Chapter 23
CE Management

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Abstract This chapter presents a deep discussion of the recent case studies on implementation of best practices and strategies for the circular economy, and an integrated approach to CE management in the built environment. The case studies were evaluated by the following aspects: Design for Circular Economy; Resource Optimization; Collaborative Approaches; Digital Technologies; Policy and Regulatory Frameworks; Consumer Engagement; Life Cycle Assessment; Circular Business Models; Smart Monitoring and Evaluation; Stakeholder Collaboration. These studies indicated the diversity of best practices in CE management in different fields. On the other hand, a strategic planning and collaborative development of circular

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practices with relevant stakeholders are crucial for the effective development and implementation of circular capabilities and initiatives in the built environment.

Keywords Circular economy · CE management · Built environment · Implementation · Circular materials · Stakeholder

23.1 Case Studies—Best Practices in Management

Circular economy (CE) management refers to the implementation of best practices and strategies aimed at achieving CE within organizations, industries, and societies. It involves adopting a holistic approach to resource management, focusing on reducing waste, maximizing resource efficiency, and promoting sustainable production and consumption patterns.

Best practices in CE management encompass various aspects, including:

- Design for Circular Economy;
- Resource Optimization;
- Collaborative Approaches;
- Digital Technologies;
- Policy and Regulatory Frameworks;
- Consumer Engagement;
- Life Cycle Assessment;
- Circular Business Models;
- Smart Monitoring and Evaluation;
- Stakeholder Collaboration.

23.1.1 Design for Circular Economy

Incorporating principles of circularity at the product and process design stage, considering factors such as material selection, durability, recyclability, and reparability.

Case Study I Design for Circular Economy: The Circle House

The Circle House project, commissioned by Lejerbo, is pioneering the construction of the first social housing units based on circular principles. This ground-breaking approach ensures a higher level of flexibility throughout the building's lifespan, with 90% of its materials designed to be disassembled and reused at a significant value.

The Circle House project consists of 60 social housing units in Lisbjerg (Aarhus, Denmark) and represents three typologies: a mix of two- and three-story terraced houses and 5-storey tower blocks with an overall 100 m^2 of communal facilities. The building density on site is 65–80%.

Lisbjerg is a development zone focusing on sustainability. Thus, the Circle House is designed and built according to the principles of the Circular Economy. Therefore, it becomes a scalable lighthouse project that will bring new know-how about circularity in architecture and construction to the building industry. The objective is that 90% of the building materials can be reused without appreciable loss of value. To enhance the re-usability, the structural system is limited to a few different elements: two sizes of wall elements and two lengths of beams and deck elements. The approach is rooted in the 15 principles within the categories Design for Disassembly, Material ID and Circular Economy, which have been developed as guidelines and strategies for implementing reuse and circular economy in the building industry. Accordingly, the Circle House consists of a range of building systems that can be disassembled, reused or reassembled into outer buildings while the value is preserved. Thereby, great architectural freedom and creativity are achieved in terms of material selection and circular construction.

A project like Circle House makes cross-industry collaboration necessary in order to enable a circular building practice. Accordingly, the entire value chain of the building industry needs to be engaged. The project Circle House involves more than 60 Danish companies from the construction sector. It was made possible by the funding's from the Danish Environmental Protection Authority and the Realdania philanthropic association.

23.1.2 Resource Optimization

Maximizing the use of resources through strategies like recycling, remanufacturing, and refurbishment. This involves minimizing waste generation and extending the lifespan of products and materials.

Case Study II Resource Optimization

The case study centers on the construction of a three-story building, where the basement is designated for parking, and the remaining two stories consist of residential flats. The project involves a variety of interconnected activities with different dependencies, highlighting the significance of resource management for successful project execution [1].

Organizing and training the project team: Human resource management plays a vital role in ensuring exceptional project achievements. Proper organization and training are crucial for team efficiency and performance

Equipment resource management: Careful selection of equipment is essential for cost control and timely completion. Factors such as availability, mobility, versatility, suitability, and equipment capability must be considered.

Material resource management: Timely provision of materials in the right quantities and locations is crucial for achieving scheduled production levels at minimum cost. Monitoring material information and flow is key to effective material resource management.

Resource levelling technique: Resource levelling ensures a balanced distribution of resources to avoid exceeding availability. It aims to maintain uniform resource levels during peak and off-peak periods. Labor and equipment resource management are fundamental parameters in resource levelling.

Techniques for resource levelling: Fast-tracking, crashing, delay-critical path tasks, extend-critical path tasks, non-sequential task divisions, authorized overtime, and MS Project are used to optimize resource allocation and meet project goals.

Resource Levelling with MS Project: MS Project offers a comprehensive resource levelling feature for efficient project management. By inputting resource schemes, activity types, and dependencies, MS Project enables automatic or manual resource levelling. It provides flexibility to resolve resource conflicts through activity delays, additions or removals, resource reassignments, and dependency adjustments. Manual resource levelling is recommended for better alignment with real-world conditions.

The case study concludes that manual resource levelling using MS Project is the preferred option due to its flexibility and ability to consider on-site conditions. Extending activity durations to address resource overallocation is acceptable. However, MS Project does not allow a single resource to be allocated to parallel activities. The study emphasizes the productivity and efficiency of MS Project, particularly for small construction projects with limited resources.

Recommendations: Based on the findings of this case study, it is recommended that project managers utilize MS Project for resource levelling and enhance productivity in construction projects. Regular checks and revisions of the project schedule are necessary to align with real-world conditions. MS Project's features enable optimal resource allocation, ensuring timely completion and cost control.

23.1.3 Collaborative Approaches

Encouraging collaboration and partnerships across value chains to promote resource sharing, product-service systems, and closed-loop systems. This includes establishing networks for material exchanges and fostering collaborations among different stakeholders.

Case Study III Collaborative Approaches

One of the newest examples of industrial symbiosis is the Port of Rotterdam in the Netherlands [2]. The port has developed an innovative circular economy program called "Rotterdam Circularity Program" that aims to transform the port into a sustainable and circular hub.

Under this program, various initiatives have been implemented to foster industrial symbiosis and resource efficiency. For example, waste heat from the refining and chemical industries is captured and used to provide heating for nearby buildings and greenhouses. The excess CO_2 emissions from industrial processes are captured and transported to greenhouses for enhanced plant growth. Additionally, residual heat from data centers is utilized to warm water for local households.

Through these collaborative efforts, the Port of Rotterdam is creating a circular ecosystem where waste streams are turned into valuable resources, reducing environmental impact and promoting a more sustainable economy.

23.1.4 Digital Technologies

Utilizing digital innovations, such as the Internet of Things (IoT), Artificial Intelligence (AI), and blockchain, to enhance resource tracking, supply chain transparency, and product traceability, enabling better management and optimization of resources.

Case Study IV Digital Technologies

Blockchain technology is mentioned as a potential enabler for circular economy practices. It can provide transparency and traceability in supply chains, facilitate material and product tracking, and enable secure transactions in circular business models [3].

One example of utilizing blockchain technology for circular economy practices is the Plastic Bank initiative. Founded in 2013, the Plastic Bank aims to reduce plastic waste in the oceans while creating socio-economic opportunities for communities in developing countries.

The initiative utilizes blockchain technology to create a transparent and traceable system for recycling plastic waste. Local communities can collect plastic waste and exchange it for digital tokens, which can then be used to purchase goods and services. The entire transaction process is recorded on the blockchain, ensuring transparency and accountability.

By using blockchain technology, the Plastic Bank provides a secure and reliable platform for plastic waste collection, recycling, and monetization. It enables individuals to become active participants in the circular economy by incentivizing the proper disposal of plastic waste and promoting its recycling and reuse.

23.1.5 Policy and Regulatory Frameworks

Implementing supportive policies and regulations that incentivize circular practices, such as extended producer responsibility (EPR) schemes, tax incentives, and waste management regulations.

Case Study V Policy and Regulatory Frameworks

The European Union's Waste Framework Directive, which sets out waste management principles, including waste prevention and recycling targets, is considered a best practice in circular economy policy.

One of the newest examples of policy and regulatory frameworks promoting the circular economy is the European Union's Circular Economy Action Plan, adopted in March 2020 [4]. This plan builds upon the Waste Framework Directive and sets ambitious targets and measures to transition Europe to a more sustainable and circular economy.

The Circular Economy Action Plan includes a wide range of initiatives and policies to promote waste prevention, improve resource efficiency, and foster the transition to CE. It sets targets for recycling and reducing waste, encourages eco-design and product durability, promotes the use of secondary raw materials, and aims to tackle key sectors such as plastics, textiles, and electronics.

The plan also emphasizes the importance of sustainable production and consumption patterns, innovation, and investment in circular economy projects. It aims to create a supportive regulatory framework that encourages businesses, consumers, and governments to embrace circular practices.

By implementing this comprehensive policy and regulatory framework, the European Union seeks to accelerate the transition to CE, reduce environmental impacts, create new business opportunities, and promote sustainable growth.

23.1.6 Consumer Engagement

Educating and engaging consumers in circular behaviors, such as reuse, repair, and recycling, and promoting sustainable consumption patterns. This can be done through awareness campaigns, product labelling, and consumer incentives.

Case Study VI Consumer Engagement—Whole House Reuse

One of the newest examples of consumer engagement in the building industry is the "Whole House Reuse" campaign launched by the Building Materials Reuse Association (BMRA) in New Zealand [5]. The campaign aims to raise awareness among homeowners and builders about the environmental and economic benefits of reusing building materials.

The "Whole House Reuse" campaign promotes the concept of deconstruction, which involves carefully dismantling a building to salvage reusable materials instead of demolishing it. By emphasizing the value of reclaimed materials and the importance of diverting construction waste from landfills, the campaign encourages homeowners and builders to consider reuse as a sustainable and cost-effective option.

Through educational resources, case studies, and partnerships with industry stakeholders, the campaign provides information and support to those interested in incorporating reuse practices into their building projects. It highlights the environmental benefits of reusing materials, such as reducing carbon emissions and preserving natural resources, while showcasing the potential cost savings and unique design opportunities that arise from using reclaimed materials.

By engaging consumers and promoting the reuse of building materials, the "Whole House Reuse" campaign contributes to the circular economy by extending the lifespan of materials, reducing waste, and fostering a more sustainable approach to construction and renovation.

Case Study VII Consumer Engagement—Reducing Waste in Fit-Out Processes through AI-Enabled Reuse [6]

The construction sector faces a critical challenge in reducing waste generated during fit-out processes to achieve net zero carbon targets and minimize environmental impact. Time pressures often hinder the reuse or recycling of materials, resulting in a significant increase in carbon footprint. To address this issue, the 'LINK' project, funded by Innovate UK, aims to revolutionize waste reduction in fit-outs using artificial intelligence (AI) and machine learning. By rapidly identifying reusable materials and connecting those who wish to

dispose of materials with those in need, the project aims to facilitate the CE approach and decrease waste in the construction sector.

The primary objective of the 'LINK' project is to develop a mobile app that enables the rapid listing of reusable materials. The project aims to engage all stakeholders in the fit-out and interior design sector to transform the reuse process and establish it as the norm in construction. By harnessing digital technology, the project seeks to revolutionize the way materials are reused, promoting sustainability and reducing waste throughout the industry.

Industry Workshop: The project partners hosted an industry workshop to gather insights on challenges and opportunities in March 2023. The workshop was held online. It invited stakeholders from the fit-out and interior design sector, including designers, clients, manufacturers, contractors, and individuals passionate about promoting reuse. The workshop aimed to explore the potential of digital technology and identify key drivers and success factors in making reuse a common practice.

Workshop Program: The workshop featured presentations covering various aspects of sustainability, reuse, and the role of AI in revolutionising the industry. The presentations include.

Sustainability for Finishes and Interiors: Iain Mcilwee, CEO, and Flavie Lowres, Sustainability Champion, Finishes and Interiors Sector (FIS).

The workshop also included interactive discussion groups focusing on information needed for facilitating reuse and exploring the roles of different stakeholders in achieving higher levels of reuse.

Workshop Registration and Contact: Interested participants can register for the workshop, and attendance is free of charge. The project team welcome individuals who are passionate about promoting reuse or seeking more information about the project.

23.1.7 Life Cycle Assessment (LCA)

Conducting comprehensive assessments of the environmental impacts of products and processes throughout their life cycles to identify areas for improvement and inform decision-making.

Case Study VIII Life Cycle Assessment [7]

This case study focuses on the development of comprehensive circular economy (CE) indicators for port clusters, aiming to support port managing bodies (PMBs) and stakeholders in monitoring the transition towards CE [2].

The study utilizes a multimethod qualitative research approach, including content analysis, focus groups, a gap analysis, and a qualitative survey, to establish a set of 12 actionable CE indicators for ports. The feasibility and relevance of these indicators are evaluated, highlighting seven highly feasible and five moderately feasible indicators. Additionally, the study discusses the limited CE ambition levels of PMBs and variations in indicator values across different port typologies. The findings of this study provide practitioners with an actionable set of key performance indicators (KPIs) to support their efforts and communication related to the circular economy transition in port clusters.

The transition towards CE in port clusters is gaining importance in facilitating regional and global transport within circular production chains. However, there is a lack of in-depth research on the development of circular economy indicators specifically for port areas. This case study aims to address this gap by developing a comprehensive set of relevant and feasible CE indicators to monitor the circular economy transition in ports.

Methodology: The case study employs a multimethod qualitative research approach. Content analysis, focus groups, a gap analysis, and a qualitative survey are conducted to gather data and insights. These methods allow identifying relevant CE indicators and assessing their feasibility and stakeholder relevance.

Development of CE Indicators for Ports: Through the research methods employed, a list of 12 actionable CE indicators for ports is developed. These indicators cover various aspects of the circular economy, including resource efficiency, waste management, reuse, and stakeholder engagement. The indicators are categorized based on their feasibility, with seven identified as highly feasible and five as moderately feasible.

Findings: The study highlights two key findings. Firstly, it reveals the overall limited CE ambition levels among PMBs, indicating a potential area for improvement in promoting circular economy practices. Secondly, variations in indicator values are observed across different port typologies, suggesting the need for tailored approaches to circular economy implementation in diverse port settings.

Value for Practitioners: This case study provides practitioners with an actionable set of CE indicators that can support their efforts and communication regarding the transition to CE in port clusters. The identified indicators enable PMBs and port stakeholders to monitor progress, identify areas for improvement, and effectively communicate their circular economy initiatives.

Developing comprehensive CE indicators for port clusters enhances the monitoring and evaluation of the circular economy transition. By offering a set of relevant and feasible indicators, this case study empowers practitioners to drive the implementation of circular economy practices in ports. The findings highlight the importance of strengthening CE ambition levels and tailoring approaches based on port typologies. The study underscores the continual

contribution of life cycle assessment in advancing the circular economy in the built environment and presents a proposal for a circular and sustainable future in the sector.

23.1.8 Circular Business Models

Adopting innovative business models, such as product-as-a-service, sharing economy platforms, and leasing arrangements, which prioritise access over ownership and promote resource efficiency.

Case Study IX Circular Business Model—The Circular Retrofit Lab in Brussels, Belgium

The Circular Retrofit Lab is an innovative project based in Brussels, Belgium, that focuses on applying circular economy principles to retrofit existing buildings. It is a collaborative initiative between various organizations, including research institutes, industry partners, and government agencies.

The pilot project tested and implemented different scenarios for reusing and refurbishing the VUB Campus' prefabricated student housing, without generating a large amount of waste. Strategies have been explored for internal transformations, external transformations, and the module's multiple functional reconfigurations.

Depending on their expected rate of change in the floor plan, three different types of walls were defined, analyzed, constructed and transformed: walls with (1) a high rate of change, (2) a high degree of flexibility for the integration of technical infrastructure and (3) a low rate of change.

The project aims to transform traditional linear renovation processes into circular ones by adopting strategies such as:

- *Material Recovery and Reuse:* The Circular Retrofit Lab explores ways to recover and reuse building materials from demolition sites or renovation projects. Materials such as bricks, concrete, and wood are carefully deconstructed, sorted, and prepared for reuse in future building projects.
- *Value Chain Collaboration:* The project encourages collaboration among different stakeholders in the construction value chain, including architects, contractors, material suppliers, and waste management companies. This collaboration enables the identification of opportunities for material recovery and facilitates the development of innovative circular business models.
- *Design for Disassembly:* The project promotes Design for Disassembly (DfD) the concept, which involves designing buildings and components

with easy disassembly in mind. This enables the separation and reuse of materials at the end of a building's lifecycle, reducing waste and maximising resource efficiency.

- *Circular Procurement:* The Circular Retrofit Lab incorporates circular procurement practices by sourcing materials with high recycled content and low environmental impact. This encourages the use of sustainable materials and supports the market for circular products.
- *Knowledge Sharing and Capacity Building:* The project organises workshops, seminars, and training programs to share knowledge and build capacity among professionals in the construction sector. This helps disseminate best practices and encourage the adoption of circular approaches in building retrofit projects.
- The Circular Retrofit Lab serves as a demonstration and research platform for circular retrofitting, showcasing innovative techniques and technologies that can be replicated in other building projects. By integrating material recovery, collaboration, DfD principles, circular procurement, and knowledge sharing, the project contributes to the advancement of circular economy practices in the building industry

Case Study X Circular Business Model—The BLOXHUB Circular Building in Copenhagen, Denmark [8]

The BLOXHUB Circular Building is an innovative construction project located in Copenhagen, Denmark. It is a collaborative initiative between BLOXHUB, a Nordic hub for sustainable urban development, and a group of industry partners.

The circular business model employed in the project focuses on the concept of "demountable construction," aiming to maximize material reuse and minimize waste generation. Some key features and practices include:

- *Modular Design:* The building is designed with modular elements that can be easily disassembled, allowing for the reuse of materials in future construction projects. The modules are carefully documented and labelled to ensure efficient disassembly and reassembly.
- *Material Passport:* Each component used in the building is assigned a unique identification code, which is recorded in a digital material passport. This passport contains detailed information about the origin, composition, and quality of the materials, facilitating their future reuse and recycling.
- *Material Reuse and Recycling:* The project prioritises the use of recycled and reused materials, including timber, bricks, and insulation. These materials are sourced from existing buildings, construction waste, and local recycling facilities.

- *Circular Collaboration:* The BLOXHUB Circular Building serves as a collaborative space for various stakeholders in the building industry, including architects, engineers, contractors, and researchers. This fosters knowledge sharing and innovation in circular construction practices.
- *Life Cycle Assessment:* The project utilises life cycle assessment methodologies to evaluate the environmental impacts of different design choices and construction techniques. This allows for informed decision-making and optimisation of resource use.

The BLOXHUB Circular Building showcases how circular business models can be applied in the building industry to promote resource efficiency, reduce waste, and enable material reuse. The project exemplifies the transition towards a more circular and sustainable built environment by integrating modular design, material passports, collaboration, and life cycle assessment

Case Study XI Circular Business Model: Resource Optimisation [2]

The Ellen MacArthur Foundation's report on the circular economy in cities highlights the case of Amsterdam's circular economy program [9] which includes initiatives like recycling construction and demolition waste, promoting circular procurement, and implementing material passports for buildings to enable future reuse.

This program encompasses various initiatives aimed at promoting circularity in the city. Some key initiatives mentioned in the report include:

- *Recycling Construction and Demolition Waste:* Amsterdam has implemented strategies to promote the recycling of construction and demolition waste. By diverting waste from landfills and reintroducing materials back into the economy, the city aims to reduce resource consumption and minimise waste generation.
- *Circular Procurement:* The city of Amsterdam has embraced circular procurement practices, which involve sourcing products and services that have a lower environmental impact and can be easily reused or recycled. Circular procurement supports the development of CE by stimulating demand for circular products and services.
- *Material Passports for Buildings:* Amsterdam has introduced the concept of material passports for buildings. Material passports provide detailed information about the composition and characteristics of building materials, enabling efficient and safe dismantling and future reuse. This approach facilitates the circularity of building materials and promotes the transition towards a more sustainable built environment.

The case of Amsterdam's circular economy program serves as an example of how cities can implement a range of strategies and initiatives to foster circularity. By adopting measures such as recycling construction waste, promoting circular procurement, and implementing material passports, Amsterdam is striving to create a more sustainable and resource-efficient city

23.1.9 Monitoring and Evaluation

Implementing monitoring and evaluation systems to track progress, measure the effectiveness of circular initiatives, and identify areas for continuous improvement.

Case Study XII Smart Monitoring and Evaluation for CE Implementation at University of Birmingham Campus Building

The University of Birmingham (UK), in partnership with Siemens, is combining digital sensor and analytics technologies, artificial intelligence, decentralized energy generation and storage, renewable energy and concepts that help change users' behavior to transform the University's Edgbaston and Dubai campuses into the world's smartest global campus, creating a 'Living Lab' where research, teaching and learning all benefit from access to new data and connectivity for circular economy and sustainability. The 'Living Lab' will capture data from the University's building technologies, estate infrastructure and energy plants and use it for innovation, R&D activities, as well as teaching. Scrutinizing energy demand and production with live data from across the sites (for both new and existing building stocks) provides students with a unique opportunity for applied learning and creates a platform for cutting-edge research. Siemens sponsors a team of PhD studentships at the University based in the UK and Dubai. Their research projects are co-designed by Siemens and the University to address important challenges in data, technology, urban systems and the NetZero goal.

In 2023, the University of Birmingham became the first university in the world to roll out Internet of Things (IoT) technology at scale. Starting in Autumn 2021, the first phase of this major energy efficiency project included the rollout of 23,000 Enlighted IoT sensors across the University estate. As one of the largest universities in the UK—with a global community of more than 38,000 students—the university is already an energy prosumer, and these technologies are further optimized in the system we are now working on together. Partnerships like this are extremely important for gathering new insights, testing and developing new technologies and creating efficient and

sustainable energy infrastructure. The university's campus in Dubai is a global example of sustainability at the rescheduled Dubai Expo 2020.

CEO Siemens, GB & Ireland stated that, "We are excited to be working with the University of Birmingham on this project and confident that together we can develop a clear pathway to the University becoming a smart campus and net zero. Our goal is to apply the University's strategic vision to their campus. We will uncover where carbon savings are possible by managing resources more efficiently in a system that is adaptable to changing demand. All of this can be achieved with a combination of connected digital technologies, artificial intelligence, decentralized energy generation and storage, renewable energy and ideas that help change users' behavior." In addition, Siemens will deliver a 10-year bureau for Energy and IoT services to ensure that the University reaps the full potential of both the technology and industry expertise. The University has already made significant progress in making its operations more sustainable, including achieving its 2020 target of reducing carbon emissions by 20% and is constantly looking to improve the environmental performance of its buildings, including a reduction of 2,856 tCO_2 annually, equivalent to 5% of the University's current emissions. Earlier this year, the University of Birmingham signed up to the United Nations Global Compact—the world's largest corporate responsibility initiative—as part of its commitment to reducing its environmental footprint and maximizing the impact of its research. The University of Birmingham is also a participant in the COP26 Universities Network and will have a presence at the COP26 conference in Glasgow in November.

This case study at the University of Birmingham highlights the implementation of the circular economy program and its real-time monitoring and performance management using advanced sensors and IoT. It serves as an example of how a cluster of integrated new and existing building stocks can implement a range of strategies and initiatives to foster circularity towards net zero.

23.1.10 Stakeholder Collaboration

Engaging a diverse range of stakeholders, including businesses, government entities, academia, non-profit organisations, and local communities, to collectively work towards circularity goals and address systemic barriers.

By implementing these best practices, organizations and societies can move towards CE, where resources are utilized more efficiently, waste is minimized, and environmental impacts are reduced, leading to a more sustainable and resilient future.

Above are a few examples of best practices in circular economy management mentioned in the literature.

These examples demonstrated the range of best practices in circular economy management across different domains, including design, resource optimization, collaboration, technology, policy, consumer engagement, and business models. Implementing these practices can contribute to the transition towards a more circular and sustainable economy.

23.2 An Integrated Approach to CE Management in the Built Environment

Following from the section above, it is clear that the extant literature suggests that both strategic planning and collaborative development of circular practices with relevant stakeholders are necessary for the effective development and implementation of circular capabilities and initiatives in the built environment. From a strategic planning perspective, first, there is a growing body of literature exploring the issues around material resource planning and management. Viewing buildings as material depots changes how resources need to be managed within the construction sector and the built environment. Such a view requires documentation and communication of which materials in what quantities and qualities become available for reuse or recycling where and when [10]. To facilitate this documentation and communication, several material cadaster projects have been developed [10–13]. Second, and in connection with the first point, there has been a growing number of publications on material flow analysis because it is only through a good understanding of the flows that effective material resource planning and allocation can be achieved. While some of these material flow analyses focus on individual material types, such as timber in residential buildings [14], some others focus on individual sectors, such as road transport [15], and others focus on specific territories [16].

Several publications implicitly or explicitly stated that issues around material resource planning and management cannot be thought of independently from wider socio-economic and technological barriers/enablers of circular economy [17]. Therefore, it is important to develop enabling legislation and policy [18, 19], develop and capture viable business models [20], circular building materials [21], and end-of-life strategies (e.g., construction and demolition waste strategies) [22]. Furthermore, considering the wide range of material types and cases, as well as stakeholders, involved in the built environment, there is a strong emphasis on the use of digital tools and capabilities as an enabler for strategic planning and management of circularity in the built environment [23].

At the same time, there has also been interest in empirical exploration of circular initiatives on the ground, which provided insights on operational development and management of circular capabilities and initiatives in the built environment. For example, [24] present a case where a team of experts from the UK and Nigeria worked with local Nigerian entrepreneurs to build a prototype home from upcycled materials, such as plastic bottles and agricultural waste in construction. They

conclude that adopting a user-centered, co-creation methodology and working with local skills, allowed for a solution (a prototype home), with improved functionality and sustainability. Giorgi et al. [25] conducted interviews with construction stakeholders in multiple European Union countries to explore the gap between the EU construction circular economy policy and practice. They found that certain strands of circular initiatives tend to be driven by certain stakeholder groups on the ground. For example, while the legislative framework promotes waste management strategies focusing on recycling, the design strategies for reversible buildings are generally private initiatives driven by market competition. Arora et al. [26] study two cases of component-focused urban-mining and highlight that what is required is the engagement of local stakeholders (i.e., potential consumers and real estate developers) with the demolition contractors to salvage the required building components. In a similar line of thought, Joensuu et al. [27] emphasize that a successful plan with the main objectives of a circular economy in the built environment could only be "achieved with inclusive and location-sensitive politics functioning from both bottom-up and top-down perspectives". This implies that there is a need for simple, innovation-positive rules which leave room for stakeholder inventions. However, so far, there has not been a universally accepted, or used, comprehensive management framework that integrated both perspectives.

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