

Circular Economy and Recycling of Pre-consumer Scraps in the Construction Sector. Cross-Sectoral Exchange Strategies for the Production of Eco-Innovative Building Products



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Abstract The chapter reports the results of a research entitled “Ri-scarto”, conducted with the contribution of the “Fratelli Confalonieri” Foundation of Milan. The research investigates the conditions that can facilitate the cross-sectoral exchange (various manufacturing sectors-construction sector) of pre-consumer by-products and scraps, that can be used and/or recycled for making building products. The research proposes the framework of a cross-sectoral virtual marketplace, where the different stakeholders (manufacturers, possible users of by-products and scraps, industrial process planners, public administrators, etc.), organised in a network, can identify, locate and exchange available reusable waste.

Keywords Circular economy · Waste · By-products · Pre-consumer scraps · Sustainable production · Construction sector and innovative building materials

1 Introduction

Reducing the production of waste through prevention, recycling and reuse is one of the sub-targets present within “Responsible consumption and production”, the twelfth of the 17 Sustainable Development Goals of Agenda 2030 (UN United Nations 2015); it also represents one of the basic strategies at the core of the many measures and guidelines of the European Commission (EC European Commission 2014, 2015, 2010) supporting the circular economy (MacArthur Foundation 2015a). The circular economy (MacArthur Foundation 2010, 2015b) perspective leads us to attribute to by-products and recyclable wastes the potential of virtuous generator of

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new markets, capable of activating new skills and entrepreneurship and innovating the production processes according to the circular economy perspective (strategies downstream of production and consumption) (Lacy and Rutqvist 2015). At this aim, the different stages of the life cycle of the products should be made interdependent and permeable, in order to facilitate the exchange of materials, information and knowledge between the various production sectors. This implies a change of paradigms-involving culture, information and production processes-in the direction of a strategy focused on recognising the economic potential of recyclable waste and the possible involvement of a plurality of subjects: the companies extracting raw materials, the manufacturers processing raw materials; the designers and manufacturers of products; the designers and manufacturers of complex systems (buildings, consumer goods, equipment, etc.); the managers of the use phase (maintenance and upgrades); consumers/users; the managers of demolition/disassembly processes; the designers and the manufacturers of secondary raw materials and recycled products. This is a very complex scenario, in which stakeholders, belonging to different sectors and disciplines, interact on both a strategic and operational level and exchange information and materials.

2 Circular Economy Approaches for the Construction Sector

If the construction sector is considered, many questions arise, connected both with the areas and ways of application of the circular economy and with the roles of the many operators involved, such as:

- how to reconfigure existing building products and/or design new ones in order to reduce waste and/or characterise scrap and by-products, so that they can be applicable, as recyclable for other sectors;
- how to reconfigure existing building products and/or design new ones in order to use scrap and by-products from other sectors, thereby lowering production costs and increasing the environmental value of buildings;
- how to design the building systems for disassembling parts for reuse/recycling;
- how to assess and communicate the environmental quality of building products involved in recycling processes.

Considering circular economy, these and other issues open up to multiple perspectives of innovation for the construction sector and to new market segments involving the need for new skills, related to various stakeholders, for example:

- the manufacturers of building materials and components, that may offer recyclable waste that can become secondary raw materials for other sectors;
- the construction firms, that may offer recyclable waste that can become secondary raw materials for other sectors;

- the manufacturers of building materials and components, that may become the receiver of recyclable waste from other sectors;
- the designers of buildings, that may orient this market and can guide environmental quality strategies;
- the environmental certifiers, that may support the demand and the supply of recycled materials by highlighting the environmental parameters (and the related data) involved in the assessment procedures.

Actually, all these stakeholders share a double field of interest, defined by the “The Waste Framework Directive 2008/98/EC” (EC European Commission 2008) recently emended by the Directive 2018/851 (EC European Commission 2018): on the one hand, by-products¹ and on the other hand, certain specified wastes, that can reach an “end-of-waste status²”, that is able to cease to be waste³ when they have undergone a recovery, including recycling, operation. Working in a circular economy perspective (Charter 2019) implies, therefore, developing all those actions, skills, knowledge and information that allow us to:

- recognise and enhance the possibilities for by-products and secondary raw materials markets;
- orientate design and production in order to decrease the percentage of waste;
- characterise and improve the knowledge and traceability of by-products and secondary raw materials;
- analyse what, coming from the production and the usage processes, is commonly considered scrap in order to recognise and select the parts of it that might have a new use (recyclable waste) in comparison with the parts to be eliminated for being conclusively deemed discardable;
- create and characterise new supply chains based on recycling activities;
- support recycling chains⁴ through information and sensitisation campaign.

¹A substance or object, resulting from a production process, the primary aim of which is not the production of that item, is a by-products if: (a) further use of the substance or object is certain; (b) the substance or object can be used directly without any further processing other than normal industrial practice; (c) the substance or object is produced as an integral part of a production process and (d) further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts (EC European Commission 2008).

²The conditions for the end-of-waste status are: (a) the substance or object is commonly used for specific purposes; (b) a market or demand exists for such a substance or object; (c) the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products and (d) the use of the substance or object will not lead to overall adverse environmental or human health impacts (EC European Commission 2008).

³A substance or object which the holder discards or intends or is required to discard (EC European Commission 2008).

⁴On the issues of overcoming barriers when launching a waste market, see the interesting study from the European Topic Centre on Sustainable Consumption and Production: ETC/SCP Working Paper No 5/2013, Approaches to using waste as a resource: Lessons learnt from UK experiences, 2013.

3 Construction Sector's Demand and Manufacturing Sectors' Supply: A Research Proposal for a Cross-Sectoral Platform

In order to apply to the construction sector the possible actions, related to circular economy approaches, a research, funded by a “Fratelli Confalonieri Foundation” fellowship, has been developed starting from 2017. The research, named “Ri-scarto”, starts from some basic assumptions:

- building products are highly cross-sectoral (according to the Italian ANCE⁵ report, 31 of the 36 economic sectors are suppliers of construction sector, that buys goods and services from more than 88% of the economic sectors);
- by-products and pre-consumer scraps, coming from various manufacturing sectors, can represent important sources of secondary materials, useful for reducing the high environmental impacts⁶ of the construction sector, due to the intensive use of raw materials and to the generation of huge amounts of waste (C&D waste)⁷;
- by-products and pre-consumer scraps, coming from manufacturing sectors, are easy to be located, characterised, forecasted, quantified, are concentrated in the site of their production and represent, if well-known, a potential supply for recycling processes oriented to the production of building products;
- information can play an important role where cross-sectoral platforms can support and strengthen the dialogue between the construction sector demand for secondary materials and the manufacturing sectors supply of by-products and pre-consumer scraps.

On the basis of these assumptions, the research has developed two parts:

- a first part dealing with an investigation of experimental cases of successful matching between the construction sector's demand for recycled products and the manufacturing sectors' supply of by-products and pre-consumer scraps recycled for building products. The output of this part is a database of cases regarding products and processes, that can be analysed and compared according to various reading keys in order to share practices and highlight trends;

⁵ANCE, The construction industry: structure, sectoral interdependencies and economic growth, in italian “L'industria delle costruzioni: struttura, interdipendenze settoriali e crescita economica”, 2015.

⁶UNEP (United Nations Environment Program Environment for Development) reports, in one of his study (UNEP-United Nations Environment Program Environment for Development 2018), that buildings use around 40% of the world's energy, 25% of global water, 40% of global resources, and emit about 1/3 of greenhouse gas emissions and are responsible for around 50% by weight of waste.

⁷Every year, the European construction sector produces about 820 million tonnes of C&D waste, which represents 46% of the total amount of waste generated (Gálvez-Martos et al. 2018). The typical composition of C&D waste shows that a percentage up to 85% is characterized by concrete, ceramics and masonry, although it can be heterogeneous depending the specific origin and it can contain large amounts of plasterboard and wood.

- a second part dealing with a study about the conditions for the development of a cross-sectoral virtual marketplace, where the different stakeholders (manufacturers, possible users of by-products and scraps, industrial process planners, public administrators, etc.), organised in a network, can identify, locate and exchange available by-products and pre-consumer scraps. The output of this part is the proposal of a framework of a cross-sectoral platform that can allow various stakeholders to share information and create trades.

4 The Database of Best Practice

In order to outline the practices, the experimentations and the trends in the field of applied research, the study has investigated the European funded researches, related to recycling and secondary resources. The examined projects are those supported by: the LIFE Programme⁸ (EEC European Economic Community 1992), the CIP programme⁹ (EU European Union 2006) and some Horizon 2020 (EC European Commissions 2011, b, c) initiatives.

In particular, focusing on the LIFE Programme projects allows to highlight both the European research strategies towards innovations in products and processes, involved in recycling (De la Paz 2014), and the trends of various manufacturing sectors towards the market generated by circular economy. In economic terms, the EU support to the programme has grown exponentially, from the 400 million euro of the first loan to the EUR 5.450 million in funds provided for 2021–2027. This is the sign of the success achieved by the initiative and the quality of the results produced by the more than 4.700 projects funded so far. Besides, LIFE Programme allocates to the area “environment and resource efficiency” more than the 30% of the total budget, showing a great interest in manufacturing initiatives that can improve the efficient use of raw materials, prevention of waste and production of secondary materials. Considering the year 2017, for this area of the LIFE programme, we have witnessed a 15% increase in projects funded, reaching a final amount of more than

⁸From 1992, the LIFE is the EU’s funding instrument for the environment. The general objective of LIFE is to contribute to the implementation, updating and development of EU environmental policy and legislation by co-financing pilot or demonstration projects characterised by European added value. For the period 2014–2020, the fifth version of the LIFE programme for the environment and climate action establishes the EU’s main funding framework for environmental and climate change policy. The programme provides action grants for pilot and demonstration projects to develop, test and demonstrate policy or management approaches. It also covers the development and demonstration of innovative technologies, implementation, monitoring and evaluation of EU environmental policy and law, as well as best practices and solutions. The European Commission is particularly looking for technologies and solutions that are ready to be implemented in close-to-market conditions, at industrial or commercial scale, during the project duration. See: <https://ec.europa.eu/easme/en/section/life/life-environment-sub-programme>.

⁹The Competitiveness and Innovation Framework Programme (CIP) supports SMEs in innovation activities (including eco-innovation), provides better access to finance and delivers business support services in the Regions.

EUR 80 million of contribution over a budget of over EUR 160 million. With regard to the nationality of the applicants, Italy and Spain have broken the record for the number of funded projects. Considering the 2014–2016 triennium, more than 50% of the projects financed were Italian and Spanish. Focusing on the issue of waste, 582 projects have been revealed during the 1992 and 2019 period. Within these, approximately 45% of the total selected projects concern recycling, reduction and use of waste, and more than 20% refer to waste from the industrial sector, from the C&D sector and the management of dangerous waste.

In the research, in order to monitor and compare the projects regarding cross-sectoral exchange of by-products and recyclable scraps between manufacturing sectors and construction sector and to identify possible trends in innovation, a database that can integrate the basic database, managed by the LIFE programme¹⁰ or others, has been developed (Fig. 1). The database collects the following information: type of the project (LIFE, CIP, etc.); code of the project; year of start; country; NACE code of applicants; type of applicant (public/private research centres, universities, local/regional authorities, international companies, big companies, SM enterprises, cooperatives, etc.); type of potential partners involved (development agencies, inter-governmental bodies, international enterprises, large enterprises, local authorities, mix enterprises, NGO foundations, national authorities, park-reserve authorities, professional organizations, public enterprises, regional authorities, research institutions, SMEs, training centres and universities); name of the project; type of proposed innovation (new production process, innovative production process, new product with recycled content, innovative product with recycled content, services); target

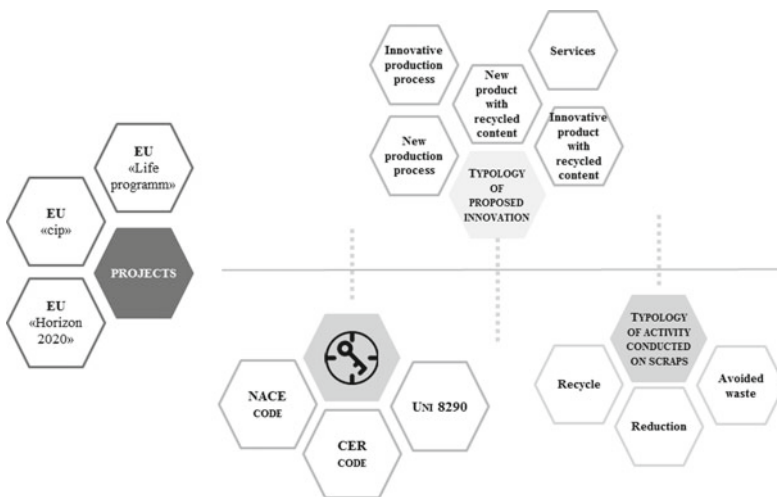


Fig. 1 Main categories of keys adopted for the database: characteristics of the companies involved (economic sectors), type of waste, type of innovation, type of activity carried out on scraps/waste

¹⁰See: <http://ec.europa.eu/environment/life/project/Projects/index.cfm>.

goals of the project (defined by the applicants); typology of activities conducted on scrap/waste (reduction, recycling, elimination); budget of the project (euro); EU contribution (%); sector of destination of the project; NACE code of destination sector; type of building product deriving from the project (according to the omniclass_21 system); type of technical element of product deriving from project (according to the classification of UNI 8290 standard); specific treated scraps/waste; code CER code of the treated scraps/waste; description of the CER code; positive impacts of the project (e.g. reduction of CO₂ emissions, reduce of energy consumption, etc.); progress of the project. At present, the selected and analysed projects are about 100 (considered period from 2004 to 2016). The database, that is periodically updated, allows to compare, according to a set of reading keys, the selected experiences and to highlight some features: referring attention to NACE economic activities, emerges that one of the sectors with more fundings assignments is that relating to the ceramic industry. Compared to the examined projects, around 40% refers to initiatives that involve the ceramic industry, the types of innovations implemented refer both to product innovations and process innovations, and in all of them there is a reduction and/or elimination of the waste, which is reintroduced into the process. The reasons that justify this trend are different: this sector has the possibility of being able to introduce very heterogeneous materials in the mixture (deriving from recycling and recovery) without compromising the final performance of the product; there is a great availability of secondary raw materials that can be used for this purpose, aggregates (Gálvez-Martos et al. 2018) and other types of scraps/waste (WEEE, sludge, etc.); and finally the positive impacts deriving from these process and product innovation are far-reaching (reduction of natural resources consumption, etc.). Depending on the type of secondary raw material, the quantity that can be introduced in the production mixture is variable, therefore it is not possible to define a univocal trend, but it is necessary to observe projects.¹¹

It emerges, in a widespread way, that when the scraps can be reduced to powder, losing main characteristics, they can be reintroduced in many production processes such as those related to the production of: thermal insulation (25%),¹² mortar and concrete (5%) (Awoyera et al. 2018), artificial stone, etc. This apparently could represent a not efficient innovation, because it represent a downcycling process, but we must consider that often the recovered material is already poor material, that could not recover value if not in this way.

Analyzing the beneficiaries of LIFE funding, it is possible to highlight the significant amount of small- and medium-sized firms (Fig. 2).

Finally, considering the most widespread types of innovation (Fetsis 2017), it emerges that most of the projects involve improvement of existing production process. There

¹¹For further details see the projects: LIFE05 ENV/E/000301, LIFE10 ENV/IT/000419, LIFE11 ENV/IT/000036, LIFE12 ENV/IT/000678, 12 LIFE12 ENV/IT/000436.

¹²For further details see the projects: LIFE05 ENV/DK/000158, LIFE06 ENV/D/000471, LIFE12 ENV/ES/000079, LIFE07 ENV/IT/000361, LIFE13 ENV/IT/001225.

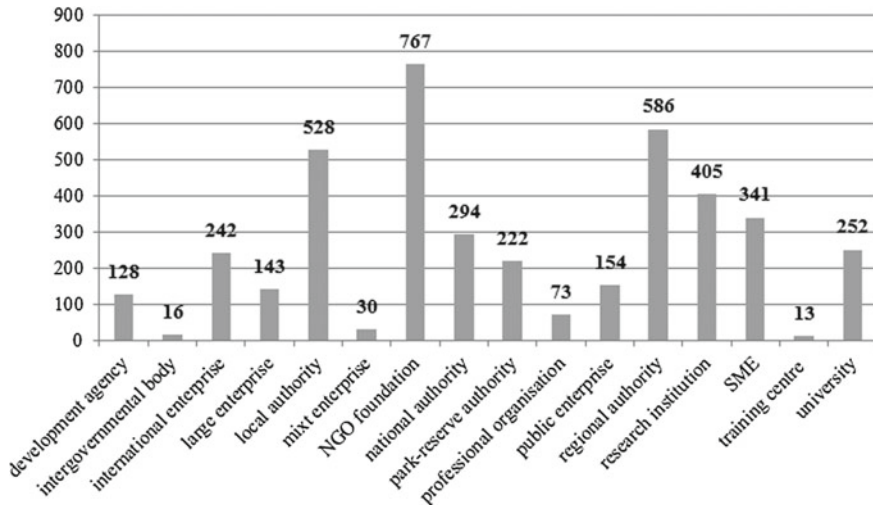


Fig. 2 Distribution by type of beneficiary of the projects (data extracted and processed from the LIFE projects database, period 1992–2019)

are very few cases in which new production processes are activated for the realisation of a new product.

5 A Virtual Marketplace for by-Products and Pre-consumer Recyclable Scraps

The objective of the second part of the research is to define the characteristics of the structure and the operating procedures of an inter-sectoral information platform (Web-based), designed to match supply and possible demand of by-products and pre-consumer recyclable scraps in order to create a virtual marketplace. The platform, according to its characteristics and structure, might have different applications: to be delivered to third parties for the development of Web applications; to be proposed for its operational evolution through participation in competitive research projects; to be a tool for activating clusters and/or industrial symbiosis networks. To this end, the research primarily has identified information sets, capable of describing various types of by-products and scraps, coming from many manufacturing sectors, in relation to different characteristics (chemical, physical, morphological–dimensional, embodied energy, in terms of the environmental impact of the equivalent CO₂ emitted, etc.). The purpose is to stimulate various operators for the collection of unified and unambiguous data and to facilitate, through a shared knowledge, the identification of possible alternative uses of by-products and scraps for the construction industry.

The structure and the contents of the platform are based on:

- a taxonomy of by-products and scraps, which are codified and classified on the basis of the economic activities they come from (according to the CER catalogue);
- a set of information related to the characteristics of the codified by-products and scraps and to the parameters useful for the environmental and economic assessment of scenarios for reuse/recycling;
- a supply/demand relationship matrix, able to correlate the taxonomy of by-products and scraps and the different classes of technical elements of the building system, in order to identify the possible construction products (materials, semi-finished products, components, systems) that can be manufactured by using entirely or partially by-product and/or pre-consumer scraps;
- the definition of a geo-referencing GIS tool, useful for mapping amounts of by-products and pre-consumer scraps, available in defined geographical areas. The GIS tools can be useful also for supporting the creation of local hubs, necessary for the collection, separation, storage, management and distribution of by-products and pre-consumers scraps, to be processed for becoming secondary raw materials or directly be used in the construction sector.

6 Conclusions

Circular economy orients to operate in a virtuous way, trying to progressively minimise waste non-recyclable because considered useless, superfluous or not convenient for new uses (Webster 2017). The aim is to pursue the “end-of-waste” status, trying to identify areas of convenience (not only economic but also environmental and social), through actions such as:

- searching for, recognising, defining, inventing a use, and a specific purpose for waste. In this sense, it is important to activate some strategies. Firstly, we must promote project activities capable, on the basis of availability of information on the characteristics of recyclable waste and semi-finished products, of pursuing innovations both by developing new products and by defining new characterisations of existing products. Secondly, we must sustain the practices of inter-sectoral “dialogue” in order to widen the view both on the characteristics, the quantity and origin of different types of waste and on the possible fields of use and of the possible markets;
- recognising supply and demand in relation to possible uses and thus, designing market scenarios. Recognising the demand means on one hand having previously defined the possible purposes of reusable portions of waste. On the other hand it means having evaluated and possibly quantified the potentially interested subjects, in terms of both consumers and manufacturers, taking into consideration these purposes. Recognising the supply means mapping, tracking and characterising waste. Designing market scenarios involves identifying the conditions for meeting supply and demand implementing information support to make the manufacturing feasible using cost/profit analysis, supported by economic and environmental indicators;

- identifying the characteristics of the waste. As long as waste represents an “opaque” material from an information point of view, it is very difficult to activate matchmaking processes between supply and demand. The characterisation of the waste is very important to understand opportunities and barriers for their usage, to verify the absence of any problems linked to regulatory requirements and to develop environmental assessments. The characteristics may regard not only the material properties, but also other aspects such as, for example, in the case of “standard” waste, the size, shape, and, for locally defined situations (for example, production districts, production centres, etc.), the amount of waste produced in specific periods (e.g. months, semesters, years);
- monitoring the flows of waste (quantity, characteristics and location) in order to determine the potential supply.

Finally, the role of information seems to be essential (in terms of the contents and methods of treatment and exchange) in order to activate and support the processes necessary for the development of a possible market and to make usable materials by reaching the “end-of-waste” status. These goals must be considered also in relation to the fact that, by 2020, the preparation for reuse, recycling and other types of material recovery, (including backfilling operations using waste to substitute other materials), waste from non-hazardous construction and demolition, excluding the material in its natural state (as defined under item 17 05 04 of the European list of waste), must increase at least 70% in terms of overall weight, according to the European guidelines.

References

- Awoyera, P. O., Ndambuki, J. M., Akinmusuru, J. O., & Omole, D. O. (2018). Characterization of ceramic waste aggregate concrete. *HBRC Journal*, 14, 282–287.
- Charter, M. (2019). *Designing for the circular economy*. New York: Routledge.
- De la Paz, C. (2014). EU LIFE programme: Contributing to waste management in Europe for over 20 years. *Waste Management*, 34(3), 571–572.
- EC European Commission (2008). Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain directives.
- EC European Commissions (2010). COM(2010)2020 communication from the commission to the European Parliament, the council, the European economic and social committee and the committee of the regions—a strategy for smart, sustainable and inclusive growth, Brussels, March 2010.
- EC European Commissions (2011a). COM(2011)21, communication from the commission to the European Parliament, the council, the European economic and social committee and the committee of the regions—a resource-efficient Europe—flagship initiative under the Europe 2020 strategy, Brussels, January 2011.
- EC European Commissions (2011b). COM(2011)899, communication from the commission to the European Parliament, the council, the European economic and social committee and the committee of the regions—innovation for sustainable future. The eco-innovation action plan (Eco-AP), Brussels.

- EC European Commission (2011c). COM(2011)808, communication from the commission to the European Parliament, the council, the European economic and social committee and the committee of the regions. Horizon 2020—The Framework Programme for Research and Innovation, Brussels.
- EC European Commission (2014). COM 2014-398 final, communication from the commission to the European Parliament, the council, the European economic and social committee and the committee of the regions “Towards a circular economy: A zero waste programme for Europe”, 02.07.2014 Bruxelles.
- EC European Commission (2015). COM 2015-614 final, communication from the commission to the European Parliament, the council, the European economic and social committee and the committee of the regions “Closing the loop—an EU action plan for the circular economy”, 02.12.2015 Bruxelles.
- EC European Commission (2018). Directive 2018/851 of the European Parliament and of the council of 30 May 2018 amending directive 2008/98/EC waste.
- EEC European Economic Community (1992), Council Regulation No 1973/92 of 21 May 1992 establishing a financial instrument for the environment (LIFE), Brussels.
- EU European Union (2006). Decision no 1639/2006/EC of the European Parliament and of the council of 24 October 2006 establishing a competitiveness and innovation framework programme (2007–2013), Brussels.
- Fetsis, P. (2017). The LIFE programme—over 20 years improving sustainability in the built environment in the EU. *Procedia Environmental Sciences*, 38, 913–918.
- Gálvez-Martos, J. L., Styles, D., Schoenberger, H., & Zeschmar-Lahle, B. (2018). Construction and demolition waste best management practice in Europe. *Resources, Conservation and Recycling*, 136, 166–178.
- Lacy, P., & Rutqvist, J. (2015). *Waste to wealth: The circular economy advantage*. Basingstoke (UK): Palgrave Macmillan.
- MacArthur Foundation (2010). The circular economy concept, regenerative economy. <https://www.ellenmacarthurfoundation.org/circular-economy/concept>.
- MacArthur Foundation (2015a). Growth Within: a circular economy vision for a competitive Europe. <https://www.ellenmacarthurfoundation.org/publications/growth-within-a-circular-economy-vision-for-a-competitive-europe>.
- MacArthur Foundation (2015b). Towards a circular economy: business rationale for an accelerated transition. https://www.ellenmacarthurfoundation.org/assets/downloads/TCE_Ellen-MacArthur-Foundation-9-Dec-2015.pdf.
- UN United Nations (2015). Transforming our world: the 2030 Agenda for Sustainable Development.
- UNEP—United Nations Environment Program Environment for Development (2018). 2018 global status report. Towards a zero-emission, efficient and resilient buildings and construction sector.
- Webster, K. (2017). *The circular economy: A wealth of flows*. Cowes (UK): Ellen MacArthur Foundation Publishing.

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