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"DRIVERS AND BARRIERS FOR CIRCULAR ECONOMY IN THE BUILDING AND CONSTRUCTION INDUSTRY"

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ABSTRACT

The growing awareness of environmental issues has led policymakers, businesses and academics to pay more attention to the circular economy paradigm as a potential solution to balance sustainable development and economic growth. After an initial introduction to the main steps that have led to the development of the circular economy concept, this research defines the principles that must be adopted for a radical transformation of the economic paradigm. Taking into account in particular the studies of the Ellen MacArthur Foundation and on circular value chains, it is highlighted how the change of approach and the move away from the linear economic model brings numerous opportunities but also challenges: the presence of drivers (internal and external), barriers and the introduction of new technologies, new materials and new business models determine a shift at all stages of the value chain. The last two chapters of this research will therefore focus on one of the sectors, the Building and Construction sector, that is most affected by this change, with an empirical analysis of the industry, the main business model innovations, and in particular the study of one of the key issues for the implementation of circular models in this field as the end-of-life treatments. Through an overview of the situation in Europe and Italy, real case examples will be used to highlight the potential benefits and challenges that companies must overcome to successfully embark on the circular transition path.

INTRODUCTION

In recent decades, growing concern about environmental issues has led to increased use of the concepts of Circular Economy. This new model of a more sustainable economy, no longer linear and unidirectional, but circular and integrated, is thus emerging as a major opportunity for businesses' growth, with innovative strategies that will be presented throughout this paper.

In Chapter 1, after identifying a definition of the terms sustainability and Sustainable Development, the most important steps that led to the creation of the concept of Circular Economy and its basic principles are presented, starting with the Conference on the Human Environment, the Kyoto Protocol, and ending with the definition of the Sustainable Development Goals and the development of an original action plan to address new environmental challenges and limit the current climate emergency, the European Green Deal.

In Chapter 2, based on studies by the Ellen Macarthur Foundation, the focus is on how EC creates value by pursuing a new "cradle to cradle" paradigm, in which materials are kept within the production loop for multiple consecutive cycles. It highlights also in general terms the main drivers that can push companies towards a more sustainable transition, as well as the most significant barriers and challenges that slow down this process of change. In the reality, however, in order to better define what actually accelerate or delay the transition, it is necessary to select a field of study and, by analyzing it individually, to identify its limitations and potentials.

For this reason, Chapter 3 aims to analyze the Building and Construction industry, a key sector for achieving social, environmental and economic sustainability targets. The construction supply chain is identified by the European Commission as one of the areas for priority action as it is among the biggest causes of pollution and creation of waste and emissions in the world. A better reorganization of the sector goes first and foremost through a more efficient use of materials, as well as a reduction in energy and water waste. Next, product innovations and new technologies (such as IoT, data sharing platforms, 3D vision, artificial intelligence) that change processes are presented. At the end of the chapter, some of the most virtuous Circular Economy Business Models are also presented, such as modular construction and design-for-disassembly strategies that aim for "end-of-waste".

Chapter 4, closely related to the previous chapter, seeks to further explore the state of the art in Building and Construction. Despite the importance of the issue, in fact the construction world is dealing with very complex challenges in an industry that has always been considered rather reluctant to change. For this motive, The main drivers and barriers of the sector will be presented, as well as identifying useful tools such as "roadmaps" towards the CE. The chapter closes with an excursus on the state of the construction supply chain, presenting the main cases in the world, Europe and Italy.

1. From Linear to Circular Economy: a process of radical transformation of the economic paradigm

In recent decades, growing concern about environmental issues has led to increased use of the concepts of sustainable development and, especially in recent years, circular economy. Businesses have a significant impact on people, society and the environment, and often have to undergo a drastic transformation process, both to meet the growth of global competition, to gain efficiency and effectiveness advantages, but also because of increased consumer awareness. This new model of a more sustainable economy, no longer linear and unidirectional, but circular and integrated, is thus emerging as a major strategic opportunity for growth that would be difficult to achieve with traditional business models. Indeed, the circular economy requires not only investment and innovation efforts, but also a different approach to resource use, the application of circular principles at every stage of product development and, above all, a radical rethinking of all activities in the value chain.

1.1. Sustainability and sustainable development

The Conference on the Human Environment, convened by the United Nations (UN) in June 1972, also known as the Stockholm Conference, can be seen as the global starting point for the recognition of the environmental issues (Pineschi, 1993). The Stockholm Declaration recognizes for the first time the seriousness of this situation and the need for common principles and cooperation among countries, calling for governments and peoples to unite their efforts "to inspire and guide the peoples of the world in the preservation and enhancement of the human environment" (United Nations, 1972) in the interest of future generations. This conference also outlines an initial list of 26 principles concerning the rights and responsibilities of social action to protect the environment and the well-being of people around the world, limit air and water pollution and the consumption of natural resources, and lastly to make the needs of developed states coexist with those of emerging countries, which are focused more on their growth at the expense of respecting environmental topics (Montini, 2001).

In 1983, United Nations' Secretary-General Javier Pérez de Cuéllar appointed Gro Harlem Brundtland, former prime minister of Norway, to head the World Commission on Environment and Development (Gerasimova, 2017). This Commission, also known as the Brundtland Commission, was an independent sub-organization of the United Nations whose goal was to determine a common plan of action to achieve sustainable development. In fact, on March 20, 1987, the chairwoman of the Brundtland Commission presented the so-called "Our Common Future" report, in which not only the concept of **sustainable development** and its basic principles were defined for the first time in an official document, but it was also presented the main problems of the production models used up to that time.

(Figure 1: Brundtland, G. H. (1987). *Report of the World Commission on environment and development:" Our common future."*. United Nations)

The report, indeed, pointed out that due to the unsustainable production model of the North, the great poverty of the South, and the attempted growth of emerging countries, there was a need for a common strategy to integrate socio-economic and environmental development needs (Brundtland, 1987). The critical issues highlighted came from the realization that resources are not infinite and that there was a need for a quick resolution of problems related to pollution, non-renewable energy resources, as well as an urgent change in lifestyles and an improvement of the living conditions of the inhabitants of the planet.

The “Our Common Future” report is divided into three parts: the first is called "common concerns" in which the centrality of non-economic issues such as education, health and nature conservation is emphasized; the second part, called "common challenges," highlights how combating waste and protecting resources and the environment should be a variable to be taken into account in the decision-making processes of governments and industries (Brundtland, 1987). The third and final part, "common endeavors" places the responsibility on governments to determine policies that can be economically and environmentally sustainable in the short and long term (Brundtland, 1987). The proposal placed great faith, perhaps overly optimistic, in future technological development, which the report said could open a new era of economic growth and the fulfillment of basic needs.

Another United Nations Conference on Environment and Development was held in 1992 in Brazil, attended by 178 government delegations from around the world and 2,400 representatives of non-governmental organizations (United Nations Conference on Environment and Development, 1992). The Rio de Janeiro Conference, better known as the Earth Summit, elaborated, among other things, the Agenda 21, which is a dynamic program described "in terms of the basis for action, objectives, activities and means of implementation. […] It will be carried out by the various actors according to the different situations, capacities and priorities of countries and regions in full respect of all the principles contained in the Rio Declaration on Environment and Development. It could evolve over time in the light of changing needs and circumstances. This process marks the beginning of a new global partnership for sustainable development" (UNCED, 1992, p.3).

It is a document divided into 4 sections:

1. "Social and economic dimensions" with the aim of creating international cooperation to accelerate sustainable development, fight poverty, increase human health condition especially in emerging and developing countries.
2. "Conservation and management of resources for development", which includes atmospheric protection, combating deforestation, protection of fragile environments and biodiversity and management of toxic, hazardous and radioactive wastes.
3. "Strengthening the role of major groups" which includes raising the status of women, young people, indigenous people and their communities, as well as workers and local communities.
4. "Means of implementation" as science, increasing awareness and education.

It was therefore the Rio Conference, but especially the 2002 Johannesburg Conference, that emphasized that the principle of sustainable development was based on three main and interdependent factors: environmental protection, economic growth and social development (Cordini, Flois, Marchisio, 2005). In fact, the problem was that, analyzing the world situation after the Rio Conference, the results obtained were not even close to what was desired; on the contrary, ecological degradation and the fight against poverty had not improved and the solutions adopted were still not very effective (Grubb, Koch, Thomson, Sullivan, Munson, 2019).

1.1.1. The Kyoto Protocol

The Kyoto Protocol, the first international treaty to impose limitations on countries' emissions of certain greenhouse gases responsible for global warming, was adopted at a conference organized in Kyoto (Japan) on 11 December 1997 but officially came into force on 16 February 2005 with the accession of Russia, as it required ratification by at least 55 states producing at least 55% of pollutant emissions (United Nations Treaty Collection, 1997). The main feature of the Kyoto Protocol is that it set legally binding emission reduction targets for the adhering countries, which also had to be monitored by UN-appointed bodies for compliance with these targets in order to limit global pollution. The adhering countries[1], of which the European Union was the main international supporter, committed to reduce greenhouse gas emissions in the period 2008-2012 by at least 5% compared to 1990 levels, with a review and verification system to guarantee transparency (United Nations, 1998); according to official data, 192 countries have incorporated the Protocol into their national policies as of August 2018[2], among them Canada (that withdrew in 2013) and the United States, responsible for 22.59% of carbon dioxide emissions in 1990[3]. The Protocol was based on the principle called “common but differentiated responsibilities”, according to which only the economically more developed states were obliged to reduce emissions as they were more responsible for air pollution, including through the so-called Flexible Mechanisms, which are market-based mechanisms (so, based on the trade of emission permits), with a target: “It does not matter where emissions are reduced, as long as they are removed from the atmosphere”[4].

In December 2012 in Qatar, after the end of the first period, the original Kyoto agreements were renewed for a second phase, from 2012 to 2020, through the Doha Amendment; actually, in 2015, 194 Parties agreed in another climate treaty, the Paris Agreement, which officially came into force in November 2016[5].

1.1.2. The Millennium Development Goals

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[1] Under the Kyoto Protocol, emerging economies such as China and India were not required to reduce their emissions because at the time they were not considered to be major contributors to climate change on a par with industrialized countries, even though they have since participated in rapid development and are among the largest producers of polluting gases (Nespor, S. (2016) and https://ourworldindata.org/grapher/annual-share-of-co2-emissions).

[2] https://www.un.org/en/climatechange/marking-kyoto-protocol%E2%80%99s-25th-anniversary

[3] https://ourworldindata.org/grapher/annual-share-of-co2-emissions

[4] https://unfccc.int/kyoto_protocol

[5] https://unfccc.int/kyoto_protocol

The steps to determine the principles of a sustainable economy have been many and the results of this long journey have certainly been encouraging but not always as clear and positive as hoped, however the conferences mentioned in the previous paragraphs (which are only some of the most important) are actually major milestones in determining the concept of sustainable development. The definition of the criteria and targets to be achieved are subject to continuous changes, improvements and additions, as can be seen with the Agenda 21 action plan and the Millennium Development Goals, which guided sustainable development governance until September 2015, when they were superseded by the United Nations 2030 Agenda for Sustainable Development (Cai, Choi, 2020).

The Millennium Development Goals, or MDGs, contained in the so-called Millennium Declaration signed at the United Nations Millennium Summit in September 2000, were the eight targets that all UN member states pledged to achieve by 2015. The Millennium Goals[6] are:

1. Eradicate extreme poverty and hunger.
2. Achieve universal primary education.
3. Promote gender equality and empower women.
4. Reduce child mortality.
5. Improve maternal health.
6. Combat HIV/AIDS, malaria and other diseases.
7. Ensure environmental sustainability.
8. Develop a global partnership for development.

On that occasion, the UN also defined specific targets and indicators and especially agreed to hold a summit every five years to review progress from the 1990 levels in achieving the MDGs. Although some of the goals were reached by many countries in the first 15 years of the 21st century, others have achieved irregular or even no results, and progress has been slow especially where there has been economic hardship and war. For example, according to the World Health Organization reports, "the proportion of underweight children under 5 years of age decreased dal 28% al 17% between 1990 and 2013", the mortality level of children and the maternal mortality ratio were reduced but not enough to meet the MDGs' target[7].

Furthermore, according to *The Millennium Development Goals Report* published in 2015 by the United Nations Development Programme (UNDP), gender inequality persists, there are large gaps between the richest and poorest regions, there have been improvements in health but

[6] https://www.mdgmonitor.org/millennium-development-goals/
[7] https://www.who.int/news-room/fact-sheets/detail/millennium-development-goals-(mdgs)

there is still a large segment of the population that suffers from hunger and lack of accessibility to primary services and the global carbon dioxide emissions did not decrease as set especially because of the accelerated growth of the developing countries.
The MDGs have undoubtedly contributed to improving the living conditions of more than a billion people, as well as providing huge advances in socio-economic conditions around the world, unfortunately, however, improvements have not been equal everywhere and in fact have been delayed and slowed down particularly in the least developed economies (Camera dei Deputati, 2015).

(Figure 2: https://unarmeniainterns.files.wordpress.com/2015/07/powerpoint-mdg.pdf)

As former UN Secretary Ban Ki-moon said in a speech at the Paris-based OECD, "2015 is a critical year for sustainable development. […] this is particularly fitting time for us to gather together. […] We must translate the post-2015 agenda into action around the world […] We are faced with global challenges that affect all countries, developing and developed. This is why the post-2015 agenda will be universal, addressing the needs and seeking contributions of all people across the planet. It will aim for economic progress, social inclusion and environmental sustainability. Sustainable development will be at the core of this agenda"[8].

1.1.3. Agenda 2030, goals of sustainable development

The plan Ban Ki-moon referred to is the "2030 Agenda for Sustainable Development", an action program signed in September 2015 by the 193 UN member states, including Italy, which in fact

[8] https://www.un.org/sg/en/content/sg/statement/2015-04-28/secretary-generals-remarks-organisation-economic-co-operation-and

complements and replaces the goals defined by the MDGs.

This global project defines the **17 Sustainable Development Goals** - SDGs - and 169 ambitious targets that the countries that signed it pledged to achieve by 2030, with the final aim of "no one left behind" as its official motto. The main and innovative feature of these goals is that they have a global nature and are closely interrelated and indivisible; it is precisely this interdependence that distinguishes them from their predecessors, the MDGs, and which seeks to remedy for their flaws. The Agenda 2030 deliberately wants to go beyond the idea that sustainability is a purely ecological issue and state that it relates to many different fields in the social, economic and environmental sphere. In fact, it envisions creating a comprehensive and shared program for achieving the ambitious goals, which are based on 5 key concepts, the so-called "5 Ps" of sustainability[9]:

- People: eliminate hunger and poverty in all forms; ensure dignity and equality.
- Prosperity: ensuring prosperous and full lives in harmony with nature.
- Peace: promote peaceful, just and inclusive societies.
- Partnership: implement the Agenda through strong partnerships.
- Planet: protect the planet's natural resources and climate for future generations.

As detailed in the resolution adopted by the United Nations General Assembly[10], 17 SDGs are:

1. *End poverty in all its form everywhere*, especially extreme poverty through global cooperation and policies to help the least developed countries.
2. *End hunger, achieve food security and improved nutrition and promote sustainable agriculture*, with "green" food production systems and practices, maintaining the genetic diversity of seeds and increasing the investments in research and infrastructure also in the developing countries.
3. *Ensure healthy lives and promote well-being for all at all ages*, reducing the maternal mortality, deaths of children and epidemics losses globally.
4. *Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*, upgrading (or building where there are none) education facilities in order to allow everyone to increase their knowledge and skills.
5. *Achieve gender equality and empower all women and girls*, ending all forms of discrimination, human trafficking, violence and other kind of harmful practices.

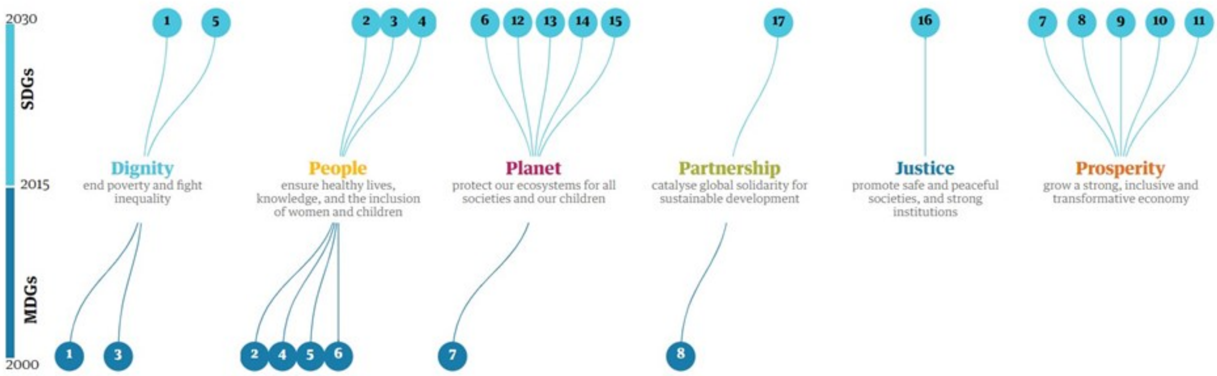
[9] https://sdgs.un.org/2030agenda

[10] https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

6. *Ensure availability and sustainable management of water and sanitation for all*, improving the quality and the water-use efficiency and dealing with the problem of the scarcity and wastes globally.
7. *Ensure access to affordable, reliable, sustainable and modern energy for all*, with the focus on the use of renewable energy.
8. *Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*, through development-oriented policies in order to increase per capita economic growth and create new jobs, reduce the number of the so-called NEET (Not [engaged] in Education, Employment or Training) and end modern slavery, protecting workers' rights, in particular precarious employees and migrant workers.
9. *Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation*, increase the share of employment and the gross domestic product, promote research and development policies and upgrade the technological capabilities in all countries, especially in the developing ones.
10. *Reduce inequality within and among countries*, with a focus on the inclusion of all, on equal opportunities and the adoption of non-discriminatory laws and the implementation of proper migration policies to facilitate the mobility of people.
11. *Make cities and human settlements inclusive, safe, resilient and sustainable*, protect the cultural and natural heritage, provide more green and public spaces, increase the air quality and the waste management of the cities.
12. *Ensure sustainable consumption and production patterns*, in order to increase the transaction to a more sustainable and efficient use of resources, reducing wastes and increase the awareness about greener development and lifestyle.
13. *Take urgent action to combat climate change and its impacts*, also according to the United Nations Framework Convention on Climate Change it important to integrate such measures into the national policies and strategies.
14. *Conserve and sustainably use the oceans, seas and marine resources for sustainable development*, protecting them reducing the pollution of all kinds and implement laws to decrease overfishing and eliminate other illegal fishing practices.
15. *Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss*, increasing the financial resources to conserve and protect ecosystems and the biodiversity, preventing new extinctions of threatened species.

16. *Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels* reducing every form of violence and corruption through practical and effective response also in developing countries.
17. *Strengthen the means of implementation and revitalize the global partnership for sustainable development*, in particular with a focus on providing additional financial resources, the diffusion of new technologies, increase the capacity-building in emerging countries, promote a universal and duty-free open market and lastly promote a global macroeconomic stability and global partnerships for sustainable development.

(Figure 3: https://unric.org/it/agenda-2030/)



While it is true that the SDGs also have some critical issues, such as the difficulty in synthesizing human rights with measurable indicators, compared to the Millennium Goals they go into more detail regarding the issues covered. The greater detail, the ability to make more precise measurements, and the interdependence of the targets make the 2030 Agenda an excellent global reference guide, which also gives states the opportunity to integrate the Sustainable Goals within national policies.

(Figure 4: https://www.theguardian.com/global-development/ng-interactive/2015/jan/19/sustainable-development-goals-changing-world-17-steps-interactive)

Through the possibility of obtaining increasingly precise data by means of reliable measurements, it makes it possible to produce a Global Sustainable Development Report (written by an Independent Group of Scientists appointed by the Secretary-General) every four years and for the United Nations Secretary General to present an annual SDG Progress report developed on the basis of global indicators and information produced at national and regional level[11]. The project is currently at the midpoint of implementation, and although progress to date has been tremendous, the goals set were so ambitious that they will most likely not be achieved by 2030. The information are actually incomplete due to the ongoing challenges in ensuring timely and correct data for all the targets; at the same time, it can be seen that there has been much progress since 2015 in many areas, but the most recent global upheavals such as the COVID-19 pandemic, have reversed decades of steady progress and positive improvements especially with regard to the targets about no poverty, zero hunger, about health and economic growth[12].

[11] https://sdgs.un.org/goals
[12] https://sdgs.un.org/sites/default/files/2023-04/SDG_Progress_Report_Special_Edition_2023_ADVANCE_UNEDITED_VERSION.pdf

Having said that Scandinavian countries such as Finland, Denmark, Sweden and Norway have reached the top places from the very beginning, other countries that currently score high in terms of the complete implementation of the SDGs are Austria, Germany, France and Switzerland[13]. Italy is firmly in 24th place in this special ranking (Figure 5), it has already achieved 17 of the 135 SDG targets and it is expected to meet another 10 additional targets very soon.

(Figure 5: https://dashboards.sdgindex.org/profiles/italy)

In Italy, a concrete attempt has been made to implement social, economic and environmental planning through the development of the National Strategy for Sustainable Development (Strategia Nazionale per lo Sviluppo Sostenibile or SNSvS) in order to achieve a policy of growth on the basis of four cardinal principles, integration, universality, inclusion and transformation. Italy has already met, or it is close to meet most of the targets related to the environment, waste management and recycling despite little economic growth, but it also shows strengths about health performance for most of the diseases achieving better performances than other OECD countries. On the other hand, Italy has some challenges in the long-term social and economic targets, showing weaknesses when it comes to increase GDP, productivity and employment and it could do better by reducing poverty rate, gender inequality and increasing inclusion[14].

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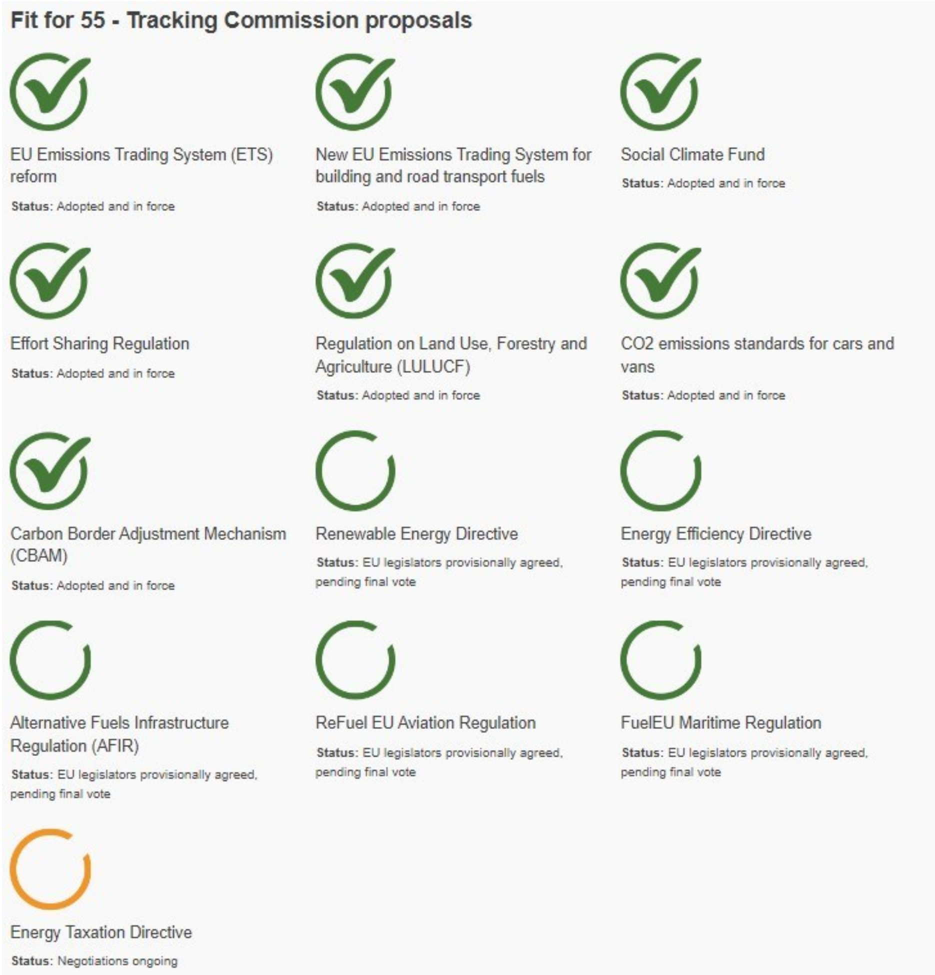
[13] https://dashboards.sdgindex.org/rankings
[14] https://www.oecd.org/wise/measuring-distance-to-the-SDG-targets-country-profile-Italy.pdf

1.1.4. The European Green Deal

The European Union has always shown interest regarding environmental sustainability issues and has set as an ambitious goal to make Europe the **world's first climate-neutral continent**[15]. For this very reason, it wants to stand as a key player in the implementation of the 2030 Agenda, seeking to achieve positive results in all sectors of the economy in an equitable, sustainable and efficient manner. Since 2017 the EU, proving the importance of this issue, has been preparing periodic reports to monitor the progress of the Agenda and to ensure that the 17 Goals are being followed up appropriately, placed them among the European Commission's 10 priorities, and once again reaffirmed the centrality of the principle of sustainability as the cornerstone of new European policies. In fact, in 2020, the European Commission led by Ursula von der Leyen proposed a original action plan to address new environmental challenges and limit the current climate emergency, the European Green Deal. Indeed, this program seeks to promote more efficient use of resources, restoration of biodiversity, and reduction of pollution, "harnessing" environmental threats as a source of new opportunities transition to a cleaner and more inclusive economy (European Commission, 2019). The main goal of the European Green Deal is to reduce emissions by at least 55 percent below 1990 levels (the so-called "Fit for 55") by 2030 and then achieve climate neutrality by 2050[16]. The Fit for 55 is a strategic EU economic and social reform package to combat climate change. The importance of these regulations is that the 55 percent emissions reduction (and recently the European Commission has proposed a further raising the threshold to 60 percent (European Parliament News, 2020)) is a mandatory and key target for achieving the 2050 target, as they are part of a European climate law (Council of the European Union, Fit for 55[17]. The zero-emissions target by 2050 is thus a binding commitment, meaning that all European states will have to zero out net greenhouse-gas emissions, increase investment in green technologies and renewable energy, and boost employment. In fact, the themes of the Green Deal cover a variety of areas, from energy with the goal of decarbonizing the European energy sector and developing one based on renewable sources, to mobility by favoring non-polluting fuels and more sustainable transportation systems, improving the energy performance of buildings by making them more efficient,

[15] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_it
[16] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_it
[17] https://www.consilium.europa.eu/it/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition

eliminating air, water and soil pollution, to respecting nature in the area of food products to radical change in the industrial sector[18].



(Figure 6: Status of proposals as of May 2023, Source: European Commission, Fit for 55: Delivering on the proposals, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal/fit-55-delivering-proposals_en)

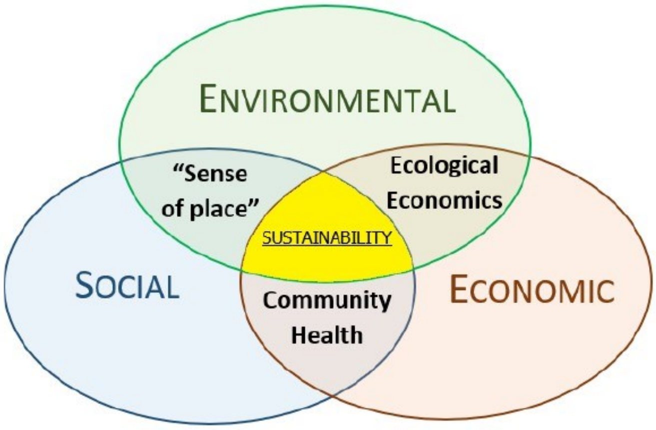
1.1.5. Corporate sustainability and CSR

The development of the concept of sustainable development has brought about a change in the role of business in relation to the environment, society and other institutions, this definition in fact takes into consideration three dimensions, namely economic, social and environmental: the so-called Triple Bottom Line (Elkington, 1997). The economic component consists, in a nutshell, of making profits and the ability to continue the business activity in the long-run; the environmental component is about the impact that companies have due to their activity and the

[18] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_it

environmental consequences due to their product, including the decrease of waste in general, water consumption and their carbon footprint; the social dimension means that the organization becomes aware of the responsibilities for its actions, from an ethical and human rights point of view, from a health and safety point of view, zeroing in on all forms of controversial activities and at the same time increasing social awareness along the global value chain, with a complete shift from short-term financial goals to a long-term vision (Elkington, 1998). Over the years, many attempts have been made to describe the relationship between these three pillars through representations and models: one of these is the Venn diagram of sustainability, which is widely used to understand this concept as it is really intuitive, although two issues are the model's lack of dynamism and that it places equal importance on the three components, although the perception of the gravity of these 3 dimensions may change according to individuals. So, in this simple model, when these three dimensions are in equilibrium, and thus in Figure 7a and Figure 7b in the intersection space of the three circles, sustainability is achieved.

(Figure 7a: Venn diagram of sustainability, adaptation from Newman and Kenwothy)



(Figure 7b: Venn diagram of sustainability, adaptation from Todorov and Marinova)

The role of business, therefore, cannot be summarized only in profit maximization or its mere production function, but its importance outside the organization itself, that is, on people, society and the environment, must also be taken into consideration: the business needs to act as "a good Corporate Citizen" (Carroll, 1999). This is why we speak of Corporate Social Responsibility (CSR), a term first officially used by the European Community in the Green Paper in 2001 but unanimously attributed to the American economist Howard R. Bowen, who published the essay *Social Responsibilities of the Businessman* in 1953. Bowen, whose work is believed to be the starting point of a discussion on the subject that continues to this day, analyzes the positive or negative effects of business management models of that era, how they impacted the lives of citizens, and what responsibilities businessmen had to take on with regard to the environment, pollution, unemployment and many other aspects of society (Bowen, 2013). The term CSR, in some ways complementary to Corporate Sustainability, therefore, aims to focus on the company's strategy, but at the same time emphasizes the "ethical component of entrepreneurial activity and creates with appropriate tools a series of pre-conditions aimed at creating value, which guarantee an objective balance in the relationship between company and society" (Favotto, Bozzolan, Parbonetti, 2016, p. 187).

1.2. The transition to Circular Economy

The economic model used in the past was based on the belief that resources were available in unlimited quantities. This at least limited view of the world had brought undoubted benefits, in fact with the industrial revolution and the mass production, that is a production of large amounts of a standardized output in a never-ending flow, the conditions had been created for rapid economic growth but at the same time also a greater amount of raw materials used. Over the years, economic development models have changed and evolved, but the idea that global development was only possible by extracting resources to generate economic value was still present, without considering the negative impact of these practices such as pollution and improper materials management. Thus, the continuous increase in demand for certain resources, partly due to technological change, has led to the so-called **Take-Make-Dispose System** (Sariatli, 2017) being challenged. This unidirectional production model is called Linear Economics, which "is a system where resources are extracted to make products that eventually end up as waste and are thrown away"[19] typically after a single use. The linear economy is obviously unsustainable, resources are consumed at a faster rate than can be replaced and could be exhausted in a very short time unless the mode of exploitation is rethought and a rapid change in the socio-economic paradigm is implemented.

Especially in the second half of the twentieth century, in fact, the many limitations of the linear economy and the devastating consequences that were not previously taken into account, such as the environmental impact and pollution phenomena on a global scale, the limitation of natural resources and the energy crisis, have emerged (Sillanpaa, Ncibi, 2019). All of this led to the development of a new system that was to be "ideally […] completely closed. All water would be purified and reused; all solid wastes would be sent back as resources for making more things." (Spilhaus, 1966, p. 488). The numerous researches conducted over the years have resulted in the emergence of new, increasingly innovative and detailed perspectives based on the idea that "the traditional model of industrial activity in which individual manufacturing processes take in raw materials and generate products to be sold plus waste to be disposed of should be transformed into a more integrated model: an industrial ecosystem" (Frosch, Gallopoulos, 1989, p. 144), in which there is an optimization on the consumption of energy and resources and the new materials used are minimized as well as the waste generation. So, the idea is that the industrial ecosystem would function as a biological ecosystem, with the magnitude of the incoming flow of raw materials are minimized and prevent potentially still valuable waste from escaping the loop (Frosch, Gallopoulos, 1989).

To try to curb this negative trend, since the early 2000s the Global Footprint Network, an international research organization that wants to bring ecological limits to the center of decision-making processes, has been offering development services and promoting new tools for advancing sustainability to people and companies, such as Footprint Calculators. The "Ecological Footprint" is a comprehensive sustainability metric created by Wackernagel and

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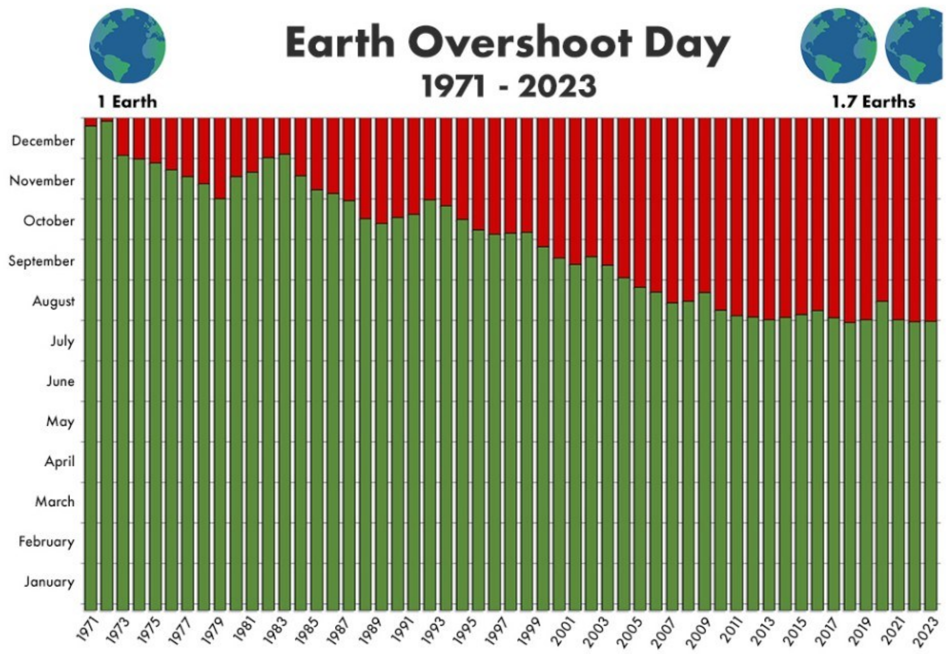
[19] https://ellenmacarthurfoundation.org/what-is-the-linear-economy#:~:text=The%20linear%20economy%20linear%20economy,extracted%20to%20make%20products%20that

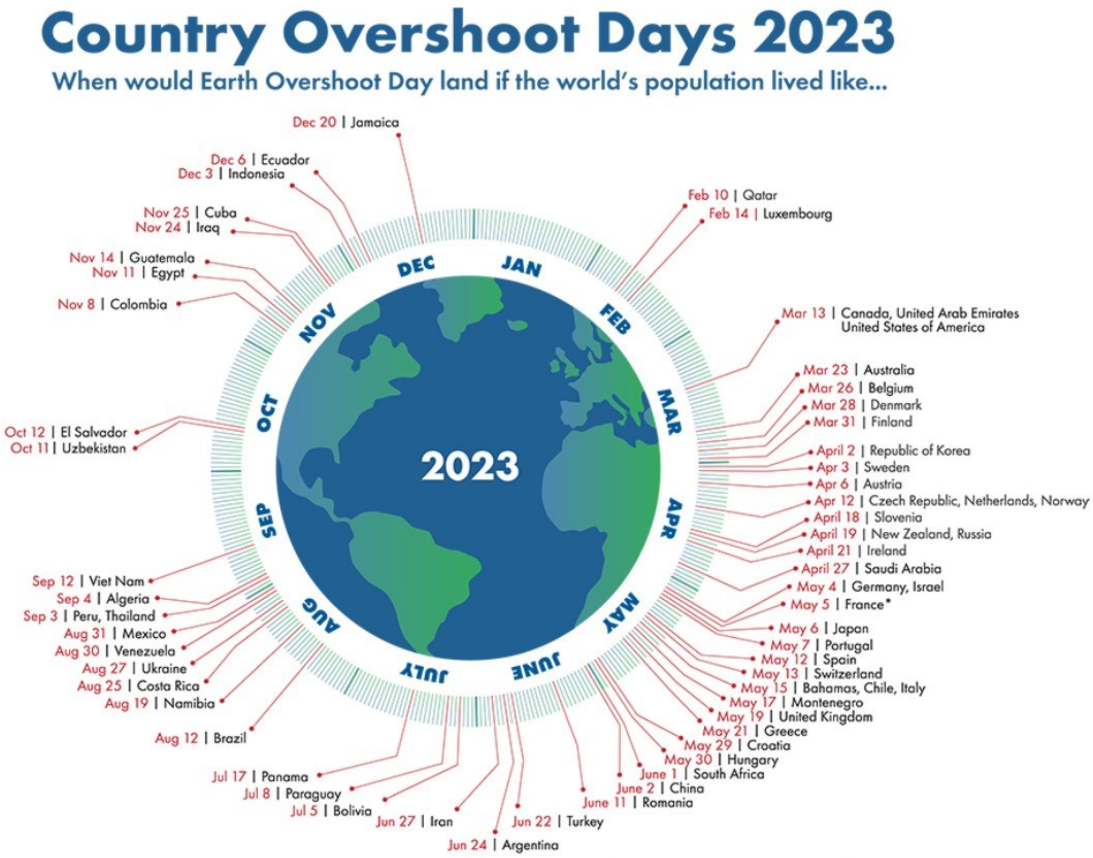
Rees indicating the impact of human behavior toward the planet (Wackernagel, Rees, 1998), in fact, the "ecological footprint can be defined as the metric that measures how much nature we have and how much nature we use"[20]. In a similar vein later the "Carbon Footprint" was also defined, which is the parameter for determining how much we weigh on the environment, that is, the environmental impact that a service, organization or individual leaves on the planet in terms of carbon dioxide (CO_2) emissions (Wiedmann, Minx, 2008). Awareness regarding the concept of a "footprint" has arisen precisely because of the increased demand for resources to the planet, and this tool can be very helpful in identifying areas where action can be taken to not further burden the fragile environmental balance. Linked to the Ecological Footprint, another service offered by the Global Footprint Network is the annual calculation of Earth Overshoot Day[21].This day represents the time when the natural resources made available by the earth run out as their demand is far greater than the amount the planet can regenerate in 365 days, and one is forced to use the available "stocks" for the future[22]. Earth Overshoot Day has always come earlier in calendars, it went from late September in 1997 to being in early August in 2017, when it has fairly stabilized (in 2023 it will be reached on August 2)[23]; this means that to date humanity is using the equivalent of more than 1.75 planet Earths per year, as visible in the Figure 8. In our country, the situation is even more critical, as 2022 reached resource depletion on May 15, placing Italy Overshoot Day a full two months earlier than the global one. All of these are key aspects that have led to the development of numerous studies regarding the need for the development of a new economic system, an alternative and more attractive model that is not only with reduced environmental impact but also capable of generating value: this is the Circular Economy model.

[20] https://www.footprintnetwork.org/our-work/ecological-footprint/
[21] https://www.footprintnetwork.org/
[22] The Global Footprint Network has calculated that since the early 1970s humanity has been in ecological deficit, and the estimate is an ecological debt of about 19 years to the Earth, as visible in FIGURE 8
[23] https://www.overshootday.org/

(Figure 8: National Footprint and Biocapacity Accounts 2022)



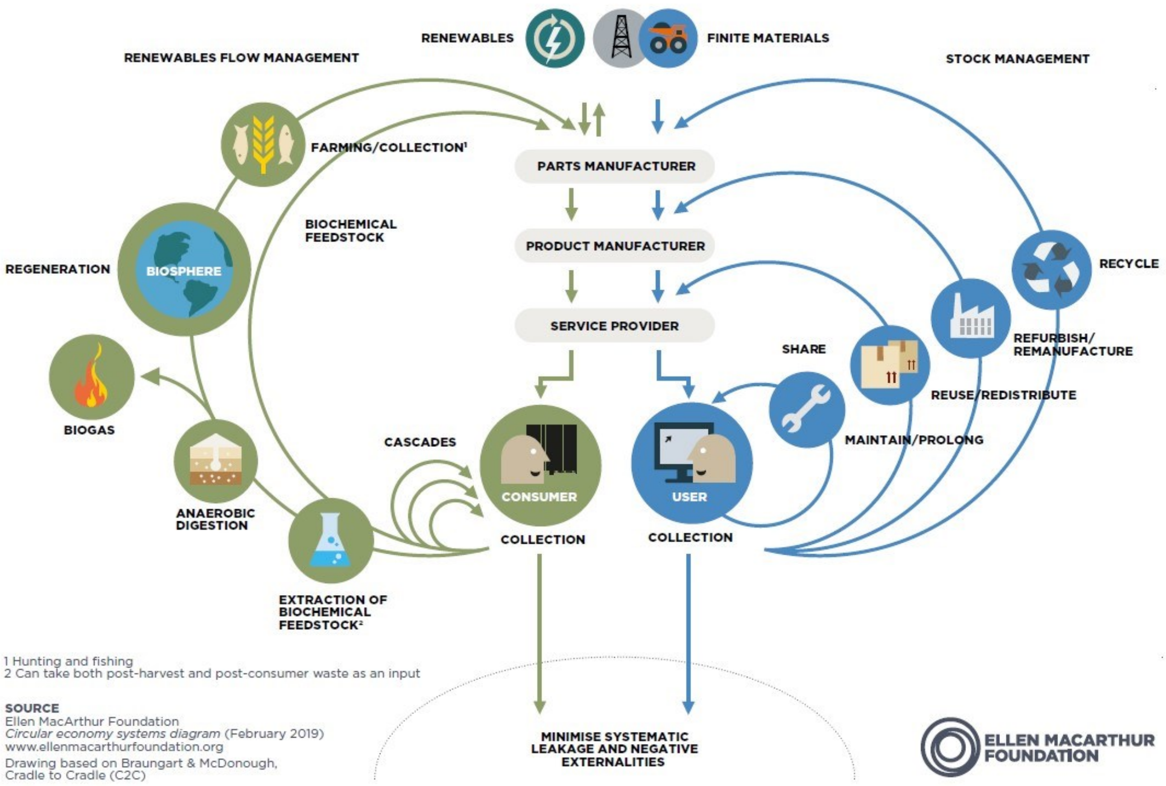
(Figure 9: National Footprint and Biocapacity Accounts 2023 Edition https://data.footprintnetwork.org/#/)



(Figure 9: https://www.overshootday.org/newsroom/country-overshoot-days/)

1.2.1. Principles of Circular Economy

The Circular Economy is currently one of the most discussed topics, it is one of the main focuses of the new European economic strategies, and in recent years it is getting more and more attention (Lieder, Rashid, 2016). One of the biggest promoters of the concept of "circularity" is the Ellen MacArthur Foundation, a private entity that since its founding year in 2010, has been the point of reference on sustainability issues and accompanies companies in their green transition process. Although the earliest definitions date back more than 50 years, it is the Ellen MacArthur Foundation that provides us with a more precise explication of the Circular Economy concept, which is "*an economy* ***designed to regenerate itself****. In a circular economy, material flows are of two types: biological ones, capable of being reintegrated into the biosphere, and technical ones, destined to be regenerated without entering the biosphere"*[24] as perfectly summarized in the circular economy system diagram (Figure 10), better known as the "butterfly diagram".



(Figure 10: Ellen MacArthur Foundation *Circular Economy systems diagram* (February 2019)
https://emf.thirdlight.com/link/7kvazph93afk-owveai/@/preview/1?o)

According to this proposed model, on the left side of the diagram is the biological cycle for all those materials that are biodegradable, such as food, and can return as nutrients to the soil[25]. The right side, on the other hand, refers to the technical cycle, in which products are used (rather than consumed) and represents how materials remain within the circle: the smaller inner loops are where it is possible to retain more of the value of the product itself and represent savings compared to the larger outer loops that surround them that involve those steps where the product

[24] https://www.sfridoo.com/en/circular-economy/
[25] https://ellenmacarthurfoundation.org/articles/the-biological-cycle-of-the-butterfly-diagram

is dismantled into its basic components and the materials used to produce new items[26]. According to the EMF, the circular economy is based on 3 basic principles, all of which are design-driven:

- Eliminate waste and pollution, which may seem inevitable but are actually a mere consequence of design choices, without thinking about what happens to the product at its end of life (designed to be disposable).
- Circulate products and materials (at their highest value), trying to keep products in use and preserve the value as a product, as components or as raw materials, as previously mentioned with the butterfly diagram.
- Regenerate nature, moving from extraction to a more regenerative model, without the use of nonrenewable resources and giving nature back its rightful place.

Indeed, the fundamental concept is that "while great strides have been made in improving resource efficiency, any system based on consumption, rather than on the restorative use of resources, entails significant losses along the value chain" (MacArthur, 2015)), Circular Economy therefore means a system in which all activities are thought of as a function of closing the "circle" of production and, inspired precisely by the natural cycle, **someone's waste becomes a resource for someone else** (Fiksel, Lal, 2018). Adopting a circular model consequently requires a paradigm shift in during the entire production process, from design and production to distribution, consumption, collection and recycling. Indeed, in such a system, one must seek to minimize waste and negative externalities, ideally with the even more ambitious goal of "**stop waste being produced in the first place**"[27] at every stage. To support this transition from the current model to circularity, the Ellen MacArthur Foundation has developed the ReSOLVE framework (Figure 11), a set of action areas that companies must undertake if they are to move toward circularity. The six business actions (REgenerate, Share, Optimize, Loop, Virtualize, Exchange) are then "a tool for generating circular strategies and growth initiatives" (MacArthur, Zumwinkel, K, Stuchtey, 2015) offered to companies that can develop in this way major profitable opportunities.

[26] https://ellenmacarthurfoundation.org/articles/the-technical-cycle-of-the-butterfly-diagram
[27] https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

(Figure 11: McKinsey (2015) Growth within: a circular economy vision for a competitive Europe. Report commissioned by Ellen MacArthur Foundation)

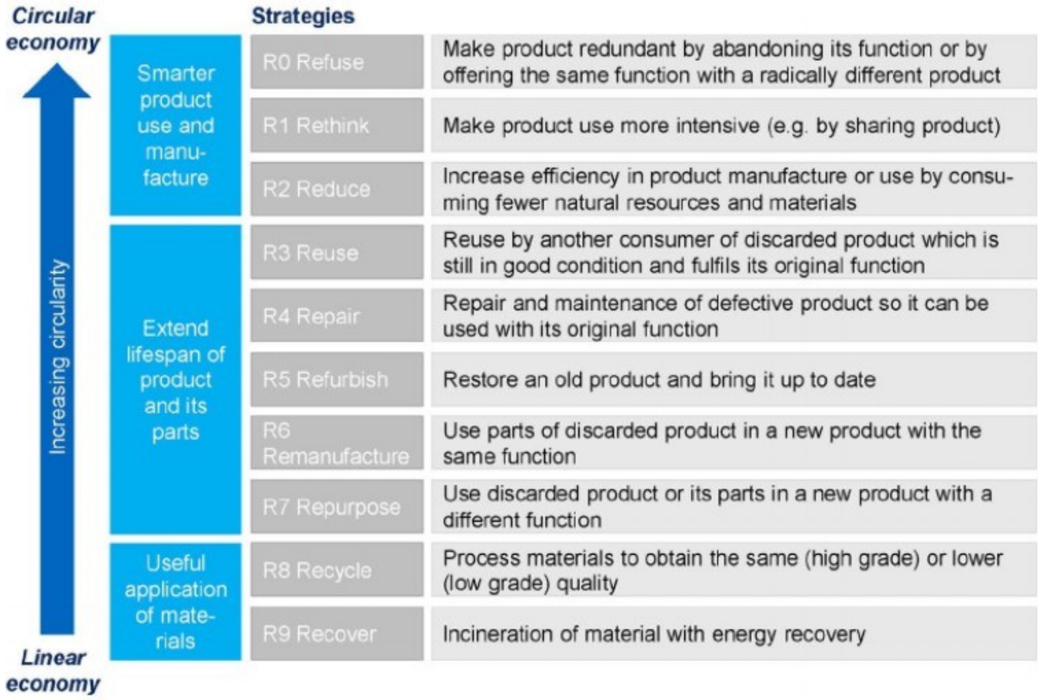
1.2.2. The 9Rs' hierarchy of circularity

Over the years, various R frameworks have been used when talking about the circular economy, and although it is very difficult to trace a certain starting point for this concept (Sihvonen, Ritola, 2015; Yan, Wu, 2011), many authors agree in defining these frameworks as the "how-to" of circularity (Zhu, Zhou, Cui, Liu, 2010). The very first model used is the 3R model, although the most widely used at the moment is probably the 4R model, which introduces the term "Recover" and is currently one of the foundations on which the European Union's Waste Framework Directive is based[28], up to the more recent 9R model. All these frameworks have in common that they follow a hierarchy whereby the first R is more important than the second, the R has priority over the third, and so on. For the European Union, therefore, the circular economy is based on[29]:

[28] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32008L0098
[29] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32008L0098

(Figure 12: Directive 2008/98/EC on waste (Waste Framework Directive, https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en)

- Reduce: at the highest point of the pyramid is Prevention (Waste Framework Directive, 2008), in that limiting or even making zero waste by creating zero-waste products should be one of the pillars for businesses and individuals, but if it is not possible, the first R is Reduce. According to the report *Ecodesign your future. How ecodesign can help the environment by making products smarter* published by the European Union in 2012, the 80% of a product's environmental impact is defined at the time of its design, which is precisely why it is first and foremost necessary to use resources with less environmental impact, limit waste during the production process, and optimize the use of raw materials and energy.
- Reuse: extend the life cycle of the product or use it several times even for purposes other than the original one.
- Recycle: in fact, it is possible to give a “second life” to the product by properly disposing of the waste (or the product itself) obtained during processing in order to turn it back into usable resources.
- Recovery: enhancing the product in the end of life, converting it for energy production.



More recently, the 4Rs paradigm has evolved and led to the definition of 9 strategies (Potting, 2017) to be implemented to bring the system to circularity in turn divided into 3 categories: "smarter product use and manufacture", "extend lifespan of product and its parts" and "useful application of materials" as can be seen in the Figure 12. Again, strategies are sorted according to gradations or degrees of circularity (according to which, simply, more circularity equals more environmental benefits because the materials used remain in the chain for a longer period and the resources needed to produce are less and so on), but the difference is that in the 9R framework you can see nuances in the meanings of the various R's that in contrast you cannot recognize in the other models (Kirchherr, Reike, Hekkert, 2017). This model aims to provide a clearer indication of the best strategies for companies to use in their transition to circularity, which involves a radical rethinking of all activities along the value chain.

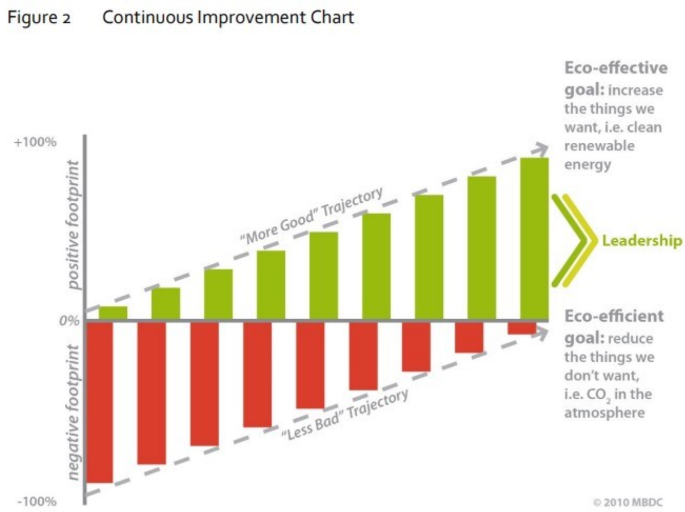
(Figure 12: The 9R Framework, adapted from Potting et al., 2017, p. 5)

2. Drivers and Barriers to Circular Economy

2.1 How does the Circular Economy create value?

Policy makers, businesses and academia are paying more and more attention to the Circular Economy paradigm as a potential solution to balance sustainable development and economic growth (Ellen MacArthur Foundation, 2012). More precisely, the transition consists in replacing the dominant linear economic model, in which cycles of producing and consuming eventually turn resources into waste (Bressanelli et al., 2019), into a greener and more sustainable one. In the so-called "throwaway society", founded on the Take-Make-Dispose paradigm and based on short-lived products, planned obsolescence and high consumption (Mont, 2008), material flows go from "Cradle to Grave", while only some of them are recycled at the end of the process. Very often, however, recycling is an end-of-pipe solution, because the products were not intended to be recovered since the initial stages of their design and the materials lose their qualities and their value within each cycle. In this case, we are not talking about true recycling, but about the so-called downcycling[30] (M. Braungart et al., 2007). Thus, it can be said that the dominant and current Cradle to Grave economic model mainly aims at achieving eco-efficiency through an optimization of the production process in order to attain an overall reduction of the negative effect on the ecosystem. Achieving eco-efficiency certainly results in lower environmental impact of the production process and improvements in the short term, but it is not sufficient in the long term (Braungart et al., 2006). For this reason, it is necessary to search for other eco-effectiveness strategies (Figure 13) to pursue a new economic paradigm called "**Cradle to Cradle**", in which the aim is no longer to "get more from less" reducing the materials used, but the real ultimate goal is to keep them as much as possible and as long as possible inside the loop. Through upcycling strategies, materials are constantly enhanced, they maintain or gain quality over time, and are used as resources for multiple successive production cycles (Sung, 2015), in order to create a positive impact between the natural ecosystem and the industrial system. By doing so, materials can be brought back to a new cradle, eliminating the concept of waste, to achieve a state of zero (zero emissions, zero extracted resources and zero toxicity) because being less bad is not good enough, as highlighted by Braungart & McDonough (2002) pioneers on the Cradle to Cradle topic.

[30] "Recycling is sometimes called downcycling when the recycled material is of lower quality and functionality than the original material" and it manifests as a change in the recycled materials' properties. (Geyer et al., 2016, p. 1011)



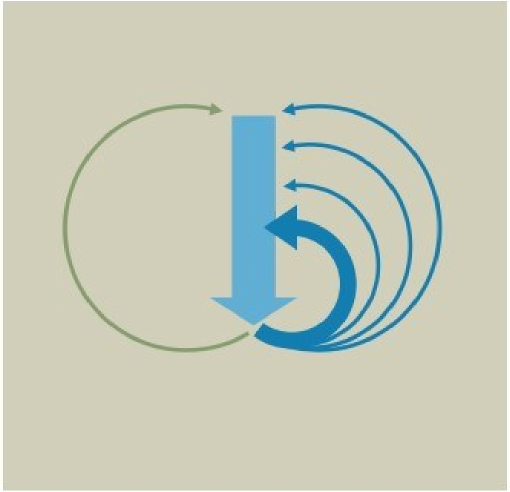
(Figure 13: Environmental Protection Encouragement Agency (EPEA) Internationale Umweltforschung GmbH, 2016, Cradle to Cradle Certified™ Product Standard (Version 3.1), document prepared by McDonough Braungart Design Chemistry)

This shift towards a circular and more sustainable model is being accelerated by three key factors (Ellen MacArthur Foundation, 2012): the increase in the price of energy and raw materials and the difficulty in their availability (as highlighted in the previous chapter), the emergence and diffusion of new technologies that can incentivize the transition to new green business models (Bressanelli et al., 2018), and finally, the rise of the consumer awareness for new environmentally sustainable products. In fact, especially in recent years, consumers have become more interested in green practices and tend to place an increasing value on sustainable products and services (Kirchoff et al., 2011). At the same time, companies that meet certain circularity standards, such as reducing their carbon footprint (Fisher et al., 1997), succeed in improving their brand image, since how a company presents itself and how it is perceived by people are two closely related concepts (Luo & Bhattacharya, 2006).

As the Ellen MacArthur Foundation has also pointed out, Circular Economy "is defined as an economy restorative and regenerative-by-design. The goal is to keep goods, components and materials at their highest utility and value at all times, by enabling several closed-loops cycles" (Bressanelli et al., 2019, p. 284). The benefits of moving from a linear to a circular economy are many and varied, and the choice of the best strategy to adopt (Section 1.2.2) depends on the materials used, the type of product you want to manufacture, and the specific stage in the supply value chain. In general, however, there are four basic principles for creating value in the Circular Economy that can always be considered valid (MacArthur, 2015):

1. Power of the inner circle: According to this model (Figure 14), the tighter the circles, the closer the materials fall to the end of the production process and the greater the

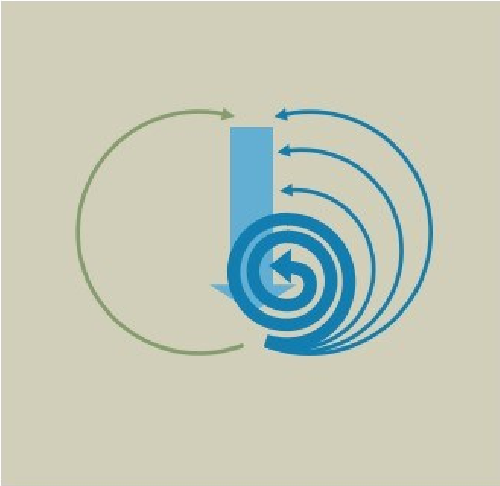
savings (MacArthur, 2012). The savings in this case are due to a reduction in the cost of virgin materials (which do not "leave" the circle as in the linear economy but remain within the various stages of the production cycle), energy and labor, which results in an economic advantage of the circular choice, as well as a reduction in negative externalities, including lower emissions of greenhouse gases, production waste and other pollutants. Furthermore, "whenever the cost of collecting, reprocessing and returning the product, component or material to the economy is lower than the linear alternative (including the cost of end-of-life treatment), it can make economic sense to set up circular systems" (MacArthur, 2012, p. 30). The benefits of implementing a circular economy at the expense of a linear economy become even more apparent with the current increase in the cost of raw materials and their transportation, and the ability to avoid dismantling costs.



(Figure 14: Ellen MacArthur Foundation (2012) Towards a Circular Economy – Economic and Business Rationale for an Accelerated Transition)

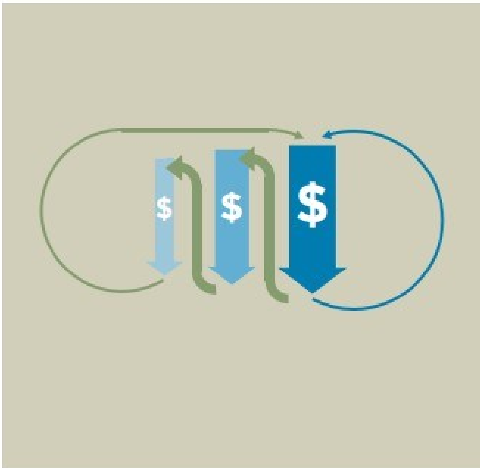
2. Power of circling longer: Another way (Figure 15) in which the circular economy can provide economic benefits is by keeping materials, components and products in use longer, either by extending the life cycle of a product (i.e., allowing it to remain within a single production cycle longer) and by remanufacturing and returning it to its original state more than once in a row (MacArthur, 2012). For this very reason, such a model is also called "of multiple cycles" and results in longer product use, less demand for raw materials and less loss of material from the loop (and thus from the economy), making it advantageous to choose a circular economy. However, it must also be considered that materials cannot remain in the cycle forever; for example, the benefits of this model may not be visible if the product reused several times is replaced by a better and more innovative one (especially in industries with a high and rapid rate of innovation), or if

maintenance costs in order not to lose the quality of the product are increased, which would cancel out the potential benefits.



(Figure 15: Ellen MacArthur Foundation (2012) Towards a Circular Economy – Economic and Business Rationale for an Accelerated Transition)

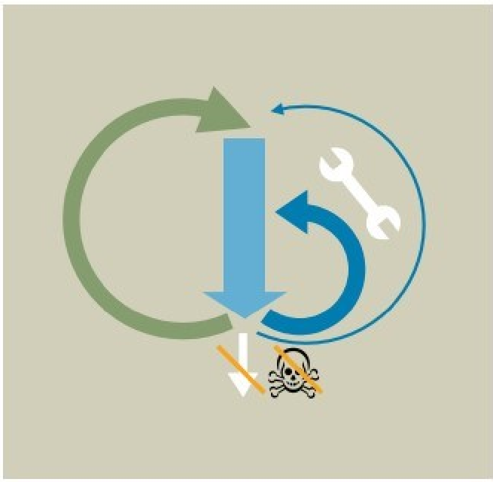
3. Power of cascaded use and inbound material/product substitution: According to this model (Figure 16), another way to create value is to cascade products, i.e. to use discarded materials in other production cycles belonging to different industries. In this case, unlike in the models described above, value is created by using products and materials in entirely new value chains. The benefits are obvious: greater reuse of materials already treated as by-products in another industry results in lower marginal costs due to reduced use of raw materials and labor, as well as a decrease in negative externalities (MacArthur, 2012).



(Figure 16: Ellen MacArthur Foundation (2012) Towards a Circular Economy – Economic and Business Rationale for an Accelerated Transition)

4. Power of pure, non-toxic, or at least easier-to-separate inputs and design: This model (Figure 17) can be seen as an extension of the three above in that it recognizes the

importance of using pure (and non-toxic) materials and high-quality products and components. At present, however, materials at the end of a product's life cycle are often difficult or impossible to recycle because of the way they are designed or the contamination of the waste itself during the collection phase (MacArthur, 2012). According to this fourth lever of value creation, a rethinking of upstream products and an improvement of the material separation and substitution system is therefore necessary to fully realize the benefits at all stages of the value chain. This model shows how high material purity and an extended end product life cycle can reduce reverse cycle costs and maximize potential benefits.



(Figure 17: Ellen MacArthur Foundation (2012) Towards a Circular Economy – Economic and Business Rationale for an Accelerated Transition)

Thus, it can be argued that, in general, a shift from a linear and unidirectional economy, in which raw materials are extracted, processed, used and finally disposed of, to a circular model can bring numerous benefits: *direct*, through a decrease in inputs' acquisition costs, disposal costs due to a reduction in waste, and the sale of reprocessed products obtained from the recovery of materials; *indirect*, because the potential benefits of the Circular Economy also affect the image that consumers have of a company (European Commission, 2001). Improving the extraction and use of raw materials therefore plays a key role in economic growth by extending the life cycle and providing the opportunity to benefit from the residual value of materials. In addition to economic and environmental benefits, social benefits should also be considered. Social benefits occur when CE brings net benefits to society, as in the case of growing employment opportunities and increasing in the job quality (Bressanelli et al. 2020). In fact, numerous studies point out that environmental innovations can have a greater positive impact on employment levels than end-of-pipe technologies (Pfeiffer & Rennings, 2001), especially in specialized jobs in more innovative and green fields and in new eco-innovations

(Horbach & Rennings, 2013). With all these positive aspects to consider, it might seem logical to say that moving to a circular economy is the best solution for a company, so why do many companies decide to keep their linear model instead of moving to a more eco-efficient (Figure 18), eco-effective and sustainable one? To answer this question, the next paragraphs will explore what the main drivers and most common barriers are for a company that wants to move to a circular business model.

Definitions of eco-efficiency from different sources

Source	Definition
Australian Government	Eco-efficiency is a management process that is designed to "produce more from less". Eco-efficiency can be achieved by increasing mineral recovery, using fewer inputs such as energy and water, recycling more and reducing emissions[a]
European Environmental Agency	Eco-efficiency is the amount of "environment" used per unit of "economic activity"[b]
Global Development Research Center	The relationship between economic output (product, service, activity) and environmental impact added caused by production, consumption and disposal[c]
Joseph Fiksel	The ability of a managed entity to simultaneously meet cost, quality, and performance goals, reduce environmental impacts, and conserve valuable resources[d]
Klaus North	Eco-efficiency, cleaner production and lean production are based on a common philosophy: to reduce "waste" in all steps of a production process. Eliminating waste will lead to improvements in eco-efficiency and thus contributes to: less energy consumption, less waste material, less materials handling, and less intermediate storage[e]
Laurent Grimal	This strategy induces the integration of cleaner production technology into the production process, aiming at a reduction in materials and energy consumption and thus at a decrease in pollution[f]
LEAN Advisors	The means by which more and better goods and services are created using fewer resources and minimizing waste and pollution. In practice, eco-efficiency has three core objectives: increasing product or service values, optimizing the use of resources, and reducing environmental impact[g]
Nokia	Eco-efficiency means producing better results from less material and energy. For us this means: minimizing energy intensity, minimizing the material intensity of goods and services, extending product durability, increasing the efficiency of processes, minimizing toxic dispersion, promoting recycling, and maximizing the use of renewable resources[h]
PrintNet	Eco-efficiency is a concept that links environmental and financial performance. It does this by focusing on the development, production and delivery of products and services that meet human needs while progressively reducing their environmental impact throughout their lifecycles. Eco-efficiency essentially means doing more with less-using environmental resources more efficiently in economic processes. The application of eco-efficiency is undertaken, but not limited, by approaches and tools such as cleaner production and environmental management systems[i]
Toshiba Group	Eco-efficiency is calculated by dividing the "value" of a product by the product's "environmental impact". The smaller the environmental impact and the higher the value of the product, the greater is the eco-efficiency. The value of a product is calculated based on its functions and performance, taking the voice of customer into consideration. The environmental impact of a product is calculated, taking into consideration various environmental impacts throughout its life cycle[j]
WMC Resources Ltd.	Maximizing efficiency of production processes while minimizing impact on the environment. Eco-efficiency can be achieved by using new technology, using fewer inputs per unit of product such as energy and water, recycling more and reducing toxic emissions. In summary doing more with less[k]

(Figure 18: Braungart, M., McDonough, W. and Bollinger, A. (2007) *"Cradle-to-cradle design: Creating healthy emissions – a strategy for eco-effective product and system design"*, *Journal of Cleaner Production*, vol. 15, 13-14, pp. 1337–1348)

2.2 Internal drivers to Circular Economy

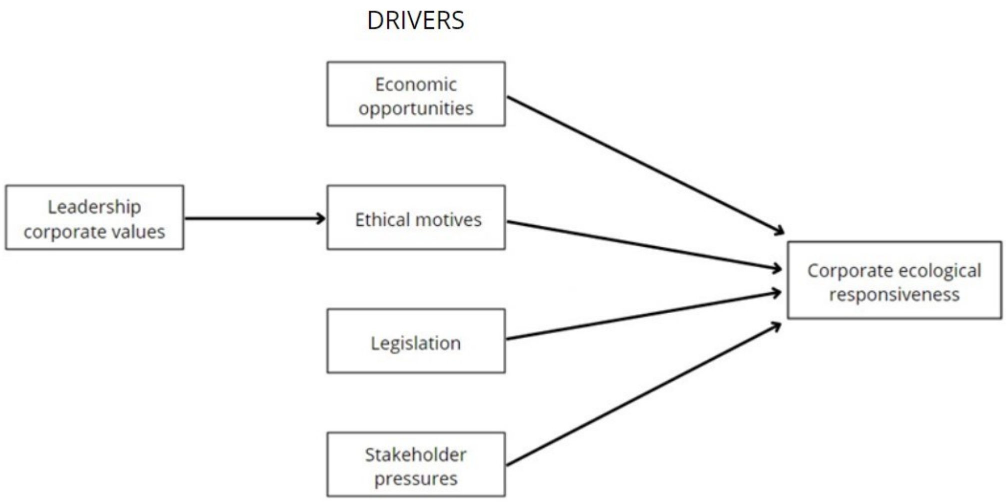
Broadly speaking, firms can be divided into two macro-categories: those that are born sustainable and have the social-environmental sphere as their main reason for existence, and those that do not pursue sustainability but only profit as their core value. The first group consists of sustainability-oriented companies (Parrish, 2010), whose type of entrepreneurship (or "Ecopreneurship" as defined by Schlange (2006)) places a special interest in the environment and the use of circular practices. The second category, on the other hand, is the most prevalent and is based on "profit-seeking" (Parrish, 2010), traditional and linear business models, in which implementing sustainable practices is a great challenge (but equally a great opportunity). **Environmental upgrading** is referred to "as the process by which economic actors move towards a production system that avoids or reduces the environmental damage from their products, processes or managerial systems" (De Marchi et al., 2013, p. 65). Therefore, stated this definition, companies can implement different strategies to achieve three types[31] of environmental upgrading, simultaneously or at a later stage, with the aim of reducing their environmental impact:

- Process improvements: Achieved by reorganizing production processes or using more advanced and environmentally friendly technologies in business practices.
- Product improvements: Reached through the use of environmentally friendly materials.
- Organizational improvements: Involves improving the company as a whole to meet a certain level of standards.

Thus, the Circular Economy aims to decrease raw material consumption, reduce waste, and improve the overall efficiency and effectiveness of production processes (Hu et al., 2011). The focus of this concept concerns the determination of what costs and benefits emerge with the implementation of sustainable practices; in fact, although these practices clearly reduce the impact on the planet, they should be considered not only as environmental but also as economic strategies, since they are primarily designed to improve the performance of the companies that implement them (Yuan et al., 2006). The Circular Economy therefore offers a number of potential benefits and also strengthens the relationship between society and business (Kumar et al. 2019). Scholars and academics therefore believe that a paradigm shift is needed among all actors in the supply chain, who must work together to integrate sustainable practices at all stages of the value chain (Geng et al., 2012). Indeed, close collaboration is needed from the product design and engineering phase, through cleaner production, to rethinking the end-of-life of products. The opportunities created by the implementation of circular models are almost endless, and the literature has been very prolific on what are the reasons for a company to go green, and for this very reason, it is difficult to be able to analyze with extreme precision all the drivers that can push companies to be born or to become sustainable. The topic of enablers to circularity is therefore very wide, as actually there is not always a single motivation that drives

[31] From personal notes of Global Firms and Global Value Chains

a company to change its business model, but rather in reality they pursue a mix of both economic and social and environmental goals. The most impactful drivers to circularity are also highly dependent on the type of enterprise being considered, size, product type, industry, geographic location, a dynamic and changing environment, and so on. Given this premise, the purpose of the following paragraphs will then be to provide a general overview of the main reasons that drive a company to change from a linear to a circular model, trying to highlight those that the vast literature considers to be the most recurrent and influential. To better analyze the drivers of circularity (Figure 19), they will be divided into internal (as the increasing of the efficiency, the profitability and other financial benefits and the business sense) and external (as the buyer's demand, the legislation and the push of the supply chain as a whole).



(Figure 19: Rielaboration from "Simple model of drivers for the implementation of Circular Economy practices". Bansal, P., & Roth, K., 2000. Why companies go green: a model of ecological responsiveness.)

2.2.1 Profitability and economic benefits

There are numerous studies that highlight the economic advantages of moving from a linear to a circular system. One of the crucial aspects that a company has to consider is the potential economic benefit of adopting sustainable practices, because if they find this shift to be profitable, they will have to change their business model and adapt to the principles of circularity (Cambra-Fierro, 2008). In addition to these potential encouraging consequences, companies also seek to adapt to ethical behavior and implement sustainable practices in order to convey a positive self-image and to try to attract the attention of new environmentally conscious customers (Adkins, 1999). Economic benefits, enhanced reputation and strengthened market position are therefore highly interrelated concepts (Hemingway & Maclagan, 2004). Companies can choose to exploit market advantages in two main ways: either by designing their business model for circularity from the beginning by developing innovative and sustainable products or services, or by imitating the best practices of other companies (follower strategy) to enter new markets. The main economic drivers can therefore be identified as:

- **Resource-use efficiency**: one of the most significant incentives for adopting sustainable practices lies, as mentioned above, in improving eco-efficiency in the use of both raw materials and energy - producing more with less - and water by implementing lean production principles (Bocken et al., 2014). "The successful implementation of a resource-efficiency strategy leads lower production costs and thus cost-reducing-oriented companies are more likely to adopt it" (Gusmerotti et al, 2018, p. 318) so as to optimize the production process to the point of achieving so-called eco-efficiency. Companies are therefore seeking to extend the life of products, reducing the need to produce new goods and thus reducing dependence on virgin raw materials. They also want to reduce waste and improve energy efficiency, including through the use of new technologies and renewable energy sources, with the aim of pursuing better business performance as a fundamental driver of circularity.
- **Reduction of production costs and supply risks**: As pointed out in the previous chapter, the rising cost of raw materials, scarcity and difficulty of procurement caused by the current global socio-economic situation are among the main causes of change. Reducing production costs therefore becomes a direct consequence of adopting the principles of sustainability and closing production cycles, as well as leading to a decrease in dependence on the demand for raw materials in the market. Designing products that from the beginning are intended to be easily recycled and repaired results in reduced costs associated with waste management and disposal and reduced supply risk, mitigating the fluctuation of market demand prices and thus creating a situation of greater economic and organizational stability for circular companies (Ellen MacArthur Foundation, 2014).
- **Economic benefits of opening to new markets, innovation and competitiveness**: Integrating circularity into business strategies is a major driver of competitiveness. It refers to the possibility that environmentally sustainable products can provide significant economic benefits and increase profitability in the long run (Hart, 1995). However, some companies exclude the environmental impact of a product from the decision-making process. They focus only on what they think will bring higher

economic returns, without paying attention to the consequences of their practices. Instead, competitive companies may take a different route by placing eco-innovation at the heart of their strategies, with the potential to strengthen their market position or gain access to new, previously unexplored market segments (Bansal & Roth, 2000). Growing consumer demand for green products therefore opens up new opportunities for increasing the global attractiveness of companies and, at the same time, potential profits for companies that choose to go green (Bansal & Roth, 2000).

2.2.2 Business sense and environmental commitment

Another key driver for the adoption of circular practices is the extent to which business owners - managers and employees consider their own actions to be important and believe that their actions and the company's practices can have an impact on the environment (Nußholz, 2018). People who have a strong commitment to sustainability issues will proactively seek to take actions in order to have both economic and environmental benefits to achieve a win-win situation (Gusmerotti et al., 2019). In some cases, managers try to limit the negative impacts of the companies they guide, even at the expense of mere profit maximization (Bansal and Roth, 2000), and this behavior can be explained by ethical reasons: the attitudes and motivations of those who control a company and the environmental commitment are thus key elements that drive a company to implement a circular business model (Testa et al., 2016a). According to the Value Belief Norm (VBN) theory, personal norms and believes influence environmentally conscious and proactive behavior in organization (Stern et al., 1999) and because of the personal attitude, when someone transgresses a personal standard, people inside the organization feel accountable for the unfavorable effects of their conduct (Lülfs & Hahn, 2013). This implies that usually companies run by this type of leader tend to adopt green practices, although this is not always the case, as research shows that "owner - manager's desire to engage in environmental improvement does not always result in associated action" (Parker et al., 2009, p. 287). In the work of Parker et al. (2009), is emphasized that businesses, and SMEs in particular, can be classified into four extreme types (Figure 20) that result from the combination of two significant factors: environmental commitment and business performance commitment. Environmental commitment refers to the sense of duty and moral obligation that companies feel they have to reduce their environmental impact or make improvements from a sustainability perspective in a proactive and voluntary manner (Roy & Therin, 2008); for business performance commitment, on the other hand, the given definition is more complex because it must take into account numerous non-financial (such as social) and financial (growth and profit maximization) objectives (Walker & Brown, 2004).

Degree of business performance commitment		Low	High
	High	Profit driven	Advantage driven
	Low	Compliance driven	Environment driven
		Low	High
		Degree of environmental commitment	

(Figure 20: Parker, C.M.; Redmond, J.; Simpson, M., 2009. A review of interventions to encourage SMEs to make environmental improvements)

Based on the degree of combination of these two factors, we can identify:

1. Environmental-driven businesses: They have high levels of environmental commitment and low degree of performance commitment, so instead of financial goals, the owner - managers of these companies prioritize environmental improvement goals. They focus on minimizing their adverse effects on the environment and they are motivated by a sense of duty or moral obligation to reduce the firm's negative environmental impact acquiring the necessary skills, knowledge and technology (Walley & Taylor, 2002). They are less concentrated on profits and business growth, even if it reduces the competitiveness in the market, and are more interested in adopting sustainable practices and encouraging customers to do the same (Revell & Blackburn, 2007).
2. Advantage-driven businesses: In this case, the owner - managers have a high degree of both environmental and business performance commitment and they try to reach sustainable goals and financial goals at the same time (Walley & Taylor, 2002). They focus on profits and growth, they are able to attract customers who value low environmental impact due to the company's innovative, proactive and opportunistic strategies (Simpson et al, 2004). So, they see their environmental commitment as a way to exploit also a competitive advantage and a way to achieve the financial goals, which is the main difference with the environmental-driven business.
3. Compliance-driven businesses: These are the companies that operate in very competitive industries and are primarily focused on survival rather than proactivity and innovation (Aragon-Correa & Cordon-Pozo, 2005; Mir, 2008). They mainly react to consumer demand or legislative requirements and often lack the knowledge and skills to implement sustainable practices but only seeking to meet regulatory compliance (Bradford & Fraser, 2008). In addition, these types of companies find it is too costly to achieve environmental achievements that is not demanded by their consumers and

believe that these investments may even end up hurting the company itself (Drake et al, 2004). The owner - managers have low degree of environmental commitment and also low degree of business performance commitment.

4. Profit driven businesses: These companies prioritize performance commitment over environmental one due to their focus on cost reduction strategy in order to achieve a leadership position in the market (Simpson et al., 2004). They have a high degree of business performance commitment and a low degree of environmental commitment and are usually defined as "free riders" (Revell & Blackburn, 2007): they, in fact, seek only to achieve their financial goals even through business models that negatively impact the environment, are neither innovative nor proactive, and do not comply with environmental regulations if it leads to a reduction in their profits (Drake et al, 2004).

2.3 External drivers

As with internal drivers, external drivers are also very important in the process of transitioning towards a Circular Economy. The difficulty in classifying and analyzing them lies in the fact that they can be perceived by companies as both enablers and challenges to circularity (Figure 21). All companies play a key role in the diffusion of green practices but are often hindered by barriers that they had initially recognized as opportunities, challenges that are particularly dangerous when faced by SMEs. Achieving a complete change of economic paradigm implies a transition of society as a whole, with a global and holistic approach that cannot only involve companies but must also come "from outside" at regional, national, but above all European and global levels (Van Buren et al., 2016). This is where the European Commission's many interventions come in, using the concepts of sustainability and circularity as the basis for current and future policy proposals. Examples of the European Union's interventions include the Circular Economy Package, also known as "Closing the Loops", an action plan defining practices and measurement tools for sustainable production, and the more recent NextGeneration EU.

Drivers/ Barriers - SME Capabilities	Drivers/Barriers-Supply Network	
Management & Organization	**Financial Resources**	---
Drivers: • Commitment (Darnall et al., 2008) & environmental championing by top management (Lee, 2008; Lee and Klassen, 2008) • Values and beliefs of the top management (Cambra-Fierro et al., 2008) • Genuine concern & compassion of the management to the welfare of its employees (Baden et al., 2009) • Existence of environmental awareness (Lee, 2008; Lee and Klassen, 2008; Wycherley,1999) • Response to stakeholders (Seuring and Müller, 2008) • Teamwork & knowledge sharing between employees (Darnall et al., 2008) • Skills & expertise (Darnall et al., 2008) • Increasing staff motivation (Baden et al., 2009)	**Drivers:** • Cost saving & economic benefits (Cambra-Fierro et al., 2008; Williamson et al., 2006; Wycherley, 1999) • Availability of financial & technical resources (Lee, 2008; Lee and Klassen, 2008) • Availability of infrastructure (Wycherley, 1999) • Fear of reputation loss (Seuring and Müller, 2008) • Complying with environmental standards for tendering purposes (Baden et al., 2009) • Seeking competitive advantage & differentiation in the market (Baden et al., 2009) • Developing competitive advantage by building a positive image in the market (Cambra-Fierro et al., 2008)	**Drivers:** • Pressure from customers (Darnall et al., 2008; Lee, 2008; Lee and Klassen, 2008; Seuring and Müller, 2008; Williamson et al., 2006) • Green supply chain practices of the customers (Lee, 2008; Lee and Klassen, 2008) • Responding to regulations, laws & local authority pressure (Seuring and Müller, 2008; Williamson et al., 2006) • Responding to environment & social pressure groups (Seuring and Müller, 2008) • Trust in long-term relationship (Wycherley, 1999)
Barriers: • Lack of top management commitment (Min and Galle, 2001; Revell and Blackburn, 2007) • Lack of management time (Hitchens et al., 2003; Simpson et al., 2004) • Culture & attitude toward environment and change (Hitchens et al., 2003; Revell and Blackburn, 2007; Wooi and Zailani, 2010; Wycherley, 1999) • Lack of environmental awareness (Wooi and Zailani, 2010; Zhu et al., 2008) • SMEs' perception that their impacts on environment is minimal (Simpson et al., 2004) • SMEs are heterogeneous & operate in different contexts (Merritt, 1998) • SME firm is family oriented (Wooi and Zailani, 2010) • Prevalence of self-interest (Wycherley, 1999) • Perception of no benefits from improving environmental performance (Merritt, 1998; Revell and Blackburn, 2007) • Perception of environmental management as financial burden (Revell and Blackburn, 2007) • Lack of human resources (Simpson et al., 2004) • Lack of skills, know-how & technical expertise (Hitchens et al., 2003; Lee, 2008; Lee and Klassen, 2008; Revell and Blackburn, 2007; Wooi and Zailani, 2010) • Shortage of information (Lee, 2008; Lee and Klassen, 2008; Wycherley, 1999)	**Barriers:** • Lack of financial resources (Lee, 2008; Lee and Klassen, 2008; Simpson et al., 2004; Wooi and Zailani, 2010) • High cost of environmental programs (Min and Galle, 2001; Seuring and Müller, 2008; Wycherley, 1999) • Uneconomic benefits of recycling activities (Min and Galle, 2001) • Unavailability of capital for investment in environmental initiatives (Hitchens et al., 2003) • Existing investments & information systems which are costly to change (Wycherley, 1999)	**Barriers:** • Lack of buyer & supplier awareness toward environment (Min and Galle, 2001) • Lack of supply chain pressure (Revell and Blackburn, 2007) • Lack of bargaining power of SMEs (Zhu et al., 2008) • Negative reaction from other actors in the supply chain (Wycherley, 1999) • Mistrust & confidentiality between partners (Wycherley, 1999) • Insufficient or missing communication in the supply chain (Seuring and Müller, 2008) • Lack or loose of governmental regulations (Min and Galle, 2001; Wycherley, 1999) • Improper communication between government & SMEs (Merritt, 1998) • Lack of awareness of existing environmental regulations (Revell and Blackburn, 2007; Simpson et al., 2004) • Lack of standards & auditing programs (Min and Galle, 2001)

(Figure 21: Meqdadi, O.; Johnsenb, T.; Johnsenc, R. The Role of SME Suppliers in Implementing Sustainability. In Proceedings of the IPSERA 2012 Conference, Napoli, Italy, 2012)

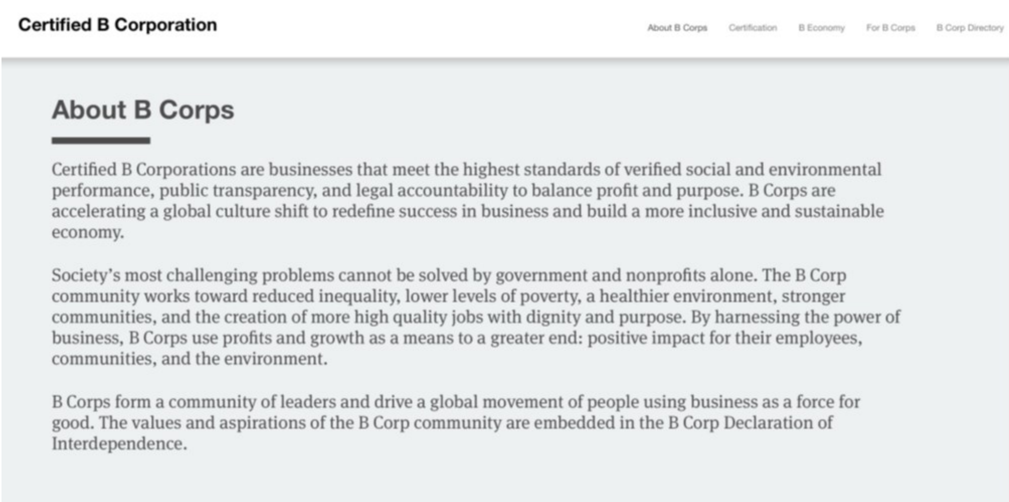
This is one of the most powerful initiatives in the history of the European Union, which envisages a series of maneuvers to develop a stronger and more sustainable economy in response to the Covid19 Pandemic and, at the same time, to resolve the numerous structural weaknesses of the European states. The various nations are also keen to seize this opportunity and have presented their Recovery and Resilience Plans to access European funds: the Italian plan is developed around three strategic points, which are digitalization and innovation, ecological transition and social inclusion.

Another external driver for circularity can come from consumers, whose awareness of green products is growing every year. Companies are driven by buyer pressure to make environmental improvements in order to differentiate their products and attract the interest of environmentally conscious customers. In order not to betray the trust of consumers and to prevent companies from being guilty of the sin of greenwashing, various certifications, including B Corporations, have emerged for companies that meet certain legal and circularity performance standards. The Circular Economy therefore requires a change in all activities in the value chain, as companies cannot achieve their sustainability goals alone, but must involve all actors in the process: all phases become relevant, from planning and design, through the choice of materials and packaging, to the actual production, transport and final distribution (Carter & Easton, 2011). This requires the development of close collaboration and synergy throughout the supply chain, because "it is insufficient to focus internally on improving the environment while suppliers provide harmful materials" (Meqdadi, 2012, p. 29) and this is one of the reasons why a single company can never achieve its circularity goals alone without involving its suppliers and other partners.

2.3.1 Consumer perception and demand for circular products

Recently, a growing segment of consumers has begun to become more aware of sustainability issues; they tend to be increasingly loyal to products that have a positive impact on the environment, and for this reason they are demanding that companies adopt more responsible business models (Fonseca & Domingues, 2018). Stakeholders are therefore exerting significant pressure for the transition to a Circular Economy, and although few studies have considered the buyer perspective as a major driver (Abbey et al., 2015), there is a need to understand how the growing interest in green products can be for the companies a significant driver for the change (Ivan Henderson et al., 2020). The difficulty in analyzing this issue is also influenced by the fact that the role of consumers in the CE can also be a barrier at the same time, as low demand for these products can be detrimental to the adoption of circular models (Rizos et al., 2016), as analyzed in Section 2.4.1. Consumers, therefore, play a crucial role and become enablers of circularity when demand-side issues are solved, because by showing a preference for sustainable products and services, companies are encouraged to adopt these business models to meet market demand (Rizos et al., 2016). Increased awareness of environmental issues and proper consumer and business education can bring long-term benefits of sustainable practices such as reduced costs and access to new markets, and it drives companies to meet consumer expectations to improve their efficiency while enhancing their reputation and competitiveness in the market (Van Buren, 2016). People who value companies' commitment to the environment have more favorable perceptions of sustainable marketing campaigns and circular product features and are positively influenced by businesses' green initiatives that meet their customers' sustainability expectations (Kirchoff et al., 2011).

The market for circular products and services is expanding and consumers are very aware of sustainability issues. At the same time, however, along with the expansion of the market for circular products and services and the growing interest in environmental issues, the phenomenon of **greenwashing**, which defined as "the intersection of two firm behaviors: poor environmental performance and positive communication about environmental performance" (Delmas, 2011, p. 65). Companies are required to communicate in clear and precise language information about the practices they have implemented and transparency in the impact of their activities. In reality, however, they may hide behind "fake environmentalism" and claim to be what they are not so as to appropriate the market share of green consumers. TerraChoice (2010) reported that at the time of their study almost the totality of products that claim to be green in Canada and the U.S. committed at least one of the "sins of greenwashing", such as the sin of the hidden trade-off or the worshiping of false labels. This can undermine consumer confidence and increase a sense of skepticism about circular products, thus slowing the adoption of this type of business model. Although Western Countries seems to have a greater sense of awareness towards these topics, it is not always possible to recognize which companies are actually greenwashing, especially when there are uncertain regulations (de Freitas Netto, 2020).
For all these reasons, in recent years the concept of Certified B Corporations, also known as **B Corp**, has become more widespread for those companies that what to prove they have a positive impact successfully reaching a balance between financial gains and their social responsibility (B Corp Spain).



(Figure 22: https://www.bcorporation.net/en-us/)

The B Corp certification is given to companies that meet legal and performance requirements (they must score at least 80 out of 200 points to receive certification) and also reach high standards of environmental impact, transparency and social responsibility (B Corp Spain). They obtain a certification that has a dual function: to specify the social-environmental aspect in which the company excels and to signal its commitment to stakeholders. According to the Global Sustainable Investment Review (Global Sustainable Investment Review) between 2016 and 2018 there has been a 34 percent increase in companies making environmentally sustainable investments among Europe, the United States, Canada, and Australia - New Zealand, and that consumers are also changing their buying habits, preferring to spend more on sustainable products according to the B Lab Spain 2018 Annual Report (B Lab Spain) demonstrating that social and environmental issues are becoming increasingly important in the market. More and more companies are part of this initiative, which includes more than 150 different sectors and encompasses more than 70 countries around the world: in 2017 there were 2300 B Corporations, in 2019 there were 3100[32] and in 2020 more than 3500. In 2024 the number even more than doubled in just four years, reaching a record 8048 certifications, more than 1300[33] (data as of 2023) in Europe alone, which highlights the centrality of environmental issues in European policies[34].

2.3.2 Regulations and local government support

Legislation is another factor that can influence the adoption of circular practices. In fact, it has two main roles: on the one hand, regulations set minimum requirements that companies have to meet, and on the other hand, they can also facilitate changes in the business models of companies (Bansal et al., 2018). In recent years, the Circular Economy has been at the center of the development plan proposed by the United Nations and, in particular, the economic policy of the EU, which seeks to promote economic growth without negatively impacting the environment. The European Union action plan includes many aspects of the circular economy and covers all stages of the production cycle, from environmentally sustainable design to the extraction and use of raw and secondary materials, to the end-of-life phase of products (Gusmerotti et al., 2019). The Circular Economy is a very broad concept and thus encompasses a wide range of policies affecting different stages of the value chain (Bicket et al., 2014). Waste management, for example, has been a central element of European legislation in recent decades.

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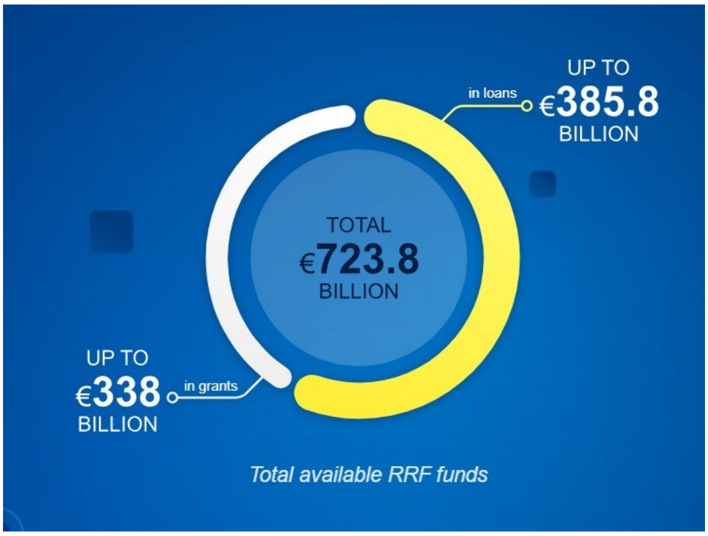
[32] https://bthechange.com/a-year-of-business-as-aforce-for-good-2019-in-review-8e744ed4d620.
[33] Information at the end of 2023.
[34] https://www.bcorporation.net/en-us/.

To strengthen the overall coherence on this topic, the European Commission published the Circular Economy Package in July 2014, a proposal for six waste-related directives aimed at improving recycling targets in Europe[35]. These directives were replaced the following year because they focused only on the topic of waste but failed to integrate the proposals to other European sustainability laws (Jackson & Watkins, 2012). The Circular Economy Package was then replaced by the first European action plan "Circular economy strategies and roadmaps in Europe: Identifying synergies and the potential for cooperation and alliance building" which included measures to improve competitiveness and speed to transition to the EC and foster growth and job opportunities (European Economic and Social Committee, 2015). This plan also suggests best practices, collaboration between different sectors, and a range of strategies that companies can use to overcome barriers to the circular economy. Along with this legislative package, the European Commission published a communication entitled "Towards a circular economy: A Zero Waste Program for Europe" (European Commission, 2014a), which provided general guidelines for businesses to improve their resource use efficiency and to modernize and implement circular economy principles. Other help, especially for SMEs, was being given by the Green Action Plan (GAP), adopted by the European Commission in July 2014, which aimed to turn barriers to the circular transition into drivers, through a series of goals and concrete actions (Europen Commission 2014c, p.1) in order to "help SMEs exploit the business opportunities that the transition to a green economy offers", recognizing as significant challenges those of cross-sector collaborations in a greener value chain and the easier entry of companies themselves to new markets.

These strategic development plans were designed by the EU to make it easier for companies to choose (or move to) circular business models. However, given the many barriers that still exist and the challenges that businesses face on a daily basis, the EU has seen the need for even more concrete improvements, especially in recent years. For example, through the European Green Deal to be launched in 2019 (as anticipated in the first chapter), the EU has set a series of very ambitious sustainability targets and, in order to encourage the adoption of circular practices using a holistic and cross-sectoral approach, has introduced a "Just Transition Fund" to financially support member states, especially those most in need. The fund guarantees €17.5 billion to help SMEs and start-ups meet the costs of a green transition, develop research and innovation, use more efficient technologies and promote employment[36]. In addition to this fund, Europe estimates that up to €55 billion will be unlocked to facilitate green business financing

[35] https://www.europarl.europa.eu/EPRS/EPRS-Briefing-573936-Circular-economy-package-FINAL.pdf.
[36] https://www.consilium.europa.eu/it/policies/green-deal/#initiatives

and investment. In addition, through the NextGenerationEU[37] (NGEU), Europe is seeking to use the new challenges posed by the Covid19 pandemic to transform the European economy, making it greener, more digital, stronger and more equal, and more resilient. The maneuver provides for massive investments over the period 2021-2027, totaling about 1.8 trillion euros, including the NGEU, which cannot be seen solely and exclusively as a recovery plan, but in fact makes available to the states about 800 billion euros (of which about 390 billion euros in grants and about 360 billion euros in long-term loans to be repaid by 2058, as shown in the Figure 23 below) to promote the development of a sustainable and healthier economy[38].



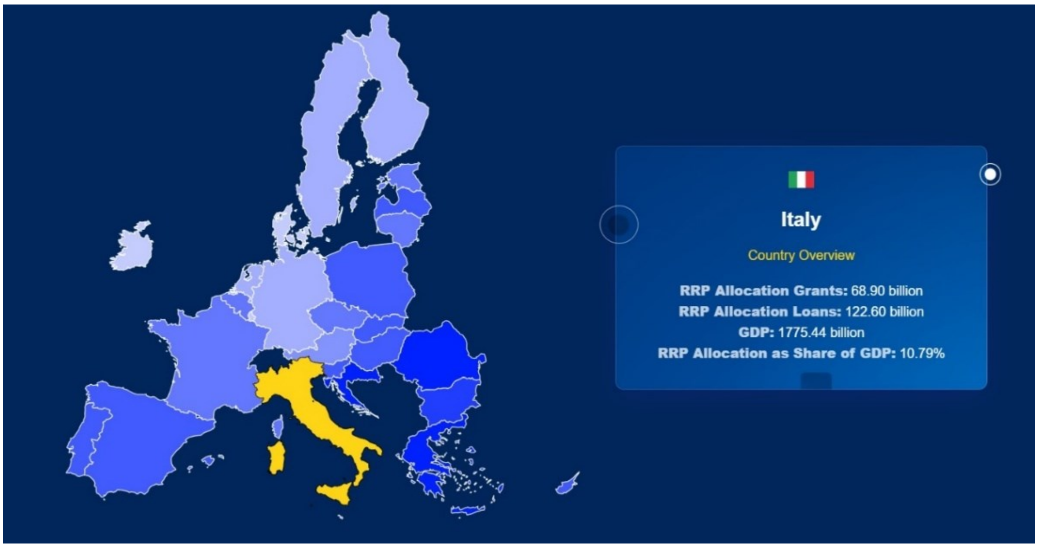
(Figure 23: Recovery and Resilience Scoreboard, available at https://ec.europa.eu/economy_finance/recovery-and-resilience-scoreboard/index.html)

Various countries, especially members of the European Union, are aware of the importance of the transition to a circular economy. Italy, for example, in its framing and strategic positioning document "Verso un modello di economia circolare per l'Italia", prepared by the Ministry of the Environment and the Ministry of Economic Development (2017), provides a number of concerns regarding the unlimited use of resources and about the current linear system and explains the potential impact that a transition to circular business models can have in our country. It highlights how Italy has promoted various incentives, including tax breaks for circular businesses (e.g., tax deductions for technologies that promote recycling, reuse and waste reduction), easier financing for green businesses, support for research and innovation as well as training initiatives and campaigns to raise awareness of environmental issues (Ministero dell'Ambiente, 2017).

More concretely, Italy also wants to take advantage of the favorable conditions in the

[37] https://commission.europa.eu/strategy-and-policy/recovery-plan-europe_en
[38] https://commission.europa.eu/strategy-and-policy/recovery-plan-europe_en

NextGenerationEU to recover from the crisis period due to the pandemic and at the same time make tangible steps towards the circular transition; for this reason they presented the Recovery and Resilience Plan (RRP), which is a package of reforms that states must submit to access European funds in the NGEU and in which, among other things, at least 37 percent of investments must be allocated to green transition and 21 percent to digital investments[39]. Italy's Piano Nazionale di Ripresa e Resilienza (Figure 24) has been approved by the government and has a total planned investment of 222.1 billion euros, divided into 191.5 billion from the NGEU and 30.6 billion through the budget variance[40].



(Figure 24: *Funding allocated to each endorsed recovery and resilience plan (RRP) to this date and what this represents as a share of each Member State's GDP with a focus on the Italian PNRR,* available at https://ec.europa.eu/economy_finance/recovery-and-resilience-scoreboard/index.html)

The aim is to foster structural interventions and modernize the country in 6 key issues:

1. Digitalization, innovation, competitiveness, culture and tourism

(Figure 25 : https://www.mef.gov.it/en/focus/The-National-Recovery-and-Resilience-Plan-NRRP/)

[39] https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility_it
[40] https://www.agenziacoesione.gov.it/dossier_tematici/nextgenerationeu-e-pnrr/

2. Green revolution and ecological transition

(Figure 26 : https://www.mef.gov.it/en/focus/The-National-Recovery-and-Resilience-Plan-NRRP/)

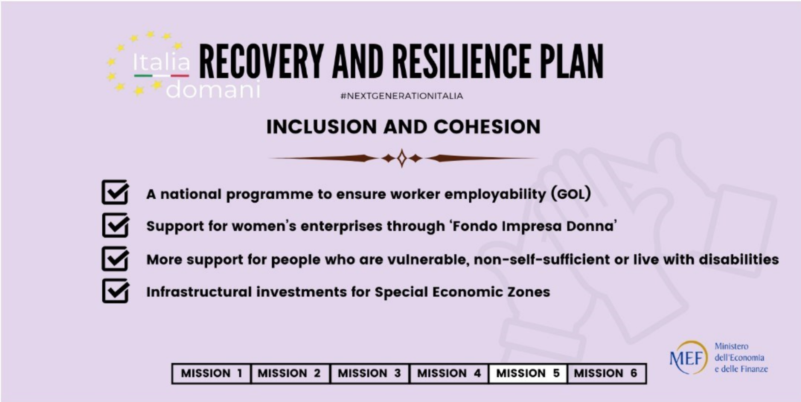
3. Infrastructure for sustainable mobility

(Figure 27 : https://www.mef.gov.it/en/focus/The-National-Recovery-and-Resilience-Plan-NRRP/)

4. Education and research

(Figure 28 : https://www.mef.gov.it/en/focus/The-National-Recovery-and-Resilience-Plan-NRRP/)

5. Inclusion and Cohesion



(Figure 29 : https://www.mef.gov.it/en/focus/The-National-Recovery-and-Resilience-Plan-NRRP/)

6. Health

(Figure 30 : https://www.mef.gov.it/en/focus/The-National-Recovery-and-Resilience-Plan-NRRP/)

2.3.3 Supply Chain

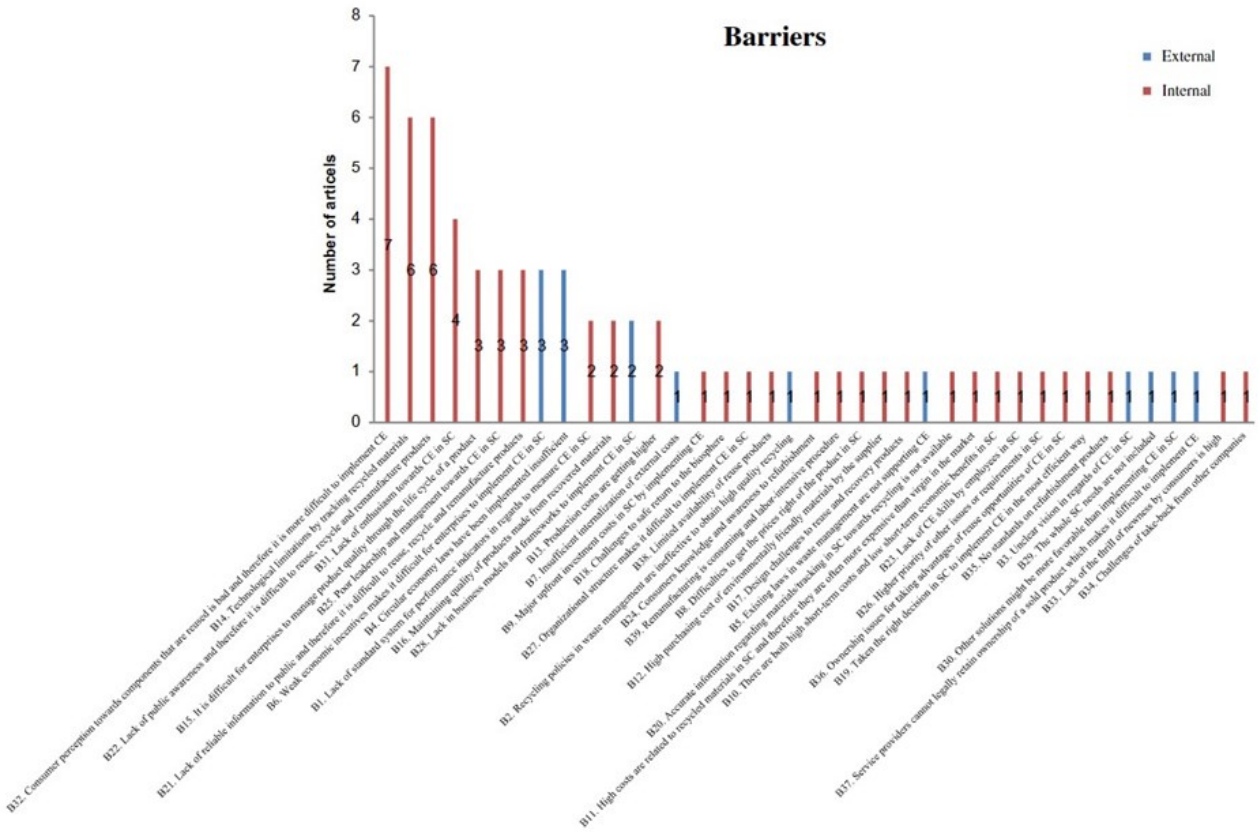
According to the European Commission, the growing global demand for materials is one of the crucial problems that states will face in the near future due to population growth and the overconsumption and overexploitation of natural resources (EU SEC, 2011). Therefore, the scarcity of resources on the European territory and the difficulty to supply them are some of the foundations of the circular economy concept (Kalaitzi et al., 2018), as well as some of the main reasons why the EU puts itself as the main promoter of this transformation. One of the most important factors, but also one of the most complex (Section 2.4.5), concerns the transition not only of a few companies, but of the entire value chain. The rethinking of the economic model must therefore involve the entire supply chain, from the management of the materials to be used to the production of the product and its distribution to the final customer. To achieve this change in the economic model and an effective closing of the loops at all stages, it is necessary to establish a series of links, relationships and collaborations between the various actors involved in the process:

- Between different stages of the same value chain: The choice of suppliers and, more generally, of the various supply chain partners takes on a particularly important aspect. In addition, greater collaboration between chain activities can facilitate product design to more easily recover resources, the choice of materials and the right technologies (Lewandowski, 2016) to achieve better control of the chain itself. In this context, the concept of "near sourcing", that is, the strategic reallocation or rapprochement of companies involved in the activities of recovery, reuse, material rework, final production and sales (Van Buren, 2016), can take on fundamental importance to promote collaboration.
- Between different sectors in the same territories: Promoting effective cross-sector cooperation in different value chains in the same territory is crucial for the development of sustainable practices (European Economic and Social Committee, 2015). It is only through the analysis of common goals, the interaction with stable relationships and the dissemination of information that stable and lasting collaboration can be created, which, especially in complementary sectors, can create competitive advantages (Luthra et al., 2022).
- Between several different territories with the same value chains: Promoting cross-border cooperation is also important to enable businesses to identify complementary resources and shared best practices (European Economic and Social Committee, 2015) and to disseminate them in order to develop synergies and partnerships to the benefit of all stakeholders (Bianchi et al. 2023).

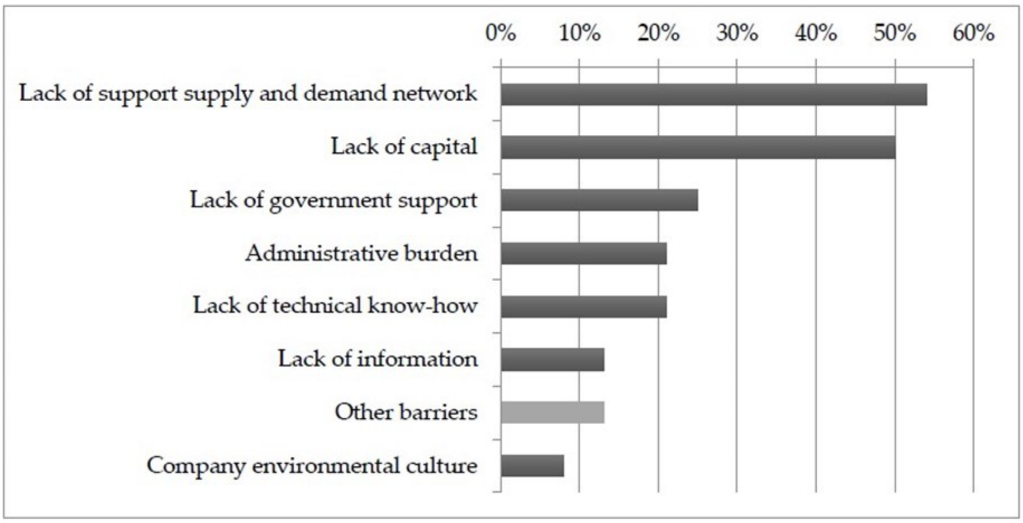
So, it is essential to rethink and redesign the product in a circular way, to optimize the production process, to reduce waste at all stages and to improve the competitiveness of all companies involved, so that the closed value chain is sustainable, regenerative and efficient in the long term. In summary, the aim of the change of approach is to have a holistic view and integrated collaboration of all stakeholders involved in the supply chain, which requires commitment in identifying best practices and continuous exchange of information to achieve a significant environmental impact (Parker, 2009).

2.4 Barriers

The decision of companies to change their business model from linear to circular, as mentioned above, can bring a number of benefits in both the short and long term. At the same time, however, there are also a very large number of barriers, obstacles and challenges that slow down or prevent this transition: identifying all of them is very complex, almost impossible, and has been the subject of numerous studies and research, especially in the last decades (Rizos, 2015). The most frequently mentioned ones are often grouped together to facilitate the analysis of studies; in reality, however, companies face several challenges simultaneously that slow down or prevent the transition to a Circular Economy if they cannot overcome them all. For example, the study by Govindan & Hasanagic (2018) shown in the Figure 31 considers 60 articles and identifies almost 40 different barriers, some of which are detected more frequently than others, but all of which are equally responsible for slowing down the implementation of sustainable practices. Given the large number of obstacles, it is difficult to analyze the barriers that have the most negative impact on enterprises: they vary according to size and type, organization, resources available, sector, and so on. For instance, a large company might cite economic uncertainty and the lack of security of short-term profits as the main barrier to changing its traditional model. Other challenges include the right environmental mindset or the difficulty of actually predicting consumer reaction. SMEs are often particularly affected by a lack of capital, while others see a lack of collaboration in the value chain as the biggest barrier to change. Depending on the different studies, it is therefore possible to identify the most problematic challenges reported. For example, in the Rizos (2016) findings, which looks at a sample of small and medium-sized enterprises, the lack of support from the value chain is identified as having a particular impact in more than half of the cases. Lack of capital is also frequently cited as an obstacle (50% of the cases), understood as both initial capital and the difficulty of obtaining finance quickly and easily, as well as lack of human resources and time (Figure 32).

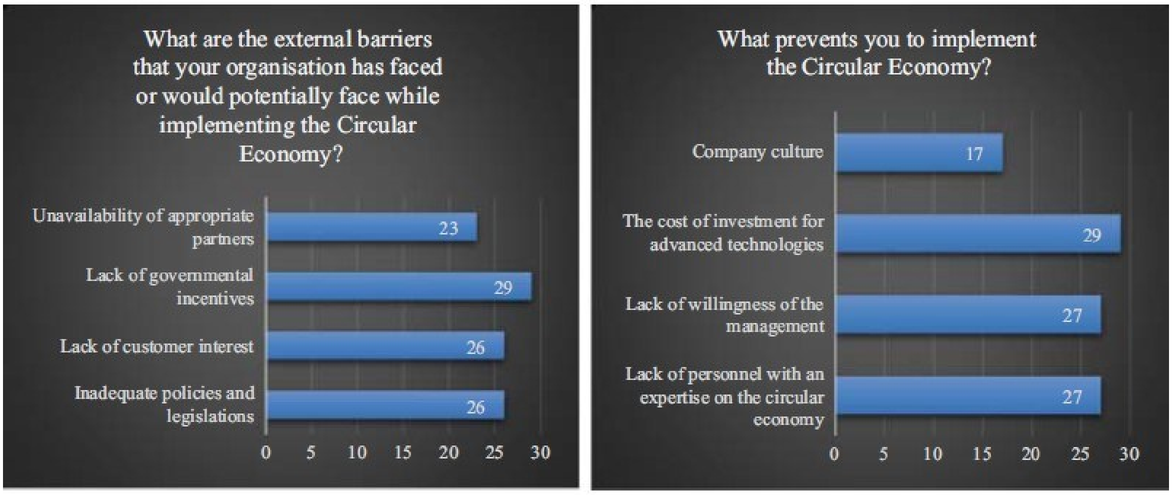


(Figure 31: Frequency of barriers to the implementation of Circular Economy mentioned in the article collection. Govindan and Hasanagic, 2018.)



(Figure 32: Percentage of SMEs mentioning the barrier. Rizos, 2016)

Despite the growing interest in the topic, the level of public awareness is still rather low, and the government has a key role to play in increasing people's knowledge about the circular economy. Government involvement is particularly important in terms of funding, duties and specialized green education initiatives. However, these solutions are not enough to facilitate the transition to sustainable practices, also due to the numerous regulatory gaps that destabilize and worry entrepreneurs who want to approach this new world. It is specifically the lack of government intervention and the absence of precise and reliable laws two of the main challenges identified in the study made by Kumar et al. (2018), as shown in Figure 33.



(Figure 33: Barriers to Circular Economy. Kumar et al., 2018)

Awareness of the importance of changing the approach to production in favor of environmental improvements is still limited, mainly due to the fact that it is seen as a costly and risky process that is unlikely to bring economic benefits and competitive advantages in the short term. As seen in the Section 2.2.2, the business sense of the owner-manager and the strategic orientation of the company have been identified as key drivers for change; at the same time, the issue of a lack of attitude to change is given particular prominence in the literature. Resistance to the adoption of sustainable practices can be found in all enterprises, and especially in SMEs, due to the fear of uncertainty and the lack of certain and quick economic benefits. The lack of technical expertise, adequate knowledge and the unavailability of suitable materials and technical equipment to support a full Circular Economy also explain the still low level of implementation of green practices (Wooi & Zailani, 2010).

Therefore, based on the various research, studies and surveys in the literature, in order to facilitate analysis, this section considers the main obstacles to sustainable transition and groups them into five categories: people-related barriers, risk associated with new business models and other economic barriers, institutional barriers, professional and technical barriers and lack of support from the supply chain.

2.4.1 People-related barriers

As explained in Section 2.3.1, the final buyer's interest is an enabler of circularity, but unfortunately it is very difficult to predict consumer response to green products (Planing, 2015). They are not always highly aware of the benefits of sustainable products and their consumption practices, and this results in insufficient pressure on companies to meet certain sustainability standards (Meqdadi, 2012.). Although people have recently started to change their interests and lifestyles, without proper education on sustainable consumption practices, the demand for circular products and services will not be sufficient and companies will be reluctant to change and will not have a strong enough incentive to implement a more innovative business model at all stages of the value chain (Wycherley, 1999). In fact, at the moment, all actors involved in the change, from producers to consumers and all steps in between, are probably not yet sufficiently aware of the consequences of their behavior to determine a sense of urgency to stimulate and boost a widespread transition to a circular economy (Kok, 2013.). Despite curiosity about environmental issues, in general a large proportion of consumers are still very much attracted by low prices and convenience (Rli, 2014.) and prefer "new" to used, recycled or second-hand. By perpetuating the idea that new is the best prospect, they tend to see recycled products as less valuable (Van Buren, 2016), which does not encourage a shift towards circular systems, but an anchoring in traditional ones. Usually, in fact, many people do not recognize the potential and value of waste and are more likely to act sustainably when they see other people acting in this way (Keizer, 2011). In reality, however, people's behaviors are influenced by many factors, including motivation, attitude to change, habits, social norms, environmental conditions but also economic conditions and emotional response (Van Acker, 2010): for example, the decision to buy sustainable products may be influenced by people's tendency to do what makes them feel most proud (or least guilty) (Onwezen et al., 2014) or by their belief that they are doing something socially useful. However, many people place little or no importance on environmental quality, or do not perceive sustainable conduct as a priority, and consider sustainable products or services to be more expensive than alternatives and therefore not their optimal choice (Rli, 2014). People's behavior is very complex and variable, and for all these reasons it is often difficult to accurately predict consumer demand for circular products and their propensity to use them.

2.4.2 Risk associated with new business models and other economic barriers

As highlighted earlier in this chapter, there are many benefits and new opportunities for value creation embedded in the circular economy, but in practice companies often face several barriers, which from an economic perspective translate into difficulties in predicting future cash flows and market attractiveness to cover the costs of adopting new technologies and business models (Van Buren, 2016). Although all companies, both large and small, face these challenges, large multinationals can overcome them through their own research and development activities, whereas SMEs rely more on the accessibility of the technology present in the market (Rizos et al., 2015). The difficulty of finding the right skills and competences, innovative technologies and technical expertise are major obstacles that companies are not always able to overcome, even though they are well aware of the potential economic benefits, such as reducing the use of raw materials, creating competitive advantages and opening up new markets (European Commission, 2011). Lack of capital and difficulty in accessing finance for circular economy proposals are two of the main barriers faced by businesses: in fact, the transition from a linear to a circular business requires a complete rethink of activities, from design to distribution planning, from transport to procurement and disposal (Eunomia Research & Consulting, 2011). Circular practices therefore often require high upfront costs and short-term investments (new equipment and other "hidden" expenses as the cost of finding new skills) that do not bring immediate benefits, in addition to the continuous improvement of products, techniques and human knowledge that do not promote the implementation of innovative sustainable business models (Van Buren, 2016). Therefore, technology plays a key role in the implementation of sustainable practices by companies; in fact, circular principles usually require a high level of technology. Technical expertise, the most advanced and innovative technologies, and new and improved facilities and equipment are expensive or not available on the market yet. The environmental upgrading of companies is seen as a time-consuming and money-consuming process, and often the lack of capital slows down the transition process (Su et al., 2013). Another reason for not adopting the circular model is the "locked-in effect": if adopting green practices and acquiring the right technology is very expensive and the potential economic benefits are only visible in the long term, companies find it difficult to "go back to where they were at the beginning" and find themselves in a situation of risk and heavy dependence on external assistance (Xing et al., 2011).

2.4.3 Institutional barriers

Nowadays among all the sectors, industry is a major source of environmental degradation. As a result, green laws and regulations have a huge impact on it and for that reason business incur on "environmental expenses" to comply with them (Calogirou et al., 2010). Companies are required to make significant investments to meet certain administrative requirements on emission and treatment of waste and toxic waste (Calogirou et al., 2010): since innovation policies prioritize efficiency and incremental innovation, they are rarely be seen as opportunities to implement circular business models (Kok, 2013). Another element that impedes a full transition to a circular economy is the lack of government support and effective legislation. In fact, companies, especially small and medium-sized ones, very often find themselves in situations of great uncertainty at the legislative level, compounded by inefficient tax policies and difficulties in finding concrete financing (Parker, 2009). This is a significant barrier that slows down the implementation of sustainable practices and can limit, if not prevent, green investments. Another obstacle to the implementation of sustainable practices is the existence of laws and regulations that are still too vague on the issue of waste: in the European Union, there is a striking lack of definition and proper classification of waste (Wilts, 2016). For example, there is not always a clear and consistent distinction between production waste and semi-finished materials (Van Buren, 2016) that can be reused and recycled in subsequent cycles. From a regulatory standpoint, waste is not acknowledged as resource, and while this can be understood from a public health perspective, as the uncontrolled movement of waste can have disastrous consequences (Van Buren, 2016), at the same time it determines two significant implications by considering its value and potential positive economic impact:

1. At the European level, there are restrictions on the transportation of waste, both into and out of the European borders and within Member States, which do not always take into account the intrinsic value of residual materials as secondary raw materials[41]. The European Waste Shipment Regulation (EWSR), the regulatory framework for the cross-border transport of waste and used materials, is often criticized as a set of policies that should encourage the implementation of sustainable practices, but due to its vagueness is often open to different interpretations by member states (Linder, 2015).
2. In addition to cross-border limitations, the taxation of production waste is also not sufficiently favorable to determine its choice at the expense of virgin materials (Sarcis et al. 2010). In fact, companies still prefer to purchase new materials and are not encouraged to opt for recycled materials, which very often require further processing (Vanner et al., 2014.).

In order to overcome these institutional barriers, the European Union on waste allows in some cases, i.e. in the absence of appropriate regulations and clear criteria set by the EWSR, to place certain production waste on a "green list" in order to use it as a resource (Van Buren, 2016) by facilitating its transport and use. With the recent adoption of new political agreements on this

[41] https://environment.ec.europa.eu/topics/waste-and-recycling/waste-shipments_en

issue, the EU is increasingly trying to facilitate the use of waste as a resource in order to promote the emergence and development of circular businesses[42].

2.4.4 Professional and technical barriers

Another major barrier slowing the transition to a more sustainable economy concerns the lack of the proper knowledge and skills of circular practices. In fact, fostering the shift from traditional, linear business methods requires the dissemination of knowledge and cooperation between companies, research institutes, and government bodies (Van Buren, 2016), so as to disseminate indispensable information regarding best practices and failures. Another key aspect to consider is how to develop the necessary knowledge and technical expertise and how to use the acquired knowledge to achieve both market benefits and environmental and social benefits (Bastein, 2013.). Therefore, for the transition to a circular economy, it is necessary to develop the right skills and competencies as very often people are lacking regarding the basic principles of circularity (Govindan, 2018).

Rethinking and redesigning products and services is another of the great challenges inherent in the circular economy concept as one does not always possess the technical and technological know-how to succeed in moving away from the current linear system and, as mentioned, skills are often lacking (Vanner et al., 2014). For this reason, companies often get stuck implementing traditional business practices and fail to implement sustainability principles in all stages of production and integrate them in the right way (Kok, 2013). Lack of adequate knowledge and technical expertise may result, especially in small and medium-sized companies, in a preference for business models with which they feel familiar (Calogirou, 2010) and which they are better able to manage and predict; moreover, the fear of facing large investments in innovative technologies and "the lack of advanced resource efficiency technologies (...) are factors that are likely to impede the adoption of circular economy approaches" (Rizos et al., 2016, p. 5).

Very often companies, especially SMEs, do not have sufficient incentives to voluntarily decide to change their practices and become more sustainable, but are more interested in minimizing costs, maintaining consistent product and delivery quality and generally maximizing their performance (Revel & Blackburn, 2007). Businesses need to have a strategic focus on the transition, provide the necessary expertise to all actors involved in the change, and be able to identify emerging infrastructure developments (Yang et al., 2020). Another bottleneck

[42] https://ec.europa.eu/commission/presscorner/detail/en/ip_23_5818

identified is the increasing difficulty of material mixes in products, and outdated and limiting technologies that make proper and complete recycling of products very challenging (Florin et al., 2015). Rethinking design and changing technological equipment is therefore essential, but the lack of sufficient start-up capital and financial support mechanisms is one of the main reasons for slowing down the circular transition, even in companies that are willing to change (Su et al., 2013). For this reason, they often choose to make less risky investments in other business activities (Benton et al., 2015), in order not to face high and risky expenditures for fear of a lock-in effect without being able to generate economic benefits in the short term. In fact, the transition process is costly and requires upfront investments without any guarantee of profitability (Liu & Bai, 2014), thus creating significant uncertainty about the impact of implementing sustainable practices on a business.

2.4.5 Lack of support from the supply chain

Unlike traditional supply chains, green supply chains must integrate sustainable practices not only at the production and distribution stages, but also at the beginning and end of the process, requiring a complete transition of all actors involved in the process with the aim of closing the loop. To be defined as a green supply chain, three elements must be in place (Wooi & Zailani, 2010):

- Eco-design or design for the environment: it is essential to rethink the final product at the design stage so that it is sustainable at all stages of its life and has the least possible impact on the environment. Using recycled materials, reducing production waste and energy consumption, and thinking from the outset about how to extend the life of the product and how to reuse it at the end of its useful life (De Mendonca & Baxter, 2001) are some of the most significant factors in the eco-design phase.
- Green purchasing: refers to the dynamics of purchasing based not only on the traditional criteria of cost, quality and delivery, but also on the sustainability of the and delivery, but also on the sustainability of the materials themselves (Lambert & Cooper, 2000). The search for materials and semi-finished products that meet certain circularity standards of circularity is one of the main ways in which a company can enter the green supply chain, although the analysis of these elements leads to additional efforts in terms of additional effort in terms of time and cost (Wooi & Zailani, 2010).
- Reverse logistics: is the process by which the finished product is returned to the supply chain and can be thought of as the reverse of the production cycle. Through reverse

logistics, companies are able to implement sustainable practices such as recycling, repairing, repackaging, reconnecting materials and remanufacturing (Rogers & Tibben-Lembke, 1999), which allows them to save on the cost of purchasing new raw materials and end-of-life treatment.

Companies need to adopt specific practices to best integrate the supply chain and the circular economy concept (Govindan, 2018). An eco-efficient industrial chain must be established, using resources in the right way and integrating advanced technologies into the process. It is also imperative that all actors in the supply chain share the same vision and goals for sustainability, embrace product and process innovation, and rethink and optimize activities at all stages of the value chain. To address social and environmental problems in an existing global value chain, codes of conduct, standards and practices can be developed that all actors need to comply with in order to meet circularity standards. The main problem is that implementing these types of codes of conduct may be insufficient if they are imposed “from above” in a top-down approach, in addition to the risk that these standards lead to increased costs without necessarily also increasing revenues in the long run (Baden et al, 2009).

The lack of environmental awareness among stakeholders in the value chain is one of the main challenges to the radical change of the socio-economic paradigm (Meqdadi, 2012). The proliferation of companies that are part of green supply chains mainly depends on the level of commitment to sustainable practices of suppliers or customers and the cooperation of all stakeholders involved in the value chain (Zhu, 2008). Suppliers are often uncertain about implementing circular practices because of the potential costs and because they do not have sufficient commitment or knowledge of the issues (Wooi & Zailani, 2010). Moreover, they may find themselves in a path-dependent situation, fearing that changing their business model may lead to a loss of competitiveness and an increase in the complexity of activities in the chain itself. For all these reasons, companies, especially if they are small or medium-sized, do not have the necessary influence to force all the other actors to change (Rizos et al., 2015) and mitigate the risks of a transition from a linear to a circular model. Companies, especially large buyers at the end of the supply chain, can act as catalysts and influence suppliers to change more. Behavioral change and the adoption of sustainable practices can be driven more by suppliers who are supported by large end-buyers (Hall, 2000) in implementing sustainable practices, especially when suppliers themselves do not have the right commitment or knowledge to make a green transition. With the support of buyers, suppliers can welcome environmental improvements as “they can likely expect cost reductions, greater operational efficiencies, and enhanced value to customers by participating in GSC initiatives with their buyers" (Lee, 2008, p. 191). At the same time, however, there can be negative aspects to being involved in the adoption of sustainable practices: radically changing a company's behavior is not easy, and the know-how and technical expertise available may not be sufficient, just as the support from other partners in the value chain or institutions may not be adequate. Change is also driven by the internal characteristics of companies, and a company that is pushed to change from the outside, but does not have the necessary factors in place, will see this ambition to change as a constraint (Lee, 2008). Therefore, the entire value chain must be ready to enter the green world in order to improve its environmental impact and, at the same time, its economic viability.

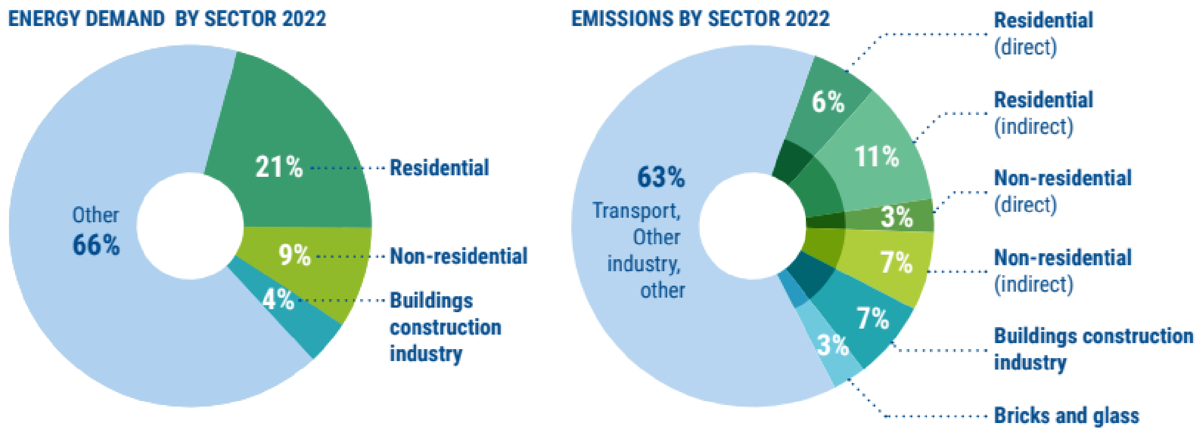
3. Circular Economy in the Building and Construction Industry

The previous Chapter highlighted in general terms the main drivers that can push companies towards a more sustainable transition, as well as the most significant barriers and challenges that slow down this process of change. However, as anticipated, in reality, all these factors that accelerate or delay the transition from a linear to a circular model can vary profoundly for numerous reasons, for example, depending on the type of company, the business environment, the nature of the people who make up the company or with whom it interacts, the sector in which it operates, the geographical location (Ghisellini et al., 2016), etc. Therefore, in order to better define and elaborate this already very broad and complex topic, it is necessary to select a field of study and, by analyzing it individually, to identify its limitations and potentials. For this reason, this and the next chapter of the thesis will focus on the Building and Construction Industry, a sector of fundamental importance for achieving the goals of environmental, social and economic sustainability.

The Building and Construction industry offers great opportunities for improvement and change (Acharya, D., Boyd, R., & Finch, O., 2018), and in fact, the possible consequences of applying and implementing Circular Economy principles in a structural and systemic manner have been studied with interest for several decades already. In December 2015, for example, in its Communication "Closing the Loops - An EU Action Plan for the Circular Economy" (European Commission, COM/2015/0614 final), the European Commission listed construction as one of the areas for priority action. As reported in the document, it, in fact, in addition to playing an essential part in people's lives, possesses a key role on the global environmental impact, as it is among the biggest causes of pollution and creation of waste and emissions in Europe mainly due to the high volumes (European Commission, COM/2015/0614 final). In order to face the many environmental challenges as well as the consequences of the current Pandemic and wars, the need for a transition that succeeds in seamlessly integrating circular economy principles to this sector is considered urgent. This not only implies improving efficiency and reducing construction and demolition waste, but also makes it imperative to radically innovate processes, from production to intermediate processing and reuse of waste materials, to a total rethinking of products from the very beginning. Despite the importance of the issue, the construction world is therefore dealing with very complex challenges in an industry that has always been considered rather reluctant to change; in fact, although most materials are recyclable and there are even alternatives that are less harmful to the environment, they are not widely used.

Currently, the Building and Construction sector is responsible for producing way more than 30% of the world's total emissions (Figure 34), placing it first in this negative ranking, and in addition to this, buildings were found to be responsible for 34% of global energy demand in 2022 (Figure 35).

(Figure 34: Circularity – Edilizia circolare applicata, https://circularity.com/settori-economia-circolare/economia-circolare-edilizia/)



(Figure 35: Share of buildings in total final energy consumptions in 2022 (left) and share of buildings in global energy and process emissions in 2022 (right). "Beyond Foundation, Global Status Report for Buildings and Construction (Buildings-GSR)")

Studies, and in particular the Global Status Report for Buildings and Construction (Buildings-GSR), a report published by the UN Environment Program (UNEP) and the Global Alliance for Buildings and Construction (GlobalABC), also show that global energy demand and emissions increased by 1% from the previous year, despite an improvement in energy efficiency. Between 2021 and 2022, a 3.5% decrease was noted in energy intensity, which is an indicator of the energy efficiency or inefficiency of a state, region or geographic area. Energy intensity[43] relates

[43] If Energy Intensity decreases, in theory the efficiency of the region under consideration should be higher; however, this ratio is an aggregate and approximate indicator as there are other factors that influence it

Gross Domestic Energy Consumption (CIL) and Gross Domestic Product (GDP), as shown in the Figure 36.

Intensità energetica = CIL / PIL

(Figure 36: Dipartimento Unità per l'Efficienza Energetica, https://www.efficienzaenergetica.enea.it/glossario-efficienza-energetica/lettera-i/intensita-energetica.html)

The statistics therefore highlight the need for a transition: the trend in recent years is a perfect representation of how the gap between the current state and decarbonization and sustainability goals is very significant in the construction sector.

Another key issue concerns the use of materials. Many materials are used in the Building and Construction industry today that are obtained from waste, which, as already seen in Chapter 1, can come from either the same or other industrial supply chains. There are many instances where construction debris and rubble are exploited, as well as rubber, plastics, the wood and rock wool, the latter reused mainly as insulation material. However, sustainable practices are still not so common in this sector, and the extraction of raw resources is still mostly used, not surprisingly the construction sector is responsible for the exploitation of about 60% of raw materials. It is estimated that about at about 95% of the materials to be scrapped can be used for the same industry or for other uses, and being able to give a second life to everything used in this industry would certainly succeed in limiting the recurrent problem of its environmental impact. This alone cannot be considered the ultimate solution for waste elimination, but to this should be added a change in the way the product is conceived and a total rethinking of all production processes.

3.1 The Circular Economy applied to Building and Construction Industry

The Circular Economy applied to the Building and Construction sector represents a radical change from the traditional, linear economic model to a new and regenerative one where materials are no longer extracted, used and finally disposed, but are continually revaluated (Figure 37). Thus, a simple first approach to circular building could be to reduce waste by increasing the efficiency of buildings or to try to recover materials and energy as much as possible. The proposal in this case sees the primary objective in the more sustainable use of

(Dipartimento Unità per l'Efficienza Energetica, https://www.efficienzaenergetica.enea.it/glossario-efficienza-energetica/lettera-i/intensita-energetica.html).

resources, especially those that are difficult to find, in order to achieve savings that are both economic and in consumption.

(Figure 37: Parlamento Europeo, 2015 - https://www.europarl.europa.eu/news/it/headlines/economy/20151201STO05603/economia-circolare-definizione-importanza-e-vantaggi)

There is, however, an even deeper and more closely related approach to the Circular Economy than pure and simple recycling, and it consists of the complete reorganization of production processes, developing a new way of thinking about construction from the design stages to the end-of-life phase. The importance of combining the concept of circularity with the Building and Construction industry stems from the realization that available resources are limited and, more importantly, that to date these are not always able to be recovered (Canepa, M., 2018). Moreover, all of these aspects are particularly visible in this area because buildings are extremely impactful during their life cycle. There is no real definition of Circular Economy in the Construction industry (Hart, J.; Adams, K.; Giesekam, J.; Tingley, D.D.; Pomponi, F. 2019), however, there are numerous concepts, strategies and options for making a construction or its components circular (Kirchherr, J.; Reike, D.; Hekkert, M., 2017). There are also many different ways in which circular principles are implemented, from the simplest to the most complex and articulated, but all of which have the ultimate goal of optimizing resource use and the production process along the entire supply chain (Minunno, R.; O'Grady, T.; Morrison, G.; Gruner, R.; Colling, M., 2018).

3.1.1 Energy and water management

A first simple way of conceiving the Circular Economy related to the Construction sector concerns limiting energy consumption. In fact, the transition to more sustainable models aims first and foremost to maximize the energy efficiency of buildings and at the same time minimize their environmental impact. The first key step to the realization of this change therefore comes through proper management of energy and water (Lacy, P., Rutqvist, J., & Lamonica, B., 2016). Although the importance of the issue has been an area of discussion among policy makers for years, the recent pandemic crisis and, even more so, the current war-related vicissitudes have further highlighted the need for concrete action. However, the general rise in costs is not the only driver of change; in fact, the climate and ecological emergency has opened up a range of growing economic opportunities (Witjes, S.; Lozano, R., 2016). For a building to follow the principles of circularity, it must first considerably reduce its environmental impact throughout its life. Making a building economically sustainable - or "green" - first involves increasing its energy efficiency through a number of factors (which will be discussed in more detail in the Section 3.1.3 on nZEBs), including positioning, materials used, technologies employed, reduction of heat and noise loss...

To improve energy efficiency, action can be taken mainly on:

- Electricity and electricity recovery systems: it includes energy from photovoltaic and wind power systems, but also the use of other performance light bulbs and technology related to smart management of stored energy and household appliances. Currently, photovoltaic systems that are very diverse in terms of both power and materials are becoming increasingly popular (Ceccherini Nelli, L., 2002). They range from small, few-kW installations connected to homes, to more powerful ones connected to apartment buildings, offices, and public and private buildings. Photovoltaic modules, the individual elements that constitute the PV system, are almost always made of monocrystalline or polycrystalline silicon, but those made of more efficient materials, such as Indium Copper Diselenide and Cadmium Telluride (CdTe), are also becoming more popular (Groppi, F., & Zuccaro, C., 2007). It is important that photovoltaic modules (PV modules) and other components and equipment (inverters, support structures, cables and connectors, electrical panels, protectors, meters, and monitoring system) ensure high quality and safety, providing high performance over time (Ceccherini Nelli, L., 2002);
- Water systems: efficient water system and wastewater management, avoiding leaks in the terminals of the house and limiting the use of running water is essential. In addition,

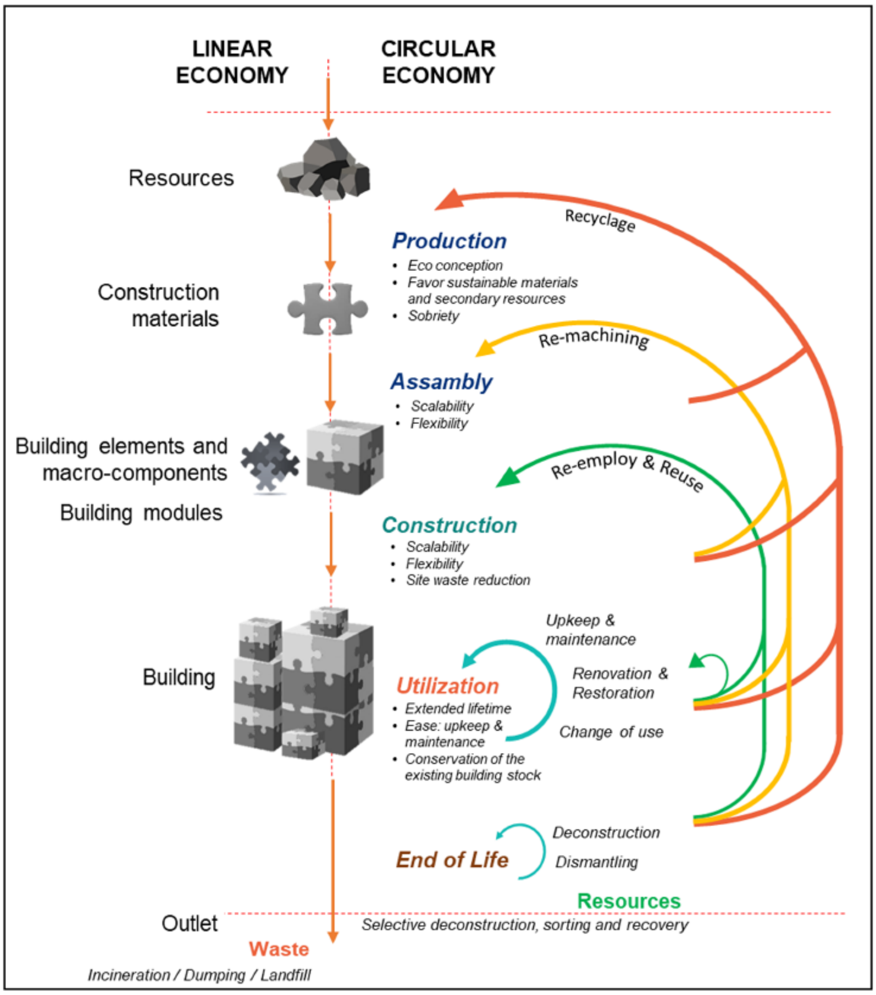
the ability to install rainwater harvesting systems can help reduce overall building or condominium consumption (Ausiello, G., Compagnone, M., & Sommese, F., 2020);

- Thermal maintenance systems: making a house efficient in terms of heat dispersion is another factor in energy efficiency. The use of fixtures (doors and windows) to limit heat loss, thermal coats, or high-performance building materials allow the building to keep warmth inside the structure, making it cozier and more comfortable in winter and cooler in summer periods (Cessari, L., Bacigalupo, C., Gigliarelli, E., 2008). There are also other systems of insulation through the exploitation of green roofs and walls, a practice developed particularly in Scandinavian countries, where the covering of a building consists of an insulating layer and an outer layer of vegetation.

Asset optimization is a great added value in the long run for buildings. In addition to being less ecologically impactful, their market value is higher than traditional ones due to savings from the perspective of consumption, lower energy requirements, and improved living comfort.

3.1.2 The resources for the B&C sector and Urban Mining

The activities of the Construction industry are still closely linked to a traditional, linear economic model in which, despite centuries of technological innovations and more sustainable actions, it has not yet succeeded in fully limiting the exploitation of natural resources, the massive production of greenhouse gases (GHGs), and the creation of massive amounts of construction and demolition waste (Krausmann, F.; Schandl, H.; Eisenmenger, N.; Giljum, S.; Jackson, T., 2017). It is estimated how each European country produces, on average, tens of millions of tons of waste each year (EU Eurostat by Statistical Office of the European Union), mainly generated by demolition activities, which, when added to the quantities that end up in illegal landfills and that often cannot be easily calculated, create unimaginable environmental damage (Lützkendorf, T., 2019). In theory, the goals for the Construction industry involve the reuse of materials for the construction or renovation of buildings, the use of production processes and resources that do not become waste at any stage of the building's life cycle (and especially at the demolition stage), and, more generally, the identification and planning of strategies to make Circular Economy principles applicable in every situation. In other words, as suggested by the Ellen MacArthur Foundation, the construction sector must also aim for a gradual decrease in waste production and the subsequent valorization of waste, effectively turning it back into usable resources.



Levels of resource valuation for the construction sector. Inspired from the Ellen MacArthur Foundation, Circular economy diagram (Tirado, R., Aublet, A., Laurenceau, S., & Habert, G. (2022). Challenges and opportunities for circular economy promotion in the building sector. *Sustainability*, *14*(3), 1569, p. 3).

Contrary to these goals, however, buildings are not meant to last forever. Its lifespan is on average about 50 years, but much also depends on what its use is: the lifespan of a residential building varies from 70 to 100 years, while that of an industrial building is much less long-lived (about 30 to 40 years) (Swiss Life Group). This huge difference is not so much related to the way it is built, but rather to the lack of capacity of industrial buildings to meet the needs of profitability and adaptability over the years (Tirado, R., Aublet, A., Laurenceau, S., & Habert, G., 2022). For these reasons, structures that are still perfectly functioning undergo continuous heavy renovation or demolition long before their actual end of life.

Thus, it can be said that the current urban infrastructure should be seen as a kind of "mine" of resources that can be used (and reused) so as not to further impact the environment. It is precisely for this reason that concept of "Urban Mining" is closely related to Circular Economy, as the idea that not only buildings, but all activities in cities should be managed effectively and efficiently in the long run can be one of the sustainability strategies in Building and Construction (Figure 38).

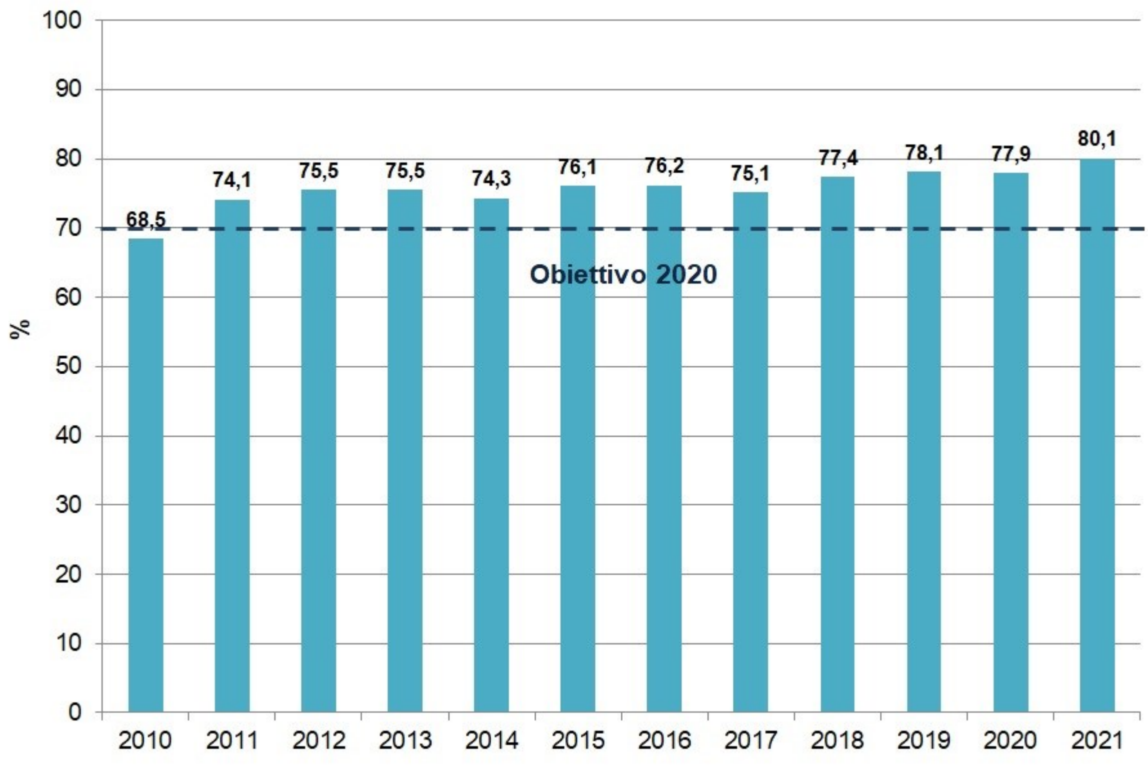
(Figure 38: Representation of Urban Mining in cities, GBC Italia, https://gbcitalia.org/wp-content/uploads/2023/01/2019_GBC-PP-Ec.-Circ.-Rev2.pdf)

Consequently, the city as a whole must enter into this Circular Economy process in which every activity must limit waste creation and everything that cannot be limited must be designed to be reusable as "secondary raw materials", including metals and other rare precious materials. Therefore, it is also crucial in the construction sector to focus on three cornerstone principles of the Circular Economy (Circularity Gap Report 2023):

1. Reuse, which is the operation by which a product can be exploited again for the same role it had before the end of its life cycle;
2. Reutilization/Repurpose, in which the product will be used for purposes other than its original purpose;
3. Recycling, in which unlike the previous two cases the product, which has become waste at the end of its life cycle, is modified to be used for the same or other functionality with which it was originally designed.

While these are all different principles from the linear "take-make-dispose" concept (Acharya, D., Boyd, R., & Finch, O., 2018), in the first two cases we should actually refer to "end-of-life" rather than "end-of-service-life", a term intended to indicate the possibility of having more potential (and therefore more useful life cycles) and the ability of a product to be used for purposes other than those originally envisaged; in the case of recycling, on the other hand, we should refer to an “end-of-waste” strategy, as it aims to conceive materials as new resources that can be used in several sectors at the same time (Circularity Gap Report 2023), without generating waste of any kind.

In this virtuous Urban Mining project, whose aim is to make urban areas generators of positive environmental, economic and social impacts, the main objectives are to reduce the choice of deficient materials such as sand and aggregates by favoring instead the use of recovered and non-polluting ones, and at the same time make buildings greener thinking from the design stage about the possible sustainable deconstruction of the same (Circularity Gap Report 2023). This, combined with other sustainable strategies, can be credible alternatives to resource extraction and exploitation in a way that significantly reduces the environmental impact of building structures, as requested in the Goal 11 – “Sustainable Cities and Communities” in the UN 2030 Agenda. Currently in Italy the material recovery rate is about 78% (equivalent to nearly 41 million tons), which is well “above the 70% target set by Directive 2008/98/EC for 2020” (L'ECONOMIA CIRCOLARE APPLICATA ALL'EDILIZIA), although it went slightly down from 80.1% in 2021.



(Figure 39: RECYCLING/RECOVERY OF WASTE FROM CONSTRUCTION AND DEMOLITION, ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale, 2023)

The problem lies in the fact that the amount of waste generated is still very high, with about 52 million tons produced in 2019 for the Construction and Demolition sector, marking a 13.6% increase over 2018 (about 6 million tons more) (Ministero della Transizione Ecologica, 2022). In addition, estimates show how the circularity rate has actually declined in three key sectors such as food, manufacturing, and construction, with a negative trend over the five-year period 2018 - 2023 (as expressed in the Circularity Gap Report, recently conducted by Circle Economy Foundation and Deloitte). Despite the growing public interest and considering the fact that by 2050 about 66% of people (or 6.7 billion people according to the Global Environment Outlook) will live in urbanized areas, it can easily be stated that these data are therefore still not comforting. These are just further evidence of how Circular Economy is a priority issue and how resources concerning the Building and Construction sector are crucial, but it is also confirmation that what has already been done is still not enough to achieve the desired sustainability targets.

3.1.3 nZEB Buildings

According to Article 2 (paragraph 2) of the EPBD Directive (2010/31/EU), an nZEB building, an acronym for Nearly Zero Energy Building, is defined as a "building with very high energy performance [whose] very low or nearly zero energy requirements should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on site or nearby" (EPBD (2010/31/EU), pag. 21). This concept is fairly recent, just considering that the first official use of this word was just over 10 years ago. As already anticipated, the Building and Construction sector is one of the most polluting and impactful on the environment, which explains the growing importance of the role of nZEBs in achieving the COP21[44] sustainability targets. These types of buildings, therefore, are designed to minimize energy consumption and, above all, limit the use of nonrenewable sources in order to achieve the goal of de-carbonization by 2050. To do this, from January 2021, all new buildings and all buildings about to undergo deep renovations must mandatorily comply with the European standards introduced by the EPBD (2010/31/EU). In Italy, this directive was translated as Decreto Legge 63/2013, although to understand the characteristics that nZEBs must have, reference is made to the June 2015, Ministerial Decree of the Ministry of Economic Development. Buildings, whether new or undergoing major renovations (interventions of the

[44] COP21: 21st Conference of the Parties to the United Nations (UN) Framework Convention on Climate Change (COP21) in Paris in December 2015, attended by 195 states (Lal, R. 2016).

external envelope (walls, roof or fixtures) if the area covered by the works is more than 25% of the surface of the building[45]), must meet a number of "minimum requirements", including meeting thermal performance indices, heat loss, heating and air conditioning system efficiencies and, of course, integration of renewable energy sources (Decreto Legge 63/2013). It is also essential for nZEB buildings to resort to the use of window and door frames and other structural elements with other performances, such as doors and windows and other fixtures that aim to insulate the building further reducing energy consumption. In addition to all these components (which are already on the market) and the use of sustainable systems (e.g., the photovoltaic systems mentioned earlier), new buildings are also strategically oriented. The so-called "Bioclimatic Design", which consists of the most appropriate building layout to maximize daily exposure to sunlight, makes it possible to make maximum use of natural resources while decreasing the building's energy requirements. Although the European directive marked 2021 as the starting date for this sustainable project, in Italy for the public buildings it was decided to move up the timetable for meeting the requirements; in addition, some more virtuous regions set an even more ambitious starting point, these include Lombardy (in 2016) and Emilia-Romagna (2019, but 2017 for new public buildings) as shown in the report made by ENEA, the National Agency for New Technologies, Energy and sustainable economic development and in the Figure 40 and 41. In Italy in 2017, there were only 600 buildings considered nZEB; as of June 30th 2018, the number has increased to about 1400 (ENEA, 2019), hinting at a positive trend for Italy, although with still very low figures compared to the total number of buildings present (it is estimated how regions on average have only 0.03% of nZEB buildings to date in relation to the current building stock). Between 2015 and 2022, moreover, 17408 EPAs were issued for structures considered nZEB, almost all of them referring to small residential buildings (especially single or duplexes) and only a small part (about 4.6%) nonresidential (such as schools, just a few dozen units per region as shown in Figure 42 below). The highest concentration of nZEB buildings is in central and northern Italy, such as in Emilia-Romagna, which has the highest share (26.7%), Veneto and Lombardy (ENEA, 2019). Another virtuous example is Puglia (20.2%), which shows a consistent increase in APA certifications issued in recent years. Although the numbers are on the rise, the data cannot yet be considered extremely encouraging, as the percentage of nZEB buildings is still very low and in mainly because a solution for energy efficiency of the remaining part of older urban architecture has not yet been found (Mohammadiziazi, R., & Bilec, M. M., 2022).

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[45] APE: The procedure for energy certification of buildings results in the subsequent issuance of the A.P.E (Attestazione di Prestazione Energetica) Raimondo, L., Mutani, G., & Massaia, C. (2014). La procedura di certificazione della prestazione energetica: dal sopralluogo all'APE.

Tabella 2. Edifici nZEB in 5 regioni italiane (elaborazione da dati APE dei Catasti Regionali)

APE	Abruzzo	Lombardia	Marche	Piemonte	Veneto
Gestore catasto	ENEA	ILSpa[1]	Regione	SIPEE1 [2]	Ve.net. [3]
2016	3	137	-	17	58
2017	2	208	11	22	88
2018*	3	159	15	23	110
Triennio 2016-2018*	**8**	**504**	**26**	**62**	**256**

* Dati aggiornati al 30 giugno 2018

FIGURE 40: ENEA, OSSERVATORIO DEGLI EDIFICI A ENERGIA QUASI ZERO (NZEB) IN ITALIA 2016-2018 A cura di Ezilda Costanzo 2019

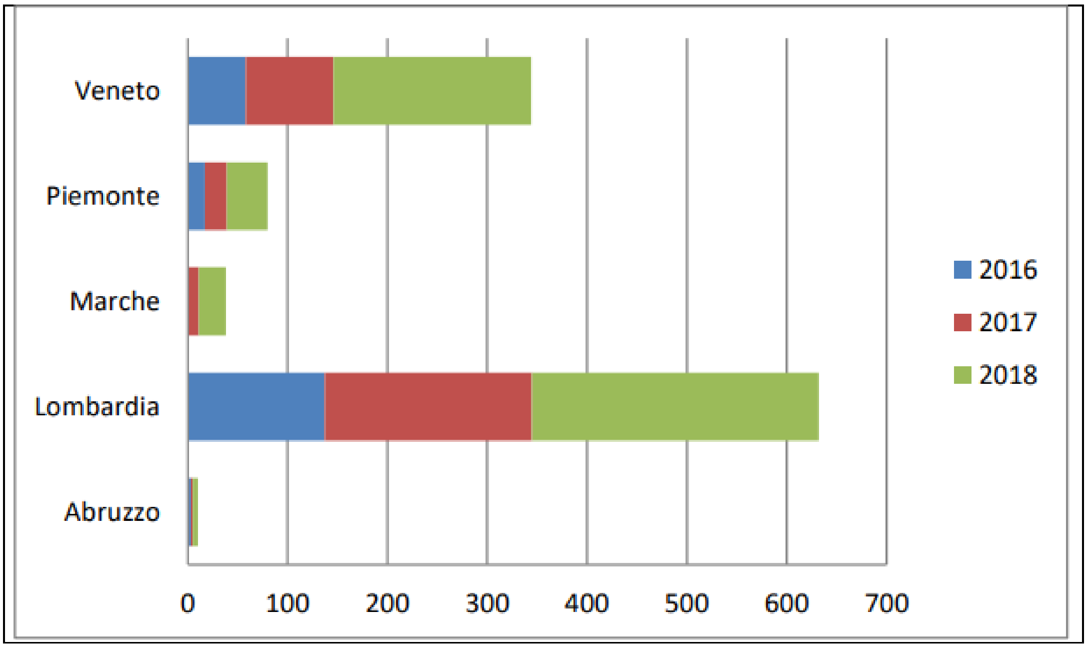


Figure 41: Number of nZEB in 5 regions in Italy up to the end of 2018, ENEA, 2019.

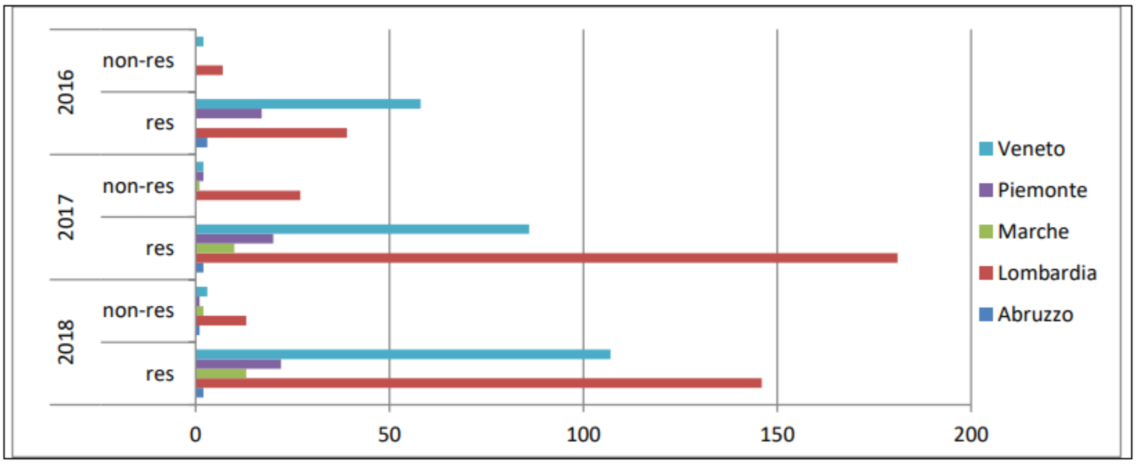


Figure 42: Number of nZEB Buildings - Residential and Non-residential in 2016-2018 (*as of 06/30/2018), ENEA, 2019

3.2 Circular Economy Business Models in the B&C industry

The application of sustainable principles results in an obligation for companies in the Construction sector to rethink all activities and all stages of their supply chain. They must therefore adapt their Business Models to the principles of circularity: that is why refer to Circular Economy Business Models (CEBMs). In reality, the economic models followed most are linear, and for hundreds of years businesses have sought only economic profit, exploiting materials "from Cradle to Grave" (Braungart et al. 2007). For this reason, changing the value chain by establishing closed-loop supply chains (CLSCs) without pursuing cost-effectiveness is not only difficult for companies but also unattractive (Schenkel et al. 2015). The concept of Circular Economy Business Models is fairly recent, and in fact a crucial constituent in the achievement of a Circular Economy is business model innovations. However, the literature for CEBM is still in its early days and still struggles to meaningfully place its focus on applying circularity principles in the industry (Lüdeke-Freund, F., Gold, S., & Bocken, N. M., 2019).
Generally speaking, a Business Model represents how businesses create economic value for a company through the creation of value for its customers (Lewandowski 2016); when activities are part of a closed loops supply-chain and these activities constitute businesses that are at the same time economically, socially and environmentally sustainable then we can talk about Circular Economy Business Models. The ultimate goal of CEBMs is to create value for companies by reusing for various cycles the use of the same resources while limiting waste as much as possible and, at best, even eliminating it (Ayres and Ayres 1996). To do so, they necessarily have to completely rethink their supply chain and business model, reorganizing all stages of the production process (Lewandowski, M., 2016). The main CEBMs, some of which are analyzed in more detail throughout this chapter, in the building and constructions sector are (Lüdeke-Freund, F., Gold, S., & Bocken, N. M., 2019):

- Repair and Maintenance Business Models: whose priority is to extend the product life cycle as much as possible by focusing on repairs and maintenance (e.g., building on "repair" (Kiørboe et al. 2015), "product life extension" (Accenture 2014), and "classic long-life model" (Bakker et al. 2014);
- Reuse and Redistribution Business Models: with the focus on reusing the same building for other functions than those for which it was designed in order to provide it with a new life;
- Refurbishment and Remanufacturing Business Models: require a combination of reuse, repair, maintenance, and reverse logistics to be able to think from the outset about new uses for the product, which retains the characteristics it had "as if it was new";

- Recycling Business Models: (e.g., building on “closed-loop production,” “rematerialization” (Clinton and Whisnant 2014)), they focus on the recovery of materials and their conversion into resources that have less value (downcycling) or greater value (upcycling).
- Cascading and Repurposing Business Models: (e.g., “co-product generation from waste”) in which products are seen as “food” (“waste is food” (Braungartand, 2007)), i.e., new resources, for the future, as in the aforementioned case of Urban Mining.

To implement an efficient CEBM, however, we need to totally rethink the value chain and consider the new players that enter and change “the circle”: entrepreneurs, policy makers, the use of new materials, digital and technological innovations are all possible factors that provide the decisive shakeup for change in the industry.

3.2.1 Product innovation in the industry

The recovery of construction materials poses many challenges to the Building and Construction sector's circular transition. Indeed, waste is very often reused primarily as filler material. One of the main problems is that Construction and Demolition Wastes (CDWs) represent a complex mix of materials (Figure 43). On average in the EU, they consist of concrete (24%), bricks (5%), ceramics and tiles (1.2%), metals (4.3%), plastic (0.2%), glass (0.2%), gypsum (1.4%), wood (2.3%), insulation (0.3%), and paper (0.2%), with a remaining high percentage of mixed (59.2%) and hazardous (1.8%) waste (Damgaard et al, 2022). The large fractionation in the composition of demolition waste is very limiting to the application of sustainable practices, resulting in large slowdowns and the reuse of non-high-quality materials.

The transformation of waste into new types of building materials thus becomes one of the main paths in the definition of new CEBMs. These resources may have different "intensity" of sustainability, but studies and research to determine new materials that are more perfomant and less impactful to the environment. Some of these, which complement or replace traditional concrete, brick and mortar are:

Material fraction in CDW	Share (% of CDW)[1]	Annual flow buildings[1] (Mt)	Annual flow buildings & infrastructure[2] (Mt)
Concrete	56.2	74.1	223.4
Bricks	6.50	8.6	25.8
Ceramics & Tiles	5.56	7.3	22.1
Steel	4.89	6.1	18.6
Glass	4.04	5.3	16.0
Wood	2.91	3.8	11.5
Aluminium	1.76	2.3	6.9
Expanded polystyrene	0.79	0.9	2.8
Polyvinyl chloride	0.79	0.9	2.8
Gypsum	0.57	0.7	2.2
Stone wool	0.35	0.4	1.2
Glass wool	0.35	0.4	1.2
Others[3]	15.6	20.4	61.6
Total	100	131.9	397.5
Total (without Others)	84.4	111.5	335.9

[1] Based on the Material Flow Accounting presented in Damgaard et al. (2022).
[2] Assuming that infrastructure waste has the same composition as building waste.
[3] Cardboard, paper, copper, electronics, other construction minerals, sand, paint and glue,

(Figure 43: Caro, D., Lodato, C., Damgaard, A., Cristobal, J., Foster, G., Flachenecker, F., et al.,2024 and based on data by Damsgaard et al., 2022).

- Self-compacting concrete: An alternative to traditional concrete, self-compacting concrete (SSC) can be a viable alternative for the circular transition in the Building and Construction sector. Its main characteristic is, as the name implies, to self-compact under its own weight, allows for greater material usage because you are able to have less loss of material during ground laying (Chandru, P., Karthikeyan, J., & Natarajan, C., 2020). Even more importantly, the SSC allows for greater use of various waste materials and industrial byproducts into its composition. Among these, those that are recovered (including from other production chains) and incorporated into self-compacting concrete are: crumb rubbers from the recycle of tyres and rubbers to the form of granules used to replace the conventional aggregates (Ganesan et al. 2013), crushed plastic wastes (Yang et al. 2015), recycled fine aggregates obtained from the old mortar and concrete pieces of the construction and demolition wastes and used as a filler (Carro-López, D. et al. 2017), ceramic wastes, granite and volcanic powder as the pumice (Kurt et al. 2016).
- Steel slag: Working with iron and steel results in the production of huge amounts of slag (Singh and Siddique 2016), for example in "2017 the global production of steel

generated around 1 billion tons of byproducts and residues, with 28% as steel slag. The incorporation of steel slag as fine aggregate has potential to reduce the river sand extraction" (Costa, L. C. B., Nogueira, M. A., Ferreira, L. C., Elói, F. P. D. F., Carvalho, J. M. F. D., Peixoto, R. A. F., 2021, p. 1)

- Other alternatives that can be used include wood, which one of the oldest building materials but to be considered sustainable must be produced in an environmentally friendly way and salvaged from existing products at the end of their life cycle; cellulose, hemp, flax sheep wool and wood wool, all of which are very insulating elements of animal and plant origin; cork and other reclaimed materials for flooring; "vegan" paints created without the addition of solvents (Chandru, P., Karthikeyan, J., Natarajan, C., 2020)

3.2.2 New technologies for process innovations in B&C

The factors that can push the Building and Construction sector toward a circular transition are many: they can be financial incentives, new sustainable designs, but also technological breakthroughs and innovations. All of these forces drive the definition of new ways in which companies adhere to CE principles and consequently new business models. While initially the focus of researchers resided solely on the choice of recyclable materials, waste reduction and disassembly methods, now the focus is also shifting to the integration of Industry 4.0 technologies, such as the Internet of Things – or IoT (Giovanardi, M., Konstantinou, T., Pollo, R., & Klein, T., 2023). So, when we talk about technological innovations, we are not only referring to technical improvements of existing elements, but also to new players entering and changing the circle. The IoT makes it possible to collect and combine usage information from connected tools with other data sources to measure and improve overall productivity and workflows, as well as provide relevant support in the efficient management of construction sites (Edilportale, 2023). The Internet of Things is also beneficial to consumers, however, as it offers the ability to monitor the state of the building and the condition of the home's systems through the use of a simple app[46]. The data are relevant because they are used by technicians to remotely detect problems, including cable breaks[47].

Another way of acquiring information can be done through the combination of digitization and the use of drones (Lavagna, M., Giorgi, S., Pimponi, D., & Porcari, A., 2023). They, in fact, can quickly and efficiently go to even the most inaccessible and hard-to-reach places, collect the

[46] https://cordis.europa.eu/article/id/413173-where-the-circular-economy-and-the-internet-of-things-meet/it
[47] https://cordis.europa.eu/article/id/413173-where-the-circular-economy-and-the-internet-of-things-meet/it

information and process it through analysis software. New technological innovations from the perspective of 3D viewers have the potential to change the way the supply chain currently operates, because of the ability to study sustainable solutions through augmented reality in such a way as to have a 3D understanding of how the building is constructed.

Therefore, 3D prints also have the potential to optimize the resources used in the construction of buildings and architectural elements, as well as entering production processes that produce less CO2, consume less energy, and create perfectly tailored elements while almost zeroing out waste (Infobuild – https://www.infobuild.it/approfondimenti/stampa-3d-economia-circolare/).

Although the Building and Construction sector has only recently begun to adopt them, the universe of new technologies and breakthroughs in Industry 4.0 is unrelenting, just think of big data, blockchain, cloud computing and even more recently artificial intelligence (EconomiaCircolare.com, 2023).

3.3 A change of prospectives: new strategies for the B&C Industry

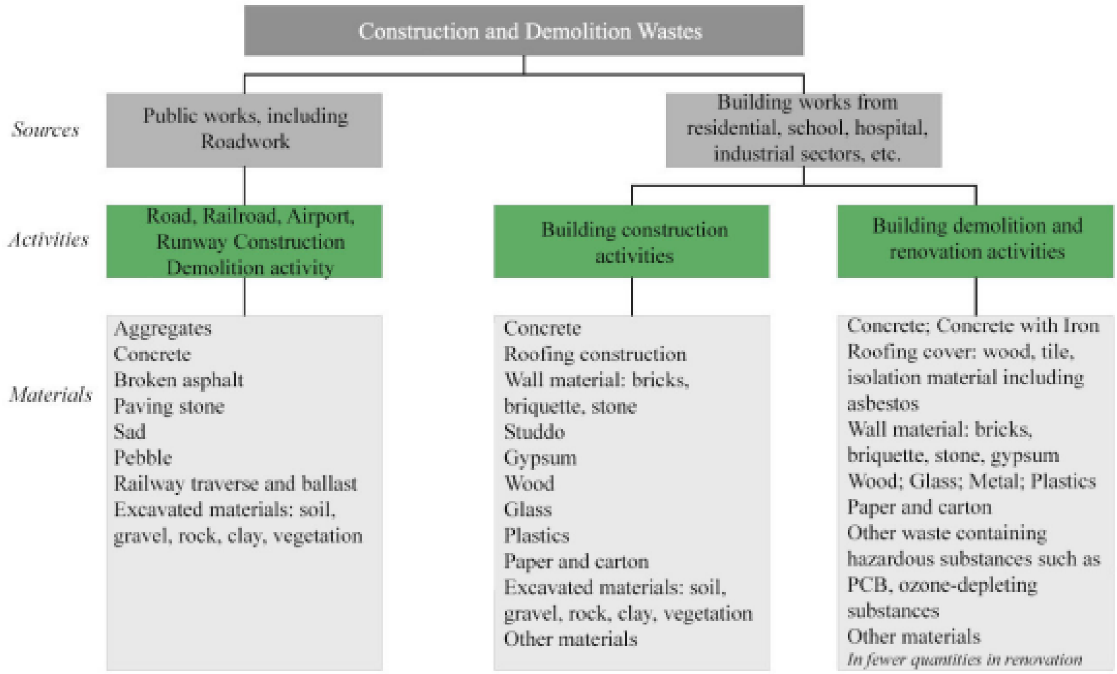
The Waste Framework Directive 2008/98/EC had set a target of 70% for 2020 for the level of reuse, recycling, and other sustainable remanufacturing strategies for production waste from the Building and Construction sector. Following what it is stated in this directive, Article 2 of Commission Decision 2011/753/EU (Annex III), establishes the criteria for determining the recovery rate for Construction and Demolition waste: it must relate to the weight of waste generated and recovered in a calendar year, as shown in the formula in the Figure below.

$$\text{Recovery rate for C\&D waste [\%]} = \frac{\text{Materially recovered amount of C\&D waste}}{\text{Total amount of generated C\&D waste}}$$

(Figure 44: Annex III of Decision 2011/753/EC, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011D0753)

In 2020, the recovery rate for Building and Construction waste reached 89% in Europe on average (Williams et al., 2020), although the differences between the states are very clear, as will be explored in more detail in the next chapter. This percentage is certainly positive and far above predictions, at the same time, however, it is a figure that can be misleading as in general most Construction and Demolition waste "is repurposed as filler material in road construction or as backfilling material. These represent the most prevalent CDW recovery routes. In a nutshell, these recovered materials do not achieve the necessary technical properties to fulfil the functions for which the original material was designed for" (Caro, D., Lodato, C., Damgaard, A., Cristobal, J., Foster, G., Flachenecker, F., et al. (2024), p 2). This means that the recovery of materials and their subsequent use in high-value activities is actually still very limited, leading to savings from the perspective of raw material exploitation, but not efficient enough to still be a viable alternative to raw material extraction.

Construction and demolition wastes are multiple and are more precisely defined and catalogued in the European Waste Catalogue (EWC) (Borghi et al., 2018). In addition, it can be seen from the EWC that the waste in this sector differs according to the type of activity, and Figure 45 tries to divide it for a more intuitive understanding into Public Works, such as for road construction and arrangement, and Works on Buildings, which include both construction and demolition and renovation of buildings.



(Figure 45: Sönmez, N. & Kalfa, S.M. (2023). Investigation of Construction and Demolition Wastes in the European Union Member States According to their Directives. *Contemporary Journal of Economics and Finance, 1(2),* 7-26)

The Circular Economy even in the B&C sector must follow some general principles that can be applied to all actors involved in the value chain. To summarize, the design of sustainable buildings must take into account from the outset what to do at the end of its life cycle, as well as carefully evaluating the costs and benefits of the various proposed actions: preparing sustainable but economically unviable recovery plans will almost certainly be considered unattractive by companies in the industry. So, in addition to the economic benefit, which must be positive, actors approaching circularity in the Building and Construction sector must try to meet 3 general principles (GBC, 2019) as shown in Figure 46:

(Figure 46: GBC Italia – Economia circolare in edilizia, https://gbcitalia.org/wp-content/uploads/2023/01/2019_GBC-PP-Ec.-Circ.-Rev2.pdf, 2019)

- Durability: it means using sustainable, high-quality products, providing the necessary tools for proper maintenance to extend the life of the building as much as possible and minimize the total cost of the building over time;
- Adaptability: it means already thinking about a future new use for the building, determining a sustainable demolition plan or transformation plan to change its function;
- Waste management: it refers to designing buildings in such a way that materials can be recovered easily, where possible through upcycling strategies and where this is not feasible due to material wear and loss of physical properties, through downcycling of elements, so that construction and demolition waste is minimized or even eliminated completely.

Thus, in addition to the reuse, reutilization, and recycling strategies already discussed at length, the B&C sector needs to get better at applying other sustainable strategies of designing products that do not create (or more realistically minimize as much as possible) waste at any of the stages of the building's life, thinking of them so that they can not only limit their negative impact, but also balance it by bringing environmental benefits in the long run, and Design out Waste aims to do just that. One strategy for minimizing the negative effects of usable construction is remanufacturing, which consists of dismantling the used product, restore it and replace the components in order to make it equivalent or better than that of the newly manufactured product (Dalla Valle, A., Atta, N., Ratti, S., & Macrì, L., 2021). From a customer viewpoint, the re-manufactured product can be considered to be the same as the new one, by ensuring that the various elements have retained their original characteristics and performances by meeting objectives of longevity, durability and maintenance of high efficiency (King et al., 2006). The concepts of Design out Waste and remanufacturing, are also significantly related to two other key concepts for the construction industry: modular assembly, i.e., the use of components (modules) that are interchangeable with each other as they are of predefined and standardized form, structure and characteristics (Llatas, C., & Osmani, M., 2016.) and design for disassembly.

3.3.1 Building in layers and modular construction

In an effort to move from a linear to a circular economy, one of the strategies that can be used in the building and construction industry is the use of “topological interlocking components”, or more commonly known as modular or prefabricated components. (Dyskin et al., 2012). Choosing modular components can be a great way to limit cost and waste, as they can be used multiple times and in various building projects. Thus, in addition to a preference of more efficient and less polluting materials, promoting reuse in the B&C sector can be a solution to make the effects of one of the absolute sectors that impact the environment the most (Eckerth et al., 1998). The concept of modular components, as will be seen in the next section, is closely related to “Design for Dissassembly”: this practice, coupled with interchangeability in the use of components and the choice of the most sustainable materials are excellent and can enhance the implementation of new circular economy business models (Eberhardt et al., 2020). In fact, to meet the Sustainable Development Goals, the growing demand for building construction must be accompanied by a limitation of new resource consumption, a decrease in waste, and a decrease in the environmental impact of the sector (Pomponi, F., & Moncaster, A., 2017).
The construction of buildings using modular components is one of the most popular circular strategies for reducing their environmental footprints (Esa et al., 2016) and their greenhouse gas emissions (Kirchherr et al., 2017), while also bringing an economic benefit related to decreasing the cost of building construction itself (Sansom and Avery, 2014). In addition to this, choosing the right materials becomes fundamental. A material that has a short life cycle would not solve the problem of a building’s environmental impact because, even by using topological interlocking components they would degrade more rapidly, which would not allow them to be fully utilized. At the same time, it is unthinkable that materials can maintain their physical characteristics unchanged for an indefinite time. Instead, what can be done is to try to choose materials suitable for construction in order to make them sustainable and with a have a long-life cycle, and make them easier to assembly and disassembly, encouraging reuse and providing greater flexibility in subsequent applications (Bocken et al., 2016; Kara et al., 2022; Rashid et

al., 2013). All of these methods emerge as strategies not only integrating but also “replacing” pure and simple recycling, in fact, despite still being the most applied practice toward the Circular Economy (Kirchherr et al., 2017), “significant research evidence suggests that recycling is the least beneficial of the 3R’s, as some recyclable materials are invariably wasted or contaminated in the process” (Minunno, R., O'Grady, T., Morrison, G. M., & Gruner, R. L., 2020).

In a modular building, the various elements are geometrically aligned and connected, as well as standardized to facilitate their reuse even in structures other than those originally planned. Modules should be connected to each other by interlocking or interconnecting elements that can be easily identified (and reached when needed) and without the use of mortar that would make them difficult to reuse in the future (Dyskin et al., 2003). Not using fixative materials of any kind also allows the modules to easily adjust to each other, allowing them to “move” to the correct location independently, even if the original positioning was not perfect, without the need for extra intervention (Dyskin et al., 2012); in addition, the shape of the elements must be simple so that they can be assembled and disassembled without having to work on the entire structure if a component needs to be replaced. The adaptability of modular components also allows them to be able to be assembled on-site or to be assembled off-site to bring the prefab to the location where the building is going to rise (Jaillon and Poon, 2014). Modular buildings can be exploited in different sectors: from outdoor auxiliary structures, such as shading structures (Zhuang, G. L., Shih, S. G., & Wagiri, F., 2023) to residential use for homes, condominiums, and temporary housing, from offices and stores to health care facilities (such as, for example, emergency facilities or in underserved areas) and schools, and also for logistical storage facilities such as warehouses. Therefore, the proper use of topological interlocking components and the choice of the right materials can result in a reduction of used and wasted resources, as well as ensure that modules remain “within the circle” for multiple successive cycles (Eberhardt et al., 2020), providing great benefits in terms of cost reduction and speed of construction.

3.3.2 Design for Disassembly

One of the most promising strategies in circular building concerns what is known as Design for Disassembly (DfD). Design for Disassembly, or Design for Deconstruction means thinking from the earliest stages of a product’s design about what will happen to it at the end of its useful life (Roberts, M., Allen, S., Clarke, J., Searle, J., & Coley, D., 2023). In this way, in Building and Construction, it is therefore possible to create buildings while minimizing, and eventually even zeroing out, the waste and loss of value of the various components because they are designed from the beginning with consideration of how they will be dismantled in the future and how materials will be recovered and reused (Ghisellini et al., 2018). Following this strategy attempts to solve the problem of what to do at the end of a building's limited lifespan so that its component parts can be reused as efficiently as possible since, as mentioned, primary resources are being depleted. Design for Disassembly is not a new concept; in fact, it dates to the 1990s although it has been gaining popularity only in recent years: "also known as "construction in reverse", deconstruction is a newer terminology for an old practice" (Rios, F. C., Chong, W. K., & Grau, D. (2015), p. 1297). Since the late 1990s, in fact, scholars cited this process as one of the most relevant and impactful in the near future (Augenbroe and Pearce, 1998), and many others have studied its main benefits and common challenges. In practice, however, it is only in recent years that awareness of the concept of DfD is spreading, mainly due to the limited availability of raw materials and the urgent need to reduce emissions. As explained by Sean Bignold and Fergus Sweeney, architectural director and research assistant respectively of Ryder Architecture in 2023 at BIMplus (one of the leading online sites in the U.K. dealing with innovative topics concerning the Building and Construction industry), the most intuitive way to grasp the shades of the principles of circularity is to compare current building architecture to Lego bricks (BMIPlus, 2023). What has determined the enormous success of this game lies in the fact that all components can be disassembled and reassembled in an infinity of different combinations to create anything a person can imagine. Once the "useful life cycle" of the creation is over, it can easily be "demolished" into its initial components in order to start again and again with this process. However, if Legos were designed the way real buildings are intended, each brick would be "chemically bonded together and […] the only way to dismantle a model once complete [would be] through destructive demolition, resulting in a pile of rubble that needed to be sent to landfill" (BMIPlus, 2023). This process would be extremely expensive and polluting, however, although the concept is presented here in a very simplified way, this is exactly how buildings are currently constructed.

Until now in modern cities the priority had always been given to durability and especially quick assembly, which is why composite materials and other parts that contain several components fixed together irreversibly are mainly used. This makes them extremely difficult, and consequently also costly and energy-intensive to recycle (Roberts, M., Allen, S., Clarke, J., Searle, J., & Coley, D., 2023). Now, however, priorities are - slowly - changing, and it is no coincidence that both the EPA (the United States Environmental Protection Agency) and the EU project Buildings as Material Banks (BAMB) in 2020 pursued to determine the core principles of Design for Disassembly. Among these, the main one that we can mention are (Guy, B & Ciarimboli, N, 2005):

- Design and Planned deconstruction: buildings must be based on a great deal of study regarding design from the design stages, creating a detailed plan on what actions will be taken to be able to recover all elements at the end of its useful life cycle.
- Material selection: the choice of materials is equally important; they must be non-toxic and non-polluting and above all very durable in order to withstand multiple stages of assembly and disassembly.
- Digital Tools: that is, using technology to identify and map resources use, for example, creating a kind of "passport of the materials" that build a edifice, labeling them to make them more recognizable at any stage of its life.
- Separate MEP System: separating the mechanical, electrical and plumbing systems makes the structure more easily assembled and disassembled at its end of life.
- A "deconstructable structure": think of a more flexible, simple, and easily disassembled structure, using standard-sized components to make them removable and reusable over several different life cycles.
- Accessible and removable connections: they should be interchangeable like the rest of the structure, avoiding using binders, sealers and glues on or in materials because they would make them difficult to disassemble, while the focus should be on mechanical joinery, using bolted, screwed or nailed connections (Figure 47).

(Figure 47: ArchDaily, A guide for disassembly, 2020, image taken by Shinkenchiku Sha (url. https://www.archdaily.com/943366/a-guide-to-design-for-disassembly)

The European Union also offered Official Communications to increase knowledge of sustainable practices in Building and Construction, increase the efficiency of resources used, and to try to increase the competitiveness of the circular building market (GBC Italia) with respect to the traditional one. It is among these pointers that he proposed LEVEL(S), a common European framework (as analyzed in Chapter 4) that lays out the main principles and indicators for assessing the sustainability of residential and office buildings (European Commission).

Unfortunately, however, although theoretically the benefits are obvious and the scope of application still partially unexplored (Crowther, P., 2005), in reality few projects have been implemented taking advantage of this strategy and thus there is a lack of real confirmation of the actual feasibility and success of Design for Disassembly in actual life cases (Akinade et al., 2017).

4. Empirical analysis of the B&C Sector

In the building supply chain, there are numerous actors who play a key role in deciding on the application of circular principles. They have the ability to determine which strategies to use, what changes to make, but also to identify opportunities and challenges in the path of sustainable regeneration of the construction context. Generally speaking, stakeholders include policy makers, entrepreneurs, managers, company owners, but investors also play a crucial role in the circular transition of the sector (Nußholz, J. L., et al., 2020). Investors, in fact, decide on the type of building to be constructed and on the targets to be achieved, as simple adaptations to current regulations or an even greater integration of sustainability principles (Giorgi, S., 2024). Investors, when analyzing and deciding on the type of operation to be carried out, are conditioned by various factors (Van Stijn, Aet al., 2023). Firstly, ownership plays a key role: the investor might decide to sell the asset or to retain ownership. In the latter case, if he decides not to sell the asset, he is likely to be more inclined to implement sustainable solutions to increase the durability of the building (Giorgi, S., 2024). Another crucial factor concerns the cost of the building, as the investor is the one who places his financial capital. Given the large sums for the construction of a building, the risk analysis and evaluation of the possible benefits of the investment become decisive for the choice (Van Stijn, A., et al., 2023). First of all, the construction must meet standards according to the law, such as earthquake compliance and, from 2021 for new buildings in Italy, also other minimum energy performance requirements for obtaining the "Attestazione di Prestazione Energetica" (APE) certification, as already explained in Section 3.1.3 of the previous Chapter. All these factors determine an initial assessment of the economic feasibility of the construction or renovation and redevelopment project. The demolition and reconstruction of the building could sometimes be the most economically viable solution, although more impactful at an environmental level (Andrade, J., et al., 2019); for this reason, investors may clash with the willingness of municipalities, provinces and regions to avoid these types of operations, favoring instead the issuing of permits for the renovation of buildings in a shorter timeframe (Giorgi, S., 2024). This is another very good reason that explains why it is necessary to rethink the project of the entire life cycle of a building from the initial stages, designing it by already thinking about how to use it for longer and how to possibly demolish it in a sustainable manner. In addition to those on minimum energy performance requirements, there is also another type of certification called "environmental certifications", which measure the sustainability of a project in its entirety by considering the whole lifespan (from the design phase and choice of materials to the energy and resource consumption, but also the production of pollution during and at the end of its life cycle), declaring its quality

(Giusti, A., 2006). These certifications are usually based on a scoring system, with the evaluation involving several macro-categories, which in turn comprise several items (or indicators) to which scores are assigned (Benedetti, A., 2021). The sum of the scores of each indicator will consequently determine the final "grade" of that category. There are several protocols around the world that are managed by autonomous bodies but generally work in a fairly similar way. In America, it can be cited the Green Building Council (GBTool), while among the protocols in Europe, the most widespread are the HQE system (Haute Qualité Environnementale) in France, Eco-bau in Switzerland, and Total Quality in Austria. In Italy instead, the most important are:

- The Itaca Protocol: created in 2001, this certification used for new buildings or buildings to be renovated is a reworking of the GBTool. Scores are assigned to sustainability indicators and range from -1 to +5 based on the building's performance[48]. For an evolution of the system, the ITACA Protocol for Residential Buildings has been replaced by the UNI/PdR 13:2015 Reference Practice which includes (in the 2023 update) 6 assessment areas: site development and regeneration, energy and resource consumption, environmental loads, indoor environmental quality, service quality, climate change adaptation[49].
- The LEED protocol: actually born in the USA in the 1990s, in its latest version it envisages compliance with 8 assessment areas (6 of which are compulsory) that are Transport and Location (LT), Site Sustainability (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), Indoor Environmental Quality (IEQ), Innovation (I), Regional Priority (PR), all in turn subdivided into prerequisites that will be assessed[50]. Unlike the Itaca protocol, in the "LEED 2010 Italy New Construction and Renovation" after obtaining a score based on the performance of the indicators, a certain classification (Platinum, Gold, Silver and Certified) is reached[51]. The LEED 2010 Italy also provides the opportunity to take additional "credits" in the "Design Innovation" and "Regional Priority" categories. The maximum score achievable for the building design is 110 points (LEED Platinum), while the score for obtaining the LEED basic rating is 40[52].

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[48] https://www.infobuildenergia.it/approfondimenti/sostenibilita-negli-edifici-classificarla-con-i-modelli-di-certificazione/
[49] BibLus - Information and technical insight for building professionals, https://biblus.acca.it/protocollo-itaca-cosa-serve-e-come-si-usa-nei-cam/
[50] The LEED certification of a building, https://www.certificazioneleed.com/edifici/
[51] https://www.infobuildenergia.it/approfondimenti/sostenibilita-negli-edifici-classificarla-con-i-modelli-di-certificazione/
[52] LEED certification of a building, https://www.certificazioneleed.com/edifici/

- The BREEAM Protocol: originated in the UK, the Building Research Establishment Environmental Assessment Method is an assessment tool that operates differently from its predecessors. In the 2014 version, it is divided into 7 categories (energy, land use and water ecology, health and well-being, pollution, transport, materials, waste, management) to which scores are given[53], but these are not simply added together algebraically, but are first "weighted" according to the importance of the various indicators (Figure 48).

≥30%	PASS	★
≥45%	GOOD	★★
≥55%	VERY GOOD	★★★
≥70%	EXCELLENT	★★★★
≥85%	OUTSTANDING	★★★★★

(Figure 48: Scores in the BREEAM Protocol, Gyproc – Protocolli ambientali, https://www.gyproc.it/Sostenibilit%C3%A0/Protocolli-ambientali/Breeam)

The certifications presented here are therefore comprehensive analyses of the sustainability of a building in its entirety and, in many cases, its quality and degree of sustainability not only guarantee lower energy consumption but also increase the economic value of the construction itself. In fact, a certification attesting its circularity achieves 17.3% longer rents and can earn the owner a 7 to 11% increase in rent compared to equivalent buildings that do not have it, against only a 1% increase in construction costs (Il Sole 24 Ore, 2024).

Besides investors, the other key figures in the construction supply chain are policy makers, a term used to identify those who are responsible for determining laws, strategies and guidelines at municipal, provincial, regional, national, European, etc. level. The role of the policy makers, already introduced in the previous chapters of this paper, will be explored further in Section 4.2.2. In the next section, on the other hand, the positions of those who actually implement the decisions taken in the political sphere will be analyzed, i.e. all the actors in the construction supply chain, from the planner to the manager, from the worker to the owner, trying to highlight the main drivers and barriers of the companies in the sector that seek to implement the principles of circularity.

[53] ESAengeneering, https://esa-engineering.it/servizi/sostenibilita/certificazioni-di-sostenibilita/certificazione-breeam/

4.1. Major challenges and opportunities in the industry

The Building and Construction sector is one of the most relevant in terms of its impact on the working and personal lives of individuals. However, it is also, as already mentioned, one of the most polluting, as well as being characterized by the extensive extraction of raw materials, the use of large amounts of resources, and above all, it is categorized by its slowness in implementing Circular Economy principles (Allwood et al., 2010).

4.1.1 Drivers and barriers towards the CE in the Building and Construction sector

One of the main problems of the construction industry is the great difficulty in recovering materials with upcycling strategies, i.e. by having their intrinsic value maintained or increased for subsequent production cycles. Most of the resources from construction and demolition processes, on the other hand, are currently landfilled or recycled with downcycling strategies, thus causing them to lose their value and be used mainly as filler (Coelho, A., 2013). This is indeed one of the main **barriers** in the sector, as construction and demolition materials are rarely and to a limited extent separated efficiently in a precise and planned manner (D'Alonzo, V., et al., 2021). In addition to disassembly, a sustainable strategy discussed extensively in the previous Chapter, which involves more labor, more time to dismantle the building and also higher costs (for training workers, designing waste-free buildings, implementing the disassembly plan...), there are two macro-categories (Figure 49) of demolition (Giorgi, S., 2024):

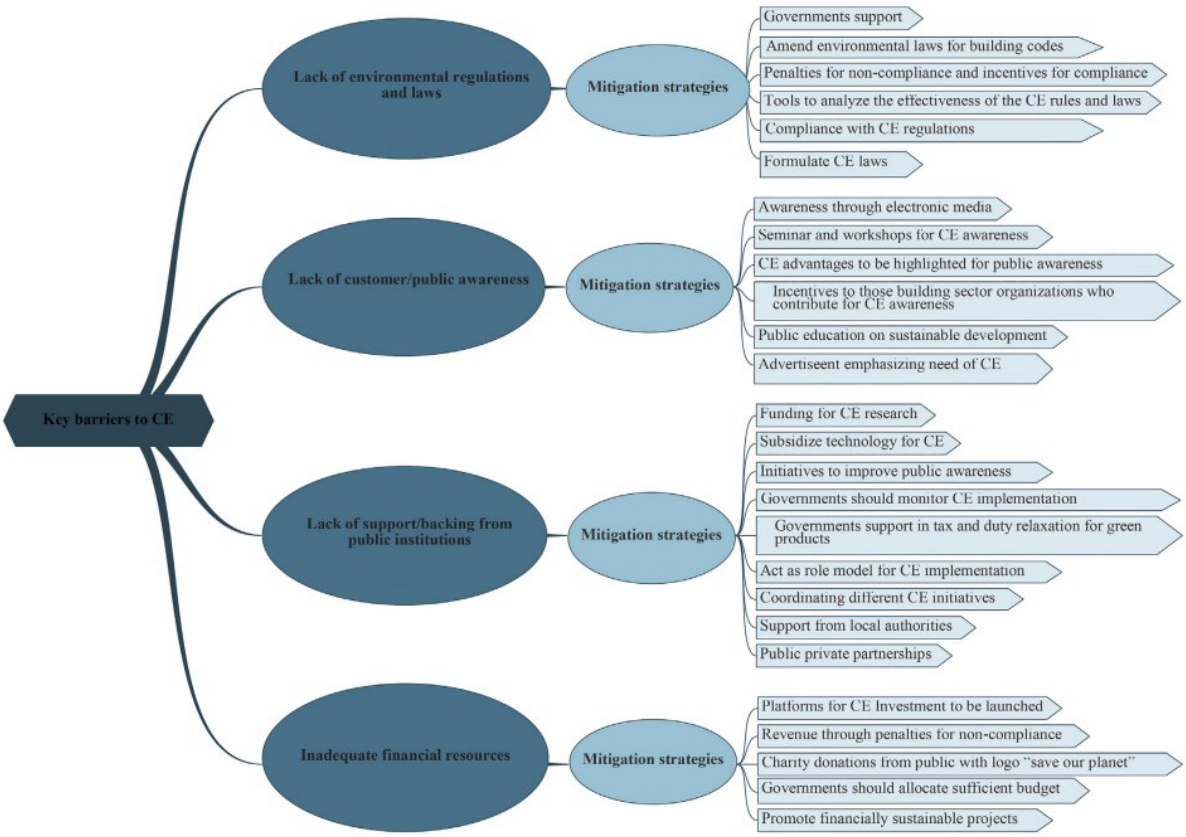
- Traditional: it involves the demolition of an entire building or part of it, turning it into mixed rubble waste, i.e. consisting indiscriminately of bricks, glass, metal or wooden parts, which are almost impossible to recover and will be disposed of in landfills (Coelho, A., 2013). It is generally carried out by huge demolition machines with the aim of quickly dismantling buildings, without having to perform any kind of analysis on the materials that make up the building (but only with the obligation to separate hazardous materials such as asbestos) (Giorgi, S., 2024). This practice is widely disincentivized, as in addition to being very polluting, it greatly limits the recovery potential of this mix of materials that cannot be properly managed (D'Alonzo, V., et al., 2021).
- Selective: it consists of the dismantling of the building in a differentiated manner according to its parts (Coelho, A., de Brito, J., 2011). It is determined by a series of "sequential" demolitions in a specific order, starting with "a strip-out of the internal finishing parts (such as flooring, false ceilings, doors, etc.) and of the light, dry internal works parts (such as vertical plasterboard partitions, installations, etc.). Successively,

demolition concerns the heavier and more massive parts of the works, such as masonry facades, and finally the load-bearing structure” (Giorgi, S., 2024, p. 94). The use of large and smaller machinery depending on the part of the construction to be worked on, and the various work phases presented, allow for a better treatment of materials, allowing them to be differentiated and recovered without damaging them, and valorizing and exploiting them more appropriately than traditional demolition (D’Alonzo V., et al., 2021).

(Figure 49: Traditional and selective demolition, Giorgi, S., 2024)

Obviously, however, the more articulated the sustainable construction strategies are, the higher the costs will be, both in economic terms and in terms of time, to be able to exploit the full potential of recovered materials (Condotta, Zatta, 2021). Even if the construction and waste disposal processes could be simplified, other barriers would still be encountered, such as the inefficiency of the process chain for the collection of material flows and, above all, a lack of a large market for “secondary raw resources” (Liu et al. 2021). One of the greatest challenges in the field of CE in the construction sector concerns precisely the change of the supply chain in its entirety, ensuring mutual interests between all actors. Currently, however, transparency and information exchange are not widespread practices, as is also limited knowledge about circular business models and ways in which the waste of resources can be reduced (Campbell-Johnston et al., 2019) caused by the competitiveness of a market that has enormous potential for development. The design of “traditional” buildings and the planning of inadequate and inefficient urban architectures are also determined by the lack of the necessary technology to recover any material at any time, which is not yet developed enough to ensure the success of circular companies in the sector and the replacement of processes that impact the environment the most (Huang et al., 2018).

In addition to these challenges that slow down the transition, another aspect to consider is that there is still no obligation to adopt sustainable end-of-waste strategies: the lack of political priority for sustainable construction is a major brake on change in a sector that has the potential but is still very much tied to tradition (Kanters, 2020). In general, however, overcoming only legislative barriers would not bring about a real change as even with clear regulations and a common plan to implement circular practices, a variation in the thinking and behavior of all actors involved in the construction supply chain is needed above all (Hart et al., 2019). The main barriers to the implementation of sustainable practices in the B&C sector are (Figure 50):



(Figure 50: Bilal, M. et al., 2020. CE barriers in the B&C industry and mitigation strategies)

- Regulatory barriers: they refer to the lack consistent regulatory and policy framework. Since there is no global consensus to around the Circular Economy, some states will be more inclined to implement sustainability principles in their regulatory packages, while others will tend to be neutral or even averse by passing laws that obstruct the transition in the sector (Hart, J., et al., 2019). Among the legislative barriers, the most impactful are the lack of effective government legislation, lack of comprehensive national regulations in support of CE (and in particular precise and comprehensive guidelines are indicated as one of the biggest challenges in the sector (Milios, L., 2018), the difficulty of having a global "vision", coherent interests and structured coordination at national and municipal level also limits funds for research and development, complex institutional structures and local administration coordination (Abdulai, S. F., et al., 2024). In fact, it is mainly regional and local activities that are crucial in promoting and supporting circular processes in construction, in educating and raising awareness among all actors involved by increasing public awareness of the issue, and in fostering traceability processes for construction and demolition waste (Danish Government, 2018).

- Informational barriers: The absence of awareness on circularity issues and the application of the practices in the construction sector is specifically one of the major obstacles to change. Negative perceptions[54] of recovered products and lack of knowledge about the potential of "secondary raw materials" and circular business models do not foster the engagement of key actors in the supply chain (Campbell-Johnston et al., 2019). The common way of thinking and social norms that favor an authentic and new product over a recovered and sustainable one is still preponderant and almost inextricably links the B&C industry to tradition (Paiho et al., 2020). The lack of interest in these issues by a still very large segment of the population and the non-prioritization of the Circular Economy in the development plan of many countries (especially developing countries) are crucial barriers and lead to slow and unsteady changes.
- Lack of support from public institutions: another barrier identified concerns the lack of backing from institutions, still insufficient initiatives and support for change slow down this process. Among possible improvements, several authors mention better tax incentives and duty relaxation strategies for sustainable resources and products, both for companies and consumers (Hart, J., et al., 2019). The absence of national and municipal support limits companies, especially SMEs in the construction sector, also show difficulties in finding adequate financial resources and funding from the outset.
- Financial and economic barriers: one of the major problems in implementing sustainable practices in the construction sector is the difficulty of identifying business models that are both economically and environmentally sustainable. The criticality of the economic

[54] "Cultural barriers concern aspects of the social, behavioural and managerial contexts in which the CE is required to develop, such as the entrenched nature of the linear economy" (Jim Hart, 2019, p.621)

barriers is obvious: no company will decide to start the circular transition process if the possibility of obtaining revenues is very low. As mentioned above, for example, it is much easier, as well as cheaper, to construct and demolish buildings without thinking about their end-of-life, producing material mixes that are difficult to recover. Furthermore, very often the prices of virgin materials are lower than those of secondary raw materials; for the latter, moreover, it is still difficult to establish their value and above all to be able to reassure users that they are equal to virgin materials (Campbell-Johnston et al., 2019). Companies are still strongly attached to tradition and prefer a quick return on investment, rather than taking a risk to develop a circular and innovative business model (Al Hosni et al., 2020). They also have to consider the demand for the recovered products or materials, which is not yet so high as to guarantee a secure economic return; on the contrary, at this moment companies mainly perceive the costs of implementing sustainable practices (high skilled labor costs, product and process certifications,...), but construction prices still fail to consider the environmental and social benefits of the Circular Economy (Akinade et al., 2019. The speed of the production process, uncertainty about the value of resources and high initial investments are the preponderant fears for circular companies in the construction sector. Furthermore, successful Circular Economy cases in the industry are still too few and unconvincing (Adams et al., 2017).

At the same time, however, the construction sector has enormous potential for improvement. However, the involvement of all actors in the supply chain is a key element to achieve sustainability targets. Greater cooperation between policy makers, designers and manufacturers from the B&C industry and other sectors would benefit the entire construction supply chain and also provide more transparency to consumers. The sharing of best practices and knowledge, and the use of digital tools such as Building Information Modeling (BIM) (Osello, A., 2012) allows materials to be tracked at all stages of their life, promoting greater clarity and easier identification of circular strategies to be implemented. The development of schemes[55], common practices and standards can be useful enablers to overcome practical problems regarding what to do with recovered materials after the end of life of buildings (Hopkinson, et al., 2018). To have a real change in the construction industry, there is therefore a need for a comprehensive and clear view of CE applications (R. Zimmann, R., et al., 2016), promoting the increase of real

[55] "In several Member States there are Quality Assurance schemes in place for specific products, like recycled aggregates. Such schemes often contain requirements concerning waste acceptance and environmental issues" (Migliore, M., Talamo, C., Paganin, G., 2020, p. 83) which must be harmonized between countries so that recovered materials can be used and exchanged more efficiently.

business cases of CEBMs and their presentation to highlight how to move from theory to practice (R. Zimmann, et al., 2016). The factors influencing the B&C industry are different from those found in other sectors, at the same time also within the construction supply chain different companies can identify different drivers and barriers to circularity according to their characteristics. In addition to a change of the entire value chain, in general it is possible to identify other **enablers**:

- Regulatory drivers: the support of politics and decision-making bodies is crucial in pushing the transition. Incentives and policy support are necessary, in addition to legislative reforms that to date often hinder sustainable development instead of promoting it, and in this regard, Hill (2015) points out that current antitrust laws are a major obstacle as they discourage collaboration between companies. Governments must support experimentation, research and the study of new innovative solutions to implement EC in buildings (Paiho et al., 2020). A change in taxation, for example, would be an important driver, as it would reduce the tax burden on green companies by charging them for the emissions produced throughout the product life cycle and thus "rewarding" companies that succeed in reducing them (Gallego-Schmid et al., 2020). Through new laws and by making the current ones more stringent, companies, which often seek the fastest and cheapest method, would be forced to rethink their activities in order to comply with the current laws (Springvloed, P., 2021). Furthermore, if policy makers imposed mandatory reporting, companies would have to be more transparent about their resource use and production processes at all stages, which would lead to the implementation of circular practices for the reduction of Construction and Demolition Wastes (Selman, A.D., Gade, A.N., 2020). Green projects need to be promoted not only through local initiatives, but also by the EU as companies, and especially SMEs, need to be assisted and guided in the process of change. As explained in section 4.2, world governments are increasingly directing their efforts towards a sustainable transition of the Building and Construction sector, with still quite limited results.
- Cultural drivers: changing the economic model from linear to circular implies great efforts, substantial resources invested in research and development, and above all, a change in the mindset of those involved. No transformation can be effectively brought about without a new ideology and new behaviors of both Building and Construction workers and consumers (Selman, A.D., Gade, A.N., 2020). In the literature, the cultural driver is reported as the first and most important of the enablers in that the corporate environmental culture, and reflexively also those who have to drive change (in this sense

Hart et al. (2019) talk about leadership) must be preponderant to even think about starting a sustainable project (Rizos et al., 2016). Moreover, the attitude and habits of companies are changed only through personal knowledge (Rizos et al., 2016), which must be fostered through partnerships and collaborations with schools and universities as well. Engagement for the circular value chain of all stakeholders stimulates demand for green products only when sufficient knowledge is acquired (R. Zimmann, R, 2016.)

- Economic and financial drivers: in both theory and practice, it is these barriers and drivers that have the greatest impact on the transition to the Circular Economy in the construction sector. Indeed, companies are unlikely to move from their traditional business model to adopt others that are environmentally sustainable but not economically viable. Value creation for the company and consumers, as seen above, is crucial and needs to be analyzed in a systematic and timely manner. For example, buildings designed in a circular way are generally more energy efficient through the integration of renewable energy systems (advanced photovoltaic panel technologies, wind turbines, thermal coats, or the use of insulation materials) that result in increased building value for the owner but also significant cost reductions for users (Il Sole 24 Ore, 2024). Green buildings also will tend to maintain or increase their value over time and be durable, without the need for constant maintenance and renovation (Il Sole 24 Ore, 2024). Another key enabler is the decrease in costs associated with the use of nonvirgin raw materials, such as transportation costs that are almost eliminated if materials are recovered locally and the drastic reduction in disposal costs (landfill costs, waste taxes, and other charges) (Hart et al., 2019).

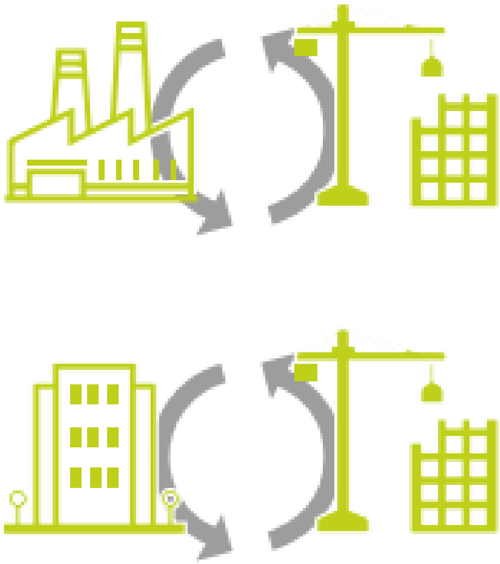
  An additional enabler is the market pressure, as consumers who are increasing awareness for green buildings and the establishment of a market for secondary raw materials are necessary economic drivers for the transition that need to be promoted through public-private partnerships in which authorities commit to supporting the choice of sustainability and innovation (Nordby, 2019). Moreover, the entry of new innovative companies and start-ups (more prone to flexibility and change than large companies), would increase competition in the market, creating a kind of “fear of missing the chance”, bringing new ideas to the market (Springvloed, P., 2021). This would allow for an increase in the “scale” of the circular B&C market, an implicit driver that would actually increase the players involved and collaborations within the industry, aggregating projects from companies in different sectors and turning obstacles into new opportunities (Hart et al., 2019).

- Technological drivers: the relationship of the building sector to technology is, as already discussed, absolutely fundamental. Improvements in production processes and resource recovery, the discovery of new materials or new, more sustainable uses of existing ones are closely linked to the state of existing technologies. Increased interest in environmental issues, while not actually considered a priority to date, has also led to increased applications of innovations coming from other sectors; these increasingly close cross-sectoral relationships result in a boost in the potential of the B&C industry. New opportunities given for example by 3D Printing, sensors, sharing platforms, can be key assets for companies that want to embark on a sustainability path (Hopkinson, P., et al., 2018). When we talk about technological enablers, however, we are not limited to just that. They can be divided into two additional groups: the integrated information system group, which covers the use of IoT for database creation and use, information sharing platforms, and component tracking (Gallego-Schmid et al, 2020); the guidelines and tools for circular buildings group, which includes the creation of development plans, definition of rules and procedures for the application of circular practices (Maerckx et al., 2019) to foster resource management and symbiosis between EC and Building&Construction (Nußholz et al., 2019), as will be explored in the next section with the definition of Roadmaps to Circularity.

4.1.2 Future trends and critiques

In order to trigger CE scenarios in B&C, it is crucial to create a system of secondary resource utilization within the industry, but also by creating systems of material exchange between different sectors (Figure 51). For example, materials from other production chains can be recycled or reused in interesting ways, thus avoiding being taken to landfills. On the Italian territory, Calzedonia and Intimissimi promote activities for the recovery of their garments that have reached the end of their lives, from which useful textile fibers will be re-obtained[56] for the production of insulating panels (thermal and acoustic).

[56] Intimissimi, Sustainability Projects, https://www.intimissimi.com/it/donna/sostenibilita/int_woman_lp_projects_it-it/



(Figure 51: GBC Italia – Economia circolare in edilizia, 2019, https://gbcitalia.org/wp-content/uploads/2023/01/2019_GBC-PP-Ec.-Circ.-Rev2.pdf)

Also, for the creation of these insulation panels, recycled sheep wool is reused, a clear example of how it is possible to exploit an issue (the disposal of shearing waste) and see it as an important economic opportunity (GBC Italia, 2019). Another interesting green building application involves waste from wood processing, and from sawdust instead, flooring panels can be made. Conversely, some waste from the construction supply chain, such as wood used for interiors, can come out of this sector and be exploited for the creation of new furniture products or pallet blocks (Figure 52).

Currently, however, construction waste has a scope mainly within the industry itself. They can be used as fill without any further processing, or they can undergo processing to produce other materials (such as concrete) that will go into the finished building (GBC Italy, 2019). These, however, are reuses that result in a decrease in the value of construction and demolition waste. Instead, the goal is to increase the reuse of construction materials and waste, maintaining their characteristics and increasing their value: this would create a system in which waste can actually be defined as secondary materials "in" construction and "for" construction, in which savings would emerge in virgin resources, energy consumed for their extraction, and (almost) zero amounts destined for landfill (GBC Italy, 2019).

(Figure 52: Cefis, imballi speciali, https://www.cefis.mi.it/pallet-in-legno-funzione-caratteristiche/)

In order to reach this target, however, it is necessary to “standardize” sustainability principles so as to simplify production processes and end-of-waste initiatives. Defining strategies and targets to be achieved and standardizing processes play a pivotal role in strengthening EC (Abu-Bakar, H., et al., 2023). In this case, the term is meant to indicate the identification of a universal language for achieving targets throughout the value chain (Rizos et al., 2015). In other words, providing the ability for all global actors in the supply chain to be able to use common procedures, performance metrics, and be able to refer to product design and material flows (Parchomenko et al., 2019) that could potentially be used by all construction companies in any geographic area would be an impressive driver toward sustainable development.

One innovative way of undertaking such pathways is through the introduction of Roadmaps toward Circular Economy, thereby outlining guidelines, actions, initiatives, KPIs (Key Performance Indicators) and targets for the Building and Construction industry (EMF, 2015). A roadmap should be used as a planning tool to help all stakeholders, such as businesses, organizations, and governments (Phaal et al., 2004), identify strategies and align their goals with a focus on optimizing resources and creating value from waste (Potting et al., 2017). “Roadmapping” is thus a useful strategic tool can be leveraged for circular development of B&C companies and sustainable urban development (Renewable Energy Agency, 2018). This type of document defines an overall vision of the goals to be achieved, thus trying to answer the “WHY” and “WHAT” questions, but also presenting the actions needed to achieve them (“HOW”) (Baker-Brown, D., 2021). The usefulness of roadmaps lies in the need to develop a comprehensive view of the tactical steps essential to changing the economic paradigm from a linear model to a more innovative and efficient one in the construction industry. “Strategies and

roadmaps can be developed at numerous levels: European, national and regional or local" (Baker-Brown, D., 2021, p. 12.) and these levels generally complement each other. In reality, however, the actions identified might differ, for example, because of the different characteristics of the geographical areas or the companies themselves: a more precise and specific vision is necessary for a well-structured analysis, but at the same time a "beyond territories" analysis is also crucial (Baker-Brown, D., 2021) for the development of innovative ideas.
A future solution could be to create networks and platforms to share information and best strategies, as well as determine the possibility of comparisons and exchanges of opinions (Migliore, M., Talamo, C., Paganin, G., 2020). Currently, companies in the Building and Construction sector are focused on how to work quickly and economically, without thinking about the next steps in the supply chain, as how to recover scraps and demolition materials. Identifying new possible uses for scraps, waste and byproducts means creating opportunities for the emergence of new companies that can create value from secondary raw materials, creating an adequate and sustainable supply chain (Migliore, M., Talamo, C., Paganin, G., 2020). In addition, if construction and demolition waste were tracked and monitored, virtual trading markets could be created in which one company's waste could become the raw material for another.

Thus, this sector has enormous untapped potential; at the same time, however, several criticisms of this type of proposal emerge. First of all, in the B&C industry initiatives are still very fragmented, failing to present solid and concrete initiatives, as well as still not being supported sufficiently by national, European and global bodies (GBC Italia, 2019). The environment can be seen as a resource mine but to date the lack of monitoring of material flows is a huge limitation and forces companies to source their resources through mining (GBC Italia, 2019). In fact, demolition waste often occurs as a mix of materials, which cannot be recovered and valorized even through selective demolition, which is gaining popularity but is often not so effective in reality, leading to coarse separations due to high costs (Giorgi, S., 2024). Design for Disassembly and modularity can somewhat try to limit the damage of the B&C industry, although the rules for applying these strategies are still not always clear and well defined (Roberts, M. et al, 2023). Moreover, recovered materials very often only in theory manage to retain their original characteristics: the quality of a recycled product is not consistent, they perform not always efficiently over time compared to their raw counterparts that are at the beginning of their life cycle, and this discourages companies and consumers to rely on circular initiatives (GBC Italia, 2019).

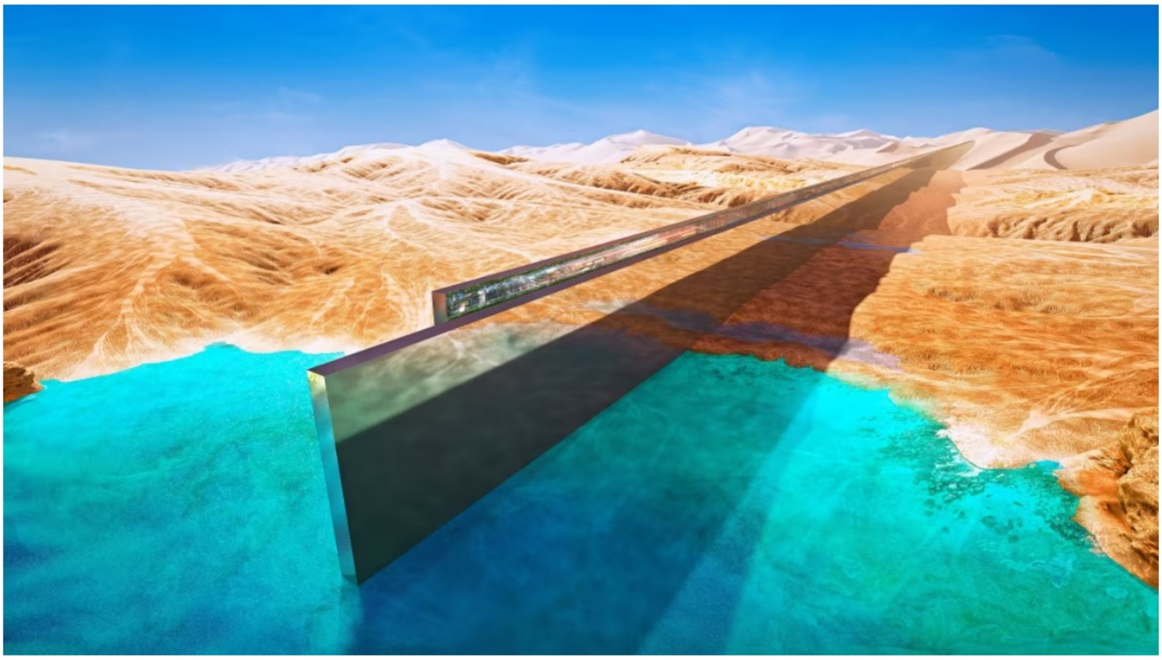
4.2 Circular Economy for B&C in the World

The construction sector is one of the most socially, economically and environmentally impactful. Population growth will result in, according to estimates, the "total global floor area of buildings is estimated to double by 2060 with over 50% of that increase likely to occur within the next 20 years. Asia and Africa will see particularly rapid growth in new buildings, while Europe faces a different challenge: an ageing existing building stocks"[57]. Waste management is still a huge problem in the industry, for example in America, 160 million tons of CDWs is generated annually (Rios, F. C., Chong, W. K., Grau, D., 2015). This amount represents a third of total solid waste stream (Kibert, C.J., 2013). In the 2000s, demolition was responsible for 90% of all C&D waste (A.R. Chini, 2005) and this certifies the need for change in the processes of the building supply chain.

One of the absolute most ambitious ideas ever conceived, however, concerns "The Line", a project to build the "city of the future". Located in NEOM, a city under construction in Tabuk province in northwestern Saudi Arabia, this visionary megalopolis has been requested directly by Crown Prince Mohammed bin Salman[58]. In its futuristic design, The Line will be developed 500 meters in height above sea level, with 170 kilometers long and only 200 meters wide (Paszkowska-Kaczmarek, N. E., 2021). The 34 square kilometers are expected to house about 9 million inhabitants in a totally innovative way (Al-Sayed, A., et al., 2022). This smart city, in fact, offers a new approach to building and urbanism, as it is expected to be the first vertical city in the world, in a Zero Gravity Urbanism project. This concept is intended to indicate the possibility for people to move "in zero gravity" in 3 dimensions (up, down, through), developing the city according to the principle of hyper-proximity, so that citizens can reach all services within 5 minutes and with green spaces no more than 2 minutes away[59]. Outside the city, a superfast train powered by electricity derived from sustainable sources will be available to get from one end of the city to the other in just 20 minutes (Paszkowska-Kaczmarek, N. E., 2021). This futuristic city will be powered entirely by sustainable energy and will be 0-emissions and will place people and nature at the center of the project: a city before roads, devoid of cars and that in its intentions will prioritize the preservation of the land, health and well-being of people according to the Saudi royal family will not be just utopia[60]. The exterior of the city will consist of a mirrored structure, which will allow it to better "blend in" with

[57] #BuildingLife EU Policy WLC Roadmap, p. 12, https://viewer.ipaper.io/worldgbc/eu-roadmap/?page=12
[58] https://www.infobuildenergia.it/the-line-arabia-saudita-citta-verticale-rinnovabili/#:~:text=The%20Line%20%C3%A8%20the%20first,by%20two%20minutes%20of%20distance
[59] https://www.infobuild.it/the-line-citta-futuro-arabia-saudita/
[60] https://www.infobuild.it/the-line-citta-futuro-arabia-saudita/

nature (even in reality it could prove to be a danger due to its "invisibility" during migration flows[61].



(Figure 53: The project of The Line, https://www.focus.it/tecnologia/innovazione/the-line-citta-futuristica-arabia-saudita-inferno-o-paradiso)

Despite the impressiveness of the project and its innovative connotation, The Line has been heavily criticized. First and foremost, according to the royal family, The Line aspires to become the "most food self-sufficient city in the world", although at least initially food will probably be mostly imported; moreover, water supply in theory will be determined by zero-emission desalination systems (despite the fact that to date about half of the water in Saudi Arabia is produced through fossil fuels and still no way to recover it through sustainable plants has been found)[62]. Another criticism concerns the actual structure of The Line, which will, indeed, have a linear shape. Instead, the best and most efficient shape is that of a circle[63], since a 34-square-kilometer city developed according to this shape would allow people to walk to any point in the city by covering at most only a few kilometers, without the need for any trains[64]. In addition to the huge CO2 emissions due to urban construction, the costs would seem unsustainable[65]: the initial estimate was about 500 billion dollars, but the numbers are rising to touch 1.5 trillions of

[61] https://www.ecologica.online/2023/05/05/the-line-arabia-saudita/
[62] https://futuranetwork.eu/citta-e-urbanistica/691-4999/larabia-saudita-sta-costruendo-la-piu-avanzata-citta-del-futuro-ma-con-forti-costi-umani
[63] https://www.spotynews.com/la-citta-lineare-dellarabia-saudita-the-line-potrebbe-essere-migliorata-facendola-diventare-the-circle/
[64] https://www.digitec.ch/it/page/la-linea-perche-lambiziosa-citta-del-futuro-dellarabia-saudita-non-e-lideale-29510
[65] https://www.focus.it/tecnologia/innovazione/the-line-citta-futuristica-arabia-saudita-inferno-o-paradiso

dollars (Corriere della Sera, 2024). Not surprisingly, the project has been heavily scaled back, as only 2.4 km will initially be built by 2030[66]. The most serious criticism, however, of this project is the accusation of greenwashing, i.e., a way for the royal family to "clean up" from the scandals of workers' conditions and the evacuation of cities to make way for this green megacity in the middle of the desert[67].

4.2.1 Eco-design in the Building and Construction Industry

An innovative and circular American example is Plantaer, founded in 2023, is an American startup that has big goals for change in the Building and Construction industry. Their goal is to revolutionize the way cities are developed and make them more sustainable through their bio-generative concrete[68]. The material they want to use is nontoxic, high-performance and carbon negative, as it captures atmospheric CO2 while supporting the growth of organisms (mainly moss and flora) on the building itself. In fact, traditional concrete intensifies biodiversity loss and as "gray is taking over blue and green world"[69], in fact human made materials (mostly concrete) now weigh more than all life on Earth, according to an article published by Nature in 2020[70]. The goal of this startup is to overcome one of the main problems of today's cities, which is that it absorbs heat from the sun and traps exhaust fumes from cars and air conditioning systems, as well as destroying natural infrastructure and choking ecosystems (The Guardian, 2019). As stated on the Ellen Macarthur Foundation website in its Circular Startup Index, which is a compilation of all the most innovative companies in the Circular Economy, Plantaer incorporates the principles of sustainability, "utilizing industrial byproducts to create sustainable materials that capture atmospheric carbon and support organic growth. Designed for recyclability and biodegradability, our materials minimize waste and enrich ecosystems. Through licensing, we extend our eco-friendly solutions across industries, amplifying circular impact"[71].

The Asian market is also slowly moving in a more sustainable direction in the Building and Construction sector; this is where Widuz, a project founded in 2019 in Singapore but with the potential to reach all continents with its products, is being developed to lead the circular

[66] Bloomberg News, https://www.bloomberg.com/news/articles/2024-04-05/saudis-scale-back-ambition-for-1-5-trillion-desert-project-neom
[67] https://futuranetwork.eu/citta-e-urbanistica/691-4999/larabia-saudita-sta-costruendo-la-piu-avanzata-citta-del-futuro-ma-con-forti-costi-umani
[68] https://www.ellenmacarthurfoundation.org/resources/business/circular-startup-index#Plantaer
[69] https://www.plantaer.com/
[70] https://www.nature.com/articles/d41586-020-03548-y
[71] https://www.ellenmacarthurfoundation.org/resources/business/circular-startup-index#Plantaer

transition of bio-based suppliers[72]. This startup is developing a new type of materials called BVL (Bamboo Veneer Lumber) that comes from fast-growing bamboo fibers and is expected to replace materials usually used in construction, furniture and sports industry[73]. BVL, besides being sustainable and renewable, has very high performance (3 times stronger than timber), is stronger and has very high durability. Moreover, as confirmed by members of this company, they work using only sustainable bamboo plantations in Asia and Latin America[74]. This species of plantation grows in only 4 years (compared to 100 for traditional bamboo), so BVL is not only offering a circular product to the market, but also combating bamboo deforestation[75].

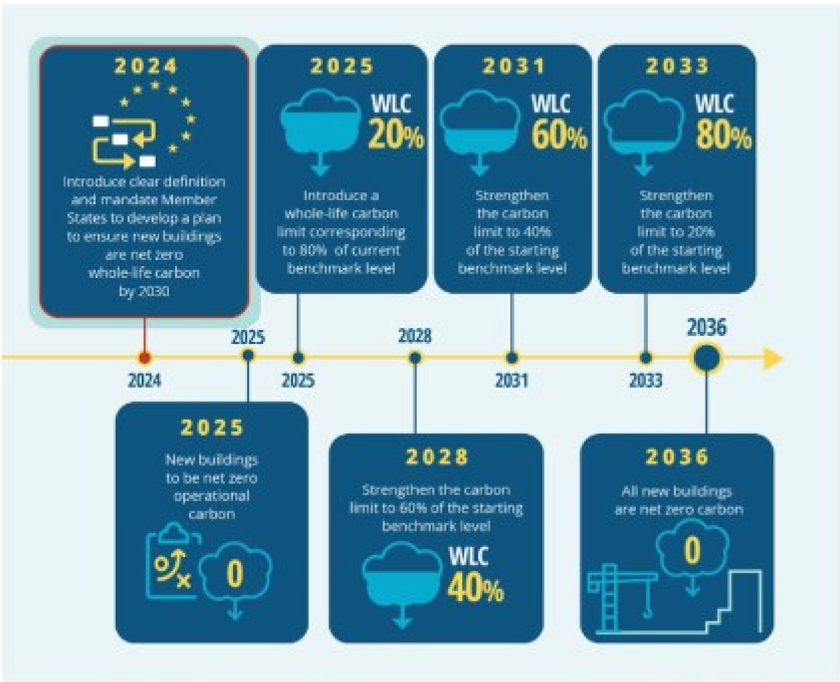
4.2.2 The situation in Europe

Construction and demolition waste is among the largest sources of waste in Europe (Lützkendorf, T., 2019). Much of it is, as explained, collected and used primarily for low-value activities, such as filler for road production. Decreasing the volumes of waste produced, increasing the rate of recovery and, above all, its applications are just some of the goals that the European Union has set for itself. Improving the management of Construction and Demolition Wastes (CDWs) is a binding target for member countries by 2050, but it actually faces issues that are still difficult to overcome[76]. Better design of all life stages of a building, considering its importance from a social point of view and its environmental impact, must be put as a priority[77]. Due to the long lifespan of these constructions, proper end-of-life management becomes necessary, as improvement in the practices of collecting and dividing materials to be able to recover them by valorizing them is also already essential (European Commission, 2015). Despite its potential, the recovery rate of CDWs varied widely among European countries, from 10% to 90%, due to different attention but also different (sometimes discordant) laws regarding the issue[78]. For this very reason, the European Union is trying to support member countries through the development of directives and other types of frameworks and roadmaps. This includes the Waste Framework Directive, with the aim of managing waste streams and being able to exploit the potential of CDWs, and the EU Construction and Demolition Waste Protocol

[72] https://www.widuz.com/
[73] https://www.widuz.com/
[74] https://www.ellenmacarthurfoundation.org/resources/business/circular-startup-index#Widuz
[75] https://www.ellenmacarthurfoundation.org/resources/business/circular-startup-index#Widuz
[76] https://environment.ec.europa.eu/topics/waste-and-recycling/construction-and-demolition-waste_en?prefLang=it&etrans=it
[77] https://environment.ec.europa.eu/topics/waste-and-recycling/construction-and-demolition-waste_en?prefLang=it&etrans=it
[78] https://environment.ec.europa.eu/topics/waste-and-recycling/construction-and-demolition-waste_en?prefLang=it&etrans=it

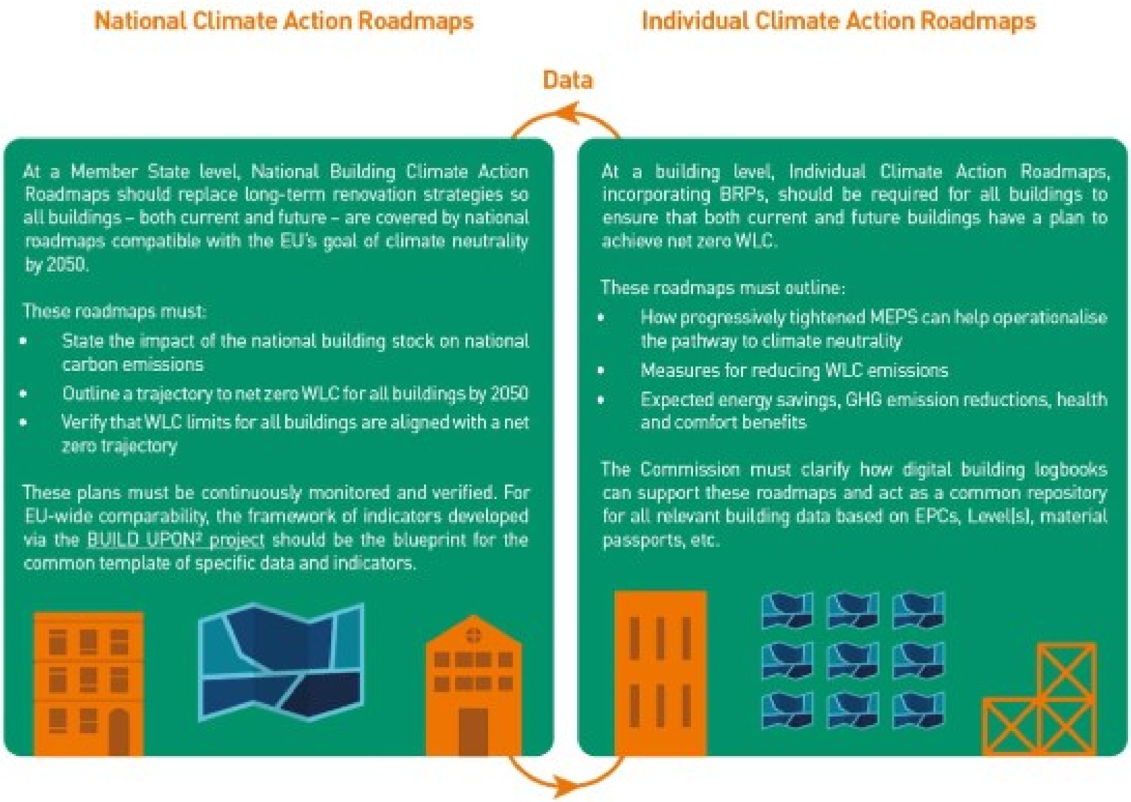
and Guidelines, of non-binding guidelines proposed to the construction supply chain for better management of demolition waste management and to increase its quality[79]. Increasing waste recovery to at least 90% and improving waste separation and identification should, according to Europe, increase demand for C&D secondary materials[80].

To ensure direct collaboration between policy makers and industry, additional initiatives should also be undertaken. "#BuildingLife EU Policy WLC Roadmap" is an action project to decarbonize and improve the impact of building construction and demolition. This covers the establishment of common building regulations, minimum requirements, targets and initiatives, as well as ambitious timelines (Figure 54) to take a comprehensive view of the issue and succeed in taking a low-emission and low-impact trajectory. Harmonization and standardization of roadmaps at individual, national and European levels are necessary for successful implementation of circular practices[81] (as summarized in Figure 55 and 56).

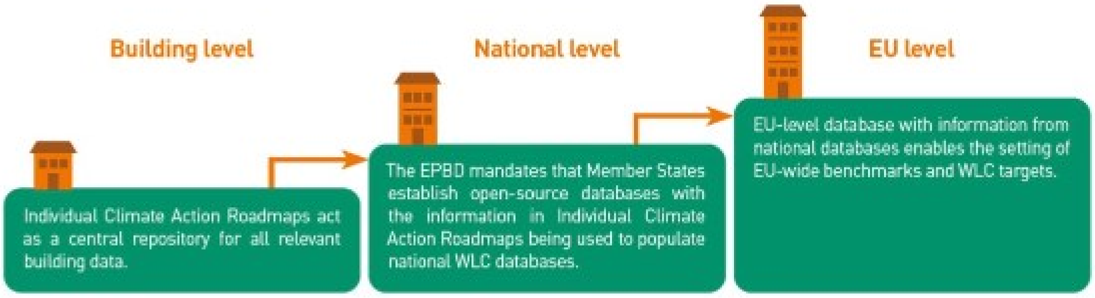


(Figure 54: Indicative timeline of introduction of sustainable buildings (#BuildingLife EU Policy WLC Roadmap, p. 12, https://viewer.ipaper.io/worldgbc/eu-roadmap/?page=12).

79 https://single-market-economy.ec.europa.eu/news/eu-construction-and-demolition-waste-protocol-2018-09-18_en
80 https://single-market-economy.ec.europa.eu/news/eu-construction-and-demolition-waste-protocol-2018-09-18_en
81 https://single-market-economy.ec.europa.eu/news/eu-construction-and-demolition-waste-protocol-2018-09-18_en



(Figure 55: Summary of roadmaps for the CE in the B&C sector (#BuildingLife EU Policy WLC Roadmap, p. 12, https://viewer.ipaper.io/worldgbc/eu-roadmap/?page=12)



(Figure 56: Importance of the hamonization of roadmaps to CE at building, national and EU level (#BuildingLife EU Policy WLC Roadmap, p. 12, https://viewer.ipaper.io/worldgbc/eu-roadmap/?page=12)

In Europe, building use alone currently produces 36% of the total emissions and they are responsible for almost 40% of energy consumption (#BuildingLife EU Policy WLC Roadmap, p. 12). In addition, 35% of urban architecture in Europe is at least 50 years old and 97% is not efficient enough, as well as still too dependent on gas and energy imports (#BuildingLife EU Policy WLC Roadmap). An important tool for assessing environmental impacts that is becoming increasingly relevant in the B&C sector is the Life Cycle Assessment (LCA) (Lavagna, M., 2008). The objective of this analysis is to consider "all resources consumed as inputs (raw materials, energy, water) and all pollutants emitted as outputs (emissions to air, water, soil, solid waste)" of a product or service (Lavagna, M., 2022). The assessment must be complete and accurate for all stages of the production and utilization process to avoid "burden shifting" phenomena, i.e., shifting impacts from one stage of the life cycle to another (Lavagna, M., 2022). Integral to this type of assessment, for the promotion of sustainable buildings and the improvement of environmental performance, the European Commission has developed LEVEL(s), a framework that collects indicators for measuring the overall impact of a building. One of the key aspects is that the assessment must be done for the life cycle, that is, considering all stages (from design to demolition) of a building[82]. LEVEL(s) is designed to support those involved in the design and planning of a building by indicating a set of common parameters that assess aspects such as environmental performance, health and well-being, cost and value, potential risks to future performance (Dodd, N., Cordella, M., Traverso, M., & Donatello, S., 2017). LEVEL(s) is organized into 3 levels of analysis depth, which provides users with the ability to choose the degree of complexity and detail of project sustainability communications:

- Level 1: is a basic qualitative assessment indicator for the conceptual design of the building and its performance, with simple indicators such as energy consumption and greenhouse gas emissions;
- Level 2: offers a quantitative and more detailed assessment of performance at the design stage. It includes more indicators such as those for monitoring the management of water and other material resources;
- Level 3: offers a comprehensive and detailed assessment of the performance of the project "as built" and the project "in use", i.e., after completion and delivery to the client. This level includes all indicators for tracking and monitoring activities from construction site to final use.

The framework is designed to ensure a minimum level of comparability between buildings, so that comparisons can be made on the basis of qualitative indicators and indicators, in order to be able to improve the urban structure.

Two interesting examples of how European companies are trying to address the issue of building sustainability are here described. The first is Betolar Plc, founded in 2016 is a Finnish company that offers innovative solutions in Building and Construction. It is the manufacturer of Geoprime, a low-carbon building material that "converts industrial side streams into a cement substitute that performs as concrete but has up to 80% smaller carbon footprint"[83]. This business

[82] https://environment.ec.europa.eu/topics/circular-economy/levels_en
[83] https://www.ellenmacarthurfoundation.org/resources/business/circular-startup-index#BetolarPlc

model is based on a unique product and the recovery of local materials, without the need for large upfront investments and without major changes to facilities compared to companies that produce traditional concrete. As reported on EMF's website, concrete is being substituted for this material, although currently they are unable to cover all demand through side streams. That is why they are at the same time also trying to identify new sustainable materials that they can use in the future.

Cube Factory kft, on the other hand, a Hungarian company founded in 2019, is a startup offering design planning and production of modular buildings. The company uses materials from other supply chains, including agricultural waste and other materials-waste in the surrounding local area, with a maximum distance of 50/100 km[84]. This innovative "CUBE Factory" project involves the production of durable, cost-competitive structures in the market, which are developed by exploiting 3D technologies for design and which reduce the construction time by about 40% (with the possibility of reaching the production of an entire building in about 3 months in the future). Their goal is to create sustainable modular buildings, whether homes, offices or hospitals, using recycled materials that result in the creation of less than 2% waste (also recyclable)[85]. They have also implemented a program to take back the modules they produce, which will be reconnected, reused for other functions or refurbished.

4.2.3 The Italian Building and Construction Industry

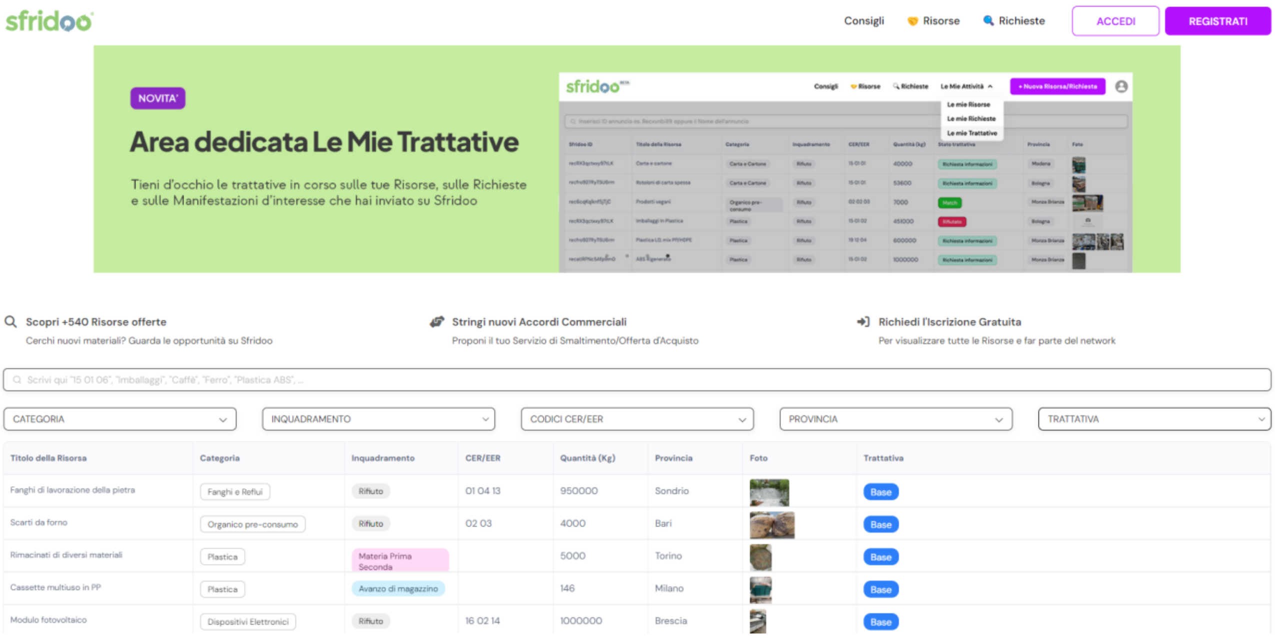
Examples of the application of circular principles in Italy include Sfridoo, a circular network established in 2017 that acts on waste prevention and industrial symbiosis, which has more than 2,500 companies and more than 328 million kilograms available on the site[86].

[84] https://www.ellenmacarthurfoundation.org/resources/business/circular-startup-index#CubeFactorykft).
[85] https://cubemmc.com/en/
[86] https://www.sfridoo.com/

(Figure 57: https://www.sfridoo.com/)

The name of this network (Figure 57 and 58) comes from the Italian technical term “sfrido”, which means “the set of residues or waste that results from the processing of any material, from wood to metals, from marble to paper or textile fibers...”[87]. As told by CEO Marco Battaglia to the online magazine Economiacircolare.com, the idea for this project stems from his father’s (a marble worker) difficulty in dealing with processing waste. Sfridoo is defined as a "matchmaking platform" in which companies can place their waste and valorize it instead of simply disposing of it[88]. In this Italian example of industrial symbiosis, companies have the opportunity to exchange and share production waste, semi-finished products and secondary raw materials to other companies that can use them instead of extracting virgin resources[89]. The platform therefore aims to act as an "intermediary" between companies that do not know how to meet, giving them the opportunity to create business agreements and invest in materials recovery[90]. To explain how the site works with an example, Marco Battaglia says that “a company that manufactures wooden furniture and [...] will have leftovers to dispose of, such as sawdust and lumber, leftover finished goods and unused raw material stocks, and perhaps even machinery that is no longer used. These materials [...] represent a cost to the company, as they must be disposed of"[91]. This is where Sfridoo steps in: through their site and with the help of consultants in the field of environmental laws, they reduce or eliminate costs for these companies by allowing them to make money from the buying and selling of waste[92].

87 Treccani, https://www.treccani.it/vocabolario/sfrido/
88 https://economiacircolare.com/sfrido-economia-circolare-scarti-rifiuti/
89 https://www.sfridoo.com/
90 https://www.ellenmacarthurfoundation.org/resources/business/circular-startup-index#Sfridoo
91 https://economiacircolare.com/sfrido-economia-circolare-scarti-rifiuti/
92 https://www.sfridoo.com/



(Figure 58: https://sfridoo.softr.app/resource)

Two success stories are highlighted for the Building and Construction sector on Sfridoo:

- The first case is that of a company producing extruded polyester goods that was producing 85 tons per year of scrap, with a disposal cost of more than 20000 euros per year[93]. Instead, the site's team of experts managed to find a partnership with another company to sell these materials, with a profit of about 100 euros per ton produced[94].
- The second project is that of a leading Italian company in the area that wanted to integrate a new second raw material into the rubber industry. Therefore, Sfridoo's team of experts was asked to conduct a research, analysis and evaluation of a material in order to determine whether it could be substituted for or integrated into existing products[95]. The result was more than satisfactory, as not only was the company able to incorporate a new recycled material into its production line, but it was also able to replace a product derived from the extraction of raw materials with this circular product, resulting in energy and economic savings and an environmental benefit[96].

An interesting case of applying the circular principles of modularity concerns an Italian company, called precisely Modularee. It deals with the design and construction of eco-sustainable, wood-based, energy-efficient green building structures. The company's goal is to optimize performance and energy savings, ensuring a perfect mix of comfort, design and

[93] https://www.sfridoo.com/casi-studio/guadagno-di-100-euro-su-scarto-in-polistirene-estruso/
[94] https://www.sfridoo.com/casi-studio/guadagno-di-100-euro-su-scarto-in-polistirene-estruso/
[95] https://www.sfridoo.com/casi-studio/integrazione-di-nuova-materia-seconda-settore-gomma/
[96] https://www.sfridoo.com/casi-studio/integrazione-di-nuova-materia-seconda-settore-gomma/

insulation[97]. Buildings are produced through the use of gypsum board for thermal, acoustic and fire insulation, wood panels of different compositions, which make the assembly of the construction extremely quick and clean[98]. The company is not actually completely circular, due for example to the use of adhesives and other fixing methods that need additional processing at the end of the building's lifespan, but it tries to reduce production waste as much as possible. The mission, through the rediscovery of wood as the material of the future for the B&C sector, is to create the right balance between man and nature[99].

One of the most interesting cases from the Veneto region concerns Manni Group, an innovative company from Verona that has been involved in steel processing since it was founded in 1945[100]. It operates in three distinct business areas, namely steel processing, production of insulating metal panels, and also in the renewable energy sector[101]. The real peculiarity of Manni Group, however, is that it offers products and solutions through "off-site" constructions[102], positioning itself not only as an expert in the production of steel buildings and constructions, but also as a promoter of a revolution in the construction industry. Thanks to their know-how and decades of study in the design of their buildings, Manni Group is able to assemble part of their products in-house, then easily manage to finish the installation directly on the final destination (ESG Report, Manni Group, 2023). Manni Group has added a phase, "dissemination", to the production of the buildings in order to make its products scalable and applicable in many areas where actors have the right competences to manage it (Tinazzi, U., 2021), making the final assembly phase easier and providing help and technical expertise to the partner companies within this network of companies. It is one of the "Modern Methods of Construction (MMC)" and involves the reorganization of production processes, leading to faster execution, better precision, lower consumption of water and soil during construction, and easier recycling (Tinazzi, U., 2021). The buildings, in fact, are mostly assembled in the factory thanks to a team of experts in steel fabrication and then it is finished on-site "dry", that is, without the use of adhesives to allow their recovery at the end of their life (ESG Report, Manni Group, 2023).

[97] https://www.modularee.eu/bioedilizia-modularee
[98] https://www.modularee.eu/bioedilizia-modularee
[99] https://www.modularee.eu/metodi-costruttivi
[100] https://mannigroup.com/it/
[101] https://mannigroup.com/it/sostenibilita/
[102] https://report.mannigroup.com/it/report-esg-2024/identita/la-nostra-vision/edilizia-off-site

CONCLUSION

Policy makers, business and academia are paying increasing attention to the concept of Circular Economy. This term is gaining importance over the years as a tool for changing the economic paradigm from a linear, take-make-dispose model to a circular, regenerative one. In addition, consumers' growing awareness of environmental issues and their preference for green products may also be a key driver of change.

During the elaboration of this thesis, the most important steps that have occurred in recent years in defining circular principles have been presented, highlighting how they can be applied in all sectors. Despite the great challenges they face, companies are very interested in this issue because, in addition to a social and environmental benefit, the Circular Economy paves the way for as yet unexplored economic opportunities. In fact, by following a sustainable approach, they are trying to redefine the idea of "waste" by identifying it as a possible new resource. In particular, the Building and Construction sector has enormous potential for improvement. It has a huge impact from the environmental point of view, as it contributes more than any other to the emission of carbon dioxide and the production of construction and demolition waste. In addition, the growing number of the world's population and the predicted phenomena of people moving to cities has directed consideration of the possible changes that can be implemented on both the current building stock and the future building stock. Business models, however, are still very much tied to tradition, in an industry where new production processes and material innovations enter the supply chain but not in a disruptive way, tending in fact to complement and complement linear strategies rather than replace them. The slow pace of change certainly has negative implications, as huge amounts of waste materials are currently produced from the construction and demolition process that cannot be efficiently recovered. At the same time, the state of the construction industry may also have to be viewed in a more optimistic light, as it leaves room for as-yet unexplored opportunities. This is where the economic impact of circular principles comes in, with the definition of new business models focusing on sustainable end-of-life management strategies, off-site manufacturing, modularity and process standardization. If companies can benefit tremendously by applying sustainability principles, why don't they all go circular? What are the main issues blocking the transition to a regenerative model? How can these be overcome? This paper aims to comprehensively answer these questions through an analysis of industry studies. In fact, the concept of Circular Economy in the construction sector has been explored in detail by numerous scientific researches, which comprehensively expose its practices and possible critical issues. These studies are used by policy makers and associations as a basis for creating laws, regulations and guidelines to guide companies toward sustainability. Unfortunately, however, very often the solutions identified remain only theorized, clashing with reality and showing how the strategies proposed are not always implementable in practice. In fact, as seen during the development of the paper, there are still not many real cases of success, and this certainly does not encourage companies to embark on paths of transformation of their business model. In addition, in the case studies reported here, although they set virtuous goals and are in line with national and international sustainability targets, they show how companies struggle with current technological limitations, failing to be fully circular at all stages of the value chain.

In conclusion, the research highlights how the Building and Construction sector is still quite reluctant to changes and very much tied to traditional linear systems, but it also shows how the construction supply chain would **have the potential to change but is still not changing**, where only with an integrated approach and through the promotion of feasible strategies future benefits can be created for companies, upcoming generations and the planet.

BIBLIOGRAPHY

Abdulai, S. F., Nani, G., Taiwo, R., Antwi-Afari, P., Zayed, T., & Sojobi, A. O., 2024. Modelling the relationship between circular economy barriers and drivers for sustainable construction industry. *Building and Environment*, *254*, 111388

Abu-Bakar, H., Charnley, F., Hopkinson, P., & Morasae, E. K., 2023. Towards a typological framework for circular economy roadmaps: A comprehensive analysis of global adoption strategies. *Journal of Cleaner Production*, 140066

Acharya, D., Boyd, R., & Finch, O.,2018. From Principles to Practices: First steps towards a circular built environment. *ARUP, Ellen MacArthur Foundation*.

Accenture, 2014. Circular advantage. Innovative business models and tech-nologies to create value in a world without limits to growth. London,UK: Accenture

Adams, K.T., Osmani, M., Thorpe, T., Thornback, J., 2017. Circular economy in construction: current awareness, challenges and enablers. Proceedings of the Institution of Civil Engineers - Waste and Resource Management 170 (1), 15–24.

Adkins, S., 1999, Cause Related Marketing: Who Cares Wins (Heinemann Butterworth, London).

Akinade, O.O., Oyedele, L.O., Ajayi, S.O., Bilal, M., Alaka, H.A., Owolabi, H.A., Bello, S.A., Jaiyeoba, B.E., Kadiri, K.O., 2017. Design for Deconstruction (DfD): critical success factors for diverting end-of-life waste from landfills. Waste Manag. 60, 3–13.

Akinade, O., Oyedele, L., Oyedele, A., Davila Delgado, J.M., Bilal, M., Akanbi, L., Ajayi, A., Owolabi, H., 2019. Design for deconstruction using a circular economy approach: barriers and strategies for improvement. Prod. Plann. Control 31 (10), 829–840. https://doi.org/10.1080/09537287.2019.1695006.

Al Hosni, I.S., Amoudi, O., Callaghan, N., 2020. An exploratory study on challenges of circular economy in the built environment in Oman. Proc. Inst. Civ. Eng.: Management, Procurement and Law 173 (3), 104–113.

Al-Sayed, A., Al-Shammari, F., Alshutayri, A., Aljojo, N., Aldhahri, E., & Abouola, O., 2022. The smart city-line in Saudi Arabia: issue and challenges. *Postmodern Openings*, *13*(1 Sup1), 15-37

Andrade, J., Araújo, C., Castro, M. F., & Bragança, L., 2019. New methods for sustainable circular buildings. In *IOP Conference Series: Earth and Environmental Science* (Vol. 225, No. 1, p. 012037). IOP Publishing.

Aragon-Correa J A, Cordon-Pozo E, 2005, ``The influence of strategic dimensions and theenvironment on the introduction of internet as innovation into small and medium-sizedenterprises''Technology Analysis and Strategic Management17 205 ^ 21

Archie B. Carroll, 1999, Corporate Social Responsibility: Evolution of a Definitional Construct, BUSINESS & SOCIETY, Vol. 38 No. 3, Sage Publications.

Ayres, R. U. and L. W. Ayres. 1996. Industrial ecology. Towards closingthe material cycle. Cheltenham, UK: Edward Elgar

Augenbroe, G., Pearce, A.R., 1998, Sustainable Construction in the United States of America: a perspective to the year 2010, Georgia Institute of Technology.

Ausiello, G., Compagnone, M., & Sommese, F., 2020. Imitare per costruire: dalla natura alla biomimetica. In *New horizons for sustainable architecture* (pp. 666-679). Edicom Edizioni.

Baden, D.A., Harwood, I.A. and Woodward, D.G., 2009, "The effect of buyer pressure on suppliers in SMEs to demonstrate CSR practices: An added incentive or counterproductive?". European Management Journal, 27, pp. 429-441

Baker-Brown, D., 2021, FutuREuse: How to build a Roadmap-The do's and dont's of reuse in the construction sector, p. 12.

Bakker, C., M. den Hollander, E. van Hinte, and Y. Zijlstra, 2014.Products that last: Product design for circular business models. Delft,the Netherlands: TU Delft Library

Bansal, P., Roth, K., 2000. Why companies go green: a model of ecological responsiveness. Acad. Manag. Rev. 43, 717e736.

Bansal, P., Anna, K.I.M., Wood, M.O., 2018. Hidden in plain sight: the importance of scale in organizations' attention to issues. Acad. Manag. Rev. 43 (2), 217e241 https://doi.org/10.5465/amr.2014.0238.

Benedetti, A., 2021. Le certificazioni ambientali. In *Diritto dell'ambiente* (pp. 207-220). Giappichelli.

Benton, D., Hazell, J. and Hill, J., 2015, “The guide to the circular economy: capturing value and managing material risk”, Do Sustainability, Routledge, London, pp. 15-86

Beyond Foundation – Mainstraming sustainable solutions to cut emissions from the building sector, Global Status Report for Buildings and Construction (Buildings-GSR) https://wedocs.unep.org/bitstream/handle/20.500.11822/45095/global_status_report_buildings_construction_2023.pdf?sequence=3&isAllowed=y

Bianchi, M., Cordella, M., & Menger, P. (2023). Regional monitoring frameworks for the circular economy: implications from a territorial perspective. *European Planning Studies*, *31*(1), 36-54.

Bicket, M., S. Guilcher, M. Hestin, C. Hudson, P. Razzini, A. Tan, P. ten Brink, E. van Dijl, R. Vanner, E. Watkins and S. Withana, 2014, “Scoping study to identify potential circular economy actions, priority sectors, material flows & value chains”, Study prepared for the EU Commission, DG Environment.

Bilal, M., Ahmad Khan, K.I., Thaheem, M.J., Nasir, A.R., 2020. Current state and barriers to the circular economy in the building sector: towards a mitigation framework. J. Clean. Prod. 276, 123250. https://doi.org/10.1016/j.jclepro.2020.123250. (Bilal et al. 2020).

Bocken, N.M.P., de Pauw, I., Bakker, C., van der Grinten, B., 2016. Product design and business model strategies for a circular economy. J. Indust. Prod. Eng. 33, 308–320.

Borghi, G., Pantini, S., Rigamonti, L., 2018. Life cycle assessment of non-hazardous construction and demolition waste (CDW) management in lombardy region (Italy). J. Clean. Prod. 184, 815–825. https://doi.org/10.1016/j.jclepro.2018.02.287

Bowen, H. R., 2013. *Social responsibilities of the businessman*. University of Iowa Press.

Brundtland, G. H., 1987. *Report of the World Commission on environment and development:" Our common future."*. United Nations.

Bradford J, Fraser E D G, 2008, “Local authorities, climate change and small and medium enterprises: identifying effective policy instruments to reduce energy use and carbon emissions” Corporate Social Responsibility and Environment Management15 156 ^ 172

Braungart, M., McDonough, W., 2002, “*Cradle to cradle: Remaking the way we make things*”, New York, North Point Press.

Braungart, M., McDonough, W., Bollinger, A., 2007, *"Cradle-to-cradle design: Creating healthy emissions – a strategy for eco-effective product and system design"*, *Journal of Cleaner Production*, vol. 15, 13-14, pp. 1337–1348.

Bressanelli, G., Adrodegari, F., Perona, M. and Saccani, N., 2018, 'Exploring how usage-focused business models enable circular economy through digital technologies', Sustainability, Vol. 10, No. 3, p.639

Bressanelli, G., Perona, M., Saccani, N., 2019. Assessing the impacts of circular economy: a framework and an application to the washing machine industry. *International Journal of Management and Decision Making*, *18*(3), 282-308.

Bressanelli, G., Saccani, N., Perona, M., & Baccanelli, I. (2020). Towards circular economy in the household appliance industry: An overview of cases. *Resources*, *9*(11), 128.

Canepa, M., 2018. *Riflessioni sullo sviluppo sostenibile in architettura: A trent'anni dal Rapporto Brundtland*. Mimesis, p. 26

Cai, Y. J., & Choi, T. M., 2020. A United Nations' Sustainable Development Goals perspective for sustainable textile and apparel supply chain management. *Transportation Research Part E: Logistics and Transportation Review*, *141*, 102010.

Cambra-Fierro, J., Hart, S. and Polo-Redondo, Y. (2008). "Environmental Respect: Ethics or Simply Business? A Study in the Small and Medium Enterprise (SME) Context". Journal of Business Ethics, 82: pp. 645-656.

Campbell-Johnston, K., ten Cate, J., Elfering-Petrovic, M., Gupta, J., 2019. City level circular transitions: barriers and limits in Amsterdam, Utrecht and the Hague. J. Clean. Prod. 235, 1232–1239. https://doi.org/10.1016/j.jclepro.2019.06.106.

Carro-López D, González-Fonteboa B, Martínez-Abella F, González-Taboada I, De Brito J, Varela-Puga F (2017) Proportioning, microstructure and fresh properties of self-compacting concrete with recycled sand. Procedia Eng 171:645–657

Ceccherini Nelli, L., 2002. Integrazione dei sistemi fotovoltaici negli edifici. In *Costruire sostenibile l'Europa* (pp. 292-301). Alinea.

Cessari, L., Bacigalupo, C., & Gigliarelli, E. (2008). Green conservation, un nuovo approccio scientifico per l'uso di tecnologie sostenibili negli edifici storici. *Technologies exploitation for the cultural heritage advancement*, *10*, 80.

Chandru, P., Karthikeyan, J., & Natarajan, C. (2020). Effect of sustainable materials in fresh properties of self-compacting concrete. *Sustainable materials in building construction*, 1-29

Chini, A.R., 2005 Deconstruction and Materials Reuse - an International Overview, University of Florida, 2005

Commission Decision 2011/753/EU (Annex III), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011D0753

Clinton, L. and R. Whisnant. 2014. Model behavior—20 business modelinnovations for sustainability. London: SustainAbility

Coelho, A., 2013, Conventional demolition versus deconstruction techniques in managing construction and demolition waste (CDW). In *Handbook of recycled concrete and demolition waste* (pp. 141-185). Woodhead Publishing.

Coelho, A., de Brito, J., 2011, Economic analysis of conventional versus selective demolition—A case study. *Resources, conservation and recycling*, *55*(3), 382-392.

COMMISSION OF THE EUROPEAN COMMUNITIES (2001), *Promoting a European Framework for Corporate Social Responsibility, Green Paper*, Bruxelles.

Commissione Europea, LIBRO VERDE Promuovere un quadro europeo per la responsabilità sociale delle imprese, 2001, https://www.europarl.europa.eu/meetdocs/committees/deve/20020122/com(2001)366_it.pdf

Condotta, M., Zatta, E., 2021. Reuse of building elements in the architectural practice and the European regulatory context: inconsistencies and possible improvements. J. Clean. Prod. 318, 128413. https://doi.org/10.1016/j.jclepro.2021.128413, 2021

Costa, L. C. B., Nogueira, M. A., Ferreira, L. C., Elói, F. P. D. F., Carvalho, J. M. F. D., & Peixoto, R. A. F., 2021, Eco-efficient steel slag concretes: an alternative to achieve circular economy. *Revista IBRACON de Estruturas e Materiais*, *15*, e15201, p. 1

Crowther, P. (2005). Design for disassembly–themes and principles. *Environment design guide*, 1-7

D'Alonzo, V., Rizzari, M., Bastos, J., Agosti, E., Hoffmann, C., & Vettorato, D., Strategia per l'Economia Circolare nella Provincia Autonoma di Bolzano - Analisi dello stato dell'arte, 2021

Dalla Valle, A., Atta, N., Ratti, S., & Macrì, L., 2021. Circolarità nel settore delle costruzioni: modelli organizzativi basati sul re-manufacturing (Circularity within the construction sector: organisational models based on re-manufacturing). *Techne*, *22*, 140-148.

Damgaard, A., Lodato, C., Butera, S., Fruergaard Astrup, T., Kamps, M., Corbin, L., Tonini, D., Astrup, T.F., 2022. Background Data Collection and Life Cycle Assessment for Construction and Demolition (CDW) Waste Management. https:// doi.org/10.2760/772724.

Danish Government, 2018. Strategy for Circular Economy - More value and better environment through design, consumption, and recycling. (Issue September). The Danish Government, Ministry of Environment and Food and Ministry of Industry Business and Financial Affairs, Copnehagen, Denmark. ISBN digital: 978-87-93635-91-3. Available at: https://stateofgreen.com/en/uploads/2018/10/Strategy-for-Circular-Economy-1.pdf

de Freitas Netto, S. V., Sobral, M. F. F., Ribeiro, A. R. B., & Soares, G. R. D. L., 2020. Concepts and forms of greenwashing: A systematic review. *Environmental Sciences Europe*, *32*(1), 1-12.

De Marchi, V., Maria, E.D. and Micelli, S., 2013, Environmental Strategies, Upgrading and Competitive Advantage in Global Value Chains. Bus. Strat. Env., 22: 62-72. https://doi.org/10.1002/bse.1738

De Mendonca, M. and T. E., Baxter, 2001. Design for the environment (DFE): An approach to achieve the ISO 14000 international standardization. Environ. Manage. Health, 12: 51-56

Decreto Legge 63/2013, Disposizioni urgenti per il recepimento della Direttiva 2010/31/UE del Parlamento Europeo e del Consiglio del 19 maggio 2010, sulla prestazione energetica nell'edilizia per la definizione delle procedure d'infrazione avviate dalla Commissione Europea, nonché altre disposizioni in materia di coesione sociale. (13G00107) (GU Serie Generale n.130 del 05-06-2013), https://www.gazzettaufficiale.it/eli/id/2013/06/05/13G00107/sg

Delmas M, Burbano V., 2011, The drivers of greenwashing. Calif Manag Rev 54(1):64–87. https://doi.org/10.1525/cmr.2011.54.1.64

Dodd, N., Cordella, M., Traverso, M., & Donatello, S. (2017). Level(s) -Un quadro di riferimento comune dell'UE per i principali indicatori in materia di sostenibilità degli edifici residenziali ea uso ufficio: Parti 1 e 2. *EUR 28899EN, CE, Lussemburgo*

Drake F, Purvis M, Hunt J, 2004, "Meeting the environmental challenge: a case of win - win or lose - win? A study of the UK baking and refrigeration industries" Business Strategy and the Environment 11 324 – 186

Dyskin, A.V., Estrin, Y., Pasternak, E., Khor, H.C., Kanel-Belov, A.J., 2003. Fracture resistant structures based on topological interlocking with non-planar contacts. Adv. Eng. Mater. 5.

Dyskin, A.V., Pasternak, E., Estrin, Y., 2012. Mortarless structures based on topological interlocking. Front. Struct. Civ. Eng. https://doi.org/10.1007/s11709-012-0156-8

Eberhardt, L.C.M., Birkved, M., Birgisdottir, H., 2020. Building design and construction strategies for a circular economy. Architect. Eng. Des. Manag. 18, 93–113.

Eckerth, G., Honker, ¨ T., Kreis, W., 1998. Intelligent disassembly systems for industrial reusing and closed loop economy. IFAC Proc. Vol. 31, 105–110. https://doi.org/ 10.1016/s1474-6670(17) 40265-5.

Elkington, J., 1997, The triple bottom line. *Environmental management: Readings and cases*, *2*, 49-66.

Elkington J., 1998. *Cannibals with forks: the triple bottom line of 21st century business*. New Society.

Ellen MacArthur Foundation, 2012, Towards a Circular Economy – Economic and Business Rationale for an Accelerated Transition, https://www.ellenmacarthurfoundation.org/towards-a-circular-economy-business-rationale-for-an-accelerated-transition

ENEA, OSSERVATORIO DEGLI EDIFICI A ENERGIA QUASI ZERO (NZEB) IN ITALIA 2016-2018 A cura di Ezilda Costanzo

Environmental Protection Encouragement Agency (EPEA) Internationale Umweltforschung GmbH, 2016, Cradle to Cradle Certified™ Product Standard (Version 3.1), document prepared by McDonough Braungart Design Chemistry

Esa, M.R., Halog, A., Rigamonti, L., 2016. Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy. J. Mater. Cycles Waste Manag. 19, 1144–1154. https://doi.org/10.1007/ s10163-016-0516-x.

European Commission, 2014a, "Towards a circular economy: A zero waste programme for Europe", Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2014) 398 final, Brussels.

European Commission, 2014c, "Green Action Plan for SMEs, Enabling SMEs to turn environmental challenges into business opportunities", Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2014) 440 final, Brussels.

European Commission, https://ec.europa.eu/commission/presscorner/detail/en/ip_23_5818 Commission welcomes political agreement on stronger control of exports of waste, 2023

European Commission. Minimizing Regulatory Burden for SMEs. Adapting EU Regulation to the Needs of Mico-Enterprises; COM (2011) 803 Final; European Commission: Brussels, Belgium, 2011.

European Commission, Waste shipments, https://environment.ec.europa.eu/topics/waste-and-recycling/waste-shipments_en

European Commission https://environment.ec.europa.eu/topics/circular-economy/levels_en

European Economic and Social Committee, Circular economy strategies and roadmaps in Europe: Identifying synergies and the potential for cooperation and alliance building, 2015, https://circulareconomy.europa.eu/platform/sites/default/files/qe-01-19-425-en-n.pdf

European Union, Ecodesign Your Future: How Ecodesign can help the environment by making products smarter, 2012

EPBD (2010/31/EU), DIRETTIVA 2010/31/UE DEL PARLAMENTO EUROPEO E DEL CONSIGLIO del 19 maggio 2010 sulla prestazione energetica nell'edilizia

EU SEC (2011) 1067, Analysis associated with the Roadmap to a Resource Efficient Europe, Brussels, 2011.).

Eunomia Research & Consulting, 2011, "Increasing SME Recycling. An examination of the barriers that exist to increasing levels of SME recycling and recommended solutions to these barriers", Summary Report.

FAVOTTO F., BOZZOLAN S., PARBONETTI A., 2016, *"Gli stakeholder e la Responsabilità Sociale", Economia Aziendale: modelli misure e casi*, McGraw Hill Education.

Fisher, R.J., Maltz, E. and Jaworski, B.J. (1997), "Enhancing communication between marketing and engineering: the moderating role of relative functional identification", The Journal of Marketing, Vol. 61 No. 3, pp. 54-70.

Florin, N.; Madden, B.; Sharpe, S.; Benn, S.; Agarwal, R.; Perey, R.; Giurco, D. Shifting Business Models for a Circular Economy: Metals Management for Multi-Product-Use Cycles; UTS: Sydney, Australia, 2015

Frosch, R.A. and N. Gallopoulos (1989), 'Strategies for manufacturing', Scientific American, Vol.261 No.3, pp.144-152, https://www.scientificamerican.com/article/strategies-for-manufacturing/

Gallego-Schmid, A., Chen, H.M., Sharmina, M., Mendoza, J.M.F., 2020. Links between circular economy and climate change mitigation in the built environment. J. Clean. Prod. 260, 121115 https://doi.org/10.1016/j.jclepro.2020.121115.

Ganesan N, Bharati Raj J, Shashikala AP (2013) Flexural fatigue behavior of self compacting rubberized concrete. Constr Build Mater 44:7–14

Geng, Y., Fu, J., Sarkis, J. and Xue, B. (2012), "Towards a national circular economy indicator system in China: an evaluation and critical analysis", Journal of Cleaner Production, Vol. 23 No. 1, pp. 216-224.

Gerasimova, K. (2017). *An Analysis of The Brundtland Commission's Our Common Future*. CRC Press.

Giddings, B., Hopwood, B., O'brien, G. (2002). *Environment, economy and society: fitting them together into sustainable development*. Sustainable development 10(4): 187-196.

Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod. 114, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007.

Ghisellini, P., Ripa, M., Ulgiati, S., 2018. Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector. A literature review. J. Clean. Prod. 178, 618–643. https://doi.org/10.1016/j.jclepro.2017.11.207

Giorgi, S. Progettare la circolarità: strategie e strumenti per l'economia circolare nel settore edilizio. Milano: Franco Angeli, 2024 - 266 p. - Ricerche di tecnologia dell'architettura - Open Access - ISBN: 9788835157731 - Permalink: http://digital.casalini.it/9788835157731 - Casalini id: 5750924

Giovanardi, M., Konstantinou, T., Pollo, R., & Klein, T. (2023). L'Internet of Things per la transizione circolare nel settore delle facciate. *TECHNE: Journal of Technology for Architecture & Environment*, *25*.

Giusti, A. (2006). Le certificazioni ambientali: EMAS. In *I sistemi di certificazione tra qualità e certezza* (pp. 225-236). EGEA.

Global Sustainable Investment Review. Available online: http://www.gsi-alliance.org/wp-content/uploads/2019/03/gsir_ review2018.3.28.pdf (accessed on 08/01/2024).

Goyal, S., Esposito, M., & Kapoor, A. (2018). Circular economy business models in developing economies: lessons from India on reduce, recycle, and reuse paradigms. *Thunderbird International Business Review*, *60*(5), 729-740.

Groppi, F., Zuccaro, C., 2007. Impianti solari fotovoltaici. *Attualitá elettronica*, *9*, 36-39

Grubb, M., Koch, M., Thomson, K., Sullivan, F., & Munson, A. (2019). *The 'Earth Summit 'Agreements: A Guide and Assessment: An Analysis of the Rio '92 UN Conference on Environment and Development* (Vol. 9). Routledge.

Guy, B., Ciarimboli, Nicholas, 2005, Design for Disassembly in the built environment: a guide to closed-loop design and building. https://www.lifecyclebuilding.org/docs/DfDseattle.pdf

Gunningham N, Sinclair D, 2002, "Partnerships, management systems and the search for innovative regulation in the vehicle body shop industry" Business Strategy and the Environment 11 236 ^ 253

Gusmerotti, N. M., Testa, F., Corsini, F., Pretner, G., & Iraldo, F. (2019). Drivers and approaches to the circular economy in manufacturing firms. *Journal of Cleaner Production*, *230*, 314-327.

Jackson, C. and E. Watkins (2012), "EU waste law: the challenge of better compliance", Institute for European Environmental Policy (IEEP).

Hall, J. (2000), "Environmental supply chain dynamics", Journal of Cleaner Production, Vol. 8 No. 6, pp. 455-71

Hart, J.; Adams, K.; Giesekam, J.; Tingley, D.D.; Pomponi, 2019, F. Barriers and drivers in a circular economy: The case of the built environment. Procedia CIRP, 80, 619–624

Hart, S. L., 1995. A natural-resource-based view of the firm. Academy of Management Journal, 37: 986-1014.

Hemingway, C. and P. Maclagan: 2004, 'Managers Personal Values as Drivers of Corporate Social Responsibility', Journal of Business Ethics 50, 33–53.

Hill, J. E., 2015, "The circular economy: from waste to resource stewardship, part I," Proc. Inst. Civ. Eng. - Waste Resour. Manag., vol. 168, no. 1, pp. 3–13.

Hopkinson, P., Chen, H-M, Zhou, K., Wong, Y., Lam, D., "Recovery and Re-Use of Structural Products from End of Life Buildings," Proc. Inst. Civ. Eng. - Eng. Sustain., 2018

Horbach, J., Rennings, K. (2013): Environmental innovation and employment dynamics in different technology fields - an analysis based on the German Community Innovation Survey 2009. Journal of Cleaner Production 57: 158-165.

Hu, J., Xiao, Z., Zhou, R., Deng, W., Wang, M. and Ma, S. (2011), "Ecological utilization of leather tannery waste with circular economy model", Journal of Cleaner Production, Vol. 19 No. 2, pp. 221-228.

Huang, B., Wang, X., Kua, H., Geng, Y., Bleischwitz, R., Ren, J., 2018. Construction and demolition waste management in China through the 3R principle. Resour. Conserv. Recycl. 129, 36–44. https://doi.org/10.1016/j.resconrec.2017.09.029. April 2017.

Kalaitzi, D., Matopoulos, A., Bourlakis, M., Tate, W., 2018. Supply chain strategies in an era of natural resource scarcity. Int. J. Oper. Prod. Manag. 38 (3), 784e809. https://doi.org/10.1108/IJOPM-05-2017-0309

Kanters, J., 2020. Circular building design: an analysis of barriers and drivers for a circular building sector. Buildings 10, 77. https://doi.org/10.3390/ buildings10040077.

Kibert, C.J., 2013Sustainable Construction: Green Building Design and Delivery, third ed., John Wiley & Sons Inc. New Jersey.

King, A.M., Burgess, S.C., Ijomah W. and McMahon C.A. (2006), "Reducing waste: repair, recondition, remanufacture or recycle?", *Sustainable development*, Vol. 14, n. 4, pp. 257-267.

Kiørboe, N., H. Sramkova, and M. Krarup. 2015. Moving towards acircular economy—Successful Nordic business models. Copenhagen:Nordic Council of Ministers

Kirchherr, J.; Reike, D.; Hekkert, M. Conceptualizing the circular economy: An analysis of 114 definitions. Resour. Conserv. Recycl. 2017, 127, 221–232.

Kirchherr, J., Reike, D., & Hekkert, M., 2017. Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, conservation and recycling*, *127*, 221-232.

Kirchoff, J. F., Koch, C., & Satinover Nichols, B. (2011). Stakeholder perceptions of green marketing: the effect of demand and supply integration. *International Journal of Physical Distribution & Logistics Management*, *41*(7), 684-696.

Krausmann, F.; Schandl, H.; Eisenmenger, N.; Giljum, S.; Jackson, T. Material Flow Accounting: Measuring Global Material Use for Sustainable Development. *Annu. Rev. Environ. Resour.* 2017, 42, 647–675

Kuczenski, R., Zink, T., Henderson, A., 2016. Common misconception about recycling. Journal of Industrial Ecology, 20(5), 1010–1017.

Kumar, V., Sezersan, I., Garza-Reyes, J. A., Gonzalez, E. D., & Al-Shboul, M. D. A. (2019). Circular economy in the manufacturing sector: benefits, opportunities and barriers. *Management Decision*, *57*(4), 1067-1086.

Kurt M, Gül MS, Gül R, Aydin AC, Kotan T (2016) The effect of pumice powder on the self-compactability of pumice aggregate lightweight concrete. Constr Build Mater 103

Il Sole 24 Ore, 2024, available at: https://www.ilsole24ore.com/art/case-edifici-sostenibili-ottengono-affitti-piu-alti-77percento-e-periodi-locazione-piu-lunghi-17percento-AGslTy

Ivan Henderson V. Gue, Michael Angelo B. Promentilla, Raymond R. Tan, Aristotle T. Ubando, Sector perception of circular economy driver interrelationships, Journal of Cleaner Production,Volume 276,

Jaillon, L., Poon, C.S., 2014. Life cycle design and prefabrication in buildings: a review and case studies in Hong Kong. Autom. ConStruct. 39, 195–202. https://doi.org/10.1016/j.autcon.2013.09.006.

L'agenda globale per lo sviluppo sostenibile, Quinta edizione, n. 89, Novembre 2020, Camera dei deputati, https://www.corsi.univr.it/documenti/IscrizCS/avvisi/avvisi552062.pdf

Lal, R., 2016. Beyond COP 21: potential and challenges of the "4 per Thousand" initiative. Journal of Soil and Water Conservation, 71(1), 20A-25A).

Lacy, P., Rutqvist, J., & Lamonica, B. (2016). *Circular economy: Dallo spreco al valore*. EGEA spa.

Lambert, D. M. and Cooper, M. C., 2000. Issues in supply chain management. Ind. Market. Manage., 29: 65-83

Lavagna, M., 2008. Life Cycle Assessment in construction. Designing and building from an environmental sustainability perspective. Hoepli

Lavagna, M. (2022). LCA in edilizia. Ambiti applicativi e orientamenti futuri della metodologia Life Cycle Assessment nel settore edilizio. *POLITECNICA*., p. 13

Lavagna, M., Giorgi, S., Pimponi, D., & Porcari, A. (2023). Tecnologie abilitanti per l'economia circolare nel settore edilizio. *Techne*, *25*, 214-224.

Lewandowski, M. 2016. Designing the business models for circular economy - Towards the conceptual framework. Sustainability8(1): 43.

Lee, S. Y. (2008). Drivers for the participation of small and medium-sized suppliers in green supply chain initiatives. *Supply chain management: an international journal*, *13*(3), 185-198.

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of cleaner production*, *115*, 36-51.

Liu, Y. and Bai, Y. (2014), "An exploration of firms' awareness and behavior of developing circular economy: An empirical research in China", Resources, Conservation and Recycling, Vol. 87, pp. 145-152.

Llatas, C., Osmani, M. (2016). Development and validation of a building design waste reduction model. *Waste management*, *56*, 318-336. ring). *Techne*, *22*, 140-148.

Lüdeke-Freund, F., Gold, S., & Bocken, N. M. (2019). A review and typology of circular economy business model patterns. *Journal of Industrial Ecology*, *23*(1), 36-61

Lülfs, R., Hahn, R., 2013. Corporate greening beyond formal programs, initiatives, and systems: a conceptual model for voluntary pro-environmental behavior of employees. Eur. Manag. Rev. 10 (2), 83e98. https://doi.org/10.1111/emre.12008

Luo, X. and Bhattacharya, C.B. (2006), "Corporate social responsibility, customer satisfaction, and market value", Journal of Marketing, Vol. 70 No. 40, pp. 1-18.

Luthra, S., Sharma, M., Kumar, A., Joshi, S., Collins, E., & Mangla, S. (2022). Overcoming barriers to cross-sector collaboration in circular supply chain management: a multi-method approach. *Transportation Research Part E: Logistics and Transportation Review*, *157*, 102582.

Lützkendorf, T. Sustainability in Building Construction—A Multilevel Approach. In *Proceedings of the IOP Conference Series: Earth and Environmental Science*; Institute of Physics Publishing: Prague, Czech Republic, 2019; Volume 290

MacArthur, E., 2015. Towards a circular economy: business rationale for an accelerated transition. *Greener Manag International*, *20*, p. 3.

MacArthur, E., Zumwinkel, K., & Stuchtey, M. R. (2015). Growth within: a circular economy vision for a competitive Europe. *Ellen MacArthur Foundation*.

Mahpour, A., 2018. Prioritizing barriers to adopt circular economy in construction and demolition waste management, Resources. Conserv. Recycl. 134 (2018), 216–227.

Meqdadi, O.; Johnsenb, T.; Johnsenc, R. The Role of SME Suppliers in Implementing Sustainability. In Proceedings of the IPSERA 2012 Conference, Napoli, Italy, 1–4 April 2012.

Maerckx, A.-L., D'Otreppe, Y., Scherrier, N., 2019. Building circular in Brussels: an overview through 14 inspiring projects. IOP Conf. Ser. Earth Environ. Sci. 225 (1), 012059 https://doi.org/10.1088/1755-1315/225/1/012059. IOP Publishing

Migliore, M., Talamo, C., Paganin, G. (2020). *Strategies for Circular Economy and Cross-sectoral Exchanges for Sustainable Building Products*. Springer International Publishing.

Milios, L., Advancing to a Circular Economy: three essential ingredients for a comprehensive policy mix, Sustain. Sci. 13 (3) (May 01, 2018) 861–878, https:// doi.org/10.1007/s11625-017-0502-9. Springer Tokyo.

Minunno, R.; O'Grady, T.; Morrison, G.; Gruner, R.; Colling, M., 2018, Strategies for Applying the Circular Economy to Prefabricated Buildings. Buildings, 8, 125

Minunno, R., O'Grady, T., Morrison, G. M., Gruner, R. L., 2020. Exploring environmental benefits of reuse and recycle practices: A circular economy case study of a modular building. Resources, Conservation and Recycling, 160, 104855, p. 1.

Ministero dell'Ambiente, (2017). Verso un modello di economia circolare per l'Italia. *Documento di inquadramento e di posizionamento strategico*.

Mir D F, 2008,``Environmental behaviour in Chicago automotive repair micro-enterprises (MEPs)''Business Strategy and the Environment17194 ^ 207

Mont, O. (2008) 'Innovative approaches to optimising design and use of durable consumer goods', International Journal of Product Development, Vol. 6, Nos. 3/4, p.227

Mohammadiziazi, R., & Bilec, M. M. (2022). Building material stock analysis is critical for effective circular economy strategies: a comprehensive review. *Environmental Research: Infrastructure and Sustainability*, *2*(3), 032001.

Montini, M. (2001). L'ambiente nel diritto internazionale. *AA. VV. Manuale di diritto ambientale,* a cura di L. Mezzetti, CEDAM, Padova.

Nespor, S. (2016). La lunga marcia per un accordo globale sul clima: dal Protocollo di Kyoto all'Accordo di Parigi. *Rivista trimestrale di diritto pubblico*, *1*, 81-121.

Newman, P., and Kenworthy, J. (1999) Sustainability and Cities: Overcoming Automobile Dependence, Island Press, Washington, DC.

Nordby, A.S., 2019. Barriers and Opportunities to Reuse of Building Materials in the Norwegian Construction Sector. IOP Conference Series: Earth and Environmental Science, Brussels, 012061. https://doi.org/10.1088/1755-1315/225/1/012061, 225, IOP Publishing.

Nußholz, J.L.K., 2018. A circular business model mapping tool for creating value from prolonged product lifetime and closed material loops. J. Clean. Prod. 197 (1), 185e194. https://doi.org/10.1016/j.jclepro.2018.06.112

Nußholz, J.L.K., Rasmussen, F.N., Milios, L., 2019. Circular building materials: carbon saving potential and the role of business model innovation and public policy. Resour. Conserv. Recycl. 141, 308–316. https://doi.org/10.1016/j.resconrec.2018.10.036.

Nußholz, J. L., Rasmussen, F. N., Whalen, K., & Plepys, A. (2020). Material reuse in buildings: Implications of a circular business model for sustainable value creation. *Journal of Cleaner Production*, *245*, 118546.

Osello, A. (2012). Il futuro del disegno con il BIM per ingegneri e architetti, The future of Drawing with BIM for Engineers and Architects. *Palermo, Italy: D. Flaccovio*.

Paiho, S., Maki, E., Wessberg, N., Paavola, M., Tuominen, P., Antikainen, M., Heikkila, ¨ J., Antuna, ˜ C., Jung, N., 2020. Towards circular cities — Conceptualizing core aspects. Sustain. Cities Soc. 59, 102143 https://doi.org/10.1016/j.scs.2020.102143. September 2019.

Parchomenko, A., Nelen, D., Gillabel, J., Rechberger, H., 2019. Measuring the circular economy - a multiple correspondence analysis of 63 metrics. J. Clean. Prod. 210, 200–216. https://doi.org/10.1016/j.jclepro.2018.10.357.

Parker, C. M., Redmond, J., & Simpson, M., 2009. A review of interventions to encourage SMEs to make environmental improvements. *Environment and planning C: Government and policy*, *27*(2), 279-301.

Parrish, B.D. (2010). *Sustainability-driven entrepreneurship: Principles of organization design*. Journal of Business Venturing. Vol. 25, pp. 510-523.

Paszkowska-Kaczmarek, N. E. (2021). –The Saudi-Arabian Linear City Concept as the Prototype of Future Cities. *Architecturae et Artibus*, *13*(2), 33-46.

Pfeiffer, F., Rennings, K. (2001): Employment impacts of cleaner production – evidence from a German study using case studies and surveys. Business Strategy and the Environment 10 (3): 161-175.

Phaal, R., 2004. Technology roadmapping - a planning framework for evolution and revolution. Technol. Forecast. Soc. Change 71, 5–26. https://doi.org/10.1016/ S0040-1625(03)00072-6.

Pineschi L., Tutela dell'ambiente e assistenza allo sviluppo dalla Conferenza di Stoccolma (1972) alla Conferenza di Rio (1992), Riv. Giur. Amb., 1993.

Pomponi, F., & Moncaster, A. (2017). Circular economy for the built environment: A research framework. *Journal of cleaner production*, *143*, 710-718.

Potting, J., Hekkert, M., Worrell, E., Hanemaaijer, A., 2017. Circular Economy: Measuring Innovation in the Product Chain. Available at. http://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2016- circular-economy-measuring-innovation-in-product-chains-2544.pdf

Raimondo, L., Mutani, G., & Massaia, C. (2014). La procedura di certificazione della prestazione energetica: dal sopralluogo all'APE, Politecnico di Torino.

Renewable Energy Agency, 2018. Global Energy Transformation: A Roadmap to 2050. Rescher, N., 2003. Epistemology: an Introduction to the Theory of Knowledge. State University of New York.

Revell A, Blackburn R A, 2007, "The business case for sustainability? An examination of small firms in the UK's construction and restaurant sectors" Business Strategy and the Environment16 404 ^ 420

Rios, F. C., Chong, W. K., & Grau, D. (2015). Design for disassembly and deconstruction-challenges and opportunities. *Procedia engineering*, *118*, 1296-1304.

Rizos, V., Behrens, A., Kafyeke, T., Hirschnitz-Garbera, M., Ioannou, A., 2015. The Circular Economy: Barriers and Opportunities for SMEs.

Rizos, V., Behrens, A., Van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., ... & Topi, C. (2016). Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers. Sustainability, 8(11), 1212.

Roberts, M., Allen, S., Clarke, J., Searle, J., & Coley, D. (2023). Understanding the global warming potential of circular design strategies: Life cycle assessment of a design-for-disassembly building. *Sustainable Production and Consumption*, *37*, 331-343

Rogers, D. and Tibben-Lembke, R. S., 1999. Going Backwords: Reverse Logistics Trends and Practices. Reverse Logistics Executive Council, Pittsburgh, PA.

Roy M-J, Therin F, 2008, ``Knowledge acquisition and environmental commitment in SMEs"Corporate Social Responsibility and Environment Management15 249 ^ 259

Sansom, M., Avery, N., 2014. Briefing: reuse and recycling rates of UK steel demolition arisings. Proc. Inst. Civil Eng., Eng. Sustain. 167, 89–94.

Sarkis, J.; Helms, M.M.; Hervani, A.A. Reverse logistics and social sustainability. Corp. Soc. Resp. Environ. Manag. **2010**, 17, 337–354.

Sariatli, F. (2017). Linear economy versus circular economy: a comparative and analyzer study for optimization of economy for sustainability. *Visegrad Journal on Bioeconomy and Sustainable Development*, *6*(1), 31-34.

Schenkel, M., M. C. J. Cani¨els, H. Krikke, and E. Van Der Laan. 2015.Understanding value creation in closed loop supply chains—Pastfindings and future directions. Journal of Manufacturing Systems37(3): 729–745

Schlange, L. E. (2006). *What drives sustainable entrepreneurs? Applied business and entrepreneurship association international*. Chur Editions.

Selman, A.D., Gade, A.N., 2020. Barriers of incorporating circular economy in building design in a Danish context. In: S, L., Neilson, C.J. (Eds.), ARCOM 2020 36th Annual Conference 2020 (Issue September 7-8. ARCOM, pp. 665–674.

Sihvonen, S., Ritola, T., 2015. Conceptualizing ReX for aggregating end-of-life strategies in product development. Proc. CIRP 29, 639–644.

Simpson M, Taylor N, Barker K, 2004, ``Environmental responsibility in SMEs: does it delivercompetitive advantage?"Business Strategy and the Environment13 156 ^ 171

Sillanpaa, M., & Ncibi, C. (2019). *The circular economy: Case studies about the transition from the linear economy*. Academic Press, p. 7, URL: https://books.google.it/books?hl=it&lr=&id=WRGnDwAAQBAJ&oi=fnd&pg=PP1&dq=line

ar+economy&ots=qg9m6fch_y&sig=s4J_c59yK58A_OZHZYO0CXMgH_k#v=onepage&q=linear%20economy&f=false

Silva, M.F., Jayasinghe, L.B., Waldmann, D., Hertweck, F., 2020. Recyclable architecture: prefabricated and recyclable typologies. Sustain. 12. https://doi.org/10.3390/ su12041342

Singh G, Siddique R (2016) Effect of iron slag as partial replacement of fine aggregates on the durability characteristics of self-compacting concrete. Constr Build Mater 128:88–95

Spilhaus, A. (1966), 'Resourceful Waste Management', Science News, Vol. 89, No. 25 (June 18), pp. 486- 498, https://www.jstor.org/stable/pdf/3950241.pdf?refreqid=excelsior%3Ae34f7b126ddfbaa3a2243d304e104c50

Springvloed, P. (2021). *The drivers and barriers for a circular economy in the built environment of the Netherlands* (Master's thesis)

Stern, P.C., Dietz, T., Abel, T., Guagnano, G.A., Kalof, L., 1999. A value-belief-norm theory of support for social movements: the case of environmentalism. Hum. Ecol. Rev. 5 (5), 713e722. https://doi.org/10.2307/2083693.

Su, B., Heshmati, A., Geng, Y. and Yu, X. (2013), "A review of the circular economy in China: moving from rhetoric to implementation", Journal of Cleaner Production, Vol. 42, pp. 215-227

Sung, K, (2015). A review on upcycling: Current body of literature, knowledge gaps and a way forward.

TerraChoice (2010) The sins of greenwashing: home and family edition. http://sinsofgreenwashing.org/fndings/the-seven-sins/. Accessed 15 June 2018

Testa, F., Gusmerotti, N.M., Corsini, F., Passetti, E., Iraldo, F., 2016a. Factors affecting environmental management by small and micro firms: the importance of entrepreneurs' attitudes and environmental investment. Corp. Soc. Responsib. Environ. Manag. 23 (6), 373e385. https://doi.org/10.1002/csr.1382

Tinazzi, U. (2021). Dissemination and Cultural Change as an Alternative Business Value Proposition in the Construction Industry: Manni Group Case Study. *Journal of Creating Value*, *7*(2), 183-188.

Tirado, R., Aublet, A., Laurenceau, S., & Habert, G. (2022). Challenges and opportunities for circular economy promotion in the building sector. *Sustainability*, *14*(3), 1569

Todorov, V., & Marinova, D. (2009). *Models of sustainability*. In: Proceedings of MODSIM 2009 International Congress on Modelling and Simulation. The Modelling and Simulation Society of Australia and New Zealand.

Van Acker, V.; van Wee, B.; Witlox, F. When transport geography meets social psychology: Toward a conceptual model of travel behavior. Transp. Rev. 2010, 30, 219-240.

Van Buren, N.; Demmers, M.; van der Heijden, R., Witlox, F. Towards a Circular Economy: The Role of Dutch Logistics Industries and Governments. Sustainability **2016**, 8, 647.

Van Stijn, A., Jansen, B. W., Gruis, V., & Van Bortel, G. A. (2023). Towards implementation of circular building components: A longitudinal study on the stakeholder choices in the development of 8 circular building components. *Journal of Cleaner Production*, *420*, 138287.

Vanner, R.; Bicket, M.; Withana, S.; ten Brink, P.; Razzini, P.; van Dijl, E.; Watkins, E.; Hestin, M.; Tan, A.; Guilcher, S.; Hudson, C. Scoping Study to Identify Potential Circular Economy Actions, Priority Sectors, Material Flows & Value Chain; European Commission: Luxembourg, 2014.

Wackernagel, M., & Rees, W. (1998). *Our ecological footprint: reducing human impact on the earth* (Vol. 9). New society publishers.

Walker E A, Brown A, 2004, ``What success factors are important to small business owners?'' International Small Business Journal22 577 ^ 594

Walley E E, Taylor D W, 2002, ``Opportunists, champions, mavericks ...? A typology of green entrepreneurs'' Greener Management International38 31 ^ 43

Wiedmann, T., & Minx, J. (2008). A definition of 'carbon footprint'. Ecological economics research trends, 1(2008), 1-11.

Williams, R., Artola, I., Beznea, A., Nicholls, G., 2020. Emerging Challenges of Waste Management in Europe: Limits of Recycling. Trinomics.

Wilts, H.; von Gries, N.; Bahn-Walkowiak, B. FromWaste Management to Resource Efficiency—The Need for Policy Mixes. Sustainability **2016**, 8, 622.

Witjes, S.; Lozano, R., 2016, Towards a more Circular Economy: Proposing a framework linking sustainable public procurement and sustainable business models. *Resour. Conserv. Recycl. 112*, 37–44.

Wooi, G. and Zailani, S. (2010). “Green Supply Chain Initiatives: Investigation on the Barriers in the Context of SMEs in Malaysia”. International Business Management, 4 (1), pp. 20-27.

Xing, X., Wang, Y.D., Wang, J.Z., 2011. The problems and strategies of the low carbon economy development. Energy Procedia 5, 1831e1836

Yan, J., Wu, N., 2011. Technology supporting system of circular economy of mining cities. In: 2011 Asia-Pacific Power and Energy Engineering Conference. IEEE. pp. 1–5.

Yang, Z., Sun, J., Zhang, Y. *et al.* Synergy between green supply chain management and green information systems on corporate sustainability: an informal alignment perspective. *Environ Dev Sustain* **22**, 1165–1186 (2020). https://doi.org/10.1007/s10668-018-0241-9

Yang S, Yue X, Liu X, Tong Y (2015) Properties of self-compacting lightweight concrete containing recycled plastic particles. Constr Build Mater 84:444–453

Yuan, Z., Bi, J. and Moriguichi, Y. (2006), “The circular economy: a new development strategy in China”, Journal of Industrial Ecology, Vol. 10 Nos 1‐2, pp. 4-8

Zhu, L., Zhou, J., Cui, Z., & Liu, L. (2010). A method for controlling enterprises access to an eco-industrial park. *Science of the Total Environment*, *408*(20), 4817-4825.

Zhu, Q., J. Sarkis, K.-h. Lai and Y. Geng (2008), “The role of organizational size in the adoption of green supply chain management practices in China”, *Corporate Social Responsibility and Environmental Management*, Vol. 15, No. 6, pp. 322–337.

Zhuang, G. L., Shih, S. G., & Wagiri, F. (2023). Circular economy and sustainable development goals: Exploring the potentials of reusable modular components in circular economy business model. Journal of Cleaner Production, 414, 137503.

Zimmann, R., O’Brien, H, Hargrave, J, Morrell, M “The Circular Economy in the Built Environment”, 2016

SITOGRAPHY

A Year of Business as a Force for Good: 2019 in Review. Available online: https://bthechange.com/a-year-of-business-as-aforce-for-good-2019-in-review-8e744ed4d620 (accessed on 05/01/2024)

Annual share of global CO_2 emissions, *Our World in Data*. https://ourworldindata.org/grapher/annual-share-of-co2-emissions [Accessed 15th May 2023]

https://www.who.int/news-room/fact-sheets/detail/millennium-development-goals-(mdgs)

B Corp https://www.bcorporation.net/en-us/

B Corp Spain. Available online: https://www.bcorpspain.es/ (accessed on 08/01/2024).

B Lab Spain—Memoria Anual 2018. Available online: https://issuu.com/bcorpspain/docs/memoria_anaul_b_lab_spain_2018 (accessed on 07/01/2024).

BibLus – Informazione e approfondimento tecnico per i professionisti dell'edilizia, https://biblus.acca.it/protocollo-itaca-cosa-serve-e-come-si-usa-nei-cam/

Bloomberg News, https://www.bloomberg.com/news/articles/2024-04-05/saudis-scale-back-ambition-for-1-5-trillion-desert-project-neom

BMIPlus, 2023 - https://www.bimplus.co.uk/introducing-design-for-disassembly/#:~:text=To%20design%20for%20disassembly%20is,end%20of%20its%20useful%20life

#BuildingLife EU Policy WLC Roadmap, p. 12, https://viewer.ipaper.io/worldgbc/eu-roadmap/?page=12

Cefis, https://www.cefis.mi.it/pallet-in-legno-funzione-caratteristiche/

CGR – Circularity Gap Report, https://www.circularity-gap.world/global

Edilportale, I vantaggi dell'IoT nell'ambito dell'edilizia, 2023, https://www.edilportale.com/news/2023/09/aziende/i-vantaggi-dell-iot-nell-ambito-dell-edilizia_95483_5.html

Corriere della Sera, https://www.corriere.it/tecnologia/cards/the-line-la-smart-city-per-9-milioni-di-persone-che-nascera-in-arabia-saudita-le-prime-immagini-del-progetto/i-costi-di-the-line.shtml#:~:text=I%20costi%20di%20The%20Line&text=Il%20principe%20Principe%20Mohammed%20bin,cifre%20che%20continuavano%20a%20salire

Council of the European Union, Fit for 55 https://www.consilium.europa.eu/it/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/

EconomiaCircolare.com, 2023, https://economiacircolare.com/edilizia-economia-circolare-tecnologie-digitali-sostenibilita/

Edilportale, I vantaggi dell'IoT nell'ambito dell'edilizia, 2023, https://www.edilportale.com/news/2023/09/aziende/i-vantaggi-dell-iot-nell-ambito-dell-edilizia_95483_5.html

Ellen MacArthur Foundation https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

Ellen MacArthur Foundation https://ellenmacarthurfoundation.org/what-is-the-linear-economy#:~:text=The%20linear%20economy%20linear%20economy,extracted%20to%20make%20products%20that

ESAengeneering, https://esa-engineering.it/servizi/sostenibilita/certificazioni-di-sostenibilita/certificazione-breeam/

ESG Report, Manni Group, 2023, https://report.mannigroup.com/yep-repository/mannireport/media/IT_MANNI_REPORT23_PEOPLE-compressed.pdf

European Commission, The European Green Deal, 2019, https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF

European Commission, European Green Deal, https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_it

European Commission, European Green Deal, Delivering the European Green Deal, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_it

European Commission, Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste and Repealing Certain Directives, 2008. Available at. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32008L0098

European Parliament News, EU climate law: MEPs want to increase emission reductions target to 60% by 2030, **Press Releases** 11-09-2020 - 12:16, https://www.europarl.europa.eu/news/en/press-room/20200907IPR86512/eu-climate-law-meps-want-to-increase-emission-reductions-target-to-60-by-2030

European Union, Sustainable Development Goals, 2015, https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

European-Union Eurostat by Statistical Office of the European Union. Available online: https://ec.europa.eu/eurostat/data/database

GBC Italia – Economia circolare in edilizia, https://gbcitalia.org/wp-content/uploads/2023/01/2019_GBC-PP-Ec.-Circ.-Rev2.pdfù

Gyproc – Protocolli ambientali, https://www.gyproc.it/Sostenibilit%C3%A0/Protocolli-ambientali/Breeam

Infobuild – Il portale per l'edilizia e l'architettura, La stampa 3D per l'economia circolare, https://www.infobuild.it/approfondimenti/stampa-3d-economia-circolare/

Intimissimi, Sustainability Projects, https://www.intimissimi.com/it/donna/sostenibilita/int_woman_lp_projects_it-it/

L'ECONOMIA CIRCOLARE APPLICATA ALL'EDILIZIA, ARM Process, https://www.armprocess.com/2022/09/02/leconomia-circolare-applicata-alledilizia/

LEED certification of a building, https://www.certificazioneleed.com/edifici/

Millennium Development Goals Report, 2015, UNDP https://www.un.org/millenniumgoals/2015_MDG_Report/pdf/MDG%202015%20rev%20(July%201).pdf

Parlamento Europeo, 2015 - https://www.europarl.europa.eu/news/it/headlines/economy/20151201STO05603/economia-circolare-definizione-importanza-e-vantaggi

Programma delle Nazioni Unite per l'ambiente https://www.unep.org/geo/

Status of proposals as of May 2023, Source: European Commission, Fit for 55: Delivering on the proposals, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal/fit-55-delivering-proposals_en)

"Strategia Nazionale per l'Economia Circolare" (Ministero della Transizione Ecologica [MITE] – June 2022, https://www.mase.gov.it/sites/default/files/archivio/allegati/PNRR/SEC_21.06.22.pdf

Swiss Life Group What is the Lifespan of a House? Available online: https://www.swisslife.com/en/home/hub/what-is-the-lifespan-of-a-house.html

The Guardian, 2019, https://www.theguardian.com/cities/2019/feb/25/concrete-the-most-destructive-material-on-earth

Treccani, https://www.treccani.it/vocabolario/sfrido/

United Nations Climate Action, Marking the Kyoto Protocol's 25th anniversary, https://www.un.org/en/climatechange/marking-kyoto-protocol%E2%80%99s-25th-anniversary

United Nations Climate Change, What is the Kyoto Protocol? https://unfccc.int/kyoto_protocol

United Nations, United Nations Conference on Environment and Development (UNCED), Sustainable Development Goals Knowledge Platform, Agenda 21 UNCED 1992, https://sustainabledevelopment.un.org/outcomedocuments/agenda21

United Nations, Declaration On The Human Environment, The United Nations Conference on the Human Environment, 1972, available at: https://documents-dds-ny.un.org/doc/UNDOC/GEN/NL7/300/05/PDF/NL730005.pdf?OpenElement

United Nations, Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1998. Available at: https://unfccc.int/resource/docs/convkp/kpeng.pdf [Accessed 28th June 2023].

United Nations Treaty Collection, Kyoto Protocol to the United Nations Framework Convention on Climate Change, *Treaty Series*, vol 2303, 1997, https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-7-a&chapter=27&clang=_en [Accessed 27th June 2023]

United Nation, Sustainable Development Goals Report, 2023, https://sdgs.un.org/sites/default/files/2023-04/SDG_Progress_Report_Special_Edition_2023_ADVANCE_UNEDITED_VERSION.pdf

https://www.mdgmonitor.org/millennium-development-goals/

https://dashboards.sdgindex.org/rankings https://dashboards.sdgindex.org/profiles/italy

https://sdgs.un.org/2030agenda

https://unric.org/it/agenda-2030/

https://sdgs.un.org/goals

https://www.oecd.org/wise/measuring-distance-to-the-SDG-targets-country-profile-Italy.pdf

https://unarmeniainterns.files.wordpress.com/2015/07/powerpoint-mdg.pdf

https://www.overshootday.org/newsroom/country-overshoot-days/

https://data.footprintnetwork.org/#/

https://emf.thirdlight.com/link/7kvazph93afk-owveai/@/preview/1?o

https://www.overshootday.org/

https://www.footprintnetwork.org/

https://www.footprintnetwork.org/our-work/ecological-footprint/

https://ec.europa.eu/economy_finance/recovery-and-resilience-scoreboard/index.html

https://www.mef.gov.it/en/focus/The-National-Recovery-and-Resilience-Plan-NRRP/

https://www.europarl.europa.eu/EPRS/EPRS-Briefing-573936-Circular-economy-package-FINAL.pdf.

https://www.consilium.europa.eu/it/policies/green-deal/#initiatives

https://commission.europa.eu/strategy-and-policy/recovery-plan-europe_en

https://commission.europa.eu/strategy-and-policy/recovery-plan-europe_en

https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility_it

https://www.agenziacoesione.gov.it/dossier_tematici/nextgenerationeu-e-pnrr/

https://www.agenziacoesione.gov.it/dossier_tematici/nextgenerationeu-e-pnrr/

https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility_it

https://commission.europa.eu/strategy-and-policy/recovery-plan-europe_en https://www.europarl.europa.eu/EPRS/EPRS-Briefing-573936-Circular-economy-package-FINAL.pdf

https://cordis.europa.eu/article/id/413173-where-the-circular-economy-and-the-internet-of-things-meet/it

https://www.infobuildenergia.it/approfondimenti/sostenibilita-negli-edifici-classificarla-con-i-modelli-di-certificazione/

https://biblus.acca.it/protocollo-itaca-cosa-serve-e-come-si-usa-nei-cam/

https://www.infobuildenergia.it/approfondimenti/sostenibilita-negli-edifici-classificarla-con-i-modelli-di-certificazione/

https://www.ellenmacarthurfoundation.org/resources/business/circular-startup-index#Plantaer

https://www.plantaer.com/

https://www.nature.com/articles/d41586-020-03548-y

https://www.ellenmacarthurfoundation.org/resources/business/circular-startup-index#Plantaer

https://www.widuz.com/

https://www.ellenmacarthurfoundation.org/resources/business/circular-startup-index#Widuz

https://www.ellenmacarthurfoundation.org/resources/business/circular-startup-index#Widuz

https://www.infobuildenergia.it/the-line-arabia-saudita-citta-verticale-rinnovabili/#:~:text=The%20Line%20%C3%A8%20the%20first,by%20two%20minutes%20of%20distance

https://www.infobuild.it/the-line-citta-futuro-arabia-saudita/

https://www.infobuild.it/the-line-citta-futuro-arabia-saudita/

https://www.ecologica.online/2023/05/05/the-line-arabia-saudita/

https://futuranetwork.eu/citta-e-urbanistica/691-4999/larabia-saudita-sta-costruendo-la-piu-avanzata-citta-del-futuro-ma-con-forti-costi-umani

https://www.spotynews.com/la-citta-lineare-dellarabia-saudita-the-line-potrebbe-essere-migliorata-facendola-diventare-the-circle/

https://www.digitec.ch/it/page/la-linea-perche-lambiziosa-citta-del-futuro-dellarabia-saudita-non-e-lideale-29510 https://www.focus.it/tecnologia/innovazione/the-line-citta-futuristica-arabia-saudita-inferno-o-paradiso

https://futuranetwork.eu/citta-e-urbanistica/691-4999/larabia-saudita-sta-costruendo-la-piu-avanzata-citta-del-futuro-ma-con-forti-costi-umani

https://environment.ec.europa.eu/topics/waste-and-recycling/construction-and-demolition-waste_en?prefLang=it&etrans=it

https://single-market-economy.ec.europa.eu/news/eu-construction-and-demolition-waste-protocol-2018-09-18_en

https://single-market-economy.ec.europa.eu/news/eu-construction-and-demolition-waste-protocol-2018-09-18_en

https://environment.ec.europa.eu/topics/circular-economy/levels_en

https://www.ellenmacarthurfoundation.org/resources/business/circular-startup-index#BetolarPlc

https://www.ellenmacarthurfoundation.org/resources/business/circular-startup-index#CubeFactorykft

https://cubemmc.com/en/

https://www.sfridoo.com/

https://economiacircolare.com/sfrido-economia-circolare-scarti-rifiuti/

https://www.ellenmacarthurfoundation.org/resources/business/circular-startup-index#Sfridoo

https://www.sfridoo.com/casi-studio/guadagno-di-100-euro-su-scarto-in-polistirene-estruso/

https://www.sfridoo.com/casi-studio/guadagno-di-100-euro-su-scarto-in-polistirene-estruso/

https://www.sfridoo.com/casi-studio/integrazione-di-nuova-materia-seconda-settore-gomma/

https://www.modularee.eu/bioedilizia-modularee

https://www.modularee.eu/bioedilizia-modularee

https://www.modularee.eu/metodi-costruttivi

https://mannigroup.com/it/

https://mannigroup.com/it/sostenibilita/

https://report.mannigroup.com/it/report-esg-2024/identita/la-nostra-vision/edilizia-off-site