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CIRCULAR ECONOMY AND THE RELEVANCE OF DIGITAL TECHNOLOGIES FOR PRODUCT TRACEABILITY

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INTRODUCTION

The circular economy constitutes a new emerging economic paradigm capable of replacing growth models centered on a linear vision, shifting away from a consumerist production process focusing on reducing waste, and radically rethinking the design of products and their use over time (Di Maria, et al., 2018). This challenge involves many players: first of all, companies and corporations, because it is they who must adopt innovative and sustainable production and consumption activities and processes, capable of consciously and efficiently managing the resources of our planet. Many companies have already started virtuous processes in waste management, applying the fundamental principles of the Circular Economy and building plants and facilities aimed at recycling materials. Another important player is the European Union, which, from the top of the pyramid, can issue new laws and propose strategic initiatives from a circular perspective, setting sustainability targets and standards that member state companies must meet. Therefore, it has a central role in driving and controlling European action. Finally, we citizens are the latest players, but equally relevant. Our role is crucial to ensure the success of these initiatives; we are the actors who must "become circular" by adopting behaviors that make us more responsible and aware of our daily actions. We need to be educated and led by companies who provide the opportunity to learn about and track their products, thus allowing us to adopt a conscious and sustainable consumption line. Whether at the European or national level, this will only be possible with a solid revolutionary strategy to implement the guidelines and remove the main obstacles and barriers that still limit the adoption of the circular economy. This transition to a circular economy is based on a new way of production and a new resource management system in which manufacturing companies are essential to the project. Through new sustainable strategies, companies can promote innovative products related to the use of new materials or eco-design and have more control over the value chain (Di Maria, et a., 2018). In this context, the digital technologies offered by the revolution known as "Industry 4.0" - IoT, Big Data, Cloud, 3D printing, etc. - are crucial. They open new frontiers of sustainable design and production, making themselves protagonists of new systems and processes of traceability of resources and products. Applying the key principles of Industry 4.0, such as decentralization, information readiness, and prompt information exchange channels, can help achieve optimized, sustainable supply chain solutions, including reduced resource utilization and environmental impacts (Prakash, et al., 2019). The following thesis intends to analyze the Circular Economy and its characteristics in detail and then link it to the concept of Industry 4.0 and its digital technologies to externalize the intrinsic relationships that connect these two macro-elements in terms of sustainability and traceability. In particular, we will see how the concept of traceability has evolved over time, becoming a key factor and increasingly sought after nowadays, both by the European Union and by consumers, who need an increasing and precise degree of information in order to act sustainably and be confident about what they buy or consume. The last chapter will focus on the case study of EZ Lab S.r.l., an SME from Padua founded in 2014 that today also operates internationally and represents an actual reality in the digital technology sector. Their turnover comes 100% from blockchain projects, promoting the cause of product traceability and supply chain sustainability, adopting their skills and technologies in multiple sectors.

CHAPTER 1 – CIRCULAR ECONOMY: MAIN FEATURES

1.1 – The Path of Revolution is Circular

The transition to a circular economy may be the biggest revolution and opportunity for how we organize production and consumption in our global economy in 250 years (Lacy, Rutqvist, 2015). It is a radical rethink of customer relationships, markets, and natural resources. The point is that businesses today compete in a rapidly changing global environment. Conclusion: there are complex and interconnected challenges that are changing how companies need to think, work, and innovate. Furthermore, an increase of geopolitical and geo-economic tensions, the pace and scale of technological change, coupled with the urgency of the climate crisis, resource scarcity and a pool of other social and environmental problems are drastically altering the landscape. The good news is that with the circular economy, we have a huge chance to turn these challenges into opportunities by revolutionizing the way we produce and consume through innovative business models, digital technologies and engineering, and enabling capabilities that support these systems (Lacy, et al., 2020). In this way, there is the possibility to create financial and economic value for business and society.

First, we need to contextualize what is already said, starting from the key macro-trends.

According to the United Nations (UN), the world population will rise to 9.2 billion by 2050. Half of the population is considered middle class, expanding to 5.3 billion by 2030. Based on current trends, as living standards rise, so will consumption and demand for more resource-intensive goods (e.g., meat and vehicles) (Lacy et al., 2020). While the expanding middle-class could be a driver for economic development, changes in consumer behavior and consumption patterns are expected to increase demand for food, water and energy by approximately 35%, 40%, and 50%, respectively, by 2030. Even though we have become more efficient in extracting value from raw materials, we can still keep up with the increase in consumption. The problem is that the estimated use of those resources is expected to grow during the subsequent years; for example, the production of mined metal commodities is expected to jump 250% by 2030 to satisfy demand, and other commodities are under similar pressure (Modak, 2017).

Moreover, according to the World Health Organization (WHO), 785 million people currently lack access to drinking water and, by 2025, half of the world's population will be living in a water-stressed area. For what concern pollution, by 2050, there will be more plastic (by weight) in the oceans than fish (Ellen MacArthur Foundation, 2019).

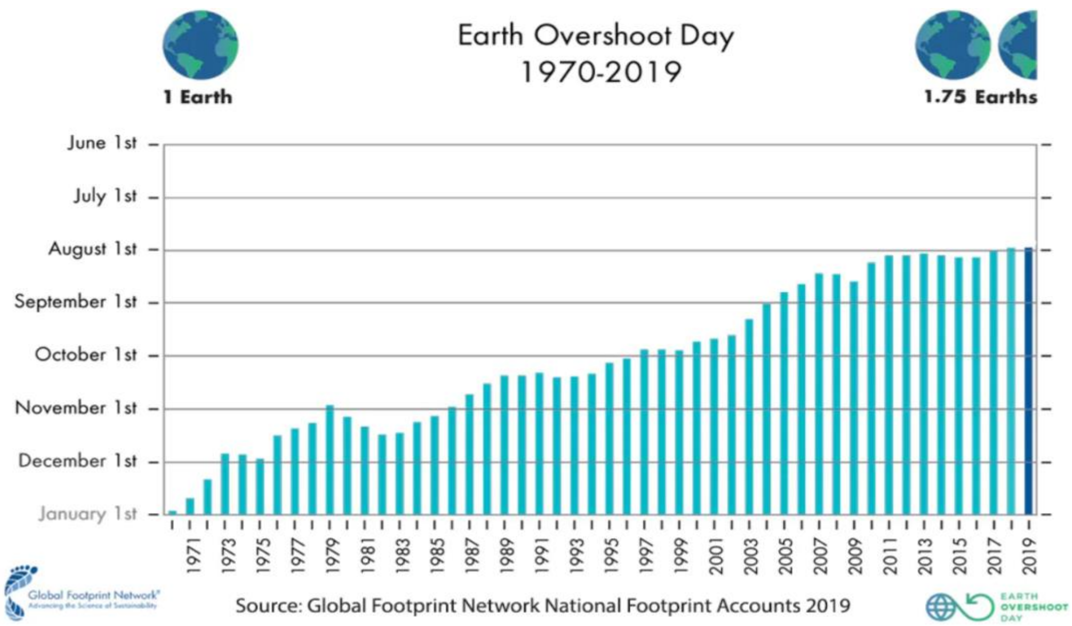
In addition, we are destroying the natural ecosystem in terms of biodiversity and habitat. According to estimates by The Living Planet Report (2018), since 1970, human activities have wiped out 60% of mammals, birds, erectile fish, and 13 million hectares of forest.

Then we have the problem related to climate change. According to an Intergovernmental Panel on Climate Change (IPCC) report, if global warming continues at the current rate, the temperature will increase by 1.5 °C between 2030 and 2052, the planet could potentially be three to five degrees warmer by 2100. The estimated economic impact for a warming of 1.5 °C by 2100 would be $54 trillion. For warming of 2 °C, it would be $69 trillion.

Unfortunately, that is not all, because one of the biggest problems that we have is that we are now consuming about 1.75 times the carrying capacity of the earth, which means that we are using 75% more natural resources than we are regenerating each year (Lacy et al., 2020). This measure of resource overshoot is called our "ecological footprint". On the demand side, the ecological footprint adds up all the areas humans occupy to produce the resources they consume, the space for urban infrastructure, and the ecosystems that absorb their waste emissions. The data is compared with the supply side, known as "biocapacity," which measures how much biologically productive area is available.

This overshoot is impossible over time (Lacy, Long, 2015).

Figure 1 – Earth Overshoot Day, 1970-2019



Source: The Conversation, link: *https://theconversation.com/resource-depletion-is-a-serious-problem-but-footprint-estimates-dont-tell-us-much-about-it-120065*

According to the California-based Global Footprint Network, an updated estimate of how fast consumption is happening suggests it is more rapid in those years than in the past 50[1]. By weighting in an optimistic scenario, despite rapid technological development, overuse of scarce resources will be 15% in 2030 and 75% in 2050 (Lacy, Long, 2015). In other words, any incremental improvements in line with the current rate of change will not solve our problems. The damage for businesses is evident, as Mathis Wackernagel[2] said during an interview on 2013, "It is quite simple, business models that require high units of input or resources that exceed availability will not succeed in the future" (Lacy, Rutqvist, 2015).

We are in a complicated situation; however, we are not out of the game yet. Fortunately, there is growing recognition that action for the climate and our planet is critical to social and economic success, which is why several countries have already taken action. The stakes are high and the numbers confirm it. The data shows that by 2030 the inability of the linear growth model to cope with the growing demand for resources will result in an eight-billion-ton gap between supply and demand for limited natural resources. In the most likely and conservative scenario in terms of estimates, this translates into $ 4.5 trillion of lost growth by 2030, rising to $25 trillion by 2050 (Lacy, Rutqvist, 2015). In other words,
only with a total shift from linear to a circular economy can we break free from limited resources and unlock $ 4.5 trillion of additional economic output by 2030.

1.2 – Circular Economy: Literature Overview

1.2.1 – Roots and Evolution of Circular Economy

In some ways, the circular economy results from the environmental awareness born in our era and represents the best alternative to the previous "take make waste" industrial linear growth model that dominated the previous centuries. While the circular economy is still in its infancy globally, it is growing in prominence with each passing year. The circular economy's roots go back to the 1798 with Thomas Malthus[3], thanks to his famous work entitled "An Essay on the Principle of Population". The main principles of his argument were radically opposed to current thinking at the time. He argued that population increases would eventually diminish the ability of the world to feed itself and based this conclusion on the thesis that populations expand

[1] The Conversation, "Resource depletion is a serious problem, but "footprint" estimates don't tell us much about it", available on << https://theconversation.com/resource-depletion-is-a-serious-problem-but-footprint-estimates-dont-tell-us-much-about-it-120065 >>
[2] President of the Global Footprint Network.
[3] Thomas Robert Malthus was an English influential economist in the fields of political economy and demography

in such a way as to overtake the development of sufficient land for crops[4]. In addition to Malthus, there were other figures who advanced theories regarding the use of natural resources, and the implications of nonrenewable resource depletion catch the interest of economists many years later. His thinking, supported and taken up by other influential thinkers after him, was that the exploitation of abundant and cheap natural resources, while profitable in the short term, is not viable indefinitely (Gaudet, 2014). Hotelling[5]'s treatment of the economics of exhaustible resources did not get serious attention before the 1970 (Gaudet, 2014), so we can say that only from that year did the real concept of Circular Economy gain momentum (Geissdoerfer et al., 2018).

However, the scientific and research content on Circular Economy is superficial and disorganized, in fact it seems to be a collection of vague and separated ideas from multiple fields and semi-scientific concepts (Korhonen et al., 2018). The idea has evolved over the past 40 years and it is not easy to identify a single definition because many exponents and authors have expressed their opinion about it by summarizing the concept under various dimensions. For this purpose, in the article named "Conceptualizing the circular economy: An analysis of 114 definitions" (Kirchherr et al., 2017), there is a collection of different definitions attributed to this concept over the years. What emerges from the article is that the circular economy is most frequently depicted as a combination of reducing, reuse, and recycling activities (Kirchherr et al., 2017).

A new wave of thinking was introduced with the release of "Cradle to Cradle: Remake the Way We Make Things" in 2002 by Micheal Braungart and William McDonough, which is the opposite point of view concerning Cradle to Grave, typical of the Linear Economy. The authors compared the natural cycle of a tree to that of industry, marking an important step for the sustainable sector. An important milestone for the theory of Circular Economy. They have proposed an innovative model of economics, in which the human being must try to replicate the concept of "biological metabolism" like that of nature, in which there is no waste. Based on this, the human being must develop a "technical metabolism" for industrial processes. The products must be designed in such a way that they are composed of biodegradable materials which become food for biological (biological cycles nutrients) or for technical materials (technical nutrients) to continuously circulate within closed technical loops as a nutrient for the industry (McDonough, Braungart, 2002).

In summary, the two authors put forward the idea that "eco-effectiveness," rather than "eco-efficiency," which means "doing more" instead of "doing less damage," should guide economic

[4] "History: Thomas Malthus (1766-1834), "BBC, http://www.bbc.co.uk/history/historic_figures/malthus_thomas.shtml

[5] Harold Hotelling was an American mathematical statistician and an influential economic theorist

development and thought. The authors argued that "reduce, reuse, recycle" was not feasible because minimizing the negative impact of a faulty system does not change its inherent defects (Lacy, Rutqvist, 2015).

At the beginning of the twenty-first century, ideologies arise that emphasized economic growth while minimizing consumption.

In 2009 one of the most influential organizations in the circular economy was born: the Ellen MacArthur Foundation. The foundation, led by famed Ellen MacArthur, is a charity funded primarily by a group of major global companies. In popularizing and globalizing Circular Economic's appeal, the foundation develops courses that stimulate innovation and encourages corporations, educators, and policymakers to follow best case studies of successful transition (Kopnina, 2019). It initially focused on incorporating multiple schools of thought on this theme, however, then developed his own circular economy thought, which is now considered the most complete and topical.

The Ellen MacArthur Foundation defines the Circular Economy as:

"A generic term that describes an economy that is regenerative by design. In a circular economy there are two types of material flow the biological kind which can be put back into the biosphere and technical waste which has to be re-purposed without ever entering into the biosphere"[6].

Therefore, A Circular Economic is an economic system designed to reuse materials for multiple production cycles to reduce waste.

Today, this definition seems to be the most accepted and complete from every point of view, which is why we will always refer to this description for the analyses that will be made in the following paragraphs.

1.2.2 – Principles of Circular Economy

1.2.2.1 – Theoretical Principles

Many industries and governments are promoting the transition to a circular economy as a way to achieve improved and long-term sustainability and human development (Schroder et al., 2020). An essential part of a circular economy involves re-using materials and products at the end of life. Despite the well-documented benefits of a circular economy, the vast majority

[6] Official website of Ellen MacArthur Foundation, https://ellenmacarthurfoundation.org/

of materials and products used by society remain part of a linear economy (Dieckmann et al., 2020). We refer to the linear economy as the traditional industrial model that follows a “take, make, waste” process in which raw materials are extracted, turned into products, and after being used or consumed, the products are typically thrown away as non-recyclable waste, or, at most, they are recycled or down-cycled (Lacy et al., 2020). This linear model is based on the assumption that natural resources are available, abundant, accessible to source and cheap to dispose of, but it is not sustainable, as the world is moving towards, and is in some cases exceeding, planetary boundaries (Reichel et al., 2016). This depletes natural resources and is, in the long-term, unsustainable (Dieckmann et al., 2020).

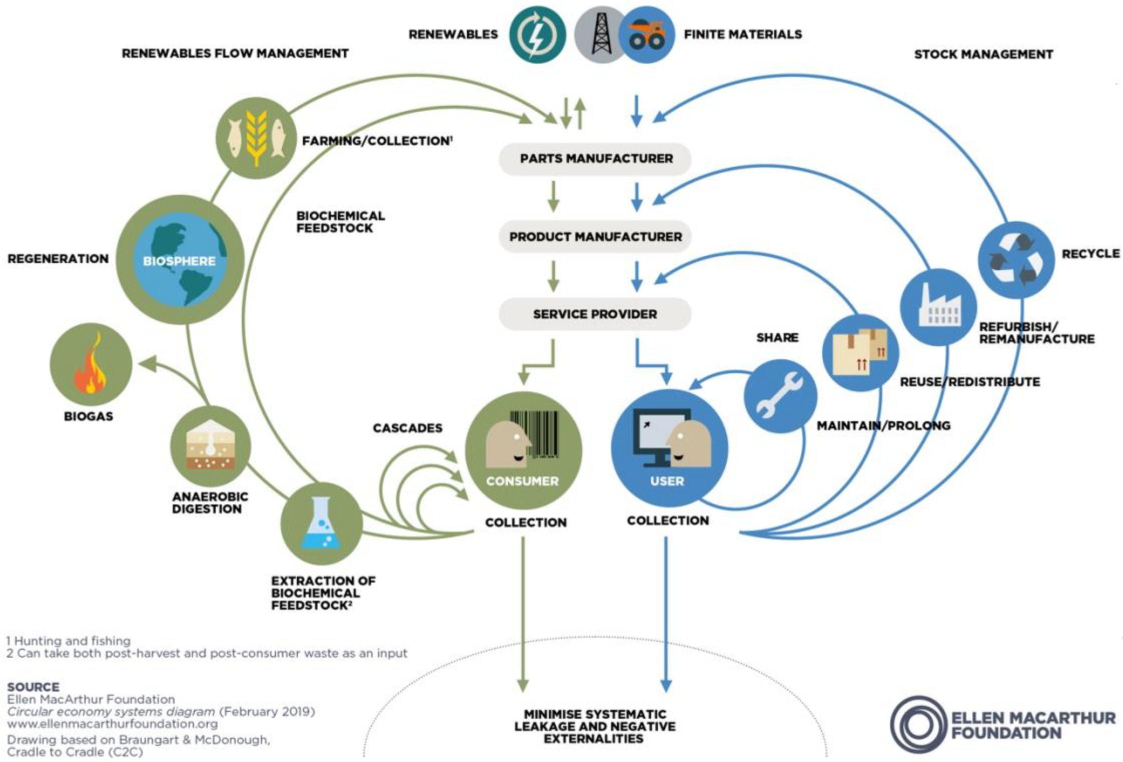
The circular economy is based on totally different principles, the so-called 3R Principles: Reduce, Reuse and Recycle (Kirchherr et al., 2017).

The principle of reducing is closely related to the concept of eco-efficiency. This means minimizing the input of raw materials and waste through improved production efficiency. Mainly you can be eco-efficient in two ways: maintaining or increasing the product's value.

Reuse refers to any operation used by products or components after its first life-cycle. This gives important environmental benefits since it implies a less waste or resources and energy for new cycle of production.

Recycling is divided into up-cycling and down-cycling. Up-cycling is nothing but in which a product cycle is modified or converted to a new product life cycle of the same or higher quality, as opposed to recycling. But it is vice versa in case of down-cycling. It is nothing but breaking down a product to its basic material and creating a new product, usually lower than the original product (Armstrong et al., 2015). It has a positive impact on the environment as it reduces the need for operations such as the extraction and processing with consequent gas emissions. In fact, more recently a fourth "r" has been approved, the Recovery. The product is disposed of in the landfill, leading to the wastage of residual energy, but when incinerated, a small portion is accounted for reuse and if it is further recycled, energy in the system is recovered (Manickam, Duraisamy, 2019).

Figure 2 – Circular economy systems diagram



Source: Ellen MacArthur Foundation, 2019, official website *https://ellenmacarthurfoundation.org/*

The diagram shown above helps to identify the processes of the circular economy by distinguishing between organic products and technical products. The flow of both technical and biological materials and products is circular, not only because they are kept in productive use for as long as possible, but mostly because at the end of their life cycle they are effectively cycle back (or looped) into the system (Lacy et al., 2020).

1.2.2.2 – Operational Principles

However, alongside the basic principles some operational principles describe theoretical strategies to explain how the circular economy system works and are closely linked to practical implementation (Suarez-Eiroa et al., 2018). The table below summarizes the seven fundamental principles that we will analyze in detail:

Figure 3 – Practical strategies of circular economy grouped by the proposed operational principles

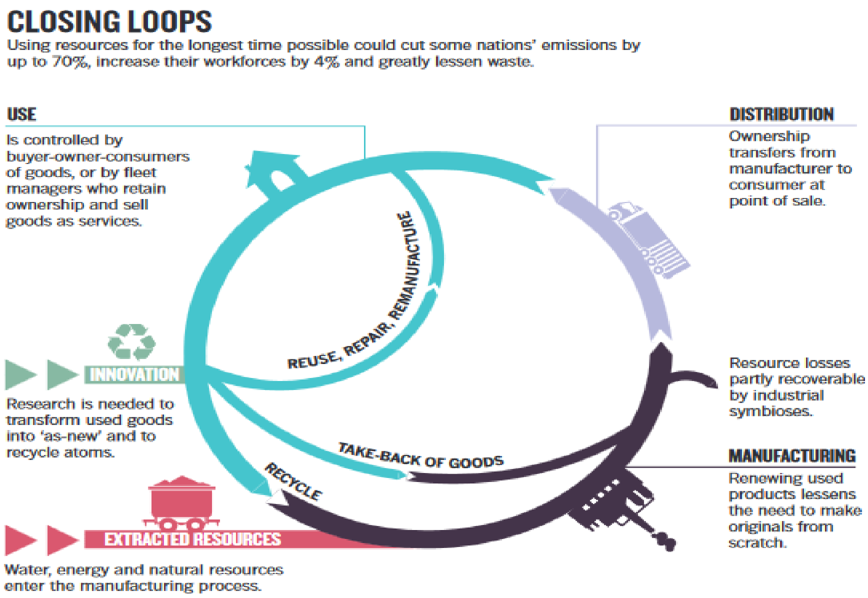
Strategies
Principle 1: Adjusting inputs to the system to regeneration rates
Substituting non-renewable by renewable inputs (e.g., bio-based materials, renewable energy)
Substituting renewable materials with low regeneration rates for other with faster regeneration rates
Adjusting taxes and subsidies of technology, products and materials based on their resource regeneration rates
Saving energy and materials (i.e. improving energy efficiency, resource productivity, virtualizing products, etc.)
Fostering renewable mobility (i.e. walking, bicycle, renewable fuels, etc.)
Principle 2: Adjusting outputs from the system to absorption rates
Substituting materials and processes which produce technical outputs by those which produce biological outputs
Substituting processes for those with lower waste generation rates (i.e. more eco-efficiency processes)
Adjusting taxes and subsidies of technology, products and materials based on their waste generation rates
Principle 3: Closing the system
Separating biological and technical wastes properly
Remanufacting products and components
Promoting and improving downcycling, recycling and upcycling of wastes (i.e. logistics, take-back systems, technology, etc.)
Promoting energy recovery by converting waste into heat, electricity or fuel
Promoting Extended Producer Responsibility
Principle 4: Maintaining resource value within the system
Interconnecting stages (i.e. redistributing second-hand goods)
Promoting industrial symbiosis (i.e. establishing standards, cascading, by-products, etc.)
Increasing durability (i.e. practical guides for reparability, preventive and corrective maintenance, repurposing, etc.)
Reducing obsolescence (i.e. updating software)
Principle 5: Reducing the system's size
Informing consumers properly (i.e. eco-labelling, product labelling, product declarations, etc.)
Expanding the Extended Consumer Responsibility
Promoting functional service economy and sharing economy (i.e. collective mobility)
Promoting green procurement (i.e. local products, season products, etc.)
Adjusting selling doses to consumer doses
Principle 6: Designing for circular economy
Eco-design (i.e. optimizing packaging, improving durability, etc.)
Designing transparent, reproducible and scalable products to build the same products in other places based on local resources
Thinking about practical utilities and consumer preferences (customization/made to order)
Designing new business models and strategies
Designing new methodologies to guarantee a continual improvement
Designing projects to promote sustainable development and circular economy
Principle 7: Educating for circular economy
Adjusting educational curricula to the current challenges
Promoting knowledge, skills, capabilities and values that ensure the proper performance of circular economy
Promoting habits and individual actions in favor of circular economy

Source: Suarez-Eiroa et al., 2018, "Operational principles of Circular Economy for Sustainable Development: Linking theory and practice", *https://pdf.zlibcdn.com/dtoken/664289f740487034771c5a1a1089ea33/j.jclepro.2018.12.271.pdf*

The first operational principle is "adjusting inputs to the system to regeneration rates". To address this kind of adjustment is fundamental distinguishing between renewable and non-renewable resources. This principle concerns strategies that minimize (or eliminate) the inputs of non-renewable resources and adjust the extraction rate of renewable ones to suitable values for planetary boundaries (Suarez-Eiroa et al., 2018). One of the most common strategies reported in the literature is based on the eco-efficiency (EC, 2014, 2015b, in Suarez-Eiroa et al., 2018), which increase efficiency of the production and consumption processes (Su et al., 2013). The transition towards renewable energies is essential to reduce inputs to the system which usually produce negative externalities (Suarez-Eiroa et al., 2018). In addition, other strategies related with dematerialization are also encompassed by this operational principle (Elia et al., 2017).

The second one is related to the "adjusting outputs from the system to absorption rates". Also, in this case it is necessary to distinguish between technological and biological outputs. This principle promotes strategies that minimize, and eliminate, the outputs of technological wastes and adjust the emission rate of biological wastes to suitable values (Suarez-Eiroa et al., 2018). Eco-efficiency becomes an important strategy (EC, 2014, 2015b, in Suarez-Eiroa et al., 2018).
The third principle refers to a business model known as "closing the loop". This can be defined in two ways: enhancing the re-use of products extending their life cycle, and the process of transforming old goods into new resources by recycling the materials. This has multiple benefits concerning recycling in energy and resource savings (Castellani et al., 2014).

Figure 4 – Circular economy closing loops



Source: Stahel, 2016, "Circular Economy Closing Loops" https://pdf.zlibcdn.com/dtoken/5eb75ed986c696bec50550178e909986/531435a.pdf

There are plenty of studies that justify shifting to a circular economy. As we can see in the figure above "using resources for the longest time possible could cut some nations' emission by up to 70%, increase their workforces by 4% and greatly lessen waste" (Stahel, 2016).
What has just been said by the "closing the loop" model acts as a springboard for the next operational principle "maintaining resource value within the system". Two main strategies have been reported: improving durability of products and recirculating resources through the different stages of a product life cycle (Suarez-Eiroa et al., 2018). The main obstacle to improve the first one is obsolescence (Guiltinan, 2009, in Suarez-Eiroa et al., 2018).
The next one is "reducing the system's size", which is the reduction of the total quantity of resources that circulate within the system, an issue identified as "social stock reduction" (Haas et al., 2015; in Pauliuk, 2018). Here the first one strategy is reducing the total quantity of

products required to meet human needs, the second one is producing and consuming more sustainable products, which implies improving the efficiency of the system (Suarez-Eiroa et al., 2018).

The last two principles are needed to promote the rest of operational principles (Suarez-Eiroa et al., 2018).

There is a total consensus in the scientific literature about the importance of this operational principle: the "design within the circular economy framework" (Kalmykova et al., 2017; in Korhonen et al., 2018). A product can be designed to be easily recovered and recycled, easily repaired, or removable into modules. These actions represent an important topic of the eco-design concept, an essential key to guarantee the success of circular economy (Sauvè et al., 2016; in Elia et al., 2017). The creation of these products is related to investment in innovation, that is a driving process toward the new paradigm, in contraposition to the simple optimization of processes (Toxopeus et al. 2015).

The last principle is "educating for circular economy". From the consumer perspective, the need to set up a new consumption culture is a widely extended topic within the scientific literature (Geng et al., 2012; SITRA, 2015; in Kalmykova et al., 2017). It is known that demanding more sustainable products favors the production of these products (Kirchherr et al., 2018). From the producer perspective, launch of circular economy strategies requires a variety of values and knowledge that should be integrated and developed into the corporate culture (De Los Rios and Charneley, 2017). A sort of collaboration should take place within the industry, in this way it will be easier to develop products with the correct "circular" design.

1.2.3 – Drivers and Barriers of Circular Economy

1.2.3.1 – Introduction

To conclude our literature analysis on Circular Economy, we will now investigate the real reasons, beyond the theoretical benefits already anticipated, that push companies to push towards this new production system. On the other hand, we will also analyze all the problems related to its implementation, the so-called "barriers" that keep companies anchored to a linear economy. The concept of "drivers and barriers" is closely related, and explains why, despite the evident positive effects and strong intrinsic motivations for change, today we are still far behind the global objectives in terms of sustainability. Of course, is not easy to calculate global circularity due to the lack of appropriate metrics (Haupt et al., 2016; in Dieckmann et al., 2020), but many research has quantified the extent of circular material use by society, and this is reported to be between 6 to 37% globally, indicating that 63 to 94% of all the materials and products we currently use are managed linearly (Haas et al., 2016; in Dieckmann et al., 2020). Identifying the barriers to moving to a more circular economy is a vital first step to enable changes to be made to core practices, materials management scenarios and business and public perception (Dieckmann et al., 2020).

1.2.3.2 – Internal and External Drivers

To identify and understand the motivational factors to evolve in the circular economy we begin by examining the drivers. A recent study[7] by Govindan and Hasanagic in 2018, identified 13 fundamental drivers, classified into categories based on their similarities. There is also a further division between the internal and external driver. The internal level identifies what has to be done inside the enterprise (Govindan, Hasanagic, 2018), producers are encouraged to implement circular economy practices in their production strategies right from the initial design (Agyabeng-Mensah et al., 2020). On external level the sustainable relationship has to be built between the industries and industrial parks in order to promote a cleaner production (Agyabeng-Mensah et al., 2020).

Furthermore, the selected drivers were then classified into five clusters:

- Policy and economy: include drivers such as laws concerning economic growth and product policies.
- Health: this cluster refers to increasing animal and public health.
- Environmental protection: includes preservation of quality of agriculture, protection of renewable resources and climate change.
- Society: here there are drivers related to population growth, urbanization, potential job creation and consumer awareness.
- Product development: this cluster refers to improving the efficiency of materials and energy use and to increase the value of products.

Table 1 – Drivers of circular economy

[7] Kannan Govindan, Mia Hasanagic, 2018, "A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective, International Journal of Production Research", https://pdf.zlibcdn.com/dtoken/4c7877cc871adb6de4ac21c5d3dbd528/00207543.2017.1402141.pdf

Cluster	Driver	Description	Internal/External
Policy and Economy	Keep within laws and policies of waste management	In some countries there are laws to promote cleaner production and consumption in order to secure resources, health and safety. In some case these policies act as mandatory drivers.	External
	Economic growth by implementing circular economy in supply chain	It could increase the long-term revenue generation through effective recycling and remanufacturing activities	Internal
Health	Public damage due to the over-consumption of resources and energy	Excessive consumption of resources can cause damage to air and water, fundamental resources for health.	External
	Animal damage for over-consumption of resources and energy	The animals have to live in a healthy environment	External
Environmental Protection	Climate change and global up warming	It's important implementing circular economy because climate changes occur due to the amount of waste produced and the greenhouse gas emissions associated with the consumption used	External
	Agriculture damage due to over-consumption of resources and energy	Modern agriculture quickly increases productivity but it pays a heavy price for over-consumption of resources and energy	External
	Demand for renewable energy is increasing, therefore it is important to protect the environment	Demand for renewable energy is increasing. Renewable resources should be protected.	External

Society	Protection of the future growth of population	Increasing population worldwide results in increased consumption. This force to implement circular economy	External
	Urbanization is increasing and the environment has been negatively affected by this increase	More people are moving into big cities and metropolies	External
	Potential job creation	Circular economy will contribute to higher local employment, especially in entry-level and semi-skilled jobs	Internal
	Consumers' environmental awareness places pressure on industries	Consumers are starting to get knowledge about industries' impact of environment	External
Product Development	Improve the efficiency of materials and energy in the supply chain	Circular economy as a strategy to improve efficiency of material and energy use	Internal
	Increase the value of products by increasing the quality	Product developed in this way will have a longer lifetime and will automatically increase their value	Internal

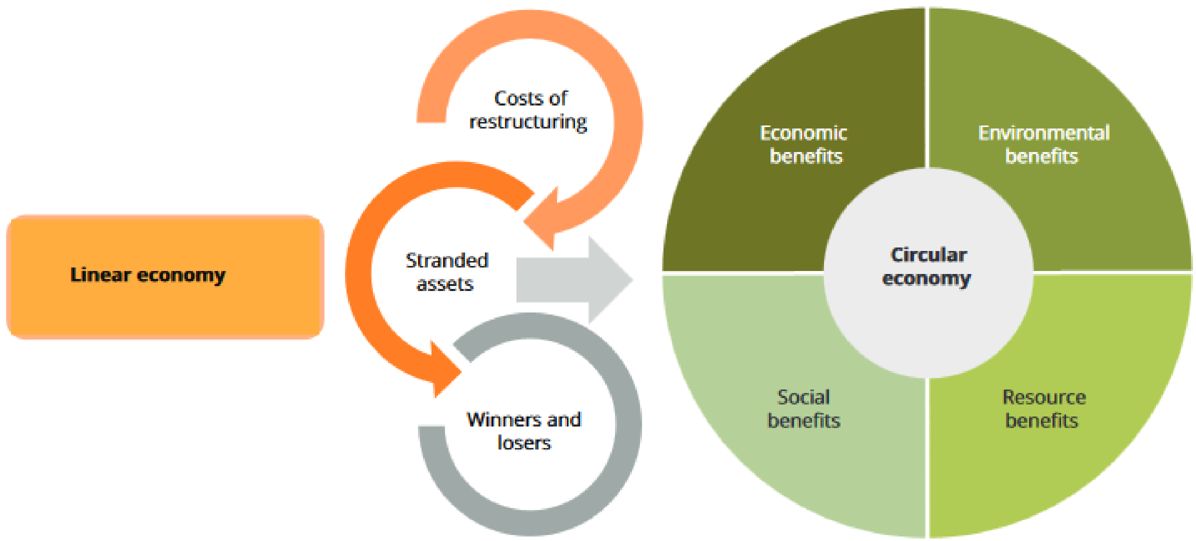
Source: Table revised by me based on what published by Govindan, Hasanagic, 2018, https://pdf.zlibcdn.com/dtoken/fa2ee8cf674782ee4e3a0d7ddbe1520c/00207543.2017.1402141.pdf

The table above summarizes all the main drivers identified by the research of other authors trying to explain how a given phenomenon actually affects the decision to invest in the transition from linear to circular economy. From the 13 drivers, 9 are related to the external environment and only 4 to the internal environment. The majority involve motivational factors outside the company that promote an investment in circular economy, the internal ones exist within the firm itself and are more related to the resources of organization (Govindan, Hasanogic, 2018).

1.2.3.3 – Benefit of Transitioning from Linear to Circular

As we have already anticipated, the transition from linear to circular economy has enormous potential from an economic and sustainable point of view. Specifically, there are 4 macro areas of interest that benefit from the transition: resource use, the environment, the economy and the social aspects such as job creation (Reichel et al., 2016).

Figure 5 – Benefits from the transition to a circular economy



Source: Reichel et al, 2016, "Circular economy in Europe"

A circular economy could increase the efficiency of the primary resource consumption in Europe and the world. By conserving materials embodied in high-value products or returning wastes to the economy as high-quality secondary raw materials. This would help to reduce Europe's dependence on imports, making the procurement chains for many industrial sectors less subject to the price volatility of international commodity markets and supply uncertainty due to scarcity and/or geopolitical factors (Reichel et al., 2016). An estimated 6–12 % of all material consumption, including fossil fuels, is currently being avoided due to recycling, waste prevention and eco-design policies; the maximum potential using the existing technology is estimated to be 10–17 %. Using innovative technologies, resource efficiency improvements along all value chains could reduce material inputs in the EU by up to 24 % by 2030 (Meyer, 2011; in Reichel et al., 2016). We have already introduced the main issues and possible counter-measures for what concern the environmental. However, measures beyond waste recycling, could further reduce greenhouse gas emissions. Indeed, it has been estimated, for example, that in the food and drink sector, resource efficiency measures could avoid around 100-200 million tons of carbon dioxide equivalent emission annually[8]. Keeping materials in the closing loop would help to enhance ecosystem resilience and the environmental impacts of mining primary raw materials (Reichel et al., 2016).

From an economic point of view, the linear approach puts a great deal of pressure on the environment and also reduces the likelihood of increasing competitiveness in various sectors of European industry (Reichel et al., 2016). The circular economy would offer new innovative approaches with new business models, and estimates say that for some consumer goods (food, beverages, textiles and packaging) a global potential of $700 billion annually in material savings is estimated, or about 20% of the input costs of materials in these sectors (EMF, 2013)[9]. We can suppose that social innovation associated with the core principles (reduce, reuse and recycle) of circular economy can be expected to result in more sustainable consumer behavior, while contributing to human health and safety. Is also expected to create job opportunities (Reichel et al., 2016). Indeed, according to the European Commission's impact assessment on a legislative proposal on waste, improved monitoring and the diffusion of best practice to achieve increased recycling targets, in combination with reduced landfill of waste, could result in the creation of up to 178 000 new direct jobs by 2030[10]. While some sectors may diminish, a net creation of jobs by 2030 is projected (Morgan and Mitchell, 2015). Furthermore, different circular strategies could generate different types of jobs. For example, labor-intensive strategies, such as preparing products and materials for reuse or recycling, would mainly create jobs for low-skilled people; medium-skilled jobs are expected to be created in manufacturing and closed-loop recycling, instead high-skilled jobs in bio-refining (Reichel et al., 2016). Also replacing products with services could provide jobs for people at each level of education.

1.2.3.4 – The Obstacles to Change: The Circular Economy Barriers

The circular economy concept is much discussed in the European Union (EU), but only limited progress has been accomplished so far regarding its implementation (Kirchherr et al., 2018). Several studies and research analyze the main factors that prevent companies from making the transition from the linear to the circular economy. Although analyzing totally different samples, every study on "circular barriers" tends to have similar research methods: desk research, semi-structured interviews and surveys, taking mainly European companies and

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[8] AMEC Environment & Infrastructure and Bio Intelligence Service, 2014 https://ec.europa.eu/environment/enveco/resource_efficiency/pdf/report_opportunities.pdf

[9] EMF, 2013, Towards the circular economy: "Opportunities for the consumer goods sector", Ellen MacArthur Foundation

[10] EC, 2015a, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, "An EU action plan for circular economy", 2015, https://ec.europa.eu/environment/strategy/circular-economy-action-plan_en

industries as a reference. In this paragraph the objective will be to summarize and explain the results obtained from multiple studies focusing on the barriers that the analysis samples have most identified.

A common feature of the various studies is to group the various barriers into 4 macro categories: technical, economic/financial/market, institutional/regulatory, social/cultural, from which other increasingly specific barriers branch out. The number of sub-barriers vary among different studies and samples, for example Govindan and Hasanagic identified 39 barriers, Van Eijk listed 21, Kircherr et al., 15., and so on. The diversity of the samples explains the difference between these numbers analyzed and with a different degree of accuracy on certain macro themes addressed, however many of these sub-barriers often appear extremely similar, therefore some of them can be combined.

Literature distinguishes between "harder factors", more closely related to techno-economic trajectories, and "softer" ones, having to do with regulatory and cultural issues (De Jesus, Mendonca, 2018). While the previous literature on this topic particularly emphasized technical barriers as key barriers for Circular Economy implementation, the most recent studies show how various cultural barriers appear as the first major obstacle (Kirchherr et al, 2018).

Figure 6 – Barriers of circular economy

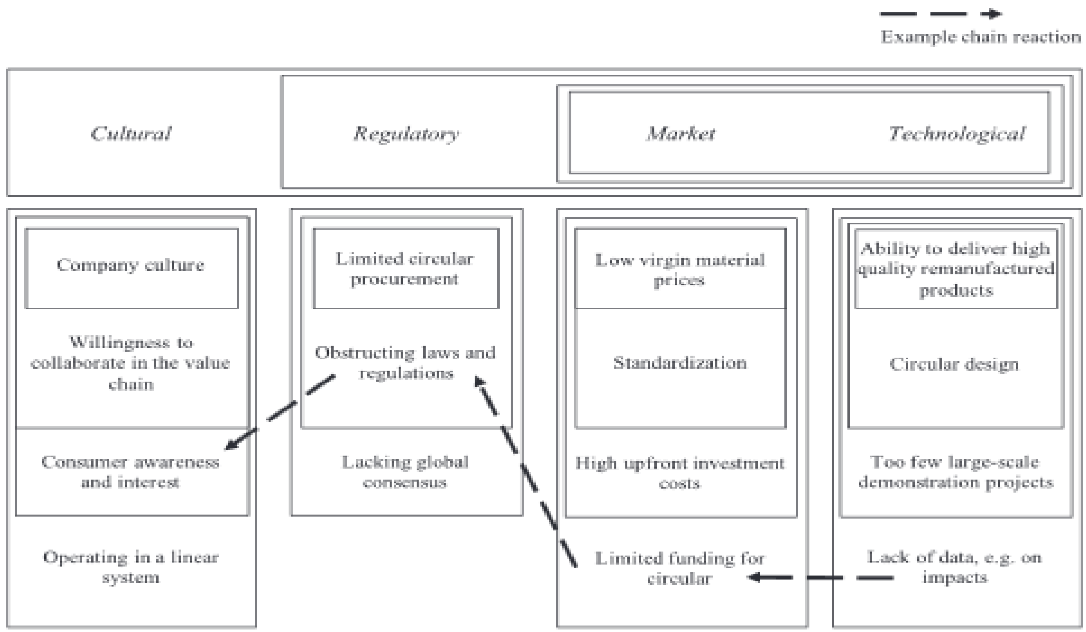


Fig. 1. Theorizing CE barriers.

Source: Kirchherr et al., 2018, "Theorizing CE barriers",
https://pdf.zlibcdn.com/dtoken/d986c6b5b6f5cbcdfbbcf1df18834cdb/j.ecolecon.2018.04.028.pdf

According to several studies, the figure above illustrates the main groups of circular barriers. We observe that the 4 categories presented can be considered nested (Kirchherr et al., 2018). For instance, it can be argued that cultural barriers determine regulatory barriers since regulation can follow culture; also, regulatory barriers can determine market barriers with regulation frequently creating markets (Marshall, 2012; in Kirchherr et al., 2018). Market barriers then can determine technological barriers since certain market forces are needed for technologies to emerge (Ahn, 2016; in Kirchherr et al., 2018).

Cultural barriers refer to the lack of enthusiasm toward enacting the circular economy, consumer perception towards reused products and the thrill of purchasing a new product (Govindan, Hasanagic, 2018) and are connected with the rigidity of consumer behavior and businesses routines (De Jesus, Mendonca, 2018). Studies show that the two more relevant are “lacking consumer interest and awareness” and “hesitant company culture”. This finding suggests that the circular economy may still be a niche discussion among sustainable development professionals, despite the increasing attention received by the concept in recent years. Those two barriers implicate that circular economy is not a “quick win”, but a major or long-term undertaking. That is because if the transition was immediately extremely profitable, cultural barriers like those two would not have emerged as key barriers (Kirchherr et al., 2018).

Regulatory barriers refer to misaligned incentives, lacking of a conducive legal system, deficient institutional framework (De Jesus, Mendonca, 2018). Among them we find also those barriers generated by “governmental issues” such as cases of existing laws that do not support the circular economy (Govindan, Hasanagic, 2018). The results regarding the real pressure of this type of barrier on the circular economy implementation are quite mixed. According to De Jesus and Mendonca (2018) regulatory barriers appear as the second most pressing barrier in the relevant literature. However, Kirchherr et al. (2018) obtained different results in their analysis sample, highlighting how this type of factor is less pressing than economic, financial, and market factors. The literature agrees that the high upfront investment costs (which appears to be one of the biggest obstacles as we will see in market barriers) for creating circular business models could be lowered by government intervention, through the provision of financial support (Kirchherr et al, 2018). If investing in a circular business model would cost as much as a linear business model, at least the excuse that “circular economy is too expensive” could no longer be used.

By market barriers we mean large capital requirements, significant transaction costs, high initial costs, asymmetric information, uncertain return and profit of the investment (De Jesus, Mendonca, 2018). Among them are all the financial and economic barriers related to implementing the circular economy in a supply chain (Govindan, Hasanagic, 2018). Economic viability, either through a direct return on investment or some other financial support mechanism, is fundamental to the transition from linear to circular in any business (Dieckmann et al., 2020). Financial viability is therefore often the primary barrier to circularity, although

this is influenced by underlying technical, operational and regulatory issues (Dieckmann et al., 2020).
The two main barriers inside this category are "low virgin material prices" and "high upfront investment costs". For instance, the low prices of many virgin materials are preventing circular economy products to outcompete their linear equivalents (Mont et al., 2017; in Kirchherr et al., 2018). It can be argued that those lower prices are the root cause of the identified cultural barriers, because if raw materials prices were higher, there would be more affordable circular products that could push consumer interest and awareness since consumers are usually very cost-conscious when making a purchasing decision (Pheifer, 2017; in Kirchherr et al., 2018). Consequently, this would spur more company interest in circular products, which then may diminish the barrier "operating in a linear system" (Kirchherr et al., 2018). The "high upfront investment costs" barrier is often related to the "hesitant company culture" barrier. Business leaders with an instinctive feeling could doubts about circular economy can refuse circular initiative based on the rationally think "circular economy is too expensive".
The last group of barriers is technological, which includes everything related to inappropriate technology, lag between design and diffusion, and lack of technical support and training (De Jesus, Mendonca, 2018). Also, in this case the studies did not lead to equivalent results. Everyone agrees that having modern technology in place is a fundamental prerequisite for the transition to a circular economy (Pheifer, 2017; in Kirchherr et al., 2018), however there are several cases of companies equipped from this point of view but which have not yet activated due to different types of barriers. Some literatures have particularly emphasized "circular design" as a major impediment to the circular economy transition (Pheifer, 2017; in Kirchherr et al., 2018). As we said, today is not clear whether or not technological barriers are the highest to overcome. Knowing that some studies claim that technology is not the main problem may be encouraging for those keen on a circular economy transition. After all, technological development is usually slow.

1.2.3.5 – Conclusions

Which factors are helping, and which factors are hindering the transition to a circular economy? What is treated in these paragraphs has tried to expose the common thought of the literature and the most recent studies, focusing on the common results in the various research articles. Globally, the circular economy is driven particularly by "soft" (social, regulatory or institutional) factors. Governments and public agencies have a crucial role in terms of supporting companies from infrastructures to legal set-ups, as well as in R&D and increasing

social awareness. The potential benefits are clear to everyone, some factors justify the transition from linear to circular in every field of analysis. However, this transition phase is proceeding slowly, due to multiple barriers that make the process more complicated and expensive. For example, there are some “hard barriers” related to the availability of technological solution and financial factors, can hamper expansion of the circular economy. Even when solutions can be technically feasible, their practical implementation is often limited by market or financial limitation, or from resilience in cultural change (De Jesus, Mendonca, 2018).
Studies on barriers give different results: some authors agree that the biggest obstacle is related to financial and technological barriers, while others argue that the biggest problems are cultural. The studies agree that the government has an important role in implementing the circular economy in the supply chain due to high upfront investment costs (Govindan, Hasanagic, 2018). Many companies are profit-driven, so profits are often considered before environmental impacts. Therefore, the government needs to make laws and policies that the organizations should follows. Moreover, an awareness of the circular economy should be highly regarded in society and consumers. These are key barriers that obstacle the transition, and be aware on these factors could be an important source of information to managers and decision-makers (Govindan, Hasanagic, 2018).

CHAPTER 2 – INDUSTRY 4.0 AND CIRCULAR ECONOMY

2.1 – Introduction

In the first chapter, we analyzed the Circular Economy as a whole, starting with a historical and evolutionary analysis of the term and then focusing on the cardinal principles that underlie it. We then discussed the main reasons why it should be adopted and the strong barriers that still limit its full diffusion.

This chapter aims to combine the Circular Economy with the phenomenon known as "Industry 4.0".

First of all, we will summarize the historical and technological path that has characterized the various industrial revolutions.

It is important to contextualize the Fourth Industrial Revolution at a historical level, because it is based on different foundations from the three previous revolutions, and is the only one capable of linking up with the Circular Economy. During the 18th – early 19th century, the First Industrial Revolution transformed our production capacity starting from the intensive use of natural resources, which seemed to be an almost inexhaustible resource, without worrying about the long-term effects on our planet. About a century later came the Second Industrial Revolution, characterized by mass production through electricity. This is a period rich in technological inventions, and compared to the previous revolution there is a radical increase in productivity margins. During the second half of the twentieth century there was The Third Industrial Revolution, also known as the "Digital Revolution" because it introduced new digital technologies that greatly impacted the way we produce. Large companies abandoned the rigid mass production system in favor of more flexible systems capable of adapting production volumes and characteristics to changing demand.

If until now industrial evolution has often been accompanied by damage to the environment in which we live, on the contrary, the current Industry 4.0 offers an enormous opportunity to reverse course and have a positive impact on our planet. The advent of new technologies allows us to create value in a circular economy, separating the process of growth from the depletion of natural resources. Moreover, it is based on the use and total integration of digital technologies in the manufacturing processes of physical goods, radically changing the relationship between man-work and work-society with strong implications on the current lifestyle. Then, we will analyze the main enabling technologies of the 4.0 revolution and see how they support the Circular Economy. Some examples are the Internet of Things (IoT), Big Data, Cloud

Computing, Cyber-Physical Systems (CPSs), Autonomous Robots and CoBots, Artificial Intelligence and all the other digital technologies that sustain the Circular Economy and the traceability. Specifically, traceability will be the key theme of the third chapter.

2.2 – Industrial and Technological Progress: "Industry 4.0"

2.2.1 – Historical Background: from the First to the Fourth Industrial Revolution

2.2.1.1 – First Industrial Revolution

Genesis of the revolutionary transition to Industry 4.0 was formed in the conditions of past industrial revolutions in the 19-20th centuries, characterized by rise of production powers and deep transformation of the whole system of public production (Pozdnyakova et al., 2019). According to the American economist W. Rostow statistics, the beginning of the 20th century marked the domination of industrial production: while in 1870 its share constituted 19.5%, in 1900 it was 58.7% and in 1913 near to 100% (Popkova, et al., 2019). Over the last three decades the volume of global industrial production grew by three times. The Industrial Revolution led to the transition from agrarian society to industrial society; continuing technological improvements led to the transition from industrial society to service society. All these processes took place differently in different countries and regions; however, their character was global. The First Industrial Revolution began in England (late 18th early 19th century), and then spread to the USA and Europe in the 19th century. It indicates the end of the modern era and the consequent birth of the contemporary age and represents a breaking point that highlights the historical transition from an agricultural-craft-commercial system to an industrial system. The fundamental "macro-innovations" in the industrial world were essentially two: in the field of energy production, James Watt's steam engine in 1775 and its application in transport and industrial production; the mechanical spinning machine invented by Arkwright in 1979, a turning point for the textile sector. The use of steam made production more efficient, laying the foundations for constructing large factories for mass production. The mechanical spinning machine increased labor productivity, which implies an increase in the number and quality of products produced and a substantial decrease in production costs.

2.2.1.2 – Second Industrial Revolution

After the Great Depression at the end of the 19th century, Europe and the United States were the protagonists of an unprecedented technological development that recorded an astonishing 378% increase in world manufacturing output in 1913 compared to 1875. These years were characterized by unprecedented technological development, in particular the key role belonged to cardinal changes in the sphere of energy: steam was replaced by electricity (Pozdnyakova et al., 2019). The revolutionary changes were started in 1867 by E. Siemens inventing the first electric generator (dynamo). Other inventions followed: in 1879, the American inventor T. Edison created incandescent-filament lamp, and in 1882 he participated in construction of the first electric plant for public use, and in 1896 was built the first hydroelectric power station. In industrialization, development of the information network was very important. Telegraphy communications was founded in 1830s and became very popular. In 1850s, transcontinental telegraph lines appeared due to underwater communication cables. In 1866, the regular telegraph line was established between Europe and America. In 1876, the Scot A. Bell invented the first telephone in the USA, and 1878 saw the creation of the first telephone station. In a context of innovation and progress, the organizational approach to work also changed. Among the processes of productive reorganization, the most important concerns the rational and scientific use of workers in large factories, through the application of the principles postulated by F. Taylor in "The principles of scientific management" to increase productivity and further lowering labor costs. The system of F. Taylor was successfully implemented by H. Ford, who applied the first assembly line at his plant in 1913.

2.2.1.3 – Third Industrial Revolution

On the other hand, the Third Industrial Revolution is conventionally traced back to the 1970s. It was based on refusal from using minerals, transition to renewable sources of energy with implementation of computers in production, automatization, and transition to digital additive production (Kupriyanovsky et al., 2016, Popkova et al., 2019). Although this time all fields of the economic-industrial sector are affected, electronics and information technology are the two leading areas of the revolution. The key inventions we remember are mainframe computing (1960s), personal computing (1970s and 1980s) and Internet (1990) (Schwab, 2017). This revolution is very different from previous ones and encapsulates three key principles (Popkova et al., 2019). First, there has been a shift in the profit center from the production stages to development and design. In addition, there has been a further increase in labor efficiency and, consequently, a reduction in the number of employees involved in production. Another key point has been the progressive replacement of traditional centralized business models with distributed structures and horizontal interaction, favored by the process of "globalization". This phenomenon is closely linked to the new means of communication which, by means of a digital language, have made it possible to break down borders and geographical limits to the transmission of informations.

In those years, the growing difficulties encountered by the mass production system in the face of saturated markets, characterized by strong fluctuations in demand and a profound change in consumer preferences, which had become increasingly hostile to standardization and more inclined to quality products, came to light. Companies therefore had to gradually abandon the rigidity of standardized mass production in favor of more flexible and automated systems capable of adapting production volumes to demand. Alongside, there has also been a significant change on the labor market, now known as "tertiarization". The term indicates the slow but progressive transition of workers from the manufacturing sector to the service sector over the years.

For some years now, the world's major industrialized countries have been trying to outline a growth path for their companies that leads them to invest more and more intensively in the field of Information Technology (IT). The prospect is to introduce the most advanced technologies in the technical, commercial, data collection, security and control, traceability along the supply chain, in industries that can take full advantage of the efficiency of new technologies. Hence, to ride the market wave, the new objective is the so-called "Industry 4.0".

2.2.2 – Fundamental Differences of Transition from the Previous Industrial Revolutions

The purpose of this section is to underline the main differences of transition to Industry 4.0 from previous industrial revolutions.
The methodology includes structural and comparative analysis, deduction and formalization of other authors who have carried out specific research in this area. In particular, the industrial revolutions, as specific economic phenomena, are studied and described in multiple scientific works from which we will take information as Khan, 2017; Huberman et al., 2017; Popova et al., 2016. Transition to Industry 4.0 is studied in Agamuthu, 2017; Thayer, 2017; Caruso, 2017. First of all, industrial revolutions have features in common that distinguish them as "revolutions" and not simply industry changes. A first prerequisite is the accumulation of such a volume of new technologies and innovations in industrial production that the production

system is completely changed (Popkova et al., 2019). When these technologies reach some threshold number and receive necessary development, which prepares them for implementation (practical application) into industrial production, the process of transition from quantity to quality starts. This causes a need for new infrastructure and generates some challenges for the country (in terms of growth of expenditures for modernization) and society (increasing the education of industrial specialists, etc.).

The end result of the industrial revolution is the transition to a new level of development in terms of quality and growth. In the table below, according to the research done by the authors, we can see the critical parameters of the industrial revolutions.

Table 2 – The essence and key parameters of three previous and the Fourth Industrial revolution

Parameters	The industrial revolution			
	First	Second	Third	Fourth
Time frame	18th–early 19th century	Late 19th–early 20th century	Second half of the 20th century	21st century
Accumulated industrial innovations	Production of cast iron, steam engines, and textile industry	Production of high-quality steel, distribution of railroads, electricity, and chemicals	Renewable sources of energy, digital technologies, network organization of business processes	Internet of things, robototronics
Type of technological mode	Industrial production	Conveyor production	Global production on the basis of digital technologies	Fully automatized production
Required new infrastructure	Industrial equipment	Conveyor equipment, railroads	Digital equipment, global infrastructure	High-speed Internet, robotized equipment
Essence of systemic transformations in industry	Formation of industrial production	Formation of conveyor production	Formation of global production on the basis of digital technologies	Formation of fully automatized production
Efficient changes in logistics	Steam transport	Railroad transport	Buildings that generate electric energy, electric, hybrid, and other transport means	Exoskeleton, manipulators, Robototronics
Efficient changes in products	Cast iron products	Steel products	Computer products	New construction materials

Source: Popkova et al., 2019, "Industrial 4.0: Industrial Revolution of the 21st Century"

https://pdf.zlibcdn.com/dtoken/61ad3b205cb7b651364c6010be24ff39/Industry_4.0_Industrial_Revolution_of_the_21st_Ce_3576067_(z-lib.org).pdf

During the First Industrial Revolution, industrial technology replaced manual work. This required significant investments in infrastructure and industrial equipment. The results were a change in logistics and manufacturing: steam transport was the driving factor; in the latter, the new manufacture of cast iron products was fundamental.

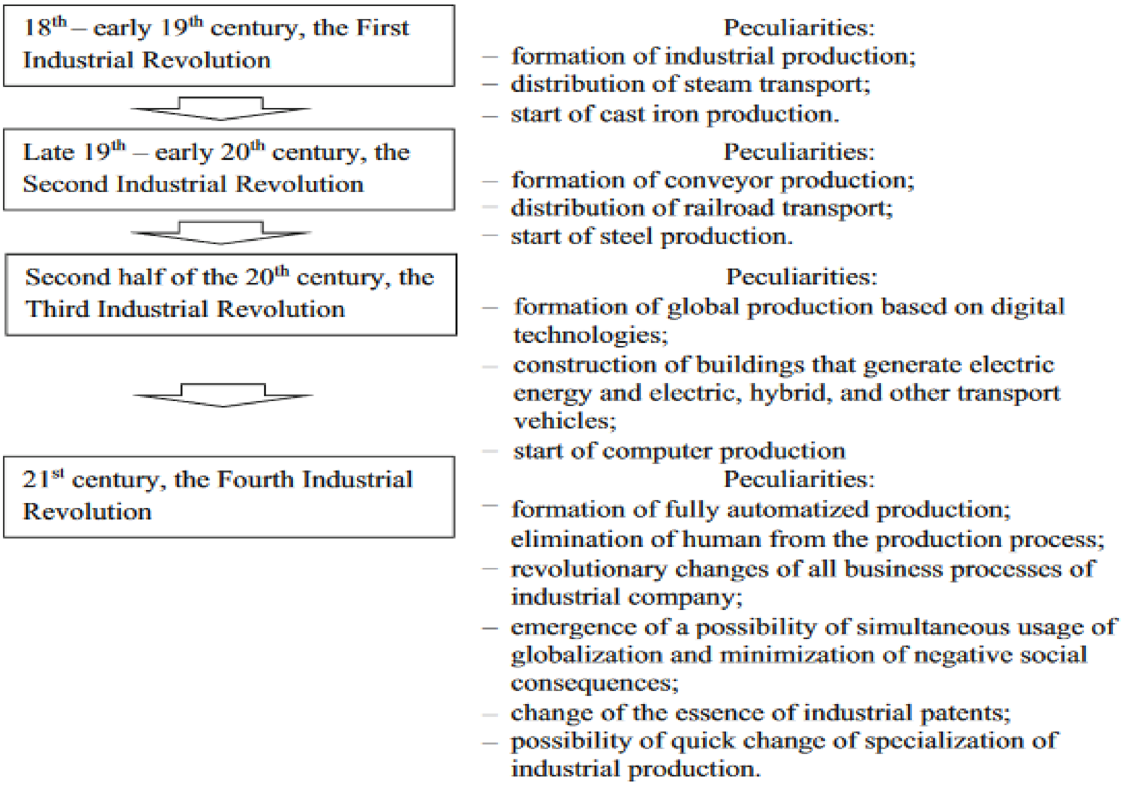
The second industrial revolution occurred at the end of the 19th and beginning of the 20th century and was led by technological innovations in high-quality steel, railways, electricity, and chemicals. As a result of this revolution, the production of conveyors was formed, requiring such infrastructure objects as conveyor belts, railways, etc. The essence of systemic transformation in industry is the formation of conveyor belts, railways, etc. The spread of railways mainly marks changes in logistics.

The third industrial revolution saw a series of technological innovations linked to renewable energy sources, digital technologies and new organizations in business processes. The technological model was global (networked) production based on digital technologies. This again required large investments in global equipment and infrastructure. As a result, electricity-generating buildings appeared, electric, hybrid and other means of transport, and the production of IT products became possible.

The Fourth Industrial Revolution is expected to occur in the 21st century. Fully automatized production is the type of technological mode that will establish during this revolution. The expected, resulting changes in logistics include some new technologies as manipulators and robotics, which allow transporting heavy loads to large distances. Even if the transition process seems to be similar to the other three revolutions for these essential characteristics, industry 4.0 is expected to become an unprecedented phenomenon in the natural development sector of the economy.

As we can see in the table below, the Fourth Industrial Revolution has more peculiarities and more serious transformation of production systems.

Figure 7 – A model of development of industrial production with revolutionary stages and their differences



Source: Popkova et al., 2019, "Industrial 4.0: Industrial Revolution of the 21st Century" https://pdf.zlibcdn.com/dtoken/61ad3b205cb7b651364c6010be24ff39/Industry_4.0_Industrial_Revolution_of_the_21st_Ce_3576067_(z-lib.org).pdf

The most important difference from the previous ones is the elimination of human beings from the production process. This is a significant turning point because even though previous revolutions allowed for a certain reduction of human participation, its importance in the production process was always preserved. On the other hand, the total elimination of humans from the production system forces some reconsideration of the essence of this system's work, as it will turn from socio-technical into a whole technical system (Popkova et al., 2019). Another difference is the possibility of simultaneously exploiting the effects of globalization and the circular economy while minimizing negative social consequences. In previous industrial revolutions, the optimization of production was accompanied by negative social externalities linked to reducing living standards in the territories where the companies themselves were located. The complete automation of production with the possibility of managing it remotely has eliminated the negative social consequences (Popkova et al., 2019). Industry 4.0 companies can therefore be built in uninhabited areas without harming employees or the population.

There is also a difference in the nature of industrial patents. In previous revolutions, the purpose was to hide technologies from rivals, but now almost everything is available through the

Internet. The aim now is to provide legal protection in favor of the owner, but without hiding the details and limiting the possibility of benefiting from positive externalities.

Another interesting difference is the possibility for a quick change of the specialization of industrial production. Previous industrial revolutions were less flexible and mobile than companies of Industry 4.0. Today instead, there is the possibility for quick re-orientation of production, and, as humans do not participate in the production process, high mobility is achieved due to a faster re-organization of machines.

Given the above, we can say that Industry 4.0 is a real revolution characterized by attributes that link the previous industrial revolutions, resulting in an adjustment in logistics and manufactured products. At the same time, this phenomenon is unprecedented in that it provides for the complete exclusion of humans from the production system, ensuring the total automation of the production process, the combination of global industrial networks reducing negative externalities, the change in the essence of industrial patents and the possibility of adapting and rapidly changing the specialization of industrial production.

2.3 – Enabling Technologies in the Industry 4.0

2.3.1 – The Era of Digital Transformation: Industry 4.0

Industry 4.0 refers to the fourth industrial revolution, which is based on the diffusion of digital technologies, profoundly transforming the industrial sector, business management and production models. Put simply, Industry 4.0 makes factories "smart".

Analysts call this process the "Digital Transformation", defined as *"the changes associated with digital technology applications and integration of that to all aspects of human life"* (Sartal et al., 2020). This new transformation will, for the first time, bring companies face to face with a double reality as they will have to manage physical resources and virtual resources equally, considering them as a single business production system:

- One captures information from the physical world to create a digital record of the physical operation and power grid;
- Machines talk to each other to share information, enabling advanced analytics and real-time data visualization from multiple sources;
- Algorithms and automations are applied to translate decisions and actions in the digital world into movements in the physical world.

Thanks to the ability to interconnect and make production resources cooperate, digital technologies can not only increase competitiveness and efficiency, but also leverage the introduction of new business models, to the point of overcoming the traditional distinction between product, production process and service thanks to the Internet of Things (IoT) and its ability to monitor the life cycles of a product.

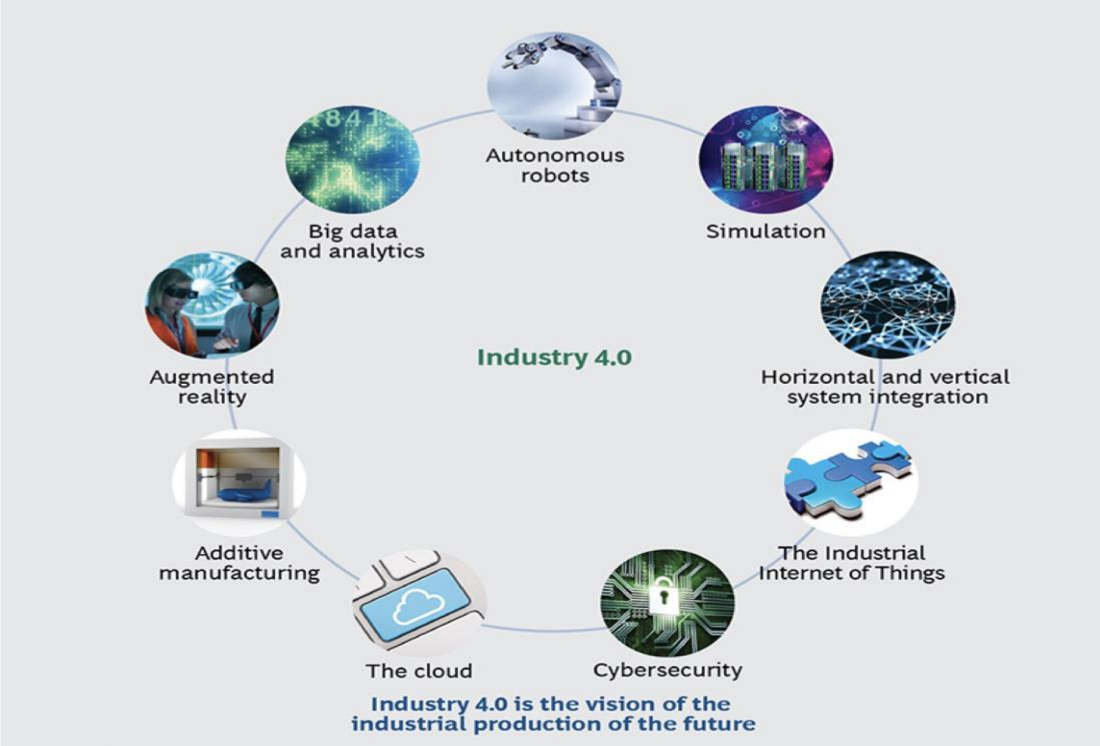
The connection between the digital of Industry 4.0 and the Circular Economy could change the job market forever, both from the point of view of processes and resource management and from the point of view of the people and skills put in place. Through the new digital technologies, it will be possible to monitor and optimize the use of resources, reduce energy waste and keep under control the waste generated in the production phase, avoiding problems of overproduction.

From a study by the Boston Consulting Group[11], it emerges how the fourth industrial revolution focuses on the application, within the new factory, of certain technologies defined as enabling. The Boston Consulting Group has defined the nine main enabling technologies that represent the pillars of the evolution of 4.0, they are: Industrial Internet of Things, Big Data, Cloud, Advanced Manufacturing Solutions, Simulation, Horizontal/Vertical integration, Cyber-Security, Additive Manufacturing, Augmented Reality;

Figure 8 – Nine enabling technologies that are transforming industrial production

[11] BCG is an American global management consulting firm, official website: https://www.bcg.com/it-it/

EXHIBIT 1 | Nine Technologies Are Transforming Industrial Production



Source: Official website BCG, 2015, "Industry 4.0: The future of productivity and growth in manufacturing industries" https://www.bcg.com/it-it/publications/2015/engineered_products_project_business_industry_4_future_productivity_growth_manufacturing_industries

These represent the tools that, if well mixed, will allow the evolution of industry towards an intelligent model, where work tools are connected to the network and interconnected to each other. Each of these I4.0 enabling technologies is now explained in more detail focusing on the interaction with Circular Economy.

2.3.2 – Enabling Technologies: the Nine Pillars of Industry 4.0 and their Relationship with the Circular Economy

2.3.2.1 – The Industrial Internet of Things (IoT)

Kevin Ashton, director and co-founder of Auto-ID Center at Massachusetts Institute of Technology (MIT), is the one who coined the term Internet of Things (IoT) in 1999, describing it as a system in which the physical world is interconnected to the Internet through sensors. Today it is more suitable define the IoT in this way:

"A concept or paradigm that considers pervasive presence in the environment of variety of things/objects that through wireless or wired connections and unique addressing schemes, are able to interact with each other and cooperate with other things/objects to create new applications/service and reach common goals" (Vermesan, et al., 2014).

The peculiarity introduces a new form of interaction that is no longer limited to just people, but between people and objects, also called Man-Machine Interaction (MMI), and between objects and objects, known as Machine to Machine (M2M). Nowadays, the internet is becoming more and more prevalent, the cost of connection is decreasing, Wi-Fi capabilities and embedded sensors enable more devices than in the past, smartphones are in everyone's hands, and all these things create a perfect storm for IoT. Moreover, through IoT, new services are created to achieve fully connected and data-driven mass customization production systems (Buyukozkan et al., 2020). IoT is the digital technology that can be most easily integrated in Circular Economy practices (Lee et al., 2015). Concretely, the role is to collect a considerable amount of data and then transfer it (e.g., through Cyber-Physical Systems) to other technologies (e.g., Big Data) that can analyze it and extract useful information to improve decision-making. In this way, IoT can inherently increase resource efficiency because the analysis identifies processes where there is excess resource consumption and at that point, they can be optimized or eliminated. Optimization of the process is eased with the availability of Big Data and cloud computing since they enabled Machine-to-Machine (M2M) communication (Buyukozkan et al., 2020). Another potential benefit is preserving or extending the life cycle of a product or a particular component. This happens because, through the mechanism of IoT, it is possible to promptly report any problem that is detected, thus facilitating the intervention of repairing the product or programming it for maintenance. By incorporating these smart materials, it is possible to monitor resources not only during the production phase but also during the life cycle of the product.
An important example is the Radio-Frequency Identification (RFID) mechanism (tags, sensors, or actuators). This enables systems built on IoT to track and monitor the state and the location of things/objects in real-time (Mboli et al., 2020) to reduce waste and increase the reuse of scarce resources. In addition, IoT also provides process-related data by optimizing remanufacturing and recycling practices, enabling better production planning and control (Rocca et al., 2020). For these reasons, IoT adoption in CE practices can enable new waste management strategies, improve the process circularity level, and create intelligent industrial environments (Rocca et al., 2020).

2.3.2.2 – The Big Data and Analytics (BDA)

Big data refers to the new information and communication technologies capable of processing and managing, at low cost, huge amounts of data, structured or not, collected and analyzed with tools that transform them into correlated and easily interpretable information. According to De Mauro et al. (2016), big data is "the information assets characterized by such a high volume, velocity, and variety to require specific technology and analytical methods for its transformation into value". The intrinsic difficulty for companies is to correctly interpret big data, i.e., to use it appropriately to solve problems and improve production. It is precisely in this passage that the difference between the pure collection of information by machines and the need to transform this data into an element of value is generated: Smart Data (Circular Mobility, 2021). The first strength of big data is the ability to promptly manage a massive amount of data, speeding up and optimizing production-related decision-making processes. It also enhances on-demand production systems with the ability to provide personalized and immediate responses to the consumer. Emerging new technologies as big data enable vast volumes of customer data to be processed and their needs anticipated, with demand identified much more accurately (Nunez-Merino et al., 2020).

From a circular point of view, BDA represents an essential technology in terms of resource conservation. BDA is also perceived to be a facilitator for decision-making (Gupta et al., 2018). In the case of the circular economy paradigm, big data functionalities can generate insights for integrating processes and sharing resources (Gupta et al., 2018). Data-driven analysis can potentially be used to optimize the sustainable solutions intended to reduce industrial systems' resource and emission intensities (Tseng et al., 2017). Companies can leverage the collected data to compare performance across companies anonymously to identify the most resource-efficient consumption pattern. Moreover, BDA can benchmark the mutual trust, corporate culture, sustainable consumption, or corporate behavior in the supply chain to enhance the foundation of the industrial symbiosis system and translate to improved industrial sustainability (Tseng et al., 2017). Data analytics allows for more accurate predictions that help reduce waste and avoid overproduction.

2.3.2.3 – Cloud and Cloud Computing

The more production-related initiatives a company undertakes, the more it must share data across sites. Meanwhile, cloud technologies continue to get faster and more powerful. Companies will increasingly deploy machine data and analytics to the cloud, thus enabling more data-driven services for production systems (BCG, 2020). The cloud is a highly flexible system that allows data, information and applications to be shared across the internet. Many years have passed since the first cloud computing was developed; however, it is not easy to find an unambiguous definition (Vidosav et al., 2020), so we summarize its concept as a system that allows one to create a virtual space in which to store and process data; through the internet, one can also access these saved data remotely.

Furthermore, it eliminates the complexity of infrastructure, extends the working area, and dramatically reduces the costs of hardware that is no longer needed, which in addition to being bulky and expensive, technologies are also subject to frequent maintenance. Cloud computing has brought many benefits for its users but, unfortunately, it has also brought risks related to the security in this concept application (Vidosay et al., 2020). This is because it is closely related to Big Data, as the cloud is a great solution to manage and store large amounts of information. This information is often highly sensitive, as it can contain information about products, business strategies, and consumers and suppliers. For this reason, this technology needs adequate protection with the most advanced cybersecurity systems, which today are increasingly necessary to avoid hacker attacks that would cause irreparable damage.

This technology also enables significant advances from a sustainability standpoint. In fact, according to Zoghlami Sammy, senior vice president of sales EMEA at Nutanix, "cloud computing and data center modernization can help reduce the environmental impact of technology" (ICT Business ecosystem, 2021). Depending on the type of data center being replaced, the cloud could save up to 95% of the energy associated with the software. The cloud is a platform that is shareable, elastic, reusable, and programmed to serve thousands of customers simultaneously, ensuring that work is efficient and sustainable in terms of resource consumption.

2.3.2.4 – Cyber-Physical Systems: Autonomous Robots and CoBots

If previous Industrial Revolutions were due to steam power, electricity and information, this Fourth Revolution is characteristic for Cyber-Physical Systems (CPS), that made possible the fusion between physical and virtual world. A CPS is a mechanism controlled or monitored by computer-based algorithms, tightly integrated with the internet and its users. It is an integration of computation, networking and physical processes. That is to say that embedded computers and network devices monitor and control the physical processes providing abstractions and modeling, design and analysis techniques for the integrated overall systems (Buyukozkan et al., 2020). A CPS is an essential concept referring to entities where “the physical and virtual world grow together” (Thoben et al., 2017). Together with the Internet of

Things (IoT) and Cloud Computing (CC), CPSs can inform users either about components and materials embedded into products or disassembly and recycling procedures in order to enable a more efficient reintroduction into new product value chains (Rocca et al., 2020). It refers to a system that collects data of itself and environment, processes and evaluates these raw data, exchanges information with other systems, makes local decisions and initiates actions by itself (Moreno et al., 2020). It communicates with the physical environment through the use of sensors, actuators, and wireless communication. In addition, there are some exciting aspects of CPS: control algorithms for self-organization, adaptability to changing conditions, new efficient communications across cross domains, embedded and Information Technology (IT) dominated systems and humans outside or inside the loop (Moreno et al., 2020). For the latter, autonomous robots and collaborative robots (CoBots) are examples of the absence and presence of the human in the loop, respectively. In fact, the human worker's role is the main difference between the two archetypes. Robots are intelligent machines capable of performing tasks independently, without explicit human control. Manufacturing is essential to get flexibility, shift from mass to customized production, and adapt to technical evolution (Pedersen et al., 2016; Alcàcer and Cruz-Machado, 2019). Someone considers them as a form of Artificial Intelligence (IA). In this way they offer speed, durability, accuracy because they can perform repetitive tasks reducing margins of error at nominal rates. Indeed, fully autonomous robots make their own judgments to execute tasks on dynamically variable atmospheres without operators' interaction (Ben-Ari and Mondada, 2018). On the other hand, CoBots introduce the proximity of robots with humans in order to work together in flexibility-required tasks (Koch et al., 2017).

Robots are also an essential technology from a Circular Economy perspective. This is because they are able to increase the efficiency of the use of resources by reducing waste thanks to artificial intelligence. They also perform exceptionally well in diligently disassembling products, enabling the possibility of re-usage and consequently minimizing pollution. Autonomous robots also make it possible to improve the resource recycling procedure. Sensors and cameras control the material analyzed by the robots, then the AI examines the collected data and provides an accurate analysis. The robot at this point decides which fraction to keep and which to discard with a higher degree of accuracy thus improving the efficiency of the recycling process. This flexibility makes them suitable for supporting current Circular Economy practices, especially during disassembly and remanufacturing operations (Rocca et al., 2020).

2.3.2.5 – Simulation

Simulation is the process of leveraging real-time data to mirror the physical world in a virtual model, which can include machines, products, and humans (Lorenz et al., 2015). This allows operators to test and optimize machine settings for the following product in the virtual world before the physical changeover, reducing machine setup time and increasing quality (Mourtzis et al., 2014; Bahrin et al., 2016). This technology is used as a forecasting tool for performance evaluations or to compare alternative solutions before the real application in the production phase. A significant advantage is implementing real-time corrections in the production process without incurring "learning-by-doing" huge costs. Simulation is used to replicate real-world behaviors in a virtual environment. In this way, the physical and virtual dimensions coexist and are synchronized thanks to a virtual representation of the physical object, called "Digital Twin", which copies its behavior through real-time data acquisition from the field. This digital twin is created using IoT, Cloud, and Big Data Analytics contains its data models, functionality (for example, data processing or behavior), and communication interfaces.

From the Circular Economy point of view, simulation is better related to complex management supply chains (e.g., closed-loop chains through disassembly process optimization, trying to control the energy consumption and valuable materials recovery) or the remanufacturing of complex kinds of products (Rocca et al., 2020). In addition, simulation allows testing products to avoid creating physical prototypes, which means less waste of resources in the testing phase. Also, the concepts of Augmented Reality (AR) and Virtual Reality (VR) are examples of simulation, and they could represent a valuable element for improving disassembly and remanufacturing processes (Rocca et al., 2020). Finally, simulation also plays an important role in the Circular Economy in terms of material longevity. This is because it is possible to simulate a product's life cycle based on the material used and the margin of reuse of the material at the end of its life.

2.3.2.6 – Horizontal and Vertical System Integration

Systems integration is the first step towards an Industry 4.0 vision and achieving its goals (Schlechtendah et al., 2014). The adoption of related technologies, able to analyze big data and create open systems for sharing data and information in real-time, will enable digitalization and integration along the value chain. Integration can be both horizontal and vertical: the former takes place across the entire organization, from inbound logistics, through warehousing, production, marketing and sales, to outbound logistics; the latter refers to the interaction and exchange of information with all key partners in the value chain, from suppliers, to companies and consumers. Vertical flow refers to company activities development and execution, including basic elements such as: the organizational structure, human factor, departments relationships, technological and management level. In a complementary way, the horizontal flow includes external relations, establishes supplier and customer networks integration, information and management systems, and others (Lee, et al., 2015; Vyas et al., 2016). These two forms of integration, made possible thanks to digital technology, provide several advantages. The possibility to be constantly interconnected with upstream suppliers allows companies to react promptly to changes in production, adjusting production in time. Similarly, meeting downstream distributors enables companies to forecast demand better and adjust production accordingly. Connecting with customers themselves is also a significant advantage because it makes it possible to accumulate data and information about their standards and preferences, allowing the company to offer more personalized products and services to its target customers.

From a circular point of view, we know that digital always has an important role. Along the supply chain, Industry 4.0 has made available several solutions to track materials and products in the supply chain, allowing for better inventory management. Another hotly debated topic is Blockchain, a digital system currently used in some commodity sectors, which represents an evolution of the supply chain with essential changes in terms of traceability and communication between chain partners. Traceability lays the evolutionary foundations to ensure recovery, reuse and recycling of materials, avoid waste, and carry out proper disposal in view of material procurement, production, consumption, and management of the final phase of the life cycle of a product (Circular Economy Network). The issue of traceability will be discussed in more detail in the next chapter.

2.3.2.7 – Cybersecurity

Nowadays, many companies use unconnected or totally closed management and production systems. With the increase in connectivity brought by Industry 4.0 and the use of increasingly advanced communication protocols, it becomes necessary to protect their industrial systems from cybersecurity threats (Lorenz, et al., 2015). Cybersecurity indicates technologies, processes, and products to protect networks, devices, and data from unauthorized access of criminal use and the practice of ensuring confidentially, integrity, and availability of information (CISA, 2019)[12]. In 2020, the average cost of a data breach was USD 3.86 million globally, and USD 8.64 million in the United States[13]. These costs are composed by the expense of discovering and responding to the system breach, lost revenue due to system downtime, and long-term reputational damage to the company and its brand. Cybercriminals attack customers' personally identifiable information (PII), credit card information and then sell it in digital marketplaces. Organizations with a solid cybersecurity strategy, using the most advanced technology systems such as artificial intelligence (AI) and machine learning, can combat threats early and reduce the impact of breaches when they occur.

Nowadays traditional approaches to cybersecurity are insufficient for the modern economy (Stifel, 2018). In recent years, the approach to cybersecurity has turned primarily to risk management. It can be effective in reducing risk in corporate networks, but it's certainly less useful in guiding administrative decisions about the security of programs and devices that might connect to those networks, particularly for companies that have suddenly become "connected”. The modern economy relies on data, but for too long the focus has been on hoarding data without concern for it is protection. The main reasons for this are inadequate education, which has contributed to poor hardware and software designs for data protection; "first-to-market" rather than "secure-to-market" business decisions, accumulating highly vulnerable products in the marketplace; lastly, also poor consumer understanding of the products and services offered (Stifel, 2018). Along with these misperceptions, current market incentives do not support adequate investment and funding for cybersecurity. Furthermore, the effects of the current unsustainable approach to cybersecurity threatens not only strong digital economies, but also nascent ones.

The concepts of cybersecurity and sustainability are not that far apart. Sustainability encompasses supply chain management, interoperability and scalability, consumer engagement, and regulatory compliance in some areas. In the context of cybersecurity, it could transform corporate and consumer perceptions from costs of time and money to savings and features, and meaningfully translate these attributes to the market. Studies say that sustainable companies are successful companies, very often enormously successful. Contrary to the common perception that sustainability takes profit away from companies, companies that have invested in sustainability are, on average, more successful than their peers. Cybersecurity is the common point between these successful companies (Stifel, 2018). This is because it is often

[12] Cybersecurity and Infrastructure Security Agent (CISA), is a United States federal agency that operate to enhance the security, resiliency, and reliability of the Nation’s cybersecurity and communications infrastructure.
[13] IBM official website, “What is cybersecurity?”, 2020, available in https://www.ibm.com/topics/cybersecurity

considered a priority by most organizational leaders and CEOs, and thus it was proven that companies that adopt responsible cybersecurity practices can reap significant financial benefits. Beyond profitability, organizations should start sustainably framing their cybersecurity activities for several reasons. To begin, ICTs (Information Communication Technologies) underpin nearly every modern transaction, from electricity and water supply to banking, shopping and manufacturing. As a result, organizations have access to massive amounts of information, including sensitive data. As is increasingly evident, failure to ensure the confidentiality, integrity, authenticity, or availability of aspects of this information can lead to critical failures for associated and unrelated information, devices, and actions. These failures risk the reputation, income, assets, and the very longevity of the organization as a going concern (Stifel, 2018). Therefore, the link between cybersecurity and sustainability is indirect because a company that wants to invest in sustainability successfully does not have a good cybersecurity system as a sufficient condition. However, it is more often than not a necessary condition for safeguarding sensitive data.

2.3.2.8 - Additive Manufacturing (AM)

Known as 3D printing (3DP), is a technique defined by ASTM[14] as a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies (Colorado et al., 2020). AM has the advantage of being able to build parts from digital designs using almost all materials and complex shapes (Colorado et al., 2020). Instead of prototyping individual components, companies can now produce small batches of customized products. The resulting advantages include the speedy manufacturing of complex, lightweight designs. AM is considered one of the most promising technologies from a sustainable manufacturing perspective because the additive and digital nature provides tremendous opportunities to save resources (Sauerwein, et al., 2019). For example, it allows on-demand production of repair parts or avoids material losses when compared to other subtractive technologies such as milling. These are important aspects that can offer new opportunities in view of product design in support of the circular economy. Companies that leverage AM have access to numerous benefits: they can create unique and customized products, thus increasing customer satisfaction but they can gain flexibility for design changes and also a reduction in time to market (Oztemel, 2020). 3D printing prevents the use of cumbersome tools with various revisions. This naturally eliminates the time and cost

[14] American Society for Testing and Materials (ASMT) is a globally recognized leader in the development and delivery of international standards.

associated with production changeover times. With this capability, additive manufacturing significantly reduces the design cycle (Oztemel, 2020).

From a circular perspective, AM represents a key technology that provides excellent opportunities for sustainability benefits. For one thing, AM is perfectly aligned with the basic principle of "reduce" in that this technology makes exact use of the minimum amount of material needed for production. Another major advantage is the ability to go directly from the design phase to the production phase, eliminating the intermediate steps requiring tools and molds. In addition, the ability to create small-scale production also offers the advantage of reducing and eliminating wasted inventory. Huge strides have been made with AM to extend the product lifecycle (Sauerwein et al., 2019). First of all, total freedom in product geometry and shape allows for more durable component designs. Moreover, as we have already mentioned, AM ensures extremely flexible production by offering the possibility to produce even a few spare parts on order, a method that is to an extent unfeasible and unsustainable for traditional manufacturing (Sauwerwein et al.'s, 2019). In addition, it is possible to avoid any environmental impact related to the transportation of spare parts, as AM allows the repair and remanufacturing of the product directly at the production site. This technology is also sustainable in recycling, with numerous studies showing that many of the materials used in 3D printing are reusable. Regarding the materials and their relationship with the environmental sustainability of the processes, metals are the most suitable for an optimal circular economy due to their high recyclability (Colorado et al., 2020).

2.3.2.9 – Augmented reality (AM)

Augmented reality (AR) refers to the enrichment of human sensory perception through information that is imperceptible to the five senses, but can be signaled through sensory input such as sound, video, or GPS data. In particular it refers to an interactive technology that integrates physical environments with virtual elements including information or images (Javornik, 2016). AR systems support a variety of services, such as selecting products and parts in a warehouse and sending repair instructions on available mobile devices. Companies can provide workers with real-time information that improves decision-making and work procedures.

Consumerism has evolved; it is no longer enough to satisfy an individual's needs or provide the final product. Now the needs of the community and the planet must also be met. Therefore, companies have turned to sustainable practices and digital marketing solutions to meet this new standard of consumerism, from ethical sourcing and fair labor to minimizing waste and maximizing recycling. AR is playing a growing role in this. Companies are using it to connect, educate and engage their audiences, and not just to sell more products (although it is still highly effective). In concrete terms, in a future of sustainable packaging, where layers of the pack get stripped down to a minimum, where material limitations might call for more straightforward print design and where the production of exclusive editions or customization is deemed too wasteful, AR can ensure that brands stand out. Brands can use AR to visualize high-quality, high-fidelity 3D products, removing the need to physically print or produce packaging examples in the early design stages. In addition, AR can significantly extend the life cycle, as it can detect defective components and repair them before they break, facilitating the repair process. This technology allows workers to operate in a digital environment both individually and collectively, among its many advantages. For this, it is also suitable for remote work, contributing to reducing greenhouse gas emissions.

CHAPTER 3 – DIGITAL PRODUCT PASSPORT AND BLOCKCHAIN: NEW PATH TOWARDS TRACEABILITY

3.1 – The Importance of Digital Traceability Technologies to Support the Circular Economy

3.1.1 – Digitalizing a Product and the Material Flow

As we have seen, human knowledge and technological development have allowed great strides forward in the Circular Economy; however, there is often a tendency to underestimate or simplify the process of recycling resources, assuming that it is all instantaneous, automated and without problems. Steel is not infinitely recycled. For instance, much of the high-grade steel recovered from vehicles are down-cycled into a lower-price material and mostly reused in lower-grade applications, such as buildings and infrastructures. Indeed, not aware of the steel quality they collect, recyclers mix different steel grades, producing a lower-quality recycled material.

Steel recyclers are the only ones having little information on materials or products they recover. Plastic recyclers are not always aware of the full chemical makeup of materials they process, including the presence of toxic substances. Repair technicians do not always have access to disassembly guidelines for electrical equipment. Remanufacturers may not know the number of operating hours of an electric engine to decide if the engine can be restored 'as good as new' or whether it should be recycled.

In order to convert a product back into a valuable resource, always maintaining its value and extending its life cycle most efficiently and effectively possible, a range of information such as its design, composition, condition and other specifics are critical to proceed correctly. As stated by Idriss J. Aberkane, in the transition to a Circular Economy, the equation "waste = resource" can no longer apply, but "waste + knowledge = resource."

As we have seen, digital technology provides a wide range of tools applicable to the cause of the Circular Economy. Building on "enabling technologies" over the years, other technologies have been developed that allow large amounts of data and information to travel through a product. They allow us to identify, store, analyze and share data throughout its entire lifecycle. Technologies of this type are divided into systems attached to the product or embedded in it. The former is physical (such as fluorescent markers or watermarks), the latter are digital (such as RFID or printed electronics). Technological development has allowed these traceability systems to be improved over time, however for each of them there are particular sectors where their use is more widespread than others.

To date, there are numerous examples of companies leveraging digital technologies to track their products. Once a product is identified, data regarding its design, condition, components or location can be easily retrieved and constantly updated. The main storage and sharing technologies are using the Cloud, digital platforms, Big Data or the digital ledger characteristic of Blockchain. For example, ThyssenKrupp collects operational data from more than 130,000 of its elevators located worldwide in its cloud to monitor their condition. In addition, to dynamically manage its global logistics network, the German group, with the help of Artificial Intelligence (AI), has optimized all transport routes and is providing faster availability of materials at the company's sites. The future goal achievable with these technologies is to process and analyze around 14 million order items per year, identifying optimal delivery routes based on material requirements for individual industries and companies at specific locations.

However, this information is barely shared across value chains, and as a result, most affected users do not have access to crucial product data. An example of this limitation is evident in the case of tires. To extend their lifecycle, manufacturers equip them with sensors that measure pressure and temperature, yet this information is not shared with collectors and processors who could improve the recycling system or increase the use of recycled rubber. The consequence is the export of lower-quality tires. Information technology is a key enabler for the circular economy, but data sharing along the value chain is equally important.

3.1.2 – Traceability and Data Sharing along the value Chain

To exchange data along with the value chain stakeholders, need to agree on a common language (Le Moigne, 2021). For example, H&M, Microsoft, PVH Corp, collaborate in a circular fashion initiative that uses a standard protocol called CircularID, which aims to establish a global standard for physical goods, which could aid in the rental, resale, and recycling of clothing and accessories (McDowell, 2019). It provides a unique digital identity throughout the lifecycle of a given product. It is based on traditional clothing tags, showing details such as the brand, price, dyeing process and recycling instructions at the point of manufacture and a record of interaction data throughout the lifecycle dubbed a "passport." The digital ID can be permanently attached to the product by RFID, NFC, QR codes or UPC barcodes. The technology allows the product to be easily tracked and transferred from one owner to another.

In Germany, a cross-industry consortium called R-Cycle is working on an applicable tracing standard to ensure the seamless documentation of recyclable packaging along the value chain, based on GS1 standards . Frequently, even fully recyclable packaging ends up in landfills or is burned. In Germany, for example, only 16% of plastic waste is recycled (official website R-Cycle); indeed, it is mainly downcycled rather than recycled because the mixture of different plastics can only be used for straightforward applications (such as black garbage bags), not allowing further recycling cycles. Particularly in this sector, a traceability standard is needed to obtain a significant circular economy's effects, recording all relevant recycling information in a digital product passport, which are key to achieving high-quality recycling.

It is important to distinguish two key concepts: traceability and re-traceability. Traceability is focused on the production cycle and along the supply chain, and is a process aimed at keeping track of all the inputs that go into creating, modifying or transforming a product. Traceability of raw materials is the first focus. Often, however, it is not enough to identify the origin and composition of a product, but it is important to understand which treatments and processes it has undergone. In this case, we talk about the re-traceability of the finished product, and it is the process that goes back in the chain of production of a good to allow the identification, at any time, of the details of each stage processing. Traceability, in general, is aimed at managing the flow of information related to a given product along the supply chain and is closely linked to the concept of information management, which must be as clear and transparent as possible.

Product passports are a convenient solution for establishing a common protocol and sharing information on the origin, durability, composition, reuse, repair, dismantling possibilities, and end-of-life handling of a product (Le Moigne, 2021). Once data is standardized, stakeholders often exchange it using digital platforms, which also supports secondary commodity trading (Le Moigne, 2021). However, it can happen that stakeholders do not want to share data on a platform operated by a private company. To solve this problem, there is the distributed ledger, the mother technology of cryptocurrencies and the Blockchain, which will be discussed in detail later. It is a type of database that is shared, replicated and synchronized between members of a decentralized network. To date, blockchain technology is being heavily pioneered in the chemicals and plastics sector to ensure maximum transparency and traceability throughout the entire lifecycle of resources, from raw materials through to the production, sale, use, and recycling of products. Knowing the details of each step in the supply chain is helpful to both the company and the buyers. The ability to track the supply chain allows it to be managed more effectively for the company. By processing the data with advanced software, costs and profit margins are better understood. In addition, in the presence of critical issues on the finished product, it is possible to identify the problem precisely, and then it is possible, for example, to identify and withdraw only the defective products. For end-users, a detailed product sheet better directs the choice and enables a faster purchasing experience. In fact, a correctly traced product gives the customer an extra sense of security towards the purchased good because they can easily retrace every step of the life and process it has undergone, consequently increasing the sense of trust towards the brand.

3.1.3 – Manufacturing Execution System (MES)

When we talk about advanced computer software to control and manage the production function of a company, we refer to the Manufacturing Execution System (MES). Since their beginning in the mid-1990s, MES has significantly evolved into more powerful and integrated software applications as computing technologies have advanced (Saenz de Ugarte et al., 2013). The MES concept was born from the demand on the manufacturing enterprise to fulfill the requirements of markets in terms of reactivity, quality, respect of standards, reduction in cost, and deadlines. As such, the functions of MES are primarily turned towards manufacturing activities, a major vector of the added value of all manufacturing firms (Saenz de Ugarte, et al., 2013). Historically well implemented in process industries (pharmaceutical, food and semiconductors industries) where MES systems meet the requirements for traceability imposed by authorities, they are now used in most manufacturing industries.

The MES monitors, in real-time, the activities carried out, the operators involved, the machines used and any downtime, and the product specifications and production times. Therefore, the MES allows to manage the dispatch of orders, the advances in quantity and time, and the deposit in the warehouse.

The functions of the MES are various: first of all, a MES system collects valid data useful to the operator in the production phase to build a high-quality product. It allows to control the progress of the production phases. The main feature of an MES is aligning management and production. This allows avoiding the differences between the planning level and the activated one, then controlling and managing the maintenance plans. The MES makes it possible to manage the resources useful for production, track the product and machine status and finally monitor the parts in production or the warehouse. Finally, another important function of the MES is the ability to analyze efficiency indices (Saenz de Ugarte, et al., 2013).

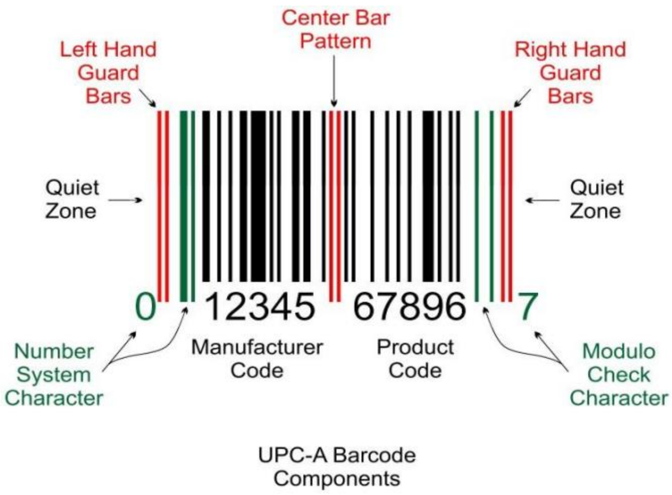
3.2 – Technological Systems of Traceability

Barcodes, QR codes, and RFID (radio frequency identification) convey large amounts of data in a small format. They offer speed, labor savings and cost savings, among other benefits. But there are distinct differences between all 3 — and differences in the purposes they are best suited for.

3.2.1 – One-Dimensional (1D) Barcode

The barcode is the most widespread goods identification system globally, consisting of an alternating sequence of dark and light bars of different thicknesses, and was first adopted in the United States in commerce in the early 1970s. Specifically, the first barcode was introduced in 1974 on Wrigley's Juicy Fruit gum package, and has since become increasingly popular. The areas where it is most widely used are primarily in retail, grocery stores, manufacturing environments, and product transportation. It is a simple technology that has evolved over the years: it can report the source, producer and type of product. It can be easily read with a scanner, is inexpensive to make, but it can only record a minimal amount of data.
There are two types of barcodes: linear - or 1D, and 2D. The most visually recognizable, the UPC (Universal Product Code) is a linear (multiple vertical lines) 1D barcode made up of two parts: the barcode and the 12-digit UPC number. The first six numbers of the barcode are the manufacturer's identification number. The next five digits represent the item's product code. The last number is called a check digit, enabling the scanner to determine if the barcode was scanned correctly.

Figure 9 – Barcode 1D – UPC-A Barcode Components



Source: Baum, 2019, "Bar, QR, RFID codes", available in https://www.uc.edu/content/dam/uc/ce/docs/OLLI/Page%20Content/PRODUCT%20IDENTIFICATION%20CODES%20BAR%20QR.pdfù

There are many categories of multidimensional (1D) barcodes, but each synthetically represents data by varying the widths and distances of the parallel lines. UPC and EAN are the most traditional and recognized barcodes (European Article Numbering). The UPC system is mainly used to label and scan consumer goods in retail outlets worldwide, although it is mainly used in the United States, the United Kingdom, Australia, and New Zealand. It has two variants: the UPC-A (shown in Figure 11), which encodes 12 numeric digits, and the UPC-E, which is smaller and encodes only 6-digit numbers. The EAN standard is divided into EAN-13 and EAN-8, which are two different versions of barcode and can encode respectively 13- and 8-digit numbers. The EAN-8 code was introduced for use on small packages where an EAN-13 barcode would be too large. All the other countries aside from the United States utilize the EAN barcode in the field of the GDO to identify the finished product that the final consumer buys, while the USA is still using the UPC code for the same purposes.

Figure 10 – Barcode 1D – EAN-8 and EAN-13

Source: Baum, 2019, "Bar, QR, RFID codes", available in https://www.uc.edu/content/dam/uc/ce/docs/OLLI/Page%20Content/PRODUCT%20IDENTIFICATION%20CODES%20BAR%20QR.pdfù

About 48% of small businesses do not track their inventory or use manual tracking process that are neither fast nor particularly effective[15]. 1D barcoding is a excellent alternative for these types of businesses that do not have a large budget to invest in traceability, because it is a low-cost but highly efficient way to manage inventory, helping reduce errors, and improve cash flow.

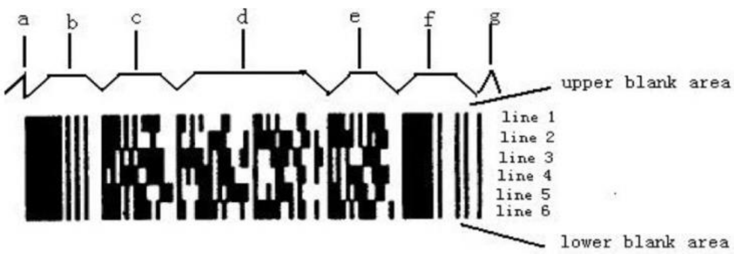
3.2.2 – Two-Dimensional (2D) Barcode

Over time, the need to store an increasing amount of helpful information has increased, leading humans to develop more advanced forms of barcodes. The evolution of the one-dimensional barcode is the two-dimensional (or 2D) barcodes, which systematically represent data using two-dimensional symbols or shapes. They are similar to the previous generation;

[15] Data from "State of Small Business Report" presented by "Wasp Barcode Technologies", 2018. Available in https://www.waspbarcode.com/small-business-report%20

however, they can track and represent more data per unit area. The most widely used 2D codes are the QR Code and PDF417.
The first QR Code was used in 1994 within the automotive industry in Japan by Denso Wave. The goal was to find an efficient way to track the parts they produced on the production line of the Toyota group, of which the company is a subsidiary. The company has chosen not to exercise its patent rights, thus encouraging widespread use of the technology (Ozkaya et al., 2015) that has been definitively used in most contexts thanks to the invention of smartphones. In this sense, the literature reports a steady growth in the use of QR Code in the last 15 years, focusing on the peak of early adopters between 2011 and 2012, in which the use of QR Code increased by 9840%. (Heltman, 2012). THEREFORE, the QR Code can be thought of as an expansion of barcodes in which an optical scanner reads both the vertical and horizontal arrangement of black dots. This expansion from one size to two allows for encoding characters and numbers in QR codes and means that you can store about 100 times more data (Ozkaya et al., 2015). QR Code (abbreviated from Quick Response Code) is often used in food traceability, reassuring the consumer on all aspects of the supply chain and the characteristics of the foodstuff and marketing initiatives, such as advertisements, magazines, and business cards. QR codes have features that allow companies to share information with their customers quickly and smoothly. Compared to previous code generation, they can handle different data types, numeric, alphanumeric, byte/binary, and Kanji. Moreover, besides storing significantly more information than one-dimensional codes, they have a flexible representation (shapes and colors of the modules can be changed), allowing even artistic representations. QR Code is also a quick and inexpensive alternative to drive new traffic to a company's website, which is among the most used marketing tools by small businesses to date (Wasp Barcode Technologies, 2018).
PDF417 code is an arranged 2D barcode with high capacity and error correction ability invented by Doctor Ynjiun Wang[16]. PDF means "Portable Data File" and each symbol character of barcode is made by 4 bars, 4 spaces and 17 modules in all, so is named PDF417 barcode.

Figure 11 – Barcode 2D – The concrete structure of PDF417



Source: Song, et al., 2012, "Design of the recognition and decoding system of PDF417 barcode"

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[16] Ynjiun Wang is a professor, doctoral supervisor in biomedical materials and tissue engineering. She created the PDF417 in the 1991 on behalf of Symbol Technologies.

This tool has multi rows with variable lengths, and each barcode symbol can express 1108 bytes, 1850 ASCII characters, or 2710 numbers information (Song et al., 2012). Those codes are mainly used for applications that require saving vast amounts of data (photographs, fingerprints, signatures). They can also hold more than 1.1 kilobytes of traceable and readable data, making them more potent than other 2D barcodes. These, as the QR codes, are also tools in the public domain and are free to use.

3.2.3 – Radio Frequency Identification (RFID)

The RFID system is a further evolution of the traceability system that is still relevant despite the first patent dating back to as far back as 1983, from US inventor Charles Walton. If barcodes are, in a sense, 1D data and QR codes are 2D, then we can image RFID tags as a 3D code. RFID is a technology and physical infrastructure that is used as a tool to identify and tag objects (Oghazi et al., 2018). Characteristically, RFID includes a microprocessor that possesses an information memory space, making it highly functional for several purposes, including tracking and control along the value chain (Oghazi et al., 2018).

Unlike barcodes, which are read with a laser scanner, and QR codes, for which optical scanners are used, RFID tags use radio waves to transmit the information stored within them. For this reason, there is no longer a need to have a direct line of sight for reading; instead, scanners need to be close to the tags. This simple RFID tag scanning allows for warehouse inventory management, ensuring that the shipped product conforms to the actual shipping order, preventing the stock-outs at the sales level, and updating managers with the current production phase. In addition, it can enhance the level of productivity, increasing the clarity of the product development process throughout the supply chain, decreasing the cost of labor and rendering inventory forecasting more accurate (Oghazi et al., 2018).

It follows that RFID technology offers a vast spectrum of practical applications, touching all environments and operational sectors, from logistics to production, passing through retail and large-scale retail trade. The main purposes of RFID technology are search, identification, spatial location and movement tracking. A big advantage is that RFID tags can be read all at once by the scanner rather than one at a time.

For example, logistics gates with RFID antennas installed, that instantly identify the contents of products passing through, are widely used. In production, by placing tags on the parts required to produce a component, it is possible to trace each stage of product development and the state of progress, as well as to know the current conditions, beginning or end of processing, or even to identify the machine or operator who carried out the operation.

For example, French sporting goods retailer Decathlon relied on the Nedap Identification Systems[17] to implement RFID technology, with the goal of increasing inventory accuracy and avoiding out-of-stocks. To benefit fully from the RFID deployment, Decathlon uses the RFID tags on the merchandise for loss prevention purposes. This enables Decathlon to track the merchandise from end-to-end from the arrival until the moment it leaves the store. In addition, Decathlon secures selected items with a high theft risk with an additional RF (Radio Frequency) hard tag.

Also Under Armour, a well-known American company also active in the sportswear industry recently established a strategic partnership with Nedap. Again, the primary goal was to achieve accurate inventory and product visibility across the company's retail stores, optimizing item availability and gaining efficiencies in day-to-day processes. However, RFID technology, said Bob Neville, vice president of global retail at Under Armour, “is key to unlocking a powerful omnichannel strategy that will enable Under Armour to create a more seamless and connected shopping experience across all consumer touchpoints. We see RFID as vital to bringing the retail experience to the next level”.

There is an important technological "leap" from the barcode to the RFID tag, but each system has its own usefulness and wider application depending on the context. Regardless of the tool used, traceability is essential to ensure transparency, security, order and truthful data.

3.3 – European Action Plans and the Digital Product Passport

3.3.1 – Previous and Upcoming European Actions and Initiatives

3.3.1.1 – The First Circular Economy Action Plan (CEAP)

The topic of the Circular Economy has been the focus of extensive European debates over the past few years. The most recent starting point that best ties in with current initiatives dates to December 2015, when the European Commission adopted its first Circular Economic Action Plan (CEAP). It included measures to help stimulate Europe's transition towards a circular economy, boost global competitiveness, foster sustainable economic growth and generate new jobs (official website of European Union). The action plan established concrete

[17] Nedap Identification Systems is the leading specialist in systems for long-range identification, smart parking and vehicle access control. It has a software platform called iD Cloud, developed specifically for retail RFID application, and provides solutions in Emergency Alert Systems (EAS) with hybrid technology combining RF and RFID systems.

and ambitious actions, covering the whole life cycle: from production and consumption to waste management and the market for secondary raw materials and a revised legislative proposal on waste. The actions under the action plan accelerated Europe’s transition by helping "close the loop" of product lifecycles through greater recycling and re-use and bought benefits for both the environment and the economy. The main sectors of reference were the plastics, chemical, electronic industries and any activity where there was an urgent need to renew the production system in a more sustainable form.

On 4 March 2019, the European Commission adopted a comprehensive report on implementing the action plan.

Keeping closely to what was drafted in Brussels, the CEAP envisioned 54 concrete actions, most of which were successfully completed, while only a smaller fraction continued beyond 2019. More than 4 million workers were employed in circular economy-related sectors in 2016, 6 percent more than in 2012. Circularity has opened up new business opportunities, giving rise to new business and market models, and activities such as repair, reuse or recycling have generated nearly €147 billion in added value, registering investment of around €17.5 billion. The report focuses on "consumer empowerment," specifying that information about the durability and repairability of products can influence an individual's purchasing decisions, steering them towards more sustainable choices. Keeping consumers wisely informed is it possible to guide them towards a responsible purchase.

Another critical point that is explored is that of "open challenges". This section sets out several goals that Europe must pursue from a circular perspective, such as achieving a prosperous, modern, competitive and climate-neutral economy by 2050. To do this, businesses and the European Union must work together to support research and innovation even in areas where, until now, the potential of the single market has not been exploited. These refer to sectors with an high environmental impact and high circular potential, such as IT, electronics, food, textiles, etc. In addition, the report shows full confidence in artificial intelligence and, more generally, in digitalization and Industry 4.0 technologies to optimize energy use and support business models and sustainable consumption choices.

3.3.1.2 – The European Green Deal (EGD)

On December 11, 2019, the European Commission announced the Green Deal, a roadmap meant to foster the transition of the European Union to secure the climate-neutral economy by reducing carbon emissions towards 55% by 2030, compared to 1990 levels, and achieving carbon neutrality by 2050 (official website of European Union). Additionally, the deal aspires to protect the health and well-being of citizens from environment-related risks and impacts and establish a toxic-free environment, deliver healthy and sustainable diets, and protect biodiversity (Haines, Scheelbeek, 2020). Europe alone cannot ensure that the increase in global average temperature is below 2°C above pre-industrial levels, as stipulated on the Paris Climate Agreement[18], but the EU's intention is to play a leadership role by rapidly reducing its own emissions and using its financial resources, knowledge and influence to encourage other nations to increase their climate actions (Haines, Scheelbeek, 2020). This project includes concrete actions: significant investments in environmentally friendly technologies, strong support for industry to innovate, introduce cleaner, cheaper and healthier forms of private and public transport, decarbonize the energy sector, ensure greater energy efficiency in buildings and work with international partners to improve environmental standards. It is clear that to achieve these goals in the stable timeframe will require high and precise investment operations, which is why the effectiveness of the EGD will be consequently measured against its capacity to mobilize climate dedicated funding (Sikora, 2020). The EGD intends to address this financial dimension, among others, through investments, mobilizing private, public funds, dedicating a part of the EU budget to climate action, providing support via the European Investment Bank (Sikora, 2020).

Overall, there are major health and environmental benefits from implementing the European Green Deal, but capitalizing on their potential will require careful design and evaluation of policy choices (Haines, Scheelbeek, 2020).

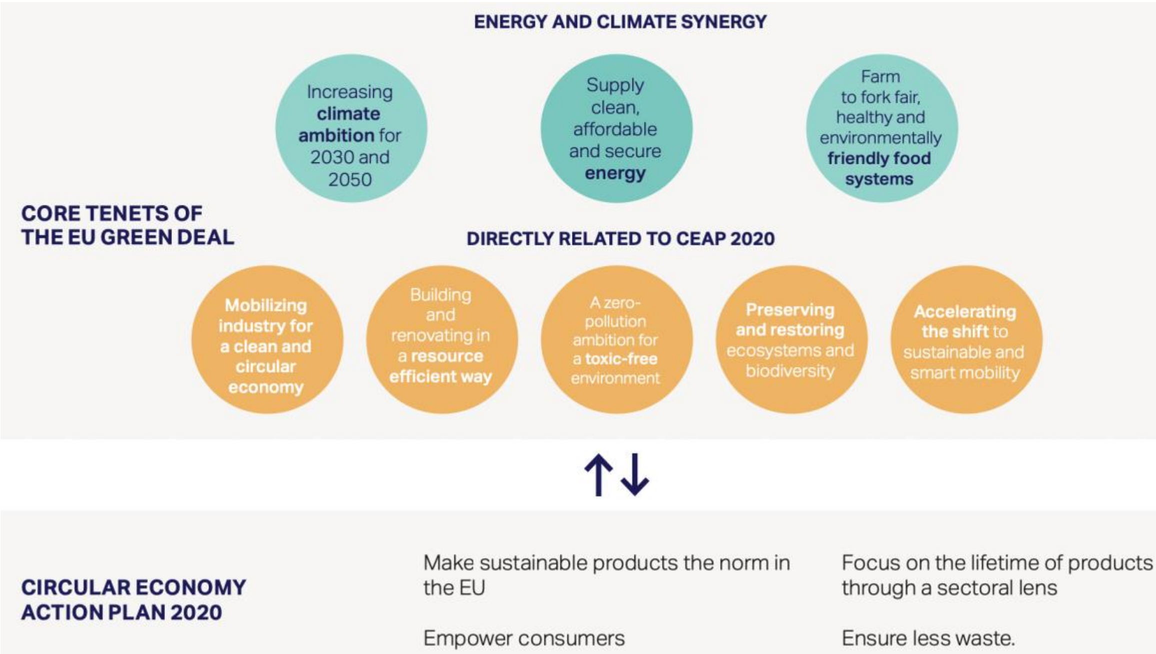
3.3.1.3 – The New Circular Economy Action Plan (NCEAP)

On March 11, 2020, was approved a New Circular Economy Action Plan (NCEAP 2020) “for a cleaner and more competitive Europe” (official website of European Union). The report premises that the macro-objective is to foster business creation and entrepreneurship among SMEs by building on the potential of digital technologies in favor of a circular economy. New innovative business models based on a closer relationship with customers, mass customization, the sharing and collaboration economy, and powered by digital technologies, such as IoT, Big Data, Blockchain, and AI, will allow to dematerialize the economy and make Europe less dependent on raw materials. For citizens, these initiatives translate into high-quality, functional, safe, and traceable products that are both efficient, affordable, and durable and designed for reuse, repair, and recycling (NCEAP, 2020).

[18] The Paris Climate Agreement is a legally binding international treaty on climate change. It was adopted in Paris, on 12 December 2015 and entered into force on 4 November 2016. Its goal is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels.

It is essential to underline that, unlike previous iterations of the CEAP, the 2020 NCEAP is a milestone of EGD (World Business Council for Sustainable Development, 2020).

Figure 12 – The Circular Economy Action Plan 2020 as part of the EU Green Deal and mutual synergies



Source: World Business Council for Sustainable Development, 2020, "CEAP 2020, implications and next steps"

Figure 20 illustrates the symbiotic nature of these overarching initiatives and their overlap. CEAP 2020 expands on the main themes introduced by the EGD, such as mobilizing industry, resource efficiency, creating a toxic-free environment, preserving biodiversity, and other similar topics. The shared goal is to achieve a cleaner and more competitive Europe in partnership with businesses, consumers, citizens, and civil society.

NCEAP 2020, unlike the previous plan, in addition to perfecting the guidelines for the disposal of plastics, investigates in depth the problems of sectors neglected in the past, such as electronics and ICT, batteries and vehicles, packaging, textiles and food, water and nutrients. In the report, each sector has its own analysis section in which the modus operandi, the objectives to be achieved and their hypothetical deadline are described.

For example, in the case of the textile sector, the strategy aims to strengthen industrial competitiveness and innovation in the sector, boosting the EU market for sustainable and circular textiles, tackling fast fashion and drive new business models. Measures include implementing the new sustainable products framework, including developing eco-design measures to ensure that textiles are suitable for circularity, ensuring the use of secondary raw materials, addressing the presence of hazardous chemicals, and enabling businesses and private consumers to choose sustainable textile products and have easy access to reuse and repair

services, and member states will need to ensure by 2025 that established levels of separate collection of textile waste are achieved (NCEAP, 2020).
However, in the case of packaging, to ensure that all packaging in the EU market is reusable or recyclable in an economically sustainable manner, the deadline is 2030. Among the new measures taken, in addition to setting new (over)packaging reduction targets, is the desire to drive design for reuse and recyclability of packaging, mainly where alternative reusable products or systems are possible, or consumer goods that can be safely handled without packaging.
Therefore, a significant step forward from CEAP was concentrating EU efforts on creating sustainable product and customer-centric value chains, ensuring maximum transparency and traceability. To do so, The EU has dedicated within NCEAP 2020 a dedicated section called "Sustainable Product Policy Framework", which brings us closer and closer to the Digital Product Passport (DPP) theme.

3.3.1.4 – Sustainable Product Policy Initiative (SPPI)

The global consumption of materials such as biomass, fossil fuels, metals, and minerals are expected to double by 2060, according to an OECD report, and 80% of product's environmental impacts are determined at the design phase, the linear economy does not provide producers with sufficient incentives to make their products more circular (Smart Waste, 2021). In order to address this situation, within the NCEAP 2020, in the "Sustainable Product Policy Framework" section, the European Commission anticipated a project called the "Sustainable Product Policy Initiative". The basic idea is to make products suitable for a climate-neutral, resource-efficient, and circular economy, ensuring that front-runners' performance in sustainability progressively becomes the norm (NCEAP, 2020). In line with the Green Deal objectives, EU product policy needs to keep climate and environmental impacts linked to resource and energy use, production, and use of products within planetary boundaries. The core of this legislative initiative will be to widen the Eco-design Directive[19] beyond energy-related products so as to make the eco-design framework applicable to the broadest possible range of products and make it deliver on circularity (NCEAP, 2020). As part of this legislative initiative and, as appropriate, through complementary legislative proposals, the Commission intends to establish principles to govern key issues in the Action Plan, some of which are listed here:

[19] The Eco-design Directive establishes a framework to set mandatory ecological requirements for energy-using and energy-related products sold in all 27 member states.

- improving product durability, reusability, upgradability and reparability, addressing the presence of hazardous chemicals in products, and increasing their energy and resource efficiency;
- increasing recycled content in products, while ensuring their performance and safety;
- restricting single-use and countering premature obsolescence;
- incentivizing product-as-a-service or other models where producers keep the ownership of the product or the responsibility for its performance throughout its lifecycle;
- mobilizing the potential of digitalization of product information, including solutions such as digital passports, tagging and watermarks;
- rewarding products based on their different sustainability performance, including by linking high performance levels to incentives.

Priority is given to product groups figured within the action plan identified in the context of value chains, such as electronics, ICT, textiles, and food, but also high-impact intermediate products such as steel, cement, and chemicals.
To gather views and evidence from the public and stakeholders on SPPI, including its possible scope, objectives, and the main policy options that should be considered for its implementation, the European Commission conducted a public consultation that closed in early July 2021. The plan was to analyze the contributions received and present an actual legislative proposal in the last quarter of 2021. However, there have been delays related to the adoption of the necessary implementation measures, which, according to the latest agenda of the College of Commissioners, the official announcement will be moved between March and April 2022.

3.3.2 – Digital Product Passport (DPP)

3.3.2.1 – Digital Product Passport as a New Way of Traceability

On the European Union (EU) level and concerning product policy, we know that the provision of data and the organization of a comprehensive information flow is promoted, among other things, by the EGD and the CEAP of the EU. Another much-discussed impetus in recent years is digitization, which makes the topic of product policy and data delivery even more relevant. Against this backdrop, the development of the Digital Product Passport (DPP), which is most prominently discussed in the context of SPPI, is gaining increasing attention at the European level. This is particularly important in combination with the expansion of the EU

Eco-design Directive beyond energy-related products to include as wide a range of products as possible to define appropriate minimum sustainability and information requirements for specific product groups. In fact, among the key points of the SPPI within the NCEAP 2020, we find a clear reference to it "mobilizing the potential of digitalization of product information, including solutions such as digital passports, tagging and watermarks" (NCEAP, 2020) and then to a DPP project.

In a context increasingly characterized by continuous information flows, even the product identification process must be innovated and integrated with current technologies (Cardesi, 2019). The DPP, which gathers data on a product and its value chain, has as main objectives to support sustainable production, to enable the transition to a circular economy, to provide new business opportunities to economic actors, to support consumers in making sustainable choices, and to allow authorities to verify compliance with legal obligations (official website European Commission). DPP is intended to provide consistent "track and trace" information on the origin, composition, repair, and dismantling options of a product, as well as on its handling at the end of its service life (Adisorn et al., 2021). However, it would be reductive to think of the DPP as only one tool to promote the circular economy because it can overcome existing barriers such as lack of information (Adisorn et al., 2021). Potentially, it can provide different actors (such as consumers and waste management companies) with relevant information on a product and thus force decisions towards sustainable development: for consumers during the purchase and use phase, for waste management companies during disassembling recycling (Adisorn et al., 2021). The European Commission said that thanks to the Product Passport, the product information will be "easily accessible and applicable to the supply chain, facilitating efficient material flows and encouraging value creation in the circular economy" (NCEAP, 2020).

While DPP's overall contribution to facilitating circularity appears to be relatively clear and policy is currently moving the topic more into the spotlight, a widely applicable and holistic DPP approach has not yet been established in practice (Adisorn et al., 2021). However, some approaches and ideas on how the DPP could be implemented.

For instance, at the EU's Member States' level, the German Government has picked up EU discussions on the DPP. According to the German Federal Ministry for the Environment, the digital product passport is a data set that summarizes the components, materials, and chemical substances or information on repairability, spare parts, or proper disposal for a product. The data originate from all phases of the product life cycle and are to be used to optimize design, production, use and disposal. At the same time, the digital product passport is intended as an essential basis for more and online retailing.

Finally, in both Industry 4.0 and the new circular economy, there is a shift to selling the function and not the product itself, so each product is ideally never considered waste and always remains the property of the company that produces them. According to a product sharing and reuse model, the DPP can certainly facilitate waste, and obsolete products can be reused to generate new ones. For example, DPP would be useful for fast-moving consumer goods, usually difficult for manufacturers to maintain.

Sticking to what the EU has planned, the sense is to pave the way for a gradual deployment, starting in 2023, of DPP in at least 3 key value chains: electronics (at least consumer electronics), batteries, and at least one other among the critical value chains identified in the 2020 NCEAP, for example, textiles, ICT, and other developing sectors. Specific contribution is expected to identify the critical DPP data in consultation with private and public stakeholders and establish protocols for secure and tailored access for relevant stakeholders. The work will also contribute to developing standardized and open digital solutions for identifying, tracking, mapping, and sharing product information along its life-cycle, ensuring interoperability across borders and a well-functioning EU Internal Market. Particular emphasis should be given to balanced and inclusive engagement of all relevant stakeholders throughout the value chain and to optimal use of digital technologies such as Artificial Intelligence, Internet of Things and blockchain.

3.3.2.2 – Blockchain Technology to Manage the Digital Product Passport (DPP)

According to the Global Brand Counterfeiting Report, in 2017, the market for counterfeit products reached $1.2 trillion. More worrisome, however, is that it was projected to reach $1.82 trillion in 2020. In 2021, the joint EUIPO and OECD study showed that counterfeit products account for 6.8% of all European imports, worth €121 billion. Considering the above, it's easy to see why regulators, supply chain stakeholders, and consumers are pushing for the creation of the DPP (Kotecha, 2021). With these product passports, consumers will know that the products they buy are authentic and that their purchases adhere to high ethical standards, whether they are luxury goods or consumer electronics.

These product passports can serve a dual purpose. On the one hand, consumers are increasingly concerned about the origin of the products they purchase and the companies' ethics and sustainability practices. In addition, there are often legal requirements related to product compliance and safety. From a company's perspective, product passports can also help them certify, for example, the origin of the product and its journey through the supply chain. It can also indicate the sustainability and authenticity of a product. Thus, a digital product passport can bring transparency to sourcing, manufacturing, supply chain, and compliance processes. In turn, this gives consumers the ability to buy with confidence and regulators to ensure compliance.

One possible obstacle in implementing the project relates to data privacy since, like their paper counterparts, digital product passports can be equally forged (Kotecha, 2021).

Blockchain can hold the solution: data collected in the blockchain network is automatically stored in a dynamically updated database, providing a reliable and immutable record of all actors in the chain, making it impossible to manipulate its content. That's why, for example, in the luxury sector, which to date is one of the industries with the highest risk of counterfeit goods, retailers are turning to blockchain technology, and more specifically non-fungible tokens (NFTs)[20], to help create secure digital passports. By providing a public ledger that is secure, unalterable, traceable, and distributed, blockchain in luxury goods is helping to verify and prove the origin and authenticity of luxury goods through the application of digital passports powered by blockchain technology.

Compared to the solutions adopted so far, where independent third parties certify the product, it will be possible to use a blockchain to record every step of the production process with the advantage that the controllers will explicitly authorize even transfers of ownership. Typically seen in the gaming and collectibles sectors, NFTs, a unique token representing a unique good or asset, is also being applied in other industries where supply chains can be authenticated. Rather than relying on a physical certificate, which could be fraudulently produced, digital passports are becoming the method of choice to certify the existence of a product. Still, within the luxury goods market, examples of NFT can be seen in fine wines, art, and Breitling watches. A perfect example of implementing blockchain technology in product passports is watching manufacturer Breitling's use of it in its new certificates of authenticity from October 13, 2020. All watches include a digital passport with blockchain that allows owners to prove the authenticity of their products and the legitimacy of their properties. By using blockchain, Breitling ensures that the certificates provide full transparency, are immutable, and remain theft-proof. The result is the elimination of counterfeiting. In addition, the passport automatically connects to the digital warranty program and allows owners to initiate and track watch repairs.

[20] Non-fungible tokens (NFTs) are a special type of cryptographic token that represents the deed and the certificate of authenticity written on Blockchain of a unique asset (digital or physical).

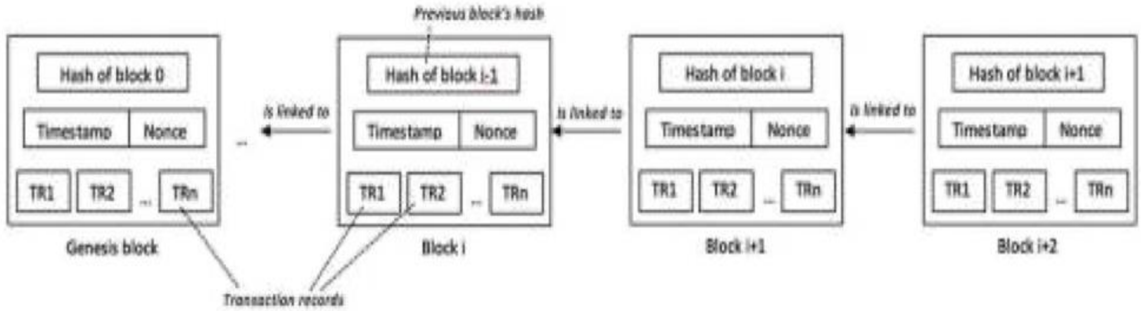
3.4 – Blockchain Technology (BCT)

3.4.1 – Characteristics and Functioning of the Blockchain

Blockchain technology and the circular economy (CE) are two emerging disruptive concepts. Socially, technologically, and economically these two concepts can transform life, business and the global economy for decades. (Kouhizadeh, et al., 2019). As we have seen, CE tends to be linked to Industry 4.0 based on a wide range of enabling technologies that we have previously analyzed. Among these, blockchain does not appear, because it tends to be associated with CE as a complementary technology, i.e., as a nuance of the master technologies (Kouhizadeh, et al., 2019). First of all, the technology in question was first presented in the winter of 2008 by its creator, Satoshi Nakamoto[21], who published his paper entitled "Bitcoin: A Peer-to-Peer Electronic Cash System", thanks to which today the world knows one of the most famous forms of blockchain, the Bitcoin system. Blockchain has also received considerable attention for applications other than cryptocurrency (Zhang et al., 2018). There is no single, universally agreed definition, but it is generally defined as a digital, decentralized, and distributed ledger in which each transaction is recorded and added to in chronological order to create permanent and unalterable evidence and traces. In more detail, each time a piece of information or data is received as a result of a transaction, a new 'block' containing that information is added to the chain; the succession of information and data forms a 'blockchain' (hence the name Blockchain). The first block in the chain, containing the first information collected, is the 'genesis block', while each subsequent block is called a 'parent block,' using a hash value. The size of the chain will grow over time as each new set of information corresponds to a block. The peculiarity that makes it a much sought-after tool is its immutable nature, as its content, once written down, can no longer be changed or deleted unless the entire structure is invalidated in some way (Wang et al., 2018). In short, the Blockchain is an ordered, solid, incremental, digital Blockchain of cryptographically linked data.

Figure 13 – A Standard Blockchain String

[21] Satoshi Nakamoto is the pseudonym used by the inventor of Bitcoin. Today there are numerous theories about his true identity.



Source: Wang, et al., 2018, "Understanding blockchain technology for future supply chains: a systematic literature review and research agenda"

Each blockchain has basic components:

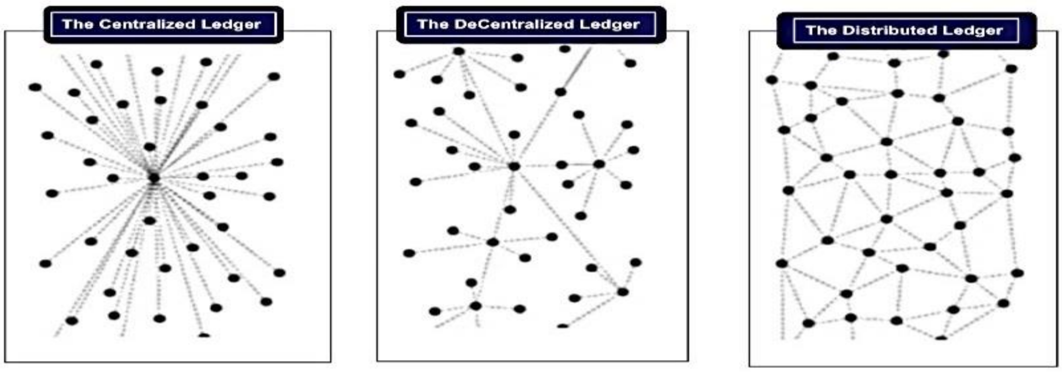
- Knot: these are the participants in the blockchain and are physically made up of the servers of each participant.
- Transaction: consists of the data representing the values being "exchanged" and which need to be verified, approved and then stored.
- Block: is represented by the grouping of a set of transactions that are joined together to be verified, approved and then stored by the participants in the blockchain.
- Ledger: is the public ledger in which all transactions are recorded in an orderly and sequential manner with maximum transparency and immutability. The ledger is made up of all the blocks that are chained together through a cryptographic function and the use of hashes.
- Hash: is a (non-Invertible) operation that allows a text and/or numeric string of variable length to be mapped into a unique and unambiguous string of given length. The Hash uniquely and securely identifies each block. A hash must not allow the text that generated it to be traced.

BCT is classified under Distributed Ledger as technologies that operate as distributed repositories (ledgers). Ledger is the "book master" of accounting, and it refers to a set of data contained within archives that allow defining the rules of analysis and verification of transactions.

Traditional ledgers, for instance, those through which banks and public administrations manage accounting and data registration, are centralized ledgers. The centralized logic is represented by a strictly One-to-Many relationship, where everything must be managed by referring to a centralized structure, authority, or system. In this system, trust is in authority, in the

authoritativeness of the subject or system representing the organization's "center. " Initially, this operating logic was never questioned.
The Decentralized Ledger again proposes the logic of centralization at a 'local' level with 'satellites' organized in their turn in the form of One-A-Many that relate to each other in a form that repeats the One-A-Many model. There is no longer one central subject but many multiple central subjects. Trust in this case too is delegated to a central subject, logically closer, but centralized.
The big change came several years later with blockchain and Distributed Ledger Technologies (DLT), a set of systems that refer to a distributed ledger that allows access to different users who can also make changes to it. DLTs are evolutions of Centralized Ledger and Decentralized Ledger technologies. No one has a chance to prevail, and decision-making goes strictly through a process of consensus building.

Figure 14 - Technologies at Centralized, Decentralized and Distributed Ledger



Source: Official website blockchain4innovation.it, 2021. https://www.blockchain4innovation.it/esperti/blockchain-perche-e-cosi-importante/

Two main types of blockchain are distinguished in access control – who can read a blockchain, submit transactions to it, and participate in the consensus process (Wang et al., 2018). Typically, the cryptocurrency blockchain is a public environment (Unpermissioned ledgers), where users do not know each other but can use the system and interact with other network participants (Olnes et al., 2017) without the need for control or validation of transactions. Each network member can contribute to updating data on the ledger and having, as a participant, all immutable copies of all transactions approved by consensus. Public Blockchains use complex algorithms to achieve consensus among network participants but, at the same time, may not be suitable for many companies, given the lower privacy protection they are subject to compared to private ones. The most famous and widespread example is the Bitcoin Blockchain. The other version is the private blockchain (Permissioned ledgers) preferred for enterprise networks and supply chains. In this case, only authorized users have access to the system and its information, and the system of approving and entering or modifying a transaction is constrained to a limited number of users. According to this model, actors can operate independently, but only one or more pre-selected actors act as validators in the network. It is precisely the ability to privatize critical information that motivates companies to use private versus public BCTs (Kouhizadeh et al., 2019).

3.4.2 – The Circularity of the Blockchain and its Potential Field of Application

3.4.2.1 – Blockchain and Circular Economy

Despite not being included as enabling technology in Industry 4.0, BCT plays a role in some features that support CE and help "closing the loop" in several ways: maximum transparency of information, reliability of processes, and the ability to track materials and products throughout their lifecycle using a global positioning system (GPS); these are all features that lay the groundwork for purposes of reuse, upcycling, recycling programs, and circularity performance management. In particular, it is helpful to dwell on the concepts of transparency-traceability, reliability-security and smart execution (Kouhizadeh et al., 2019). This technology provides a platform for recording and sharing data in terms of transparency and traceability. All transaction information is visible to authorized participants of a network and this visibility increases transparency and traceability in the system (Francisco, Swanson, 2018). BCT also adds transparency to supply chains (Stainer, Baker, 2015), giving the ability to track the entire life cycle of products. This cycle starts from the origin of raw materials to recycling, revitalization, or disposal. These activities can be monitored, verified, and tracked in real-time (Kouhizadeh, Sarkis, 2018). Blockchain ledgers incorporate encrypted and secure information from a reliability and security perspective, minimizing the risk of system failures and cyber-attacks through encryption systems and distributed consensus mechanisms, called "proof of work" (Kouhizadeh et al., 2019). The problem is that these systems consume a significant amount of energy and this runs counter to a key premise of blockchain, sustainability (Mougayar, 2016), which is why there is an urgent need to develop more eco-friendly consensus mechanisms (Kouhizdeh et al., 2019). Another advantage is the low probability of information forgery, fraud, or corruption (Zheng et al., 2017), as information cannot be removed from the network and the data history persists. Blockchain technology connects users directly without the need for central authorities or intermediaries. This allows stakeholders to exchange information and execute transactions digitally. Speed in transactions is supported by the smart contract, a decentralized application running on the blockchain platform (Macrinici et al., 2018). The system automatically evaluates the terms and conditions embedded in the smart contracts, and the moment the conditions are met, the activity associated with that term is executed instantly, and the parties involved are acknowledged. These automated systems have great potential to save cost and time by minimizing communication problems in supply chains (Kouhizadeh et al., 2019).

3.4.2.2 – The Potential of Blockchain in the Food and Textile Sector

As we have already mentioned, the Blockchain can be used to record different types of data, from transactions to any other type of information, without relying on intermediaries. BCT has recently been introduced as a technology for enhancing product data traceability (Behnke et al., 2019) and verifying their origins to offer consumers greater transparency on the food chain and the actors involved. Nowadays, it is crucial to achieving greater control over the food supply chain because it is strongly required to meet the growing consumer demand on product safety and quality, triggered by several food scandals (Benhke et al., 2019). A very prominent example of a food scandal with disastrous consequences was China's Melamine milk powder scandal in 2008 (Xiu, Klein, 2010). In this case, at least six babies are confirmed to have passed away because of Melamine contaminated infant milk powder. The food safety incidents and crises have brought the regulators into action and increased consumers' awareness. Food traceability is nowadays regarded as an essential aspect in ensuring the food safety and quality of the products and increasing consumers' confidence and satisfaction. In order to increase product traceability, companies need to exchange quality assurance information. The problem is that this mechanism often encounters a lack of trust between partners along the supply chain, which can generate commercial insecurities. Moreover, this is where BCT, which has been heralded as a trust-building technology, comes into play (Behnke et al., 2019).

The food sector is not the only one needing a modern and secure traceability system. Information asymmetry, visibility, and security are just some of the main concerns for multi-level supply chains. Supply chain operators often find it challenging to recognize and access all suppliers and sub-suppliers involved. Furthermore, with globalization and the diversification of chains in general, these problems have further intensified (Agrawal et al., 2018). The textile and clothing (T&C) supply chain is one such example that is suffering significantly from these challenges (Agrawal et al., 2018). It is well known that T&C industries are among the largest employers in developing countries; however, they have also been at the center of serious scandals such as unsustainable practices in the form of child labor, irregular wages, sweatshops and toxic waste treatment/discharge. Because of these events, governments, under constant pressure from customers and social welfare organizations, have pushed to implement mandatory transparency and information-sharing rules to regulate and protect supply chains.

On the other hand, an opaque and insecure supply chain facilitates the counterfeiting process that has always been a significant threat in this sector. These products affect the fashion brand image and economy and are also detrimental to consumers' health due to their inferior quality (Agrawal et al., 2018). Although millions of euros worth of counterfeit products is confiscated each year, trade-in them remains virtually uncontrollable due to the enormous volumes and weak links in the T&C supply chain (Agrawal et al., 2018). As per the report from the European Union Intellectual Property Office Observatory, due to counterfeit products, the T&C industry loses 9.7% of sales, 26.3 billion euros of revenue per year in the sector, 36,300 direct jobs, and 8.1 billion euros of revenue by the government (Wajsman et al. 2015 in Agrawal, et al., 2018). As mentioned in the same OECD report (2017), traceability is one of the mechanisms that can be used to counter these issues. In particular, a blockchain is a key tool in product tracking in the luxury sector; traceability gains more relevance in an industry with a high counterfeiting rate where maximum transparency is demanded from companies by consumers.

A recent example is the Aura consortium, a platform launched in June 2019 that uses Blockchain technology. The LVMH, Prada, and Richmond groups are currently collaborating. The consortium was created to create a unique system that cannot be tampered with while at the same time ensuring that member groups are acquiring original raw materials that will go to make up the final product. Thanks to Aura, the groups will have full control over the value chain, while consumers will be guaranteed to buy original products. The ability to track products and provide them with digital identity (like the DPP) allows the consumer to investigate the timeline of the product, including the raw materials with which it was made, it is processing, shipping data, and other critical pieces of information. The Blockchain also aims to remove doubts about identifying authentic products in a transparent and immutable record by using a 'digital twin,' a virtual representation of a physical product that cannot be duplicated or modified. Since the digital twin cannot be assigned to more than one physical product, but more importantly, it cannot be falsified, the Blockchain application and its protocols will significantly improve the transparency of the supply chain and the product itself. It is not only companies that will benefit from the increased transparency, but also consumers. In this specific case, products of the LV brand or others of the LVMH group being registered with a digital twin, or token, it will be possible to provide consumers or other users with a wide range of verified data related to that product, including an immediate and reliable confirmation that the product is authentic.

CHAPTER 4 – SUSTAINABILITY AND TRACEABILITY THROUGH BLOCKCHAIN: EZ LAB S.R.L.

4.1 – Introduction

This chapter analyses the real case of a market leader in traceability and digital solutions, which are offered and proposed to other companies and partners interested in investing in projects of traceability and certification of the supply chain through blockchain tools. The fourth chapter will follow a precise sequence in order to make the content of the research and the final considerations as clear and fluid as possible.

First, the main purposes of this research will be defined.

Afterward, the reference company will be analyzed, first exposing its general characteristics, history, and main players in the company, and then investigating the projects and initiatives they manage related to the theme of circular economy and traceability. In particular, we will focus on the most emblematic case studies for each of the reference sectors for which the company has worked, which I have obtained direct feedback through a targeted interview on these issues. The details and questions can be seen at the end of the chapter.

The next step is the exposition of the results obtained, with the consequent implications and conclusions.

4.2 – Research Objectives and Methodology

The study aims to investigate how the digital technologies of Industry 4.0, with particular attention to the most modern blockchain technologies, contribute to meeting the principles of sustainability and consumption control typical of the Circular Economy in multiple sectors, focusing in particular on why today it is essential, both for consumers and producers, the link between product traceability and environmental sustainability. To do so, we will use the emblematic case study of the company EZ Lab S.r.l., a market leader in digital traceability solutions through blockchain. The chosen method is an interview that took place directly with Monica Bortolami, Marketing and Communication Manager of the company EZ Lab S.r.l and CEO & Founder of Noima, an innovative start up specialized in Web Reputation and Risk Management. The interview was conducted remotely, using the Zoom platform, and lasted just over an hour. Before the call we had been in contact by email, in which I was able to anticipate the focus of the interview. Monica Bortolami was very helpful, because in addition to the classic "question and answer" typical of this type of survey, she presented me with the company's latest content, relating to the most recent projects and initiatives that are being developed, using PowerPoint. I am not allowed to publish the specific images, including data (as they are sensitive to the company), but I am allowed to argue the contents concerning the projects launched. The content of the interview touched on many topics. Initially, we talked about the foundation of the company and the difficulties encountered both at its launch and in the subsequent phases, then we focused on EZ Lab's business plan: the design of digital solutions that make use of Industry 4.0 and blockchain technologies to guarantee security, anti-counterfeiting and total transparency of products and the production chain, both for the consumer and the producer. To this end, several case studies, projects and collaborations that EZ Lab has had (and is still having) with many companies/customers in many sectors were discussed, giving further evidence of how these technologies can positively impact not only the agri-food sector (with which EZ Lab started) but also completely different markets in which traceability, and its relationship with sustainability, is increasingly the protagonist of the strategic choices of companies, independently of the reference sector.

4.3 – Sample Description – EZ Lab S.r.l.

4.3.1 – Company features

The reference company is EZ Lab S.r.l., an innovative SME specialized in advanced digital solutions mainly for the Smart agri-food sector. Following are the general characteristics of the company:

- Massimo Morbiato founded the company in 2014 and today is based at StartCube, a university incubator in Padua. Today (2021-2022) the company has 21 employees and is also based in San Francisco (California) in Silicon Valley and, from 2019, also in Reims (France), for the Champagne market. The work team comprises IT professionals, agronomists, legal business managers, business development advisors and marketing and web reputation experts.
- The turnover of EZ Lab S.r.l. to the year 2020 reports a range of "less than 300,000 euros", derived 100% from blockchain projects. Compared to the values of 2018, it has grown by about 18% and is estimated to grow also for the following years, up to €7 million for the year 2025.

- The target industry is the information technology and services sectors. Blockchain solutions were first used in the agri-food sector, and later also in other industries. The business generated by the AgriOpenData platform for the agri-food sector has enabled the company to reach a break-even point.
- The Mission of EZ Lab S.r.l. is to ensure transparency and safety from the producer to the final consumer, who today wants to be informed for a conscious and sustainable purchase. It aims at enhancing the value of Made in Italy, promoting high quality production.
- In 2016, thanks to a collaboration with Ernst&Young (EY), the company presented the first case of a wine company in the world certified blockchain - Wine Blockchain - a technological innovation able to guarantee, through a smart label placed on the bottle of wine (QR Code), the traceability of the production chain (from the vine to bottling) and the transformation of agricultural products, certifying their quality, territoriality, the origin of the chain, ensuring authenticity and transparency to the consumer.
- Since 2017, it has also operated internationally, and in the same year it was the only European innovative business reality to be selected by the US incubator Thrive in Silicon Valley. It is a business partner of IBM food trust and collaborations enhance EZ Lab S.r.l.'s research activity with the Law and Agripolis departments of the University of Padua and the Economics department of the University of Verona.

Today, the company enjoys an excellent reputation and is highly sought after, especially at a national level, for the services it offers companies for Made in Italy products. However, "it is not easy to open a business like ours," says Monica Bortolami, "when you think that the companies that come to us have to invest money, resources and time in new technologies since they already incur many costs and are committed to producing a quality product. It was not easy, especially initially, to find customers willing to invest". These issues emerged mainly in the agri-food sector with which EZ Lab started because although the agricultural sector indeed has a diversity of revenues, it tends to be a low return market, so adding more costs was not seen as a positive value. Monica Bortolami goes on to say, "after the technology was introduced, both our customers and we realized how much it helped to increase the value of the product, which can then be sold at a higher price, offsetting the expense in some way". The company has always believed in the potential of digital technologies deriving from Industry 4.0, particularly in IoT, Cloud and Cybersecurity systems. As we will see later, AgriOpenData is an application that perfectly combines these technologies with a perspective of traceability and sustainability in the agri-food sector.

4.3.2 – AgriOpenData

One of the company's first and most critical winning projects is the AgriOpenData software, the most powerful online platform for optimization in the agri-food sector, created to support farmers and agronomists in the correct management of herbicide and fertilizer treatments through the collection and use of Open Data integrating directly with the information processed during field activities.

Figure 15 & 16 – AgriOpenData – by EZ Lab S.r.l.

Source: Official website EZ Lab, 2022, https://www.agriopendata.it

It uses blockchain technology and smart contracts for traceability and certification of agricultural products as a system of security and protection of origin, environmental sustainability, and ethical values, ensuring an increase in the economic value of the product. Moreover, thanks to the constant and historical information, it is possible to use the resources and fertilize products more correctly and efficiently. AgriOpenData blockchain solutions have already been applied to production realities like wine, Asiago cheese, beer, ancient wheat, soy, rice, cotton, tomato, canape and milk. As Monica Bortolami explained, interfacing with this technology is straightforward "at any time and in any food outlet, the consumer can easily and transparently verify the origin, the properties of the product and the entire food chain, consulting the information collected during the production process, simply by bringing their smartphone close to the QR Code on the product." Massimo Morbiato, in an interview for StartupItalia, said that AgriOpenData "is a transparent application, because it does not add anything to the supply chain. We take data in any form, and we certify it"[22]. EZ Lab uses many Industry 4.0

[22] Available on << https://startupitalia.eu/99182-20181022-agriopendata-campo-blockchain >>

technologies, especially IoT, cloud, and cybersecurity systems, which are most involved in managing, analyzing, and protecting large amounts of data linked to the production chain. For example, as Massimo Morbiato said for StartupItalia, the cloud is a fundamental technology for their business because "in a supply chain where the actors are scattered throughout the territory, often in different countries, it is unthinkable to have a local program installed on a PC. Everything we do is on the cloud so that those involved in the supply chain can enter our work system directly". The cloud represents an advanced system to help reduce costs and constant innovation over time, guaranteeing high performance and maximum reliability. In addition, it adds Monica Bortolami, "we use dual technology inside the product via QR Code. There is an inbound technology, useful for the consumer, as it tells the story and the path of the product, and an outbound technology, useful for the producer to locate the product and understand if, for example, it has been sold abroad. In this way, it is possible to profile the target consumer from a marketing point of view and check whether the product has been subject to fraud. In all of this, continues Monica Bortolami, "Noima comes into play, a company that works with EZ Lab S.r.l. and that uses a program developed by the same company, to monitor the entire reputation of the brand and the product from the point of view of risk management and cybersecurity".

The CEO of EZ Lab goes on to say that "for us, the value of the supply chain is not only economical but also ethical: we demand that the people who work in it are paid fairly and that there is no exploitation of child labor. A sustainable supply chain also means attention to the environment and calculation of CO2 consumption".

In 2016, AgriOpendata won the Lamark Smau Milano award, given to the most innovative start-ups ready to meet the industry world. EZ Lab S.r.l. was selected along with two other companies from over 200 start-ups present at the reference event in the innovation and digital sectors.

4.4 – Analysis of New Frontiers for the Implementation of Digital Technologies

4.4.1 – The Equity Crowdfunding Campaign

On 15 February 2020, just before the lockdown due to the Covid-19 pandemic, EZ Lab launched a fundraising project on the MamaCrowd platform, with a target of €200,000 and a minimum participation threshold of €250, also entitling investors in innovative SMEs to a 50% tax deduction. This is because, says Monica Bortolami, "We already have projects started in new sectors, but in order to develop them and achieve our goals, we need the right resources.

Although there were a lot of players interested in the projects, in practice, no one was ready to invest adequately, so we chose to rely on the internet and the power of sharing. In this way, EZ Lab S.r.l. has devised a business plan that can be identified in two phases: the first is to consolidate and enhance their role as a market leader in the agri-food and Made in Italy sectors, the second phase intends to extend the company's area of expertise, exploiting the creation of 7 strategic partnerships with as many market leaders, one for each sector. There are two exit windows for interested investors; the first is 2-3 years from the end of the campaign when the company will return to the market to finance the scale-up of the acquired partnerships. The second is at five years, upon completion of the industrial plan envisaged by the company. In support of this project, the four years preceding the equity crowdfunding campaign, in which EZ Lab S.r.l. has emerged as a leading player in the agri-food sector, have served as a perfect guarantee for interested investors.
After an initial success of €120,000 raised in a couple of weeks, Covid-19 seemed to have stalled the fundraising campaign. However, EZ Lab managed to win investors' confidence and, by the end of the campaign on 15 June 2020, €742,737 had been raised, exceeding its target by 337%. Monica Bortolami added, "beyond the substantial financial contribution we have achieved, it is important to underline that we have collected 329 contributing members, who are of considerable value to us, as they are in a sense our brand ambassadors. We will do everything we can to nurture this value and repay the trust of the contributors".

4.4.2 – New Investment Sectors

According to estimates by the World Economic Forum, by 2025, 10% of the world's GDP will be produced by activities and services delivered and distributed through blockchain technologies (Ogee & Guinard, 2019). The Ministry of Economic Development has made available €45 million as an initial investment allocation for developing blockchain, IoT, and AI technologies to promote the competitiveness and productivity of Italy's business system in various sectors through research and technological innovation projects linked to the Transition 4.0 program. In addition, the European Union Fund has made available approximately €150 billion - 20% of the package of incentives agreed to EU leaders in July 2020 for economic recovery from the COVID 19 pandemic - in blockchain and digital technologies to strengthen technological development in the area.
EZ Lab S.r.l. has understood the potential of these technologies and, thanks in part to the success of its crowdfunding campaign, has invested in new projects and expanded its boundaries of expertise, using its knowledge of blockchain technology to operate in new areas.

There are many company projects; some have already taken place, others are ongoing, and others are still in the planning stage. I had the opportunity to talk to Monica Bortolami about some of these projects, which I have collected in the table below, before analyzing them one by one.

Table 3 – New Investment Sectors of EZ Lab S.r.l.

MARKET SEGMENT	PARTNER/CUSTOMER	START DATE	PLATFORM/PROJECT
Art	Noima	November 2019	Art.Certo
Agrifood	Consortium for the Protection of Pachino Tomatoes PGI	February 2020	AgriOpenData
Medical	AB Analitica	April 2020	Blockchain on RQ-2019-nCoV
Real Estate	REinventi	May 2020	RElabs
Textile	Carrera jeans	September 2020	Made in Block
Space-Tech	ESA	December 2020	SmartAgrisat
Nautical	Noima	May 2021	DiportoChain

Source: Table of my own production

4.4.2.1 – Art

Since November 2019, EZ Lab S.r.l. has started collaborating with its technology partner Noima to launch the Art.Certo application, designed to serve artists. As we mentioned, Monica Bortolami is also CEO and founder of Noima, an innovative startup founded in 2017, specializing in advanced digital solutions for web reputation and risk management. Monica Bortolami said that "through Art.Certo we give to the artists the possibility to create their digital archive and certify their works".

The way it works is very simple: just a few simple steps and the artist - or the art gallery itself - can create its own digital archive inexpensively and securely, "depositing" its works with a click and certifying them with blockchain technology to protect their value and protect them from the risk of plagiarism.

The artist is simply asked to take a photo of the artwork, upload it to the application with a short description and obtain a real-time blockchain certificate of authenticity, which is applied to the artwork with a sticky tag. At this point, the buyer or visitor needs to use a Smartphone to read the QR code attached to the work, so that they can view the artist's name, archive number, year

of creation and also all the changes of ownership that have taken place, as well as all the other works signed by the same artist. On the other hand, the artist can monitor the progress of all his creations in real-time and have an unassailable tool in case he wants to expose fakes, as everything is based on blockchain protocols.
In this way, there is a double protection mechanism: the artist will have at his disposal a secure and immutable digital archive that allows him to verify all the steps in the custody of his works, while the buyer can have an additional guarantee on the authenticity of the work and its history.

4.4.2.2 – Agri-Food

"We started in agri-food," said Monica Bortolami, but "we intend to strengthen and remain competitive in this sector". EZ Lab S.r.l. has carried out more than 40 traceability projects with blockchain on supply chains such as wine, beer, Asiago cheese, rice, soya, and pumpkin. In addition, shortly before launching its equity crowdfunding campaign on the Mamacrowd platform, the company agreed with the Consortium for the Protection of Pachino Tomatoes PGI. This is a non-profit organization recognized by the Ministry of Agriculture; its mission is to protect the reputation of the authentic Pachino tomato on the markets and to defend it against countless attempts at commercial counterfeiting, through appropriate legal action, on a national and international scale. The PGI mark - (Protected Geographical Indication) - presupposes that it is only used by companies operating in a specific territory, respecting a strict and extremely precise specification, from the methods of cultivation and sale, to packaging. Yet at the end of 2018, Coldiretti data say that the value of fake Made in Italy agri-food products in the world has risen to over 100 billion, with an increase of 70% over the last decade due to international piracy that improperly uses words, colors, locations, images and denominations that recall Italy. Therefore, despite the severity of the controls, the Consortium has decided to rely on blockchain to further guarantee the consumer. In the absence of proximity between consumer and production and direct knowledge of the producers, only technology can bridge this distance.
The collaboration aims to be able to trace Pachino tomatoes from the field to the supermarket and combat counterfeiting, ensuring environmental and social sustainability. From then on, the producers of Sicilian tomatoes will use the platform we have already talked about, AgriOpenData, to record all the supply chain information in an unchangeable way to protect the excellence of Made in Italy. By reading a QR code printed on the packaging, the consumer can access the product's "digital passport" from the field where those tomatoes were picked to the factory where they were packaged, going back up the entire distribution chain.

Figure 17 – Pachino tomatoes trakced by EZ Lab S.r.l.

Source: YouMark, 18/02/2020. Available on << https://youmark.it/ym-interactive/il-pomodoro-pachino-e-tracciato-con-la-tecnologia-blockchain-grazie-alla-piattaforma-agriopendata-di-ez-lab/ >>

Monica Bortolami added that "blockchain also allows us to defend the ethical and social values that we hold dear. In the case of Pomodoro Pachino, this digital solution makes the supply chain more transparent, becoming an additional weapon against the problem of caporalism, which often plagues this sector".

4.4.2.3 – Medical

Since April 2020, EZ Lab S.r.l has been working with another company from Padua, AB Analitica S.r.l., which specialises in developing, producing, and selling diagnostic systems for professional use. AB Analitica S.r.l. was one of the first Italian companies to operate in molecular diagnostics and now has over 30 years of experience in the design, development, and production of in-vitro diagnostics. AB Analitica S.r.l. is one of 11, of which only 3 are Italian, indicated in a circular of 3 April 2020 by the Ministry of Health as certified producers of diagnostic kits for Coronavirus.

EZ Lab S.r.l. has made available its field knowledge of blockchain technology to guarantee laboratory operators, by simply reading a QR Code placed on the packaging, that they have material that complies with the law and is of certified origin. The method developed by EZ Lab S.r.l. is applied on the Diagnostic Kit, RQ-2019-nCoV entirely designed and produced within AB Analitica, available on the market and supplied to laboratories in the area that perform diagnostic and screening tests. A kit that can analyze up to 100 samples from nasopharyngeal swabs in about three hours, capable of extracting viral RNA, amplifying it and replicating it in real-time to detect the possible presence of Coronavirus infection; it is incredibly efficient, in one working day it can analyze up to 400 samples.

Figure 18 – Partnership between EZ Lab S.r.l. and AB Analitica

Source: Ganz, B., Il Sole 24Ore & EZ Lab S.r.l. 20/04/2020. Available on << https://www.ezlab.it/it/notizie/il-sole-24ore-tamponi-e-kit-eccellenza-veneta/ >>

Since 8 September 2021, the Regional Council has officially recognized the "RIR" (Rete Innovative Regionale Tech4Life, a digital innovation network) an initiative to push research in the biomedical sector, of which EZ Lab S.r.l., Norma Web Reputation and AB Analitica S.r.l., are part, together with 55 other companies, universities and regions. The aim is to develop substantial independence from foreign supply networks and to make up for the shortcomings of the Veneto region, especially in terms of the availability of masks and respirators, which emerged during the height of the pandemic. Monica Bortolami points out that "it is essential to start being autonomous again in the medical sector, especially in this delicate phase. Because the traceability process is more challenging when we are dependent on certain foreign countries, such as China, that is exactly what the RIR is for.

4.4.2.4 – Real Estate

Another new sector for digital technologies, particularly for blockchain, is undoubtedly the real estate sector. This is the field of action in which RElabs, the first company in Italy specializing in using this technology in real estate, operates. The founding partners are two leading companies in their respective sectors, who have chosen to merge their skills in a new project: the first is EZ Lab, the second is REinventi, a company providing IT consulting and real estate management services to public and private, Italian and international institutions. The new company president is Andrea Migliore, president and owner of REinventi, and is a lawyer who has been active for more than 25 years in real estate. The CEO of the new company is Massimo Morbiato.

Figure 19 – RElabs – Blockchain for Real Estate

Source: Official website RElabs Blockchain for Real Estate. Available on << https://www.relabs.it >>

RElabs was created to provide a tool that can cut costs and simplify procedures for all public and private entities, from public administrations to institutional investors, responsible for the management, maintenance, and redevelopment of many properties. Leveraging EZ Lab S.r.l.'s digital expertise and blockchain technology, RElabs can develop a wide range of solutions and exploit multiple functions of blockchain in the Real Estate sector.

For example, RElabs can create smart buildings that combine energy efficiency and automation. In addition, blockchain makes it possible to digitize any contract (Smart Contract) for buying, to sell, managing, building and subcontracting, recording and verifying contractual conditions during the work, making contractual relations more secure and efficient, lowering costs, and minimizing costs the use of intermediaries. Another benefit to the real estate sector is the phenomenon of "tokenization," i.e., the transformation of the property into tracked and certified 'digital tokens,' facilitating the transfer of ownership, reducing costs, and making real estate assets more liquid. In addition, tokenization provides greater accessibility to the real estate market, translating into guaranteed access to Investments for a wider public.

In an interview published on 14/05/2020 for VenetoEconomia, Andrea Migliore stated that "IT in the Real Estate sector is becoming increasingly important. The workforce in this sector is historically the main cost item. Technology is the winning solution to emerge in this market because it brings two advantages: higher quality of services, lower error margins, and lower costs. Relabs was created for this reason: as of today, we are ready to support all operators in the sector, from real estate funds to construction companies and design studios, who wish to explore what blockchain can do for them"[23].

[23] Available on << https://www.venetoeconomia.it/2020/05/ez-lab-blockchain-immobiliare-relabs/ >>

4.4.2.5 – Textile

EZ Lab S.r.l. has also been selected as an official partner in the textile sector, thanks to collaborating with Carrera Jeans, a historical Italian brand founded in 1965 in Verona. The project is called "Made in Block" and aims at the total traceability through the blockchain of jeans produced by Carrera. The two companies are joined by the University of Verona, which will launch a study on consumer perception and the impact of this transparent supply chain project on sales.

Once the QR code has been scanned with a smartphone camera, it will be possible to find out all the steps and details of the supply chain, from picking the cotton to distributing the product in stores in Italy and around the world.

Carrera Jeans has decided to make its supply chain as short and sustainable as possible, starting with the harvesting of cotton in the Tajikistan plantations strictly and exclusively by hand, guaranteeing the integrity of the fiber and better respect for the environment. They have also set up production centers that offer the best conditions for harvesting the top-quality cotton, Tajiko, one of the best in terms of strength. The facilities used by the company are also designed to have the least possible environmental impact. The factories in Tajikistan, one for blue jeans and one for colored cotton trousers, produce around 4 million pieces a year, employing thousands of workers and maintaining a high-quality standard. In addition, thanks to a short supply chain, many truckloads of goods are avoided, which significantly reduces CO2 emissions into the air. At the end of processing, the product is ready for the marketing phase and is then shipped to stores in the various countries where the company operates.

Thanks to this initiative with EZ Lab S.r.l., Carrera Jeans, a company that has always stood out for the attention it pays to its garments, wants to share with its customers, transparently, all the information guaranteeing the quality of its quality standards, as well as its ethical and moral values linked to the theme of environmental sustainability, now officially visible and verifiable by everyone. Monica Bortolami added, "the company has benefited from the inventiveness and entrepreneurial and innovative skills of its owner, who has been able to relaunch the brand and give a new impetus to their projects." Carrera Jeans has been officially under the management of Gianluca Tacchella since 2001, who now has complete control of the entire supply chain.

4.4.2.6 – Space-Tech

A further collaboration has also arisen between EZ Lab S.r.l. and ESA (European Space Agency), which has placed its trust in the Padua-based company for a sustainable agriculture project in the sphere of Space-Tech. EZ Lab S.r.l. is the only Italian company, out of more than 80 from across Europe, to have won the European Space Agency's "Aspire with ESA" tender for a project that exploits the potential of space technology and blockchain to combat the wastage of water resources and reduce CO2 emissions. Aspire with ESA is a co-funding mechanism. The European Space Agency provides resources to projects that use technological innovations to produce positive social and economic impacts, in line with the 17 sustainable development goals set by the United Nations for 2030.

The space-tech and space-economy sectors are two emerging industries and represent a new frontier for innovation, which EZ Lab S.r.l. is entering for the first time with a Precision Farming project.

In particular, the company has created a platform called SmartAgrisat that acquires and processes images from satellites to provide farmers with data, tracked and certified with blockchain technology, from which they can draw precise indications on the use of water and fertilizers for their land. The aim is to combat the waste of water resources and generate a virtuous cycle that can considerably reduce CO2 emissions. The SmartAgrisat project is based on photographs provided by satellites such as Sentinel2, which produce very high-resolution images.

Figure 20 – Satellite made available by ESA for the project with EZ Lab S.r.l.

Source: Costa, C., Agrifood.tech, 24/01/2022. Available on << https://www.agrifood.tech/blockchain/space-tech-e-sostenibilita-esa-sceglie-ez-lab-per-unagricoltura-piu-sostenibile/ >>

Through the collection and automatic analysis of multispectral images of agricultural plots, which record the light reflected by vegetation in the infrared bands, the platform created by EZ Lab produces detailed maps of the vegetative state of plants, their physiological needs, soil moisture, and areas subject to water stress. From these maps, calibrated according to the type of crop and the type of soil present, plans are drawn up indicating the variable doses of fertilizers, phytosanitary products, and water to be administered according to the area to be treated. This data is then sent to individual farmers via fast (including 5G) and secure connections, guaranteed by the blockchain technology built into the platform. The data is also compatible with the onboard computers of semiautomated tractors and automated irrigation systems capable of varying the volume of distribution and the amount of product dispensed in the field.

"This project is really important for us, not only because it was the first time we put our technology at the service of the space-tech sector, but also because the possibility of automating certain processes is of great importance from the point of view of environmental sustainability," specifies Monica Bortolami.

4.4.2.7 – Nautical

In May 2021, EZ Lab S.r.l., again in collaboration with Norma Web Reputation & Risk Management, developed and presented the platform called DiportoChain, the first registry that protects vessels in the full respect of privacy, revolutionizing the nautical sector. Monica Bortolami confirmed that "Italian legislation, to date, does not provide for any regulatory obligation. This has led to cases of abandonment of these vehicles on the bottom of canals or rivers, which then become waste from which it is impossible to trace the owner." This is a gap in the legislation, which creates an undoubted disadvantage due to the lack of protection for the purchased goods, which, because they are not unique, are exposed to many risks, including theft, loss of value and tampering.

The DiportoChain tool has been designed to meet these needs. It uses blockchain technology to make boats unique and distinctive, allowing the asset's value to be enhanced by making the registered data that the owner chooses to notaries secure and immutable. It allows access to the digital identity of the vessel, tracing its entire life, from the purchase phase to the sale, passing through maintenance activities, improvements, and even transfers in total confidentiality. "In this way, its ownership and value over time is protected while fully respecting its privacy," says Monica Bortolami. To register, the owner logs on to the http://www.diportochain.it/ portal and enters the data they want to transmit, such as general characteristics, model, size or even photos. Blockchain technology secures the information and guarantees data confidentiality. An immutable virtual number plate is then generated, which will accompany the boat over time to enhance the value of the investment thanks to the NFT (Non-Fungible Token), which records the transfer of ownership. In this way, each boat becomes unique and distinctive, meeting the need for value protection. Once registration is complete, the user is sent a number plate with a QR Code to apply to the vessel, a real digital passport that can be consulted using a simple smartphone.

DiportoChain is designed for dealers and hirers because it allows them to increase the value of the asset purchased or hired by the customer because "the possibility of tracing and certifying the history and maintenance carried out on the boat is a way of protecting its value," adds Monica Bortolami.

Figure 21 – DiportoChain – EZ Lab S.r.l. & Noima Web Reputation

Source: Mediterranean Boat Magazine, 27/05/2021. Available on << https://www.barcheamotore.com/registro-diporto-natanti/ >>.

The platform is also useful for boatyards and repair shops, which can record the birth of the vessel through an identification code and keep track of repairs and improvements; for marinas and boat clubs, which will be able to monitor access thanks to the sending of a simple QR Code that will identify the vessel with a simple, fast and effective system; for insurance companies, making it possible to accurately estimate the value of the boat and therefore its insurable capital, but also for private owners who will be able to keep track of maintenance, modifications, and equipment of their boat, which thus acquires more value on the market.

4.5 – Discussion

The case study of EZ Lab S.r.l. fits well with what was intended to be the theme of the last chapter: demonstrating that the digital technologies of Industry 4.0 and the proper

management of skills and investments in innovative projects make it possible to meet the need for product traceability, with the utmost respect for the environment, with sustainable systems characteristic of the circular economy. In particular, blockchain technology, which is the core technology of the case study and the one that best combines some of the enabling technologies of Industry 4.0, is proving to be a reliable solution in multiple contexts.
The Circular Economy promises to help build a positive human future by using technology and intelligent design to maximize resource usage and reduce waste. One part of making the Circular Economy successful is incentivizing new behaviors, like sustainable resource production and consumption, product repurposing and recycling. Another part is assuring that the repurposed or recycled goods people and organizations but are not made from virgin materials. Without that trust and transparency, we will revert to our current linear economy. Blockchain has the potential to build that trust (Lancelott et al., 2021).
This is because the blockchain design itself supports two main features of the circular economy: demonstrating the origin and provenance of products and incentivizing consumers to make sustainable behavioral changes.
The new technologies complement each other, as the goal of certifying the product by providing it with a 'digital passport' is precisely what EZ Lab S.r.l. has set out to do through blockchain solutions. On the other hand, it is not enough to own the contents and generalities of a product if you do not have a tool to safeguard and certify the veracity of the data. Blockchain is the most effective and secure method. Monica Bortolami added: "Digitising a product is not just a way to increase its value or tell its story. There are many cases in which it guarantees concrete sustainability actions through careful control of resources and waste. It also has significant potential to protect ethical and social values, for example, in the case of the Pachino tomato caporalism."
EZ Lab S.r.l. and other companies exploiting blockchain technology have understood how important it is to give resources and products a digital identity, which does not stop at the product's authenticity or its general characteristics but opens the door to a new form of the market among users. This makes more evident the value of resources whose life cycle is extended thanks to technologies and traceability systems, facilitating a new system of prices and exchanges of natural resources that condition the consumer to adopt circular behavior.
In the following table I have summarized the sectors in which EZ Lab S.r.l. has decided to operate with their blockchain solutions, highlighting the traceability effects and the consequences of sustainability and circularity.

Table 4 – Summary table of EZ Lab S.r.l. projects.

MARKET SEGMENT	PLATFORM/PROJECT	TRACEABILITY EFFECTS	SUSTAINABILITY AND CIRCULARITY EFFECTS
Art	Art.Certo	The artist can safely trace the ownership of his work. The buyer can investigate the history of the work and verify its authenticity.	There is no clear and direct relationship in terms of sustainability or circularity. However, the digital certification of work increases its value by favoring its inclusion in a new market.
Agrifood	AgriOpenData	Products are tracked throughout their life cycle. Transparency acts as a guarantee for the consumer and represents added value for the producer.	Transparency in the production system means greater control of resources by reducing raw materials and water waste. In addition, information shared with consumers encourages them to act consciously by buying sustainable products.
Medical	Blockchain on RQ-2019-nCoV	At a pandemic emergency, traceability via the blockchain system has reduced the time needed to check the provenance and safety of the diagnostic kits used.	Mass production of diagnostic kits requires a reliable traceability system to manage stocks and reduce waste.
Real Estate	RElabs	The use of blockchain and smart contracts makes it possible to digitize any contract, making traceable relationships safer and more efficient, cutting costs, and minimizing the	By exploiting the blockchain, RElabs develops smart buildings: intelligent buildings that combine energy efficiency and automation, contributing to the cause of

		use of intermediaries. In addition, the "tokenization" of real estate makes it possible to certify all information relating to ownership and land registry practices.	environmental sustainability. In addition, it is possible to certify the maintenance or progress of a building site in real-time, improving resource management.
Textile	Made in Block	The technology tracks each product and makes each processing stage, from cotton picking to packaging, transparent and meticulous.	The blockchain ensures the sustainability of the integrated jeans production chain by certifying its products. The supply chain is short, which avoids many truckload goods, reducing CO2 emissions. Blockchain control of the production process reduces the waste of resources such as water, which is among the most important in jeans processing.
Space-Tech	SmartAgrisat	The blockchain certifies all the information obtained from satellites and compiles detailed maps of plants' vegetative state, physiological needs, soil moisture, and much more. Every step in the agricultural process is controlled and guaranteed by digital technology.	The platform captures and processes images and information to be made available to farmers. This provides precise indications regarding the necessary use of water and fertilizer, reducing the waste of water resources, and cutting CO2 emissions. The data is compatible with the onboard computers of semiautomated tractors and automated irrigation

			systems. This optimizes the use of energy and resources.
Nautical	DiportoChain	Vessel information is recorded and notarised on a blockchain platform. This is a safeguard for both buyer and seller, as it makes ownership transfers more secure and the "digital passport" certifies the vessel's entire life.	The blockchain makes it possible to extend the life cycle of a vessel. This is because, in addition to the traceability at the time of purchase and sale, all maintenance activities and improvements that increase or preserve the boat's value are also recorded.

Source: Table of my own production.

It would be superficial to think that blockchain technology does not have any kind of negative facet or that there are no problems in applying the technology. The first critical issue, mainly related to the fact that we are talking about a new technology, deals with the problems related to the difficulty of adopting and adapting such a system to traditional regulatory schemes. In fact, based on the data of a research carried out in 2021 by the Blockchain and Distributed Ledger Observatory of the School of Management of the Politecnico di Milano, there are about 370 initiatives, including projects and announcements, developed by companies and public administrations, up 39% compared to 2020. However, explains the research, in the face of this international fervor, the Italian market, despite being third in Europe in terms of the number of projects, is still in a waiting phase (Rociola, 2022). The primary brakes are the lack of knowledge of the technology and the lack of skills, a "skill gap" that is likely to be attenuated and then filled as the number of active projects grows. The main problems encountered at the technical level concern the complexity of validation operations, which are currently very time-consuming processes. The consequences are that on the one hand, the number of simultaneous operations within the chain is very limited compared to traditional payment methods, while on the other hand, it makes the transaction slower. The biggest problem remains the enormous amount of energy used to create new blocks and invalidate each one. Blockchain turns out to be one of the most energy-intensive activities. Therefore, when diving into this field, it is crucial to have the right skills to compensate for this energy expenditure in results that benefit the environment.

EZ Lab S.r.l. is splendidly demonstrating how skills and a usual business plan can push innovation towards new horizons, responding to the ever-increasing demands of the customer in terms of traceability and respecting the environment from the point of view of sustainability. To demonstrate that we are talking about a land rich in the future, we need only think that the Padua-based company was founded in 2014, focusing exclusively on the agri-food sector, and after only three years, it was already operating internationally. Six years after its birth, it has comprehensively won investors' trust with a hugely successful crowdfunding campaign. It has managed to build solid alliances and partnerships with leading companies in many sectors unexplored to them, leveraging their skills and their desire to get involved, demonstrating that digital technologies can support any sector while espousing the cause of environmental sustainability.

CONCLUSION

This paper aims to understand if the Circular Economy can be fostered by adopting digital technologies typical of Industry 4.0 in product traceability while maintaining the core principles of environmental sustainability.

The literature on Circular Economy is extensive, and it is clear to all that we are fast approaching a tipping point, where our consumption patterns and demand exceed the capacity of our planet to regenerate itself safely and sustainably. The literature and supporting data show that we have been locked into an unsustainable resource production and consumption system, particularly in the last decade. We have asked ourselves what the possible solutions to unscathed this situation are. The answer lies in technological progress. We have seen this by analyzing the previous industrial revolutions, where the literature and research are evident. We have realized how much the production process and the efficient use of resources has changed in correlation with the development of new technologies, so it is logical to think that it is fundamental to refer to them to respond to the planet's needs. On the other hand, the Circular Economy can create significant financial and economic value for businesses and societies, so it is not limited to the concept of "doing good" for the community, but also has intrinsic value for the companies themselves, as it represents an opportunity to innovate and aspire to new markets, reducing harmful environmental impacts and improving socio-economic outcomes. This is what circular advantage means (Lacy et al., 2020).

The technologies of the Fourth Industrial Revolution are making it possible to implement innovative production and development systems that were inconceivable a few decades ago. The collection and sharing of data, combined with greater precision in design, order fulfillment, and logistics optimization, lead to highly sophisticated processes in companies that are highly responsive to market demand. Lean production models are increasingly reducing energy use and material waste while at the same time reducing production time and costs.

In all of this, the European Union itself is pushing for new policies for sustainable production through initiatives and directives that guide the behavior of companies, pointing them towards a circular product that must comply with precise standards. In line with the European Green Deal and the NCEAP 2020, the European Commission will strengthen national plans and measures to accelerate this transition to a circular economy. Although the DPP project is already being used in some sectors, it is logical to assume that it will not be an immediate process, since, at the basis of everything, there are complex traceability mechanisms to be applied to different types of sectors and industries in which it is not always easy to certify every stage of the supply chain. In particular, the most significant difficulties are encountered in highly

fragmented markets with multiple suppliers from different parts of the world, making it difficult to control every resource or component used. The EU has decided to focus on the most polluting sectors and then direct and control all other sectors with great potential for circularity.
The consumer also plays a central role in these new models of sustainable consumption, as he demands to know the details of what he is buying, not only to verify its authenticity but also to investigate the production chain, respecting the environment and production standards. Companies, both to meet customer needs and to comply with current European regulations, are working to promote traceability, which means putting in place control activities and systems necessary to validate, verify, and guarantee the origin, handling, and processing of raw materials into finished products, regardless of the sector they belong to. All this is made more immediate and more accessible thanks to digital technologies and blockchain systems, which are proposed as the most effective way of guaranteeing traceability, transparency, and decentralization, which are all properties that fully meet the requirements of the UN in its 17 Sustainable Development Goals.
In light of the above, I think digital technology represents a "bridge" between traceability and sustainability, with the common goal of achieving a future increasingly oriented towards the Circular Economy.

APPENDIX

The interview was conducted remotely via the Zoom application on 18/01/2022 at 14:30 and lasted approximately 1 hour and 15 minutes.
The interviewee is Monica Bortolami, Head of Marketing and Communications at EZ Lab S.r.l., CEO and founder of Noima Web Reputation & Risk Management.
In addition to the questions below, Monica Bortolami enriched the interview content with a recent PowerPoint presentation from EZ Lab S.r.l.
It contains general information about its current projects and new initiatives and strategies to expand into new areas. There are also sensitive data that I am not allowed to disclose.

1) Your company was founded in 2014. What were the main difficulties encountered at the beginning of your journey?

2) AgriOpenData was designed to empower the agricultural sector in product traceability and certification. How does this platform work? How can the average customer interface with this digital technology?

3) The idea of digitizing a product by providing a 'digital passport' is highly innovative. How important is digital technology nowadays for traceability and sustainability actions? How is the agri-food sector changing as a result of these new solutions?

4) Still on the subject of technology, which of the main enabling technologies of Industry 4.0 are the most important for your projects? Why?

5) What conditions must a product have in order to benefit from your solutions? Do you have a particular method for choosing your customers or partners?

6) Apart from the agri-food sector, in which other sectors do you have (or intend to have) other collaborations in terms of blockchain solutions and traceability systems? And how?

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