



Waste Management and Circular Economy in the French Building and Construction Sector

Arnaud Diemer^{1,2*}, Claudiu Eduard Nedelciu¹, Manuel E. Morales^{1,3}, Cécile Batisse^{1,2} and Carmen Cantuarias-Villessuzanne⁴

¹ ERASME, CERDI, UCA, Clermont-Ferrand, France, ² Circular Economy and Industrial Ecology, Clermont-Ferrand, France, ³ IN4ACT, SEB, KTU, Kaunas, Lithuania, ⁴ ESPI Paris, ESPI2R Research in Real Estate, Paris, France

OPEN ACCESS

Edited by:

Jaroslaw Górecki,
UTP University of Science and
Technology, Poland

Reviewed by:

Giacomo Di Foggia,
University of Milano-Bicocca, Italy
Raimondas Šadzevičius,
Kauno University of Applied
Sciences, Lithuania

*Correspondence:

Arnaud Diemer
arnaud.diemer@uca.fr

Specialty section:

This article was submitted to
Circular Economy,
a section of the journal
Frontiers in Sustainability

Received: 20 December 2021

Accepted: 18 January 2022

Published: 03 March 2022

Citation:

Diemer A, Nedelciu CE, Morales ME,
Batisse C and
Cantuarias-Villessuzanne C (2022)
Waste Management and Circular
Economy in the French Building and
Construction Sector.
Front. Sustain. 3:840091.
doi: 10.3389/frsus.2022.840091

The impact that European and French legislation have on the circular economy implementation between market-driven incentives and state regulation emerges as the main challenge addressed in this chapter. Circular economy principles and the normative aspects of legislation constitute the best available frameworks to foresee how circular economy implementation will evolve in the building and construction sector in France. The Eiffage case study can be explained by the evolution of the normative arena composed by the current codes, environmental laws, roadmaps, and directives that frame the dynamic behavior of individual actors submitted to market pressures. A literature review of the current scientific and gray literature on circular economy in the building and construction sector was carried out in order to identify the required conditions to improve circularity in a normative way in France. Seven circular economy principles have been identified in the state of the art of Building and construction sector in France with emphasis on four of them: (1) Building lighter structures, (2) Waste reduction in the production process, (3) Intensive use of floor space, and (4) Extension of product life or recycling. Finally, we claim that the advantage of the normative approach implementation and analysis is to set the social agreement of compulsory foundation over which the market-driven initiatives and innovation could make the difference for the outstanding stakeholders of the economic sector.

Keywords: circular economy, market-driven incentives, buildings, construction sector, resource efficiency, EU legislation

INTRODUCTION

The building and construction (B&C) sector experiences challenging issues concerning the reduction of carbon footprint resulting from the GHG emissions and the materials consumption (cement and iron steel) as part of the 2030 SDG objectives. Circular Economy (CE) emerges as the most suitable strategy for resource minimization in the productive processes resulting from closing, extending, and intensifying material/energy loops (CGDD, 2014; Diemer and Dierickx, 2020) and the adoption of eco-efficiency enhancements and technologies gaining momentum in the Building and construction sector in the past 10 years (Ellen Macarthur Report, 2020). CE entails a systemic

solution to maintain the value of products, materials and resources in the building and demolishing sectors for as long as possible, as evidenced by the studies published by Bilal et al. (2020) and Akhimien et al. (2021). This chapter opens the door to analyse and discuss regulatory and prescriptive issues that challenge the role of the CE in the B&C sector (Norouzi et al., 2021), considering questions like: What constitutes attractive investments in a circular economy? How does the B&C sector explore these opportunities? How do policymakers engage cities toward resilient pathways? How do European and national norms transform the B&C sector and which dynamics govern the entry of new actors?

At the same time, the outbreak of the COVID-19 crisis has deeply impacted the B&C sector which is already very sensitive to economic cycles (ILO, 2021). Local and global lockdowns led to labor shortages, while disruptions in supply chains slowed down delivery periods for construction sites. This period has reinforced a number of existing trends (Uzzal Hossain et al., 2020) such as smart manufacturing shift, the global demand for bio-inspired infrastructure, light structure buildings, the growing building stock for renovation, the improvement of energy efficiency (a key driver to lift out people from energy poverty) or the strategies to mitigate greenhouse gas emissions like the more intensive use of the floor space and extending the product life length. This period also accelerated the adoption of circular strategies (Leising et al., 2018) that reduce the waste in the B&C process, improving the use of high-quality and smart products especially through building modularity and adaptability, renovation and upgrade of buildings, building materials reuse or recycling infrastructure (Di Maio and Rem, 2015).

Since 2009 and more recently with the European Green Deal, the European Commission has reaffirmed the key role of the B&C sector, providing 18 million direct jobs and about 9% of the EU's GDP (European Commission, 2020a). The European Commission aims to help the B&C sector become more competitive, resilient, resource efficient and sustainable, providing the resources and means to tackle greenhouse gases emissions, material and energy efficiency and other social related challenges (European Commission, 2020b). However, as long as we increase our stock of buildings, closing loop strategies alone will never be enough to accomplish zero waste balance (European Commission, 2018). In order to achieve this goal, systemic strategies need to be implemented beyond recycling principles. In the EU, strategies aim to address carbon footprint, greenhouse gas emissions, zero net waste and resource efficiency through the key following action areas: European legislation, internal regulations, markets, and sustainability forecasting tools (European Commission, 2014). The first area seeks to help in the B&C sector to increase digitalisation rates and implement building information systems (BIS) in the public sector. The second area controls the implementation of the Construction Products Regulation (CPR) and analyses its influence on the consolidation of the B&C internal market. The third area governs sustainable competitiveness of the B&C sector (European Commission, 2012), i.e., implementing lighter building structures, building waste reduction, intensive floor space use, and life cycle extension of products. Lastly,

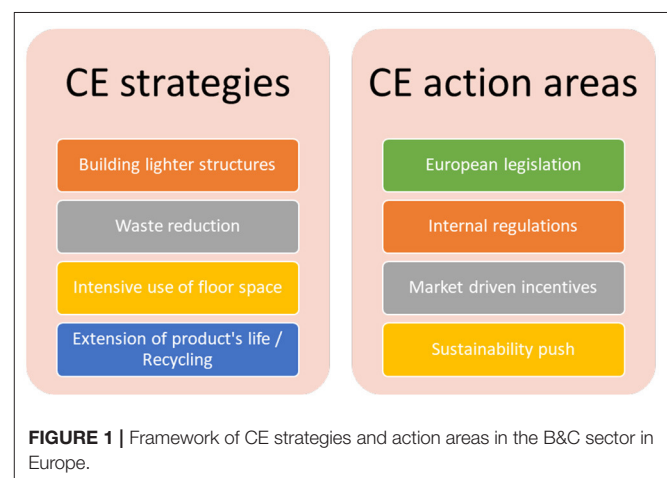
sustainability forecasting tools seek to supply the necessary means to predict and anticipate the B&C sector's behavior. Such tools are also essential in assessing progress on the Construction 2020 Strategy and the Circular Economy Package.

The four previously defined action areas in the B&C sector looking to address carbon footprint, greenhouse gas emissions, zero net waste and resource efficiency strategies through Circular Economy cross eight business economic sectors: (1) Manufacturing industries, (2) Biomass and bio-based products, (3) Energy, (4) Food, (5) Construction and demolition, (6) Critical raw materials, (7) Water, and (8) Chemical industries. The CE action areas applied in the B&C sector are predominantly approached through mesoscale analysis (50%). The relevance of the CE action area prioritization is also defined by the CE strategy suitable for the CE macroeconomic context and the level of analysis. Having a better understanding of the action areas the CE strategies we will bridge the gap in the current state of the art on how the implementation of CE strategies influence the B&C sector (Figure 1).

This paper aims to identify how the application of the appropriate CE strategy and action areas influence the outcome of potential conflicts, dilemmas and synergies between private and public actors. The French case (Section Circular Economy Strategy of Eiffage) displays the existing tensions between national and European regulation and the interaction of the stakeholders in the current building sector transition.

THE WASTE ISSUE IN THE BUILDING AND CONSTRUCTION SECTORS IN FRANCE

The B&C sector is the largest consumer of resources and the largest producer of waste (ADEME, 2013, 2014, 2021) in France. The construction sector alone represents 70% of the annual waste produced in France and amounts to 227.5 million tons or an equivalent of 3.4 tons per person per year. Of the total waste coming from the B&C sector 49% comes from demolition, 38% from rehabilitation and 13% from new construction. This waste can be reduced by 2.7 tons per year per person if acting on the



recycling rate of construction and demolition waste, particularly on the recycling of mineral wastes.

The recycling rate of B&C waste has slightly varied in France between 2014 and 2018, according to Eurostat database, from 70–72%, which represents between 55 and 70 million tons slightly above the EU average recycling. This rate varies greatly depending on the activities: 60–80% for demolition, 10–30% for rehabilitation, and 40–70% for new construction.

Building and construction waste, this sector includes 300,000 annual construction sites, which translates into a consumption of 360 million tons of granules, 72% of which are new granules from quarries and the remaining 28% from recycling. Authors estimate that from 20,000 to 30,000 tons of granules are needed to build 1 km of highway.

The Circular Economy Legislative Framework in Europe and France

Over the last 10 years, a series of laws and regulations have been introduced to carry out the CE principles into the B&C sectors, both in the EU and in France. We have identified two main pathways of enacting CE principles in the legislative framework: (1) the transposition of European standards at the national level and; (2) the interplay between market-driven incentives. Both strategies can influence normative public behavior in the B&C sector.

The 2018 revision of the 2008 Waste Framework Directive, which follows the Grenelle French Environmental Act, is the new reference text for waste management policy in the European Union. The Grenelle Act is an example of a national legislative framework that has set the tune for all the European Member States until they adopted the CE Principles for building design by 2020. In addition, consultation work was carried out in 2012 and 2013 within the framework of the National Waste Council's prevention working group and resulted in the drafting of a National Waste Prevention Programme for the period 2014–2020. The programme has provided a reduction of 7% in the production of household and similar waste per inhabitant in 2020 compared to the 2010 level, as well as a stabilization of waste production from economic activities (DAE) and construction. The plan stands for a gradual implementation of 54 concrete actions, divided into 13 strategic areas, which will contribute to achieving 4 actions in the B&C sector, the first of which has already been completed:

1. Sector-wide voluntary recycling protocol for construction and demolition waste;
2. Whitepaper of possible uses of the environmental footprint of products, including certain materials in the construction sector, to measure and indicate environmental information (PEF) (in progress);
3. Guidelines on pre-demolition analysis for the construction sector, the French version of which is a diagnosis (currently being drawn up);
4. Guidelines to develop indicators for assessing the environmental performance of buildings throughout their life cycle and measures for their use, also known as Levels.

Law n° 2015-992 of 17 August 2015 on the Energy Transition for Green Growth (LTECV in French) has set targets (Diemer, 2015)¹ for the recovery of the following materials: 60% of the use of road construction materials must be derived from reuse, re-utilization or recycling of waste (“inflows”); 20% of the use of road construction materials must come from reuse, re-utilization or recycling of waste materials in surface layers (“inflows”); 30% of the use of road construction materials must come from the reuse, recycling or recycling of waste materials in the sub-base layers (“inflows”); 70% must come from the reuse, recycling or material recovery of materials and wastes generated on road construction or maintenance sites, excluding “natural geological materials” (category 17 05 04) (“outflows”) (Figure 2).

Article 79 of the Energy Transition Law for Green Growth (LTECV) sets a target for the State and local authorities to recover at least 70% of the materials and waste produced on construction sites for which they are the contracting authority (reuse, recycling or other material recovery) in accordance with the 2008 European framework directive on waste.

The regulation implementing Article 93 of the LTECV sets out the terms and conditions for the creation of a network of professional waste collection centers for the building and public works sector and obliges them to organize the collection of waste from the same types of materials, products, and construction equipment that they sell.

Article L.541 of the Environmental Code

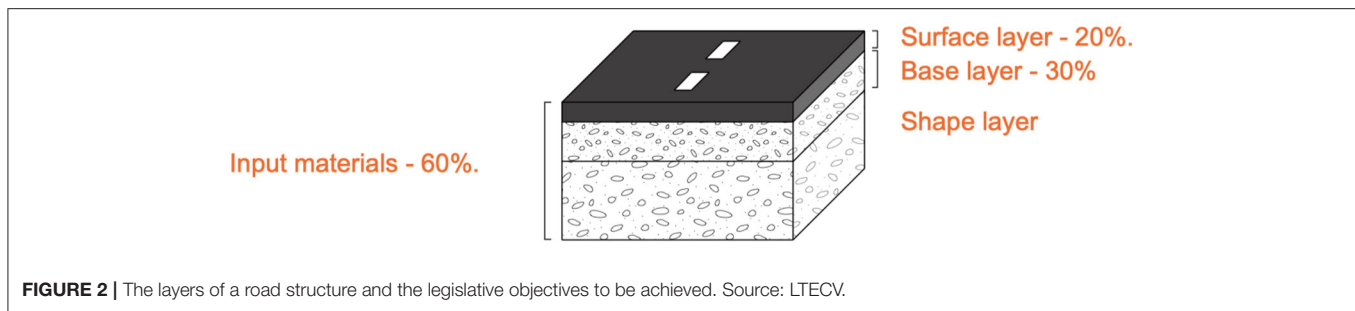
According to the Environmental Code, waste is “any substance or object, or more generally any movable asset, which the holder discards or intends or is required to discard.”² Waste introduces the notion of responsibility. The Environmental Code defines the project owner as the responsible for the waste from the construction site until its final disposal or recovery. The project owner has a duty to follow up the waste by any appropriate means and must be able to provide any information concerning the origin, nature, characteristics, quantities, destination, and management methods of the waste. Finally, it must ensure the traceability of the waste until its final disposal or recovery. However, it is interesting to note that each actor in the waste management chain remains responsible for the traceability obligations.

Law on Anti-waste and Circular Economy (AGEC Law)

The current waste status is relatively restrictive in administrative, organizational, and economic terms; therefore the Anti-Waste and Circular Economy Act (AGEC) was issued on April 1, 2021, seeking to address this problem. This regulation allows materials or products to be removed from their waste status under the guise of being useful, reused or recovered *in situ*. To do this, however, it is necessary to have an ISO 14 001 certified facility. In addition, the AGECE law facilitates the removal of excavated soil from waste status. Until now, it was compulsory to go through the figure

¹ Article 79 of Law n° 2020-105 of 17 August 2015 on the energy transition for green growth.

² Article L541-1 of the Environment Code.



of Installation Classified for the Protection of the Environment (ICPE) to obtain their removal from waste status. Today, this process is no longer mandatory. In return, an accredited third party expert must come and check the land looking for dangerous wastes. In order to respond to the intervention of this third-party expert, several conditions must be respected and are applicable to all construction wastes. It is therefore necessary that:

- the substance or object must be commonly used for specific purposes;
- the substance or object meets a market demand;
- the substance or object meets the technical requirements for the specific purpose and complies with the legislation and standards applicable to the products;
- the substance or object use does not have an overall negative effect on the environment or human health.³

The AGECE law is also devoted to the traceability of materials and in particular of excavated soil, thus, since January 1st, 2021, producers and retailers of excavated soil and sediments must make a declaration to the administrative authority to be able to provide detailed and transparent information. The information asked by the AGECE law quantities to the construction firms excavating soil and sediments is: nature, origin of the waste produced, handed over to a third party or taken in charge, quantities of products or materials resulting from reuse, recycling or other recovery operations, destination, frequency of collection, means of transport, and method of treatment or elimination. The excavation companies and the firms embedded in the aforementioned supply chains should implement strategies to ensure the traceability of dangerous or polluted waste, incineration and storage facilities for non-dangerous non-inert waste and facilities where waste loses its waste status, with the exception of the materials used in their original location and not far from the site of their excavation.

The AGECE law also proposes to increase to 12 the number of sectors concerned by the principle of Extended Producer Responsibility (EPR). In 2025, 10 more channels will be added, including the B&C sector. To understand the implications of this legislative decision, it is first necessary to understand that EPR principle means that the polluter pays. EPR is about transferring responsibility and, therefore, costs and

waste management to the producers of the waste, which means that the cost of waste management is integrated directly into the cost of the product. Thus, eco-organizations, financed by an eco-contribution paid by the producer, set up waste prevention, collection, sorting, and recycling services. The aim of such a measure is to make producers integrate in the products' cost the end-of-life processing and to encourage them to better design products that facilitate their recovery. An eco-modular system makes the regulation possible to discriminate regarding the cost of waste management according to whether the product integrates environmental criteria (bonus) or entails a polluting debt (malus).

Finally, the AGECE law stands as the flagship against illegal dumping providing the possibility for mayors to impose administrative fines in the event of illegal dumping and also to implement video-protection measures. Thus, herein we describe the measures implemented during the past 10 years in what concerns the environmental dimension of the B&C sector. Government authorities seem to be taking up the issue, but not all laws have a normative scope, some are set up as market-driven indicative benchmarks. For example, the objectives set by the LTECV are not enforceable in the B&C industry. The legislative framework for the public works in the B&C sector remains less restrictive on environmental issues.

The B&C sector is subject to the requirements of the Environmental Regulation (RE) from 2020 and to the obligation to carry out Products, Materials, Waste (PMD) diagnosis from a certain scale of building projects. To limit the waste generated in construction, renovation, and demolition sites, two measures resulting from the AGECE law have been applied since July 1st, 2021: (1) waste guidelines are now compulsory and (2) waste collection facilities must issue a traceable document to the company depositing its waste.

Waste mentions are now mandatory to appear in the budget estimation, containing the following mentions: (1) the estimate of the total quantity of waste generated by the company over the duration of the work; (2) the modalities of waste management and collection on the site (sorting effort made, nature of the waste for which a specific collection is planned); (3) the collection point(s) to which the waste will be transported by the constructors or subcontractors (identification by their company name, address, and type of installation); (4) the estimated costs associated with the management and removal of this waste. If they fail to comply with this new obligation, they risk an

³Regulation of 4 June 2021 setting the criteria for the removal of waste status for excavated soil and sediments that have been prepared for use in civil engineering or development.

administrative fine that can reach up to €3,000 for individuals and €15,000 for legal structures.

The managers of waste collection facilities (public or professional waste collection centers, distributors, etc.) must issue a receipt or proof delivered to the waste depositing company. The receipt must be given free of charge by the collection facility where the inert waste (concrete, rubble, tiles, bricks, etc.) or non-hazardous waste (wood, plastic, metal, plaster, etc.) from the B&C and/or gardening companies is to be deposited. All collection centers and collectors are targeted by this new approach, including public waste collection centers if they receive construction waste collections. This document must be filled in and signed by both the collection facility and the manufacturer. The collection facility must specify the contact details, the date on what the waste was deposited, the nature and quantity of the waste diverted (after visual examination or weighing), and the building professional must mention the company name, the firm identification number (SIREN or SIRET) and the address of the company; information on the project owner(s) of the sites from which the waste comes (name or company name, address, and identification number if applicable).

This receipt must be kept by the company, which can present it to the project owner on request or in the event of an inspection. Failure to comply with this obligation can result in stringent penalties: up to two years' imprisonment and a €75,000 fine. These new obligations have three aims: (1) to fight illegal waste dumping, which is unfortunately very common in the construction sector, (2) to guarantee the traceability of materials, and (3) to raise clients' awareness of the impact and challenges of managing waste from their sites.

From Circular Economy Principles to Circular Economy Roadmap

The linear production paradigm taking place in developed countries consisting mainly of extracting, producing, consuming and throwing away no longer allows for a sustainable future. We need to move to a circular model based on zero waste and increased intensity of resource use while reducing environmental impacts (ADEME, 2012). According to the *Ministere De L'environnement, De L'energie et De La Mer* (2016), CE can be defined as “an economic system of exchange and production that, at all stages of the product (goods and services) life cycle, aims to increase the efficiency of resource use and decrease the impact on the environment while developing the wellbeing of individuals.” The transition toward circular economy implies environmental gains but also sectoral reallocations of resources between material-intensive activities and those that contribute to the reduction of the environmental impact (France Strategy, 2016). Circular economy can be understood using three areas (production and supply of goods and services; consumption through demand and consumer behavior; waste management with priority given to closing the loop strategies) and seven principles (sustainable procurement, eco-design, industrial and territorial ecology, functionality economy,

responsible consumption, life length extension, and recycling) (Figure 3).

- *Sustainable procurement* concerns the mode of exploitation/extraction and purchasing of resources aiming at an efficient allocation of resources by limiting negative impact on the environment, in particular in the exploitation of energy and mineral materials (mines and quarries) or in the exploitation of agriculture and forestry for both renewable and non-renewable materials/energy.
- *Eco-design* takes into account the entire life cycle, from the design of a process, good or service, to the reduction of environmental impacts at the end of its life (ADEME, 2019). The concept of eco-design was established at international level in 2002, with the publication of the ISO/TR 14062 standard. This standard specifies that ecodesign aims to “integrate environmental aspects into the design and development of products.” Subsequently, in 2009, Directive 2009/125/EC established a framework for the setting of ecodesign requirements for energy-related products, defining eco-design as “the integration of environmental aspects into product design to improve the environmental performance of the product throughout its life cycle.”
- *Industrial and territorial ecology*, also known as industrial symbiosis, is a mode of organization between companies consisting in the mutual exchange of flows or the collective answer to common needs. A pillar of the circular economy, industrial and territorial ecology aims to optimize resources on a territory, whether energy, water, materials, waste, but also equipment and expertise, via a systemic approach inspired by the functioning of natural ecosystems.
- *The functionality economy* favors use over possession and tends to sell services linked to products rather than the products themselves.
- *Responsible consumption* is understood as the active and leading role of the buyer, whether an economic actor (private or public) or a citizen-consumer, making decisions while taking into account the environmental impacts at all stages of the product's life cycle (goods or services).
- *The extension of the duration of use takes place* when the consumer accomplishes to extend the loop through repairs, second-hand sale or purchase, donation, reuse, or refurbishment.
- *Recycling* aims to use raw materials from waste.

In April 2018, the French Prime Minister presented the *Government's Roadmap for the Circular Economy* (FREC), a set of coherent, balanced and structuring measures that will enable all stakeholders to “get into the loop.” FREC pushes France to achieve some of the targets of the sustainable development goals of the United Nations Agenda 2030, in particular the SDG12 establishing sustainable consumption and production patterns. Among the fifty measures included in the FREC, three aim to strengthen the sorting, reuse and recovery of construction waste. Out of the previous seven CE principles, we identify four strategies that represent the most relevant for the French B&C sector, especially after considering the impact of those in

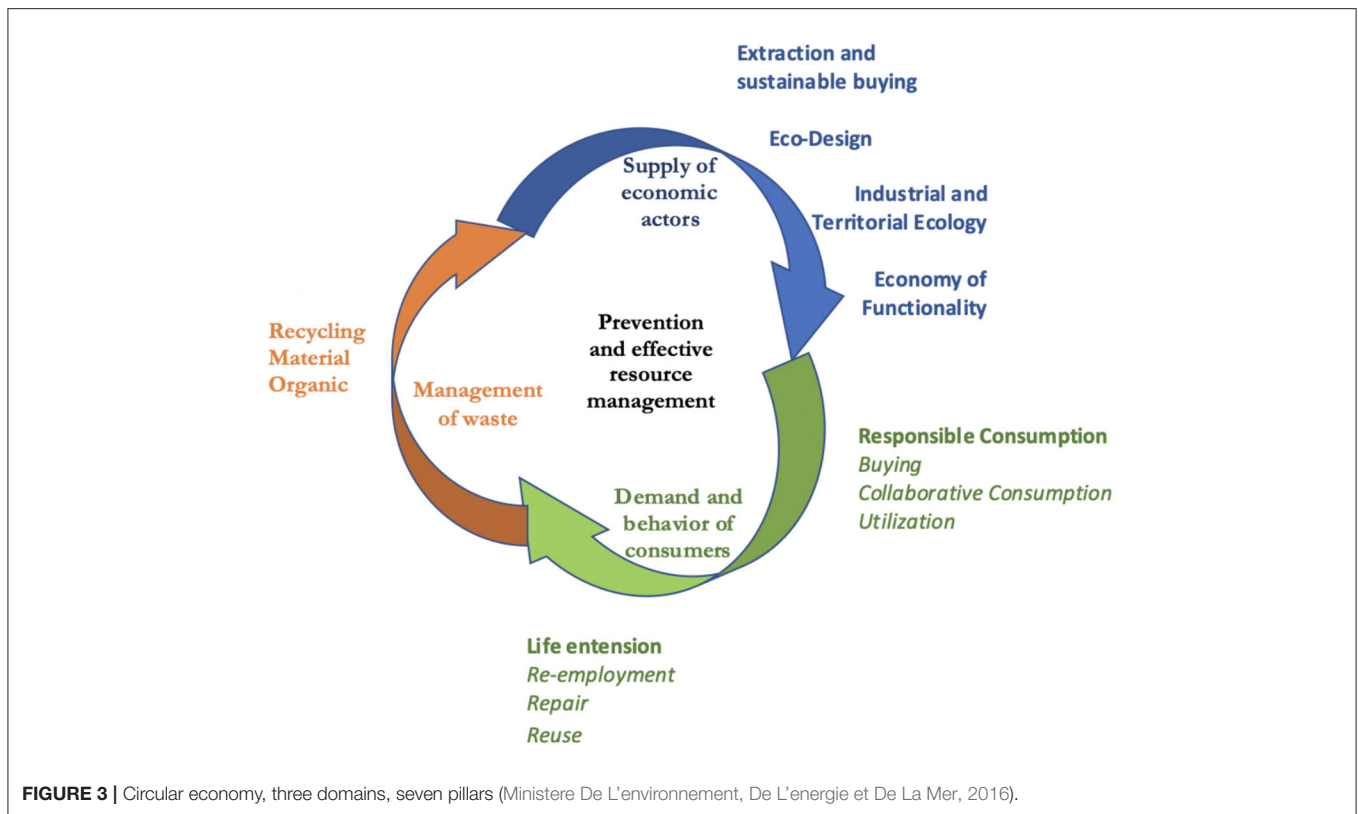


FIGURE 3 | Circular economy, three domains, seven pillars (Ministere De L'environnement, De L'energie et De La Mer, 2016).

the Sustainable Development goals. The first CE strategy is the design and construction of lighter structures which requires less material inputs. The second strategy concerns waste reduction in the construction process, improving the use of products. The third strategy concerns the intensive use of floor space, i.e., the increase in the construction of multi-family homes with higher energy efficiency as well as the collective action research where infrastructure like guest rooms and sports facilities is shared among multiple owners. Finally, the fourth strategy encouraged is the life product extension or the recycling of building and construction products.

Action 33 established that the provider is compelled to take back the construction waste. The FREC provides for a review of the management of construction waste by making collection more effective. FREC took into account the technical and economic impacts for the construction sector to reduce the landfills diversion. In particular, the introduction of an extended producer responsibility channel applied to construction waste will be part of the solutions studied.

Action 34 recalls that since 1 March 2012, project owners have been obliged to carry out a diagnosis of waste from demolition or heavy rehabilitation work for the buildings with a floor area of more than 1,000 m²; and the use of one or more hazardous substances (classified as such under Article R. 4411-6 of the Labor Code).

This diagnosis must be carried out prior to the application for a demolition permit or the *ad hoc* authorization request under

the urban planning, construction and housing code or, before the demolition or rehabilitation contracts are awarded. ADEME has a dedicated website to obtain the Cerfa declaration forms and to fill in the data at the end of the demolition site.

Action 34 of the Roadmap for a Circular Economy (FREC) provides the guidelines to develop a diagnostic/inventory for the reuse and recovery of construction site resources and waste. This involves in particular:

- extending the scope of operations covered by major building renovation works;
- dematerialising the system and promoting the use of open data to encourage the emergence of digital applications to link the supply of reusable materials with the demand;
- strengthen the skills and professionalism of those carrying out the diagnosis;
- to raise awareness and train project owners.

Action 35 provides technical guidelines allowing the recognition of reused or re-employed materials' performance (technical, on the one hand, and health and environmental on the other).

Types of Waste

There are several types of waste. When working on the CE, it is necessary to know how to identify them. The French regulatory agency classifies them into three types:

- Dangerous waste, representing 3% of the total waste produced in France, this waste presents risks for the population and the environment. The classification of their hazardousness is based on the presence of one or more of the 15 hazardous properties proposed by the Environmental Code. Dangerous waste is represented by packaging soiled with toxic products, treated wood, aerosols, glues, paints, materials containing asbestos, etc.
- Non-dangerous and non-inert waste, representing 27% of the total waste produced in France. This waste is not dangerous and it may be recyclable, it is composed by plaster, insulation, polystyrene, plastics, ferrous, and non-ferrous metals.
- Inert waste is not dangerous either, does not decompose, does not burn and does not produce any physical or chemical reaction. This is the most common category in the construction and building sector. This type of waste includes concrete, asphalt aggregates, excavated material, etc. And this waste represents the biggest share of volume in France with 70%.

CIRCULAR ECONOMY STRATEGY OF EIFFAGE

Circular Economy Policy

Eiffage is one of the 33 major French companies that are members of the French Association of Private Enterprises (AFEP) that committed to a voluntary circular economy approach in 2017. This commitment was renewed in the second half of 2019. To limit the use of raw materials, Eiffage has sought to give priority to reuse and material recovery activities. Crushing of demolition waste and its reuse in recycled “gravel” - gravel with a controlled granulometry - for the construction of roads and buildings or as part of major urban development projects, recovery of materials from construction sites and exchanges of recoverable equipment or tools, selective deconstruction, shared heating networks. The circular economy is integrated into all of the Group’s businesses, with still very significant potential for development.

Aware of the need to tackle the scarcity of resources, Eiffage has sought to reduce and optimize the use of virgin raw materials (aggregates, oil, metals, etc.) as often as possible, right from the design phase of its projects. Ecodesign and material recovery are two priorities of the Group’s “circular economy” policy (Eiffage, 2021). Working methods, business models and services have evolved in line with the principles of the circular economy, in order to meet the following challenges:

Upstream of Production

- Reducing the consumption of extracted materials: sand, minerals, gypsum, phosphorus, water, etc. Globally, the continuous increase in demand is leading to the overexploitation and disruption of the natural renewal capacity of resources and, consequently, of available stocks.
- Combating the fragmentation and depletion of natural environments, including the fragmentation of ecological spaces and corridors. Pressure on resources reduces the

resilience of the ecosystems from which materials are derived. The over-presence of extraction and transformation sites, transport and waste treatment sites contribute to the fragmentation of natural habitats for fauna and flora species. Resource management practices (e.g., water management and pollution treatment) can also weaken the quality of ecosystems. More details are available in our Biodiversity Action Plan.

Downstream From Production

- Reduce pollution of soil, water and air.
- Reduce land pressure to fight against the phenomenon of land occupation and achieve the “zero net artificialisation” (ZAN) objective.
- Promote material recovery cycles and recyclability: replace the extraction of virgin raw materials with the reuse of existing elements or the generation of recycled raw materials.

All of these circular economy initiatives, because they contribute to the reduction of greenhouse gas emissions, also play an important role in our low carbon strategy.

At the end of the first half of 2019, a charter dedicated to Eiffage’s commitments in terms of the circular economy was drafted in order to raise awareness among teams and share best practices in the Group’s various businesses (Figure 4).

Circular Economy Charter of Eiffage “Being eco-responsible means entering the loop.” Eiffage’s ambition: to preserve natural resources and optimize waste management. Consist on evaluating and reducing raw material requirements at the source:

- Give priority to recycled materials / materials from reuse
 - Develop local synergies (sharing of materials and energy)
 - Promote our rehabilitation and recycling offers to our customers - Mobilize our suppliers
 - Be exemplary in our waste management: selection and traceability.
1. Eco-design our works to reduce the consumption of materials
 - Source renewable or recycled materials from our suppliers - Train employees in eco-design
 - Innovate to make our structures more adaptable
 - Increase the lifespan of structures.
 2. Commit to the reuse and recovery of waste
 - Measure and limit waste production
 - Favoring reuse and recycling
 - Enhancing our waste recycling and contaminated soil recovery expertise of polluted soil
 - Develop our selective deconstruction activities.
 3. Raise awareness and share best practices in all the Group’s businesses
 - Turn waste into a new raw material
 - Share initiatives and feedback within the Group
 - Supporting innovations in the field
 - Make the circular economy an innovative asset in our commercial offers.



FIGURE 4 | Eiffage eco-responsible conception. Source: Eiffage website.

Circular Economy Issues

A series of principles have been listed: (i) Develop the integration of recycled or renewable materials in the activities; (ii) Extend the life of structures and materials by facilitating their reuse and recycling; (iii) Promote the transition of manufacturing processes, and reduce as much as possible the share of non-recovered waste; (iv) Work with professional, scientific and associative stakeholders via collective progress initiatives.

The conditions for success have been described: (a) Implement a sustainable resource management policy; (b) Deepen and accelerate the eco-innovation approach; (c) Measure, manage and control the performance of solutions.

Eiffage's circular economy policy has been designed around three challenges (Table 1).

From Ecodesign to the 7Rs

Ecodesign, which optimizes all resources, is integrated into all of Eiffage's projects. In addition to materials, this involves developing service sharing systems or proposing offers that directly integrate multiple uses (Figure 5).

Doing More and Better With Less

Eiffage relies heavily on building information modeling (BIM) to design its building and infrastructure projects. A digital tool of the future, BIM makes it possible to model a project in detail and to optimize its progress in terms of organization and resources

(EUBIM, 2017). For example, digital simulations provide our teams with the means to manage materials and equipment. In the future, it could also help to manage waste. BIM thus provides a global and precise vision of a project. The environmental impact could be integrated into it and, by extension, the existing means to limit it.

Green chemistry, plant-based substitutes for bitumen, carbon-neutral maintenance processes. Eiffage Route's laboratories have been developing innovative, environmentally friendly solutions for 20 years. In particular, they have designed Recyctal-ARM[®], a solution for recycling existing pavements using plant-based binders, which makes it possible to reduce the carbon footprint of road works by a factor of 10. The use of Recyctal emulsion, which is of plant origin, makes use of co-products from forestry and the paper industry, advantageously replacing bitumen emulsion derived from oil. At the same time, the implementation of the mobile recycling workshop (ARM), which recycles the pavement in place on the worksite itself, greatly limits the carbon impact of the production and transport of materials and waste.

Pooling Services

Noé⁴ is a physical circular economy platform that brings together and pools the needs of 170 member companies (VSEs/SMEs, demolition companies, public works companies, etc.), providing

⁴<https://plateformenoe.fr/>

TABLE 1 | Challenges from Eiffage to achieve circular economy.

(1) Avoid, reduce, compensate	(2) Developing a low-carbon “material mix”	(3) Maximizing the material recovery
<p>To avoid damaging a natural habitat - a river, wood, pond, meadow, wetland, etc. - Eiffage strictly adheres to the principle of avoidance, reduction and compensation. -To avoid damaging a natural habitat, such as a watercourse, woodland, pond, meadow or wetland, Eiffage strictly follows the regulatory sequence of Avoid, Reduce, and Compensate (ERC) and uses specific actions, planned from the project design phase, that make it possible, for example, to bypass sensitive natural areas. The first step is to avoid the impacts of activities on species and natural environments as early as possible.</p> <p>When negative impacts cannot be totally avoided, the developer/constructor takes appropriate measures to reduce them, for example by building suitable environmental structures or installing mitigation devices on site. The aim is to reduce as far as possible, from the start of the activity, its ecological footprint, its level of pollution or its impact on wild fauna and flora.</p> <p>Finally, if residual impacts are identified, they must be assessed and then compensated for in kind so that the project does not cause any “net loss” of biodiversity in the long term.</p> <p>Around Eiffage’s motorway and rail infrastructure, for example, wildlife crossings have been installed and entire waterways restored and rehabilitated. Protected natural areas of several hectares have also been created to protect threatened species and natural environments. In addition, environmental studies are systematically carried out to ensure the medium- and long-term benefits of the actions undertaken.</p> <p>At the Corbigny quarry site, Eiffage is working in partnership with the Bourgogne Conservatoire d’Espaces Naturels to create areas that encourage the preservation and development of animal and plant species.</p>	<p>Biosourced and geo sourced materials, new ranges of concrete with reduced carbon impact, recycled concrete capable of storing carbon, development of solutions from the “dry sector,” modularity, reuse, prefabrication, rehabilitation, etc. Eiffage’s industrial and commercial offerings are based on a number of innovative processes that enable the industrialization of low-carbon design and construction. Moreover, these solutions are perfectly duplicable and better adapted to the variability of uses and respectful of the life cycle and sobriety of natural resources.</p> <p>The challenge of the “dry process”: in 2018 and 2019, Eiffage’s Construction division strengthened its position in the “dry process” for on-site assemblies through the acquisition of Savare and B3 EcoDesign. The dry process does not use water, as opposed to the traditional process (concrete construction in particular), which is known as “wet.” B3 EcoDesign designs ecological and economical housing from used maritime containers that have lost their carbon load; Savare has specialized in the manufacture of wooden components, frames, beams and posts for 40 years.</p> <p>Bio-based materials have a low ecological footprint and their manufacture contributes to the sustainable development of the local economy, when available in the region where we operate.</p> <p>In Bordeaux, Eiffage is building the tallest wood-frame tower in France. The building, called “Hypérior,” comprises 82 flats on 17 floors. It is designed with a concrete core and solid wood floors, supported by a post-and-beam structure. All the timber in the Hyperion project comes from Corèze and Limousin and is certified by the Wood Label.</p>	<p>Selective dismantling, reuse, or recycling of materials. Eiffage seeks to optimize the use of raw materials from the project design phase onwards, and then to use them in an environmentally responsible manner. To this end, the company favors material recovery processes, either internally or in partnership with local structures.</p> <p>LaVallée: an eco-district “demonstrator” of circular economy approach</p> <p>As part of the future LaVallée eco-neighborhood in Châtenay-Malabry supported by Eiffage Aménagement, a large-scale circular economy demonstrator was set up in 2018 to carry out the selective deconstruction of the former École Centrale. Firstly, a “resource diagnosis” was carried out prior to the deconstruction phase of certain buildings of the former École Centrale. The objective was to identify the potential for reuse of the finishing work (lighting, doors, sanitary facilities, handrails, emergency units, etc.) in order to recover everything that could be reused. What was once seen as waste to be processed has become a source of materials to be recovered.</p> <p>This is why Eiffage Aménagement has encouraged its partners, from the tendering phase for cleaning and demolition, to favor the selective deconstruction of the buildings in question, in order to improve the quality of the materials and products deposited for recycling. Crushed and recycled, 98% of the concrete resulting from the deconstruction of the buildings could be reused <i>in situ</i>.</p>

Source: Eiffage (2021).

them with a wide range of services that reduce the rotation of trucks and the risk of congestion: relay parking, living bases, management of excavated material and backfill, storage for treatment and waste traceability. The platform, which has been put into service in Bordeaux as part of France’s largest urban development project - 2.5 million square meters to be built over 20 years - provides a concrete solution to the risks of congestion and carbon emissions associated with construction sites. A highly innovative tool, Noé makes it possible to adapt current organizational methods to the constraints of construction in dense urban areas, while achieving real environmental performance.

DISCUSSION

The building and construction sector is one of the key action areas for EU’s Circular Economy Action Plan. Achieving

circularity in this sector is not only highly dependent on EU and national legislation - and its enforcement - but also on how proactive private actors are when it comes to implementing circularity principles. In France, the national legislation is aligned - and in some aspects is leading - EU legislation on circularity in the building and construction sector. Private actors have also committed voluntarily to circularity principles and Eiffage, the case study used in this analysis, has been ahead in many aspects. The company focused on waste reduction and high quality waste management, which would prolong material life cycle in the building and construction sector. Those are central elements of the EU’s Construction 2020 strategy and the Commission’s Circular Economy principles for building design (European Commission, 2020c). Durability is another one of the Commission’s priorities, which is reflected in Eiffage’s goal to increase the lifespan of structures. Eco-design is another one of the company’s central circularity strategies, which aligns

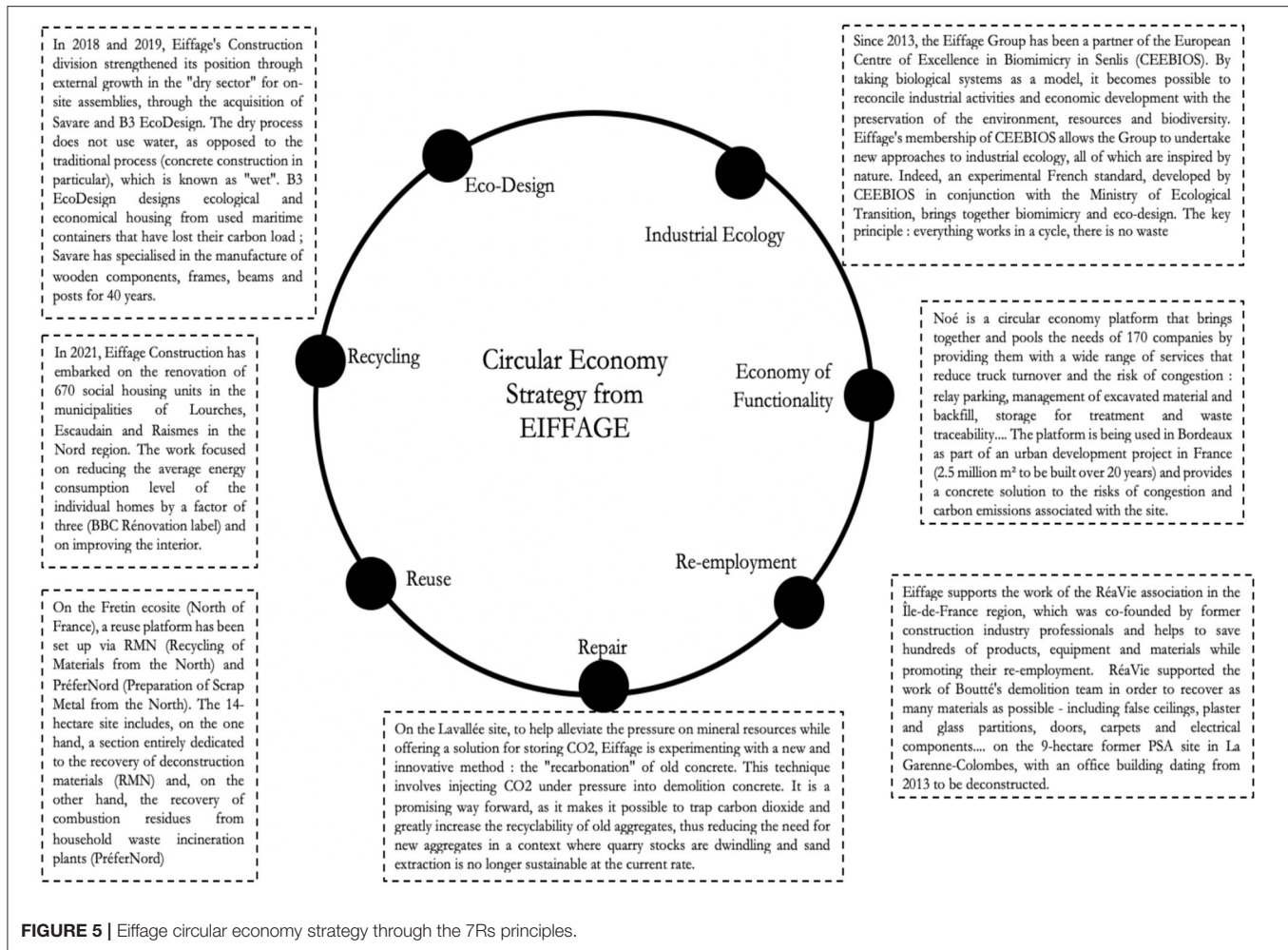


FIGURE 5 | Eiffage circular economy strategy through the 7Rs principles.

with some of the 10 Ecodesign implementing regulations of the Commission. Most importantly though, the CE charter of the company can contribute to some of the EU Green Deal priorities in the coming decade, such as longer lasting products and a globally competitive and resilient industry. Nonetheless, questions related to the social impact remain for both the French legislation and private actor-led initiatives - such as Eiffage's CE Charter. While Eiffage has a strategy of training staff in ecodesign, a lot more is needed to reach the EU Green Deal's objective of future-proof jobs and the CEAP 2020 objectives to make CE work for people, regions and cities, including a Skills Agenda and a Just Transition Mechanism (European Commission, 2020b). A more thorough assessment of the supply chain, as well as all branches of activity is required by private actors so that workers acquire the necessary skills to adapt to new technological and economic conditions. This is also tightly connected to the loss of jobs in some of the activities related to the building and construction sector and how those losses will be justly compensated. Studies in the literature have also called for more focus on the social aspect of CE (Schröder et al., 2020) and a growing body of literature calls for more focus on employment, health and safety,

participation, poverty eradication or gender equity (Padilla-Rivera et al., 2020). Thus there is also a need to move beyond jobs-only discourse and address a plethora of other social aspects. The EU Green Deal can be a good catalyser for this due to its comprehensiveness and complexity - indeed, recent studies such as the one launched by Sistemiq and the Club of Rome have called for a transformative and systemic implementation of EU's Green Deal, which would require redefining many of the European socio-economic metrics. This type of approach is linked to new economic thinking, which calls for an economy that delivers for all while keeping within biophysical planetary boundaries. Circular Economy and its associated implementation at national and private sector levels is still lagging behind in integrating these principles.

CONCLUSION

In its Circular Economy Action Plan for a "Cleaner and More Competitive Europe," the Commission is moving beyond recycling and emphasizing the need for more sustainable products and consumer services. The European

Commission intends to make the circular economy a pillar of carbon neutrality in 2050. The plan aims to reduce the carbon footprint of consumption, and double the use of materials from the circular economy. The new rules address the sustainability, re-usability, and reparability of products, including tackling the presence of hazardous chemicals, and increasing their recycled content. For the construction and buildings sector, the Commission has adopted a comprehensive strategy that promotes the principles of circularity throughout the life cycle of buildings. This includes the revision of the Construction Products Regulation, which could include recycled content requirements for certain construction products.

Several measures envisaged at the European level are already implemented in France and for several years, building and construction companies such as Eiffage have been developing charters and tools for the implementation of the circular economy. From 2022, the Anti-Waste and Circular Economy Law (AGEC) will be transposed in the building sector by the implementation of an extended producer responsibility (EPR) channel for construction products or materials in the building sector. This EPR “building site waste” will give rise to an ecotax which will make it possible to set up and/or structure the reprocessing of waste from the building sector, but also to massify its recycling. This means (1) the creation of a polluter-pays system for the building sector, (2) the setting up of new reprocessing centers to fight against illegal dumping and to be

able to treat the new volumes to come, and (3) the obligation for these reprocessing centers to take back the waste of the building professionals for free.

Both national legislation and private-sector initiatives in France are aligned to EU circularity principles, as laid down in the Commission’s CEAP. Nonetheless, more work is required on the social impact of CE, on one hand when looking at employment and on the other hand when looking at broader social aspects such as equity, health and safety or poverty eradication. Most likely, these aspects would require new CE metrics, which are now mostly missing from both state and private sectors.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

FUNDING

This research was funded by the ERASMUS + Programme of the European Union (Jean Monnet Excellence Center on Sustainability, ERASME), Chair Jean Monnet Europe, Circular Economy and Industrial Ecology and CAP 20 – 25 (Academia).



Co-funded by the
Erasmus+ Programme
of the European Union



I-SITE Clermont
Clermont Auvergne Project

REFERENCES

- ADEME (2012). *Osons l'économie circulaire*. n°59, octobre. Available online at: <https://www.ademe.fr/sites/~default/files/assets/documents/ademevous59dossier.pdf> (accessed September 8, 2021).
- ADEME (2013). *Economie circulaire. Notions*. Available online at: <https://www.ademe.fr/sites/default/files/assets/documents/fiche-technique-economie-circulaire-oct-2014.pdf> (accessed September 10, 2021).
- ADEME (2014). *Guide méthodologique du développement des stratégies régionales d'économie circulaire en France. Rapport Final, ADEME Paris – Angers*. Available online at: <https://www.ademe.fr/sites/default/files/assets/documents/guide-strategie-eco-circulaire-201410-rapport-final.pdf> (accessed September 25, 2021).
- ADEME (2019). *L'économie circulaire en dix questions*. Available online at: [https://librairie.ademe.fr/cadic/922/guide-pratique-economie-circulaire-10-questions.pdf?modal\\$=false](https://librairie.ademe.fr/cadic/922/guide-pratique-economie-circulaire-10-questions.pdf?modal$=false) (accessed November 12, 2021).
- ADEME (2021). *Etude de préfiguration de la filière REP produits et matériaux de construction du secteur du Bâtiment. Synthèse*. Available online at: <https://librairie.ademe.fr/dechets-economie-circulaire/4573-etude-de-prefiguration-de-la-filiere-rep-produits-et-materiaux-de-construction-du-secteur-du-batiment.html> (accessed November 25, 2021).
- Akhimien, N. G., Latif, E., and Hou, S. S. (2021). Application of circular economy principles in buildings: a systematic review. *J. Build. Eng.* 38, 102041. doi: 10.1016/j.job.2020.102041
- Bilal, M., Khan, K. I. A., Thaheem, M. J., and Nasir, A. R. (2020). Current state and barriers to the circular economy in the building sector : towards a mitigation framework. *J. Clean. Prod.* 276, 1–16. doi: 10.1016/j.jclepro.2020.123250
- CGDD (2014). Comparaison internationale des politiques publiques en matière d'économie circulaire. *Etudes et Documents* 101, 1–53.
- Di Maio, F., and Rem, P. C. (2015). A robust indicator for promoting circular economy through recycling. *J. Environ. Protect.* 6, 9. doi: 10.4236/jep.2015.610096
- Diemer, A. (2015). Loi sur la transition énergétique, croissance verte et développement durable. *Revue Francophone du Développement Durable* 6, 23–46.
- Diemer, A., and Dierickx, F. (2020). “Circular economy, a new paradigm for Europe?,” in *Paradigms, Models, Scenarios and Practices for Strong Sustainability*. *Oeconomia*, eds A. Diemer, E. Nedelciu, M. Schellens, M. Morales, M. Oostdijk (Clermont-Ferrand: Oeconomia Editions), 159–178.
- Eiffage (2021). *Economie circulaire, les engagements du Groupe Eiffage*. Available online at: <https://www.eiffage.com/transition-ecologique/l-economie-circulaire-un-enjeu-cle-pour-eiffage/economie-circulaire-les-engagements-du-groupe-eiffage> (accessed December 2, 2021).
- Ellen MacArthur Report (2020). *Circular Investment Opportunities for a Low Carbon and Prosperous Recovery*. Report, 11.
- EUBIM (2017). *Handbook for the Introduction of Building Information Modelling By the European Public Sector*. Available online at: http://www.eubim.eu/downloads/EU_BIM_Task_Group_Handbook~_FINAL.PDF (accessed September 20, 2021).
- European Commission (2012). *Communication from the Commission to the European Parliament and the Council, Strategy for the Sustainable Competitiveness of the Construction Sector and its enterprises*. Com/2012/0433 Final. Brussels: European Commission.
- European Commission (2014). *Communication from the Commission to the European Parliament, The Council, the European Economic and Social Committee and the Committee of Regions on Resource Efficiency Opportunities in the Building Sector*. COM/2014/0445 Final. Brussels: European Commission.
- European Commission (2018). *EU Construction and Demolition Waste Protocol and Guidelines*. Brussels: European Commission.
- European Commission (2020a). *Circular Economy, Principles of Buildings Design*. Report. Available online at: <https://ec.europa.eu/docsroom/documents/39984> (accessed October 15, 2021).

- European Commission (2020b). *A New Circular Economy Action Plan For a Cleaner and More Competitive Europe. COM/2020/98 Final*. Brussels: European Commission.
- European Commission (2020c). *Designing Buildings in the Context of the Circular Economy, February 25th*. Available online at: https://ec.europa.eu/growth/publications/designing-buildings-context-circular-economy_en (accessed December 17, 2021).
- France Strategy (2016). *L'économie circulaire, combien d'emplois. La note d'analyse* 46, 1–8.
- ILO (2021). *Impact of COVID 19 on the Constructor Sector*. International Labour Organization, 12.
- Leising, E., Quist, J., and Bocken, N. (2018). Circular economy in the building sector: three cases and a collaboration tool. *J. Clean. Prod.* 176, 976–989. doi: 10.1016/j.jclepro.2017.12.010
- Ministère De L'environnement, De L'énergie et De La Mer (2016). *Economie circulaire, les avancées de la Loi de Transition Énergétique pour la Croissance Verte*. Available online at: https://www.ecologie.gouv.fr/sites/default/files/9-1-17_PLAN_DECHET_2016-2025_pour_BAT.pdf (accessed December 20, 2021).
- Norouzi, M., Chafer, M., Cabeza, L. F., Jimenez, L., and Boer, D. (2021). Circular economy in the building and construction sector: a scientific evolution analysis. *J. Build. Eng.* 44, 1–18. doi: 10.1016/j.job.2021.102704
- Padilla-Rivera, A., Russo-Garrido, S., and Merveille, N. (2020). Addressing the social aspects of a circular economy: a systematic literature review. *Sustainability* 12, 1–17. doi: 10.3390/su12197912
- Schröder, P., Lemile, A., and Desmond, P. (2020). Making the circular economy work for human development. *Resour. Conserv. Recycl.* 156, 1–9. doi: 10.1016/j.resconrec.2020.104686
- Uzzal Hossain, M., Ngs, T., Antwi-Afari, P., and Amor, B. (2020). Circular Economy and the construction industry: existing trends, challenges and prospective framework for sustainable development. *Renew. Sustain. Energy Rev.* 130, 109948. doi: 10.1016/j.rser.2020.109948

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Copyright © 2022 Diemer, Nedelciu, Morales, Batisse and Cantuarias-Villessuzanne. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.