused or materials so that they can be recycled. Advancing disassembly and deconstruction practices and moving away from demolition will increase reuse and recycling rates and reduce the amount of waste generated. This can be achieved through the following measures:
    - **Design** with components and materials that allow and facilitate deconstruction and disassembly.
    - **Increase the use of material passports and BIM**, enabling urban mining by documenting what buildings are made of and where different components and materials could be found for reuse and recycling.

- **Enable the uptake of selective demolition,** that is, identifying recycling potential and removing hazardous materials via pre-demolition audits to then deconstruct and dismantle each part of a building to recover pure material fractions.[29]

Although deconstruction will be the approach adopted for circularly designed buildings, it may be difficult in current buildings, which were not designed for this, even though there are several examples of this being carried out in an economically viable way. While private companies may be reluctant to take the added risk, local governments could lead the way and develop pilot case studies.

- **Pre-demolition audits.** Audits and surveys provide an inventory of materials and components that could arise from future demolition or renovation projects, giving an indication of what can be reused on/off site or recycled. Such audits are efficient for increasing high-quality reuse and recycling of building components and CDW, and an important measure to avoid spreading hazardous materials in the environment through improved demolition activities.[30]
- **Identify reuse opportunities.** Identifying opportunities before deconstruction increases the levels of reuse and reduces the need for storage and transport. Focus should be on local opportunities to the greatest extent possible to reduce transport. Aligning the planning of deconstruction with the construction of other projects is the best way to facilitate reuse.

The Cadran Solaire project

The redevelopment of a former military hospital complex into mixed-use residential and public facilities in the district of La Tronche in France was used as the testbed for a circular demolition process. The aim was to put the materials used to build the hospital in 1922 back on the market for reuse.

- **Local community involvement.** The key to success in rethinking the construction-renovation-demolition loop was to involve local residents and exploit their demand for building materials. All the material that could not be reused was offered for sale at the Batitec store. The store was one of the many examples of how the city found creative ways to involve people in an operation that is too technical to be directly carried out by residents. Open to the general public and professionals, it allowed the direct resale of materials recovered on site, without transporting the materials from one place to another. It also functioned as an information point for interested residents.
- **Education and awareness.** Where recovered materials were in such a bad condition that they could not be reused, workshops were set up to demonstrate their upcycling potential. A series of additional activities with a circular economy focus were carried out during the demolition: donations of plants on site were complemented by classes from the local horticultural college and a grant to procure tools and equipment for the development of parks.
- **Job creation.** The project also created ten new jobs for its duration, which later turned into six permanent jobs.

2.6 End-of-life waste management

The end-of-life phase includes the activities related to management of waste generated during the demolition phase. Currently, most CDW is recovered in mixed form and used for backfilling, incinerated or sent to landfill. This has become a pressing issue in many urban areas due to the large volume of CDW, which often is the biggest proportion of the total waste stream generated in a city.

Improving separation of different materials at demolition sites and establishing or improving facilities for sorting and refinement of different materials and fractions increases the share that can be recovered, thereby allowing for value to be retained within the local economy. This also reduces the costs and impact of urban CDW management and helps cities achieve more resource-efficient urbanisation. Some ways to improve the management of CDW are presented below.

- **Physical and digital infrastructure for increased reuse.** Mismatch in the demand and supply, uncertainty in the amounts, timely availability and quality of secondary components or materials, and insufficient storage space are some of the prominent challenges that complicate reuse or recycling. Many of these challenges are logistics related and can be solved through innovative supply chain solutions. The development of adequate digital infrastructure (such as digital marketplaces) and physical infrastructure (such as sorting, refinement and processing centres with storage) are well-established solutions to facilitate reuse and recycling.

Local governments can influence the type of waste management infrastructures developed within the city's borders, as well as how different facilities throughout the city connect to and complement one another. They can invest in and support developing infrastructure, both physical and digital, that can facilitate the closing of material and energy loops throughout the urban built environment. This can take the form of CDW recycling facilities, facilities for reconditioning of deconstructed building components, and material and component marketplaces to collect and recover disassembled, pre-used building components and materials. Lastly, they can invest in and facilitate inventories of the building stock to determine the amounts and types of components.[16]

- **Research and development of technological solutions.** Although the technology for the sorting, separation and recovery of CDW is well established, readily accessible and generally inexpensive, it currently still focuses mainly on processing significant waste flows into relatively simple outputs such as aggregates.[12] More can be done to extract higher-quality materials from CDW that meet the product requirements of circular material.

- **Regulation.** More ambitious waste management policy objectives, for example the introduction of requirements for reuse or recycling of CDW, would make current waste management practices more circular. Moreover, many local governments are taking a step forwards by banning specific CDW streams from landfill disposal, as well as using taxation to increase the competitiveness of secondary materials. Standardisation of secondary raw materials at EU rather than national level would help overcome the lack of credibility of these materials. [29]

Resource Rows

The residential area Resource Rows in Copenhagen is made partly from recycled materials, upcycled wood from the Copenhagen Metro, upcycled bricks from the Carlsberg Brewery, residual products from wooden floor producer Dinesen and other brick modules from old schools and industrial buildings around Denmark. There is extensive use of these upcycled materials, for example in facades made of recycled bricks, and surplus wood used for facades, rooftop terraces, pavilions, floors and solar panels. There was a strong focus on CO2 reduction in the construction and operating phases. Instruments such as life cycle assessment and life cycle costing analysis of the construction revealed about a 12% reduction in CO2 emissions based on the choice of materials and a 29% reduction in CO2 emissions based on embodied CO2 and CO2 emissions arising from operations across a 50-year lifetime.

3 Changing roles of stakeholders in a circular built environment

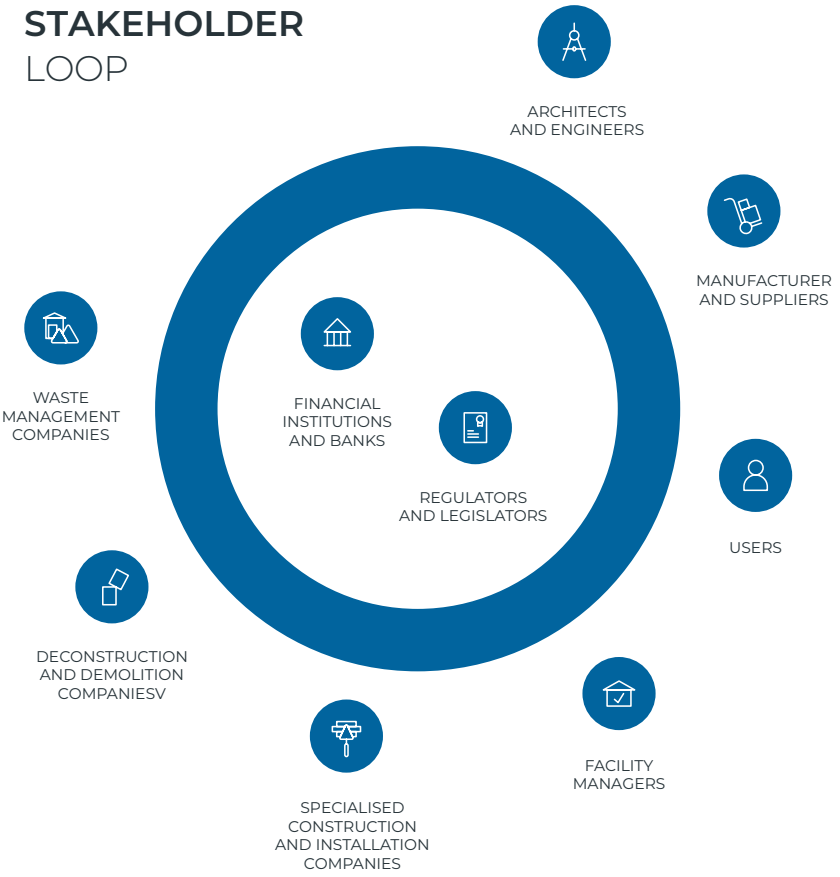
The traditional built environment value chain is still nested in the linear "take-make-waste" model in which resources are extracted, used to construct buildings and infrastructure, and then become waste. Moreover, the built environment is often criticised for being a conservative sector in which design practices have not changed much compared with other industries and the adoption of new technologies has been slow. The change towards circularity therefore requires systemic changes combined with innovative solutions and active participation of all stakeholders in the value chain.

The previous chapter highlighted the difference between a linear and a circular built environment value chain and how different phases of the circular value chain are interdependent and interconnected, implying the need to develop ecosystems for transition. This section describes how the roles of different stakeholders, from architects to waste managers (Figure 2), need to change to co-create this circular ecosystem and allow changes across the whole value chain.

Cities will not be able to achieve a circular built environment alone: they will have to cooperate with the stakeholders in this changing ecosystem. It is therefore important to understand each stakeholder involved in the built environment sector and how their role will change in a circular economy.

To ensure that stakeholders are supported during the built environment transformation, city governments must adopt a collaborative approach. This means, for example, analysing how the shift to circular practices will reshape business models, offering reskilling and upskilling programmes for workers and introducing new supportive policies. Every aspect of the industry, from design to supply chains, will undergo significant changes. Establishing clear communication channels, such as regular meetings and workshops, fosters participation and co-created solutions. Collaboration and knowledge-sharing through partnerships drive innovation. Transparency and accountability in decision-making ensure inclusivity and trust. Lastly, providing financial incentives and training programmes helps stakeholders transition to circular practices, fostering sustainability and resilience in the built environment.

Figure 2. Stakeholders in the built environment. Source: adapted from Circle Economy.[8]



3.1 Stakeholders in a circular built environment

Architects and engineers

What is their role?

Architects and engineers plan and design constructions, renovations and redevelopments in the built environment. They focus not only on the client's wants and needs but also on the environmental and social impacts of the building.

How will it need to change in a circular economy?

In a circular economy, architects and engineers need to consider the entire life cycle of a built asset, since their decisions and specifications will influence the environmental performance of such assets throughout the lifetime of the building. For this reason, this stakeholder group is key in transforming the sector.[31] For instance, designing buildings using screws and bolts rather than glue or cement makes it easier to disassemble for reuse, thereby reducing the generation of waste. For this to happen, architects and engineers need to actively communicate with a range of stakeholders, such as manufacturers of circular building components and materials, demolition companies and waste management companies, to explore options for the use and recovery of reusable components and materials, as well as construction contractors to ensure that they can implement the circular designs.

Manufacturers and suppliers

What is their role?

Manufacturers are key for increasing the choice of circular construction components and materials that are introduced into the built environment value chain. The availability of such options has long-term consequences, given the long life of buildings and infrastructure.

How will it need to change in a circular economy?

In a circular built environment, manufacturers need to change their supply of building components and materials in the built environment value chain. For example, they can manufacture new circular components and components that can easily be dismantled and reused or materials that can be easily recycled. To do this, they will need to gather knowledge on how to increase the circular potential and reduce the environmental footprint of their products across their whole life cycle. For instance, the physical and chemical composition of manufactured products has an impact on their future reuse potential, while different mechanical processes can consume more or less energy and materials. Moreover, new circular products will need to be tested to guarantee structural safety and technical performance when integrated into a new project and after reuse and recycling.

Construction and installation companies

What is their role?

The role of construction and installation companies is to carry out the building process and comply with the specifications prepared by the architects and engineers.

How will it need to change in a circular economy?

In a circular economy, construction and installation companies need to implement innovative circular design solutions and business models, such as the servitisation of building systems, take-back contracts at the end-of-life phase and efficient disassembly of building components for reuse. For this, such companies may need to be involved from the design phase to the decommissioning phase, with extended responsibilities, including resource management at the end of life.

Users

What is their role?

The users are individuals, companies or organisations that make use of buildings as owners or tenants.

How will it need to change in a circular economy?

In a circular economy, users should take an active role in the different phases of a building's life cycle, from design to end of life. Until now, users' involvement has been limited to building operations and maintenance. Owners can press for circular designs and solutions, and tenants or housing associations can opt for circular strategies such as introducing smart devices or retrofitting for energy efficiency. In a circular economy, creating a building stock that can better respond to users' needs over time is key. One of the main reasons for tearing down structurally sound buildings is that they are no longer able to meet the expectations of the user. Buildings should be developed to match the users' current needs and be able to adapt to their or other users' future needs. For this to happen, the users need to play an active role by pressing for designs to be modular and adaptable to changes in future needs and uses.

Facility managers

What is their role?

Facility managers are responsible for ensuring that buildings within their portfolio can fulfil the desired performance in accordance with their functionality requirements through regular maintenance and repairs.

How will it need to change in a circular economy?

In a circular economy, the role of facility managers becomes more data oriented, with a focus on ensuring efficient and long-term use of the building. Facility managers need to ensure that the building is used optimally and efficiently, and that maintenance and repairs are performed on time and using circularity principles. They will also have an important role to play in implementing servitisation in the built environment sector, for example by prioritising product-as-a-service models and related new contractual requirements.

Deconstruction and disassembly companies

What is their role?

Deconstruction and disassembly companies are responsible for the activities that take place at the end of life of a building and for the handling of recovered components, materials and waste, which in a circular economy context takes particular relevance.

How will it need to change in a circular economy?

In a circular economy, the focus needs to change from demolition to selective deconstruction and disassembly for maximum recovery of all components and materials in place. The role of such companies will effectively become that of "urban miners" with responsibilities for the recovery, sorting, refinement, storage and supply of secondary components and materials to the market. Therefore, new responsibilities will arise to guarantee the health and safety of construction workers who may encounter hazardous materials during deconstruction. Lastly, with the introduction of material passports, 3D scanning for digital twins, BIM, selective disassembly and deconstruction technologies, etc., such companies will need to become increasingly versatile in their use of new technologies.

Waste management companies

What is their role?

Currently, most CDW management companies treat the CDW collected by either incineration or disposal in landfills. There is limited retention of value from materials, and the vast majority of the small share of CDW that is recycled is used for backfilling or downcycling, both low-value, suboptimal applications.

How will it need to change in a circular economy?

In a circular economy, CDW management activities need to shift towards recovery, reuse and recycling of secondary materials. Waste management companies must therefore increase efforts to achieve high-value reuse or recycling of materials from the CDW stream. This will require more collaboration with deconstruction and demolition companies to recover material streams of good quality, and with manufacturers, suppliers and construction companies to encourage them to use such recovered materials as a resource and building material. This could be facilitated by the uptake of various digital technologies (robotics, artificial intelligence, etc.) for efficient sorting and decision-making on reuse paths for different material types.

Regulators and legislators

What is their role?

Regulators and legislators provide stakeholders with the regulatory framework in which they operate. In other words, they are responsible for the development of the rules and standards that govern the built environment.

How will it need to change in a circular economy?

In a circular economy, regulators and legislators are responsible for creating a level playing field between circular and linear solutions and driving market mechanisms to stimulate the innovation needed to move towards a circular built environment. They can shape policies that remove critical barriers while cultivating an ecosystem of innovation and collaboration. In addition, regulators can also promote the harmonisation of definitions and classifications of circular activities. For instance, the EU Taxonomy is a framework that defines environmentally sustainable economic activities based on Regulation (EU) 2020/852, including clear criteria for new construction and renovation of buildings.[32]

Financial institutions and banks

What is their role?

Financial institutions and banks are responsible for providing financing for construction and renovation projects and providing financial support or guarantees to innovations and entrepreneurial initiatives.

How will it need to change in a circular economy?

To enable a circular economy, financial institutions and banks need to develop new financial instruments adapted to the particularities of circular economy projects. This will, for example, involve incorporating externalities into the risk assessment of non-circular alternatives, adapting the risk assessment to new service-based circular business models with new contractual relationships and extended balance sheets, absorbing more risk in innovative solutions, and accounting for new financing models such as crowdfunding and value assessment. According to the *Roadmap Circular Finance 2030*, financial institutions and banks could take the following four steps to further support the circular economy: (1) integrally assess linear and circular risks; (2) factor circular metrics into financing; (3) gain experience by closing landmark deals; and (4) expand and optimise financing instruments.[33]

3.2 Circular value chains and ecosystems in the built environment

The introduction of the Circular Economy Action Plan as part of the European Green Deal in 2020 increased the momentum of the EU circular economy transition. This is evident from the emergence of several circular programmes, initiatives, projects and small and medium-sized enterprises (SMEs) at European, state and regional levels. Although many new initiatives emerged, they are often isolated and scattered, resulting in parallel activities, misalignment and slow progress. For example, different businesses offer material passports in different formats, while the finance sector still uses different indicators to evaluate circularity performance. Moreover, the value flow within value chains is neither continuous nor complete. For example, building owners often have complete information about their buildings, but that is not communicated to the building user or demolition contractor. Although demolition contractors often have access to a large supply of secondary building materials, that does not necessarily match the demand for such materials created by architects and designers of new buildings. As a result of this fragmentation and misalignment of information and interests, the potential use and value of materials and built assets are lost along the value chain.

To address this there is a need for a systemic transformation in the sector, which can be made possible by developing and promoting dedicated circular ecosystems. This section explores how this can be done in the built environment value chain and how stakeholders can be engaged in circular value creation.

> A circular ecosystem can be defined as "a multi-actor entity in which interdependent stakeholders such as companies, industry players, public and government stakeholders, universities, non-profit organisations, and individuals/consumers play complementary roles in working towards a common system-level goal related to resource circularity, circular economy knowledge, or circular economy business and business models."[34]

With the introduction of climate targets, changing market conditions and the need for high-end expertise, it is becoming increasingly difficult for businesses in the built environment sector to develop and deliver all the necessary products and solutions in house. As a consequence, there is an increasing dependence on partners and networks, as a result of both the technical complementarity of different building parts and the complementary processes and activities of the different stakeholders.[35] Such interdependency will inevitably need to rely on increased ecosystem collaboration models.

A city can be visualised as an ecosystem because of the many interconnected parts and activities that work together. Creating an ecosystem in which circular businesses can thrive through collaboration is crucial and can be achieved, for example, through raising awareness of the possibilities and benefits and offering training and financial support. Creating such an ecosystem will facilitate the improved collection, sorting and recycling capacity for CDW to facilitate product, material and resource recovery and recirculation.

Local governments have an important role to play in strengthening and facilitating collaboration in such ecosystems to enable innovative, circular solutions for the built environment sector. Section 4.3 elaborates on public-private collaboration models that can support the creation of circular ecosystems.

The article 'Circular ecosystem innovation: an initial set of principles' outlines the following nine essential steps to form a fully functioning, efficient ecosystem.[36]

1. **Define a partner selection process** means identifying how many partners can be part of a specific project.
2. **Involve new stakeholders from different industries and sectors**, as ecosystems emerge when stakeholders from different backgrounds connect to create value.
3. **Establish and maintain trust** – doing so means prioritising communication and fulfilling obligations.
4. **Get commitment and buy-in** early in the process, as it is an important success factor.
5. **Align individual and shared interests** by creating a mutual shared vision for stakeholders.
6. **Re-define stakeholder roles and responsibilities**, which means clarifying the roles of the stakeholders in the project.
7. **Develop a decentralised and collaborative governance structure**, as ecosystems work best when hierarchical structures are decentralised and spread among many stakeholder groups.
8. **Develop joint circular strategies and goals**, establishing a common language and knowledge of the systemic, higher-order problem space.
9. **Ensure fair value capture among stakeholders**, for instance through contracts that specify how they will collect value.

While the steps listed above outline clear approaches to forming an efficient ecosystem, another crucial aspect to consider is how to sustain this ecosystem in the long term. While the city government plays a vital role in promoting environmental stewardship through a circular economy agenda, it must also promote economic viability and acceptance of circular approaches within such an ecosystem. Some examples of how this can be done are presented below.

1. **Financial incentives for circular buildings.** Offer financial incentives such as tax reductions or grants to encourage circular building practices among developers and homeowners.
2. **Circular procurement policies.** Policies prioritising the construction of circular buildings and purchase of goods and services with circular attributes. By influencing market demand for circular buildings, products and services, cities encourage suppliers to adopt circular practices, ensuring cost-effective solutions.
3. **Promote long-term views in financial assessments and models.** Circular design and construction may increase the costs of construction but reduce the cost and material and carbon footprint over the life of a building. By promoting long-term views in financial assessments and models, the benefits of circular design and construction approaches become more evident and convincing.

Examples of ecosystems for circular cities

Development of circular ecosystems is taking place in different cities across Europe for various sectors, including the built environment. These ecosystems are created by bringing together a diverse group of stakeholders with common interests and opportunities for collaboration.

- DigiPlace: Framework facilitating Digital Ecosystem for the Built Environment sector

DigiPlace is a project that acknowledges digitalisation as a major driver in solving the issues in the built environment value chain, such as fragmentation, different languages and a lack of scalable innovations. DigiPlace is a framework that supports the development of digital platforms and services as a common ecosystem that will support innovation and e-commerce in the built environment sector. The main focus is to create synergies among the digital technologies to facilitate interoperability of data and publicly driven, open digital platforms for collaboration. Such platforms can help with the exchange of materials and knowledge in the value chain.

- Impact Hub Circular Ecosystem – Amsterdam

The Impact Hub in Amsterdam brings together impact entrepreneurs, investors, consumers, corporations, local government and other organisations to work collaboratively on specific sustainability challenges such as food, textiles, circularity and inclusion in cities. In addition to knowledge development and capacity building, the Impact Hub enables innovation through partnerships. There is also emphasis on scaling up solutions through successful business models and value chains. Although this ecosystem does not have a dedicated focus on the built environment sector, it showcases examples of successful industrial symbiotic initiatives, for example lightweight modular roads using recycled plastic waste.

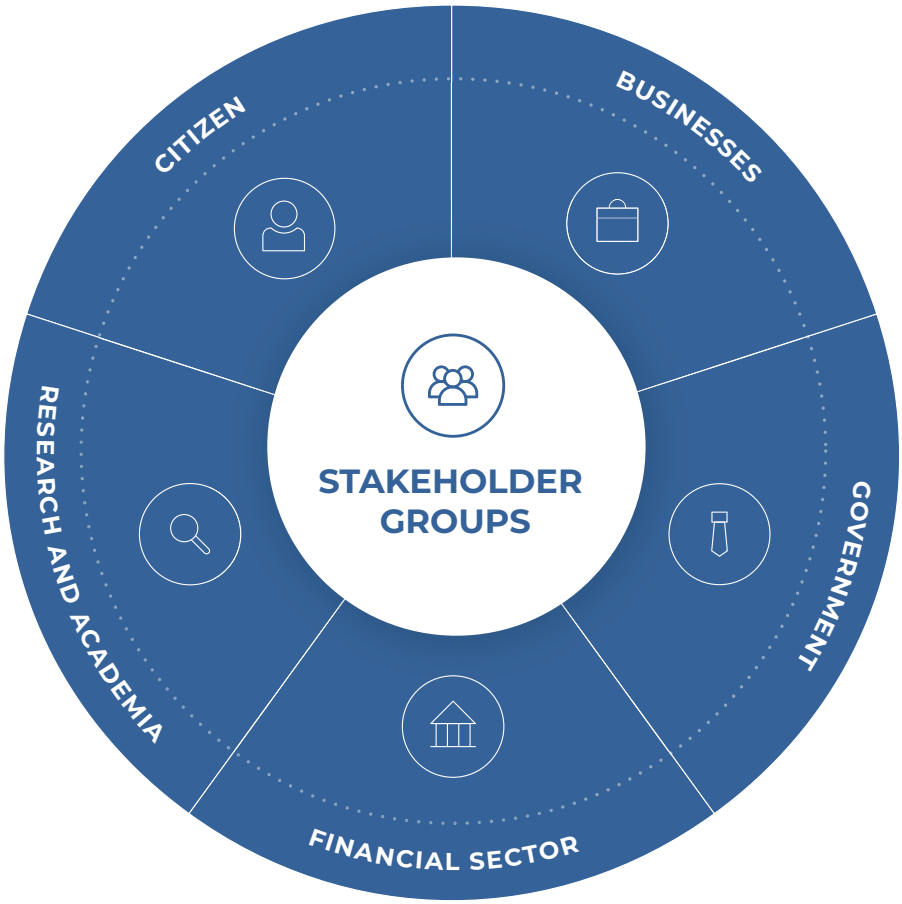
- Reflow project: Co-creating Circular and Regenerative resource flows in cities

Reflow is an EU Horizon 2020 project that tests and prototypes urban material flows through the co-creation of innovative solutions by local businesses, policymakers, knowledge institutions and residents. The project has launched six pilot projects across cities in Europe, focusing on multiple sectors such as textiles, food, wastewater, built environment, plastics and energy. This is a great example of an ecosystem that requires active participation from all the members through initiatives such as communities of practice, involvement of local businesses in testing the solutions and designing governance structures in collaboration with local people.

3.3 Potential for circular collaboration and exchanges in the value chains

In the traditional built environment sector, the notion of "value" was determined by the market value of the property. In a circular economy, the value encompasses a much wider meaning: market value, residual value, social value and environmental value. This naturally calls for much more active collaboration and exchanges among stakeholders to preserve the value of the built assets and all the components and material they contain. Collaboration is a major enabler of an effective transition to a circular economy, which is especially true in the context of the built environment. Such collaboration requires redesigning existing supply chains to accommodate exchanges of resources, materials and information in such a way that they maximise value retention and creation and minimise environmental impact. Figure 3 shows the key stakeholder groups that need to be considered in designing strategies in the built environment sector.

Figure 3. Stakeholder groups in the built environment sector. Source: author's own elaboration.



Engaging stakeholders cannot be accomplished by the introduction of a technical solution or model. It is a continuous evolutionary process that can be achieved only by considering and aligning the needs and priorities of different stakeholders, compromising to maximise the benefits for all involved.

Stakeholder engagement strategies can be implemented through different schemes: circular ecosystems (as described in section 3.2), public-private collaboration models (as discussed in section 4.3) or the introduction of networking platforms to connect stakeholders. There is no ideal engagement strategy, with several relevant factors to consider depending on the scope and objectives of a project or programme.

Several initiatives and programmes exist at the European level to promote collaboration among stakeholder groups, as listed in Table 1. In many ways, the market is ready for more environmentally friendly and circular materials and products, from paving stones and carpet tiles to "made in a day" home projects, and many businesses have successfully introduced circular products. Local governments should lead the efforts to scale up these products and procedures since they can serve as the first clients and promote collaboration among industry participants. They can also start up pilot projects and living labs to encourage innovation and information sharing. The circular criteria that are currently lacking could be "co-created" and better adapted with longer-term goals through the government commissioning of living labs.[16]

Table 1. Stakeholder engagement strategies for a circular built environment

Initiative	About	Engagement strategies
City Science Initiative	The City Science Initiative provides an opportunity for cities, city networks, experts and the services of the European Commission to reinforce their cooperation and strengthen the science and policy interface.	Bring together professionals from different EU cities working on the interface between city policies and research (city science officers), and promote discussion on ways in which science could help address the challenges faced by cities.
Community of Practice in Cities	CoP-CITIES is an initiative of the European Commission that is open to external stakeholders (cities and networks of cities, international and intergovernmental organisations and research bodies).	A community of practice is formed by a group of people who share a common concern, a set of problems or an interest in a topic and who cooperate to fulfil both individual and group goals.
Living-in.EU Movement	The Living-in.EU Movement is a collaborative platform for cities and communities to accelerate their digital transformation in the "European way".	Through co-creation with residents, the aim is to bring the economic and social benefits of this transformation to all local communities and implement an inclusive digital Europe.
New European Bauhaus	The New European Bauhaus brings people, experts, businesses and institutions together to reimagine sustainable living in Europe and beyond.	The co-design phase involves ambassadors across Europe; conferences bringing together students, practitioners, scientists, local representatives and creative minds; citizen engagement activities; shared learning platforms; and financial support.
The Urban Development Network	The Urban Development Network is made up of more than 500 cities/ urban areas across the European Union and is responsible for implementing integrated actions.	Networking, learning and drawing lessons from one another's experiences, identifying good practices to improve urban policies, transnational exchange networks, Urbact knowledge hub and capacity building.
European Urban Initiative	European Urban Initiative (formerly Urban Innovative Actions) is an initiative of the European Union that provides urban areas throughout Europe with resources to test new and unproven solutions to address urban challenges.	Bring together local businesses to test innovative solutions to the main urban challenges, and capture the knowledge and share it with other urban policymakers and practitioners across Europe.

4 Key recommendations and action points

The relevance and scale of the built environment, and the awareness of the huge impact of the sector on the environment and climate are increasing. It is therefore highly justified to take circular action to reduce the negative impact and to capture related benefits and opportunities. The intention of this document is to improve understanding of the circular potential in the built environment and the roles of different stakeholders in such a transition. This chapter highlights key recommendations and immediate action points for cities.

4.1 Policy and regulatory instruments

Cities have the most important role in driving this transformation because of the role they can take as enablers, facilitators and catalysts of the circular transition. At the same time, it can be a challenge to choose the right instruments or levers depending on the objectives to be achieved. Experience shows that a combination of policies, regulations and/or recommendations can be used as levers to enable the circular transition.

Municipalities can start by changing the policies for construction and CDW management to ensure that good circular practices are promoted and incentivised. Moreover, through permits for new construction, they can make sure that circular approaches and measures are used where necessary and relevant. Cities can also use legislative and other instruments such as public procurement, permits and regulations to promote circular action. Cities can also influence stakeholders by promoting circular activities and incentivise life cycle thinking for components, materials and products used in buildings. At the end of this chapter, Table 2 provides an overview of the various instruments that city governments can use at different project stages.

4.2 Investments in infrastructure to scale up the secondary materials market

Provision of adequate **physical infrastructure** is essential to facilitate a circular supply chain and advance the high-value reuse, recovery and recycling of secondary components and materials. A brokerage system or material exchanges to fill the gaps in the supply chain will be useful in this respect. It may also be necessary to establish new collection and drop-off facilities, space for storage, facilities for sorting and refinement to facilitate reuse and recycling, and remanufacturing centres. Such facilities should preferably also consider cross-industry supply chains to facilitate industrial symbiosis.

Digital infrastructure is an essential driver for tracking and mapping resources for dematerialising the economy. A massive amount of information needs to be collected, analysed and processed on a daily basis to support a circular built environment while at the same time ensuring data privacy and security. Provision of sufficient data can lead to major transitions in the sector by increasing the demand and enabling higher levels of element and material recovery and facilitating circular design and construction of projects. Digital infrastructure such as digital marketplaces, material passports, BIM and the installation of smart devices during renovation of buildings are some examples of how to ensure a smart and circular built environment.

4.3 Public-private collaboration

The discussion on the creation of circular ecosystems in Chapter 3 pointed to the importance of stakeholder engagement. The public and private sectors must work together and collaborate to enable and facilitate this engagement. The New European Bauhaus is a great example of how the public sector can actively involve different stakeholder communities. Several cities around Europe have already initiated exemplary initiatives that show how engagement with the private sector is beneficial and necessary for accelerating the circular transition. While policies and regulations are essential, cities also have an important role in identifying and promoting opportunities for public-private collaboration, as exemplified below.

SMEs/startup incubation and scale-up programmes. Startups often represent good examples of innovation and entrepreneurship. A government plan that supports circular innovation by SMEs or startups can help them overcome initial hurdles and bring circular ideas to stages where there is potential for real circular impact in the built environment. Local and national government policies, guarantees or grant schemes can also support the growth of SMEs, including startups that are dedicated to circular solutions and actions.[37]

Cities as living labs. Living labs provide cities with a platform that uses co-creation and continual feedback processes based on community involvement to support circular and urban development. Cities can, for example, focus on bringing together different circular businesses in an ecosystem of urban living labs. This will facilitate the development and scaling up of new innovative solutions that not only provide new business opportunities for SMEs but also contribute to the development of cities.

4.4 Capacity building

The built environment sector needs to build knowledge and skills to embrace the full potential of the circular economy. Chapter 3 emphasises the changing roles of stakeholders, which also implies the need to upgrade skills in the sector. Several new roles are emerging for different stakeholders in the wake of circular developments and digital transformation.

Training employers and staff. Training within relevant departments in city administrations needs to be initiated. Cities can also promote awareness raising and **skill development** for the sector through other means such as educational programmes and training.

With innovation being a key aspect of the circular transition in the built environment, roles such as material innovation specialists and product developers will be increasingly important. Apart from the development of skills, such roles also require sufficient opportunities and investment in **research and development.**

Digital skills. It is a critical issue in the built environment sector that only 42% of employees take up any opportunity to reskill or upskill in their roles, which further highlights the resistance to change.[38] There is considerable discussion in academia and research on the advantages of using digital technologies such as robotics, additive manufacturing techniques, the internet of things, big data, artificial intelligence and BIM. However, the application of such new technologies is limited due to the lack of skills in the industry. The city can create awareness and develop educational programmes in collaboration with educational institutions to mitigate this skill gap. Furthermore, the sector needs to attract a talent pool from varied backgrounds, such as strategists, cognitive and systems thinkers, data analysts and scientists, digital operatives and robotic programmers, that will enable cross-sector collaboration.[39] Such collaboration can be made possible through the opportunities of public-private collaboration, as elaborated in the previous section.

Table 2. City instruments to promote a circular economy at different project stages

	Project life cycle stage						
Instrument	**Planning**	**Design**	**Construction**	**Maintenance and use**	**Renovation**	**Deconstruction**	**Next life**
Manage – city administration (urban design and planning department)	• Setting vision: regenerative circular cities. • Compact urban design and space planning for areas where biodiversity is not required. Spatial design for green areas, facades and roofs when relevant.	• Integrating circular design principles in public projects. • Multi-purpose buildings.	• Site inspections for material assembly and installations.	• Monitoring through yearly reports/inspections.	• Include higher ratio of renovation projects. • Adaptive re-use/re-purposing.	• Reuse strategy requirements as part of deconstruction permits.	• Establishing urban salvage yards.
Mobilise – governance/ policies	• Lobbying. • Setting circular objectives in public tenders • Policies for new construction.	• Policies for upcycling and design. • Integrating reuse in green building rating systems.	• Policies for waste management and resource optimisation on construction sites.	• Policies for preservation.	• Policies for urban planners that foster the re-purposing of buildings and/or the optimisation of the built environment footprint.	• Lobbying (construction on existing built-up sites).	• Establishing a unified approach regarding the fitness of reuse.
Regulate	• Mandatory material passports. • Reuse criteria for permits. • Defining proper ownership to reduce gentrification, zoning ordinances for mixed use development or reusing existing assets, and establishing the role and responsibilities of the owners of green areas.	• Circular architect/ engineer design permits. • Upcycle design priority permits. • Circular strategy plan as part of permit application.	• Circular contractors' permits. • Procurement audits. • On-site reuse strategy.	• Mandatory record of the entire life cycle analysis and life cycle costing, (including the end-of-life phase).	• Fast track renovation permits. • Renovation audits. • Mandatory strategy for extension of the building life cycle duration (such as modularity of the design to easily repair and extend life duration).	• Mandatory reclamation audits. • Mandatory material passports.	• Assessment and certification of reusable products. • Mandatory end-of-life strategy for greenfield projects.

Table 2. City instruments to promote a circular economy at different project stages (continued)

	Project life cycle stage						
Instrument	**Planning**	**Design**	**Construction**	**Maintenance and use**	**Renovation**	**Deconstruction**	**Next life**
Incentivise – economic/ financial instruments	• Investments to promote circular practices in the built environment. • Landmark and monument buildings protection to avoid demolition and incentivise circular practices.	• Higher taxation on raw materials. • Adapted insurance schemes. • Incentivise biophilic design (increasing user connectivity to the natural environment) and integrate the bioeconomy	• Circular public procurement.	• Circular business models (extended producer responsibility and product-as-a-service).	• Incentives to renovate buildings instead of demolishing, or to prioritise building in brownfield rather than greenfield areas. • Subsidies to reuse high percentage of recovered components and materials from previous buildings.	• Subsidies for adopting deconstruction practices.	• Subsidies for promoting enterprises adopting reuse. • Tax incentives for secondary materials/ regenerative materials. • Higher taxation on landfill to incentivise reuse and recycling.
Education – knowledge, data and information	• Capacity building. • Innovation and incubator programmes.	• Experimentation and research. • Education and training programme	• Living labs. • Education and training programmes.	• Living labs.	• Education and training programmes.	• Information campaign on adopting deconstruction over demolition.	• Data and information exchange platforms. • Information campaign on adopting reuse practices.

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Annex 1 – Additional resources

Source	Description	Strengths	Limitations
Circular Economy in the Built Environment **Author:** ARUP **Date:** 2016	The research outlines the key principles of the circular economy, using the Ellen MacArthur Foundation's ReSOLVE framework (Regenerate, Share, Optimise, Loop, Virtualise and Exchange) to explore and contextualise practical applications in the built environment. It identifies how the circular economy can benefit the built environment sector. It also reflects on the economic, social and environmental advantages of employing circular principles.	• This report uses the Ellen MacArthur Foundation's ReSOLVE framework to outline key principles of the circular economy and explore practical applications that can benefit all parties working in the built environment sector. • The case studies included in this report provide practical examples of how each element of the ReSOLVE framework can be applied, together with the benefits these can deliver. • An outline of how the circular economy would function for a commercial building has been developed. The concept shows stakeholders their role and the benefits available to them. • To complement the building illustration, a matrix and diagram mapping the Ellen MacArthur Foundation's ReSOLVE framework to an adapted version of Stuart Brand's "Layers" diagram (System, Site, Structure, Skin, Services, Space, Stuff) has been developed.	• The examples used in the report are not all entirely circular. Nevertheless, it represents an important stepping stone in the form of case studies that could be scaled up.
Barriers and drivers in a circular economy: the case of the built environment **Author:** Jim Hart and others **Date:** 2019	To facilitate the pathway towards circularity, this paper attempts to identify the barriers to and enablers of the circular economy within the built environment.	• Very well structured and concise paper summarising 200 separate references. • In-depth analysis of the barriers to and enablers of a circular built environment, divided into four categories (cultural, financial, regulatory and sectoral). • This paper demonstrates that, while many technical and regulatory challenges remain, the real obstacles to a more circular built environment are the cultural and financial/market issues.	• Does not disclose the list of the 200 references that were analysed to draw these conclusions. Therefore, it remains unclear if the analysis is global or region specific.
First Steps Towards a Circular Built Environment **Author:** Arup and Ellen MacArthur Foundation **Date:** 2018	Arup worked with the Ellen MacArthur Foundation to examine how the principles of the circular economy can be translated into everyday built environment practices. This document outlines the barriers to, opportunities for and enablers of the adoption of a circular economy while highlighting the key stakeholders and what their first steps might be.	• To write this report over 100 interviews were conducted across five cities, and 116 case studies that employ circular economy elements were selected and categorised based on their scale, application of circular building blocks and ReSOLVE levers. • The research report provides clear first steps towards implementation by dividing them into different types of stakeholders (investors, policymakers and construction clients). • The research demonstrated that stakeholders throughout the value chain remain insufficiently familiar with how circular economy principles do or could operate in the built environment.	• The research for this report was limited to five European countries. • First steps to the implementation of a circular built environment are limited to barriers presented by European cities.

Source	Description	Strengths	Limitations
How do we make construction work circular? **Author:** Het Groene Brien **Date:** N/A	This article discusses the opportunities for and barriers to closing material flows in the construction industry, with examples of entrepreneurs who have done so.	• The article provides good case studies of the application of circular principles in the built environment. • The article provides links to continue reading about the case studies. • The article provides a great introduction to the opportunities for, barriers to and examples of the circular built environment.	• Only introductory content.
Circular economy and design for change within the built environment: preparing the transition **Author:** Wim Debacker and others **Date:** 2017	Two innovative solutions are highlighted to support the circular transition in the built environment: materials passports and reversible building design protocols. Based on desk research and interviews with frontrunners, this report outlines the key opportunities and barriers that have been identified relating to the implementation of innovative solutions within the policy, commercial, societal and research and development realms.	• The paper clearly outlines the four systemic shifts that need to happen to support the transition towards a more circular built environment. • Key opportunities and barriers have been clearly defined. • The paper outlines the importance of stakeholders being involved in the conceptualisation and design and construction. This way they will have a better understanding of the potential consequences of the decisions made during the crucial design and construction phases within the value chain.	• The paper is short and provides only a list of key opportunities and barriers. • It does not go into detail of how to implement materials passports and reversible building design protocols. It merely states that these can be solutions.
Circular Economy in the Built Environment **Author:** Margherita Finamore **Date:** 2017	This report published by One Planet Network is a collection of case studies demonstrating the application of circular economy principles. It also includes a short summary of policies devised by a few of the leading European countries.	• The presentation of case studies in the report is more informative for public authorities or other practitioners to understand the implications of circular economy principles. • The report analyses the case studies based on the ReSOLVE framework. • The case studies cover a broad range of examples including individual projects, business cases and city-level strategies.	• The study provides examples mainly from European countries and only a couple of examples from other parts of the world. • While describing the impact of the European legislative framework on the countries, only a few leading countries such as the Netherlands, Germany and Denmark are considered. • The report does explain how to extract and apply the best practices or lessons from the list of case studies.

Source	Description	Strengths	Limitations
Circular Digital Built Environment: An Emerging Framework – Specifically Dedicated to Digital Technologies for Circular Built Environment **Author:** Sultan Çetin, Catherine De Wolf and Nancy Bocken **Date:** 2021	Although digital technologies are essential enablers for circularity, very few studies have focused on investigating these in the built environment sector. This framework acts as a starting point to provide a novel direction for research at the intersection of the circular economy, built environment and digital technologies. The framework is the result of a literature study, expert workshops and practical reviews from the industry.	• The framework can be used as a guideline by practitioners to understand the functionalities of available digital technologies and how to modify them based on practical aspects. • The framework is the first ever representation of digital technologies based on the circular economy principles (regenerate, narrow, slow and close) while taking into consideration the stages of a building's life cycle.	• The research takes into consideration several digital technologies focusing on their enabling functionalities alone without considering their implementation barriers. • Several digital technologies mentioned in the framework are at early stages of development. Their application in the current scenario is limited. • The workshop conducted to gather feedback included only a small share of the built environment industry.
A Roadmap to Foster Reuse Practices in the Construction Sector **Author:** Emilie Gobbo, Michaël Ghyoot, Corinne Bernair and Anne Paduart **Date:** 2021	The roadmap has been prepared as part of the Interreg Northwest Europe FCRBE project that aims to enhance the quantity of building components being reclaimed and reused in north-western Europe. Between 2018 and 2021, the project developed a series of actions and tools addressed to professionals in the construction sector. As part of this project, FCRBE also assisted 36 pilot operations to test the tools and methodologies developed.	• This project did not just focus on developing methodologies and tools, it also took it a step forwards by testing these on 36 pilot operations. The feedback received was incorporated to improve the methodologies and frameworks. • The report presents a set of tangible actions, recommendations and ideas that could be initiated and implemented by public authorities. • The project adopted a collaborative approach by inviting all the relevant stakeholders to two workshops, which resulted in the development of a consolidated roadmap and potential scenarios for implementation.	• The roadmap developed is based on the collective action of stakeholders and project feedback from north-western Europe. Hence, it should not be looked at as a single entity, but public authorities must be aware and motivated to adapt the roadmap based on territorial contexts, targets and stakeholder interests.
How can cities live by the doughnut? **Speaker:** Kate Raworth **Date:** 2021	In this webinar by Urbact, Kate Raworth describes doughnut economics and how this can help cities live by these principles. There are multiple examples of how cities have taken action to promote a city that thrives within the planetary and social boundaries.	• The webinar provides many examples of how cities can incorporate doughnut economics in the local context.	• The webinar does not go into detail about the cases.

Annex 2 – Good circular built environment practices and examples

No.	Type	Good practice example
1	Circular public procurement	Circular Procurement – Municipality of Amersfoort
2		Increasing brick recovery for reuse when procuring demolition services – Hjørring municipality (Denmark)
3		New Venlo City Hall
4	Collective ownership	Co-Operate ownership model
5	Community of practice	Circuit Project
6		Building Value
7		Platform CB'23
8	Crowdfunding	Hof van Cartesius: taking circular action
9	Deconstruction/selective demolition through community participation	The Cadran Solaire project
10	Digital and physical infrastructure for reuse	Fair Tracker
14	Industrial symbiosis	The Fissac Project
15	Land use planning using digital information	3D mapping project supporting policies for low carbon buildings
16	Measuring circularity performance of the construction works	Nationale Milieu Database
17	Product-as-a-service	Road-as-a-service
18		Facades-as-a-service
19		Circular Facade Service by Alkondor
20		Pay-per-lux by Philips
21		M-Use: Mitsubishi circular elevators
22	Reuse and recover	1 Triton Square
23		Circle House Denmark
24		Resource Rows
22	Take-back programme	Grundfos pump solutions
23	Tax allowances to increase circular practices	Urban case study: temporary use of buildings – Riga
24	Urban mining	Urban mining in Heidelberg

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