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TESI DI LAUREA

"THE RELATIONSHIP BETWEEN SERVITIZATION AND CIRCULAR ECONOMY IN THE INDUSTRY 4.0 SCENARIO"

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Firma dello studente

Alla famiglia,
Solida presenza
E agli amici,
Insostituibili compagni
Di viaggio.

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INTRODUCTION

The world is changing. The economic scenario in which companies today are competing is characterized by deep transformations that led to the development of new and innovative business models. In the background of these changes, we find the digital revolution, the so-called Industry 4.0, with its new technologies and relative disruptive opportunities. At the same time, also the consumers have changed their behaviour towards requests more sustainable, social-oriented and customized. To respond to the numerous pressures and to avoid giving in failure, many companies began to evolve their approaches to the market and started to rethink their businesses.

One of the main discussed theme in this regard is the servitization defined as the transition from a product-centric business model to a service-oriented one. This model, as will be illustrated in the following chapters, represents a powerful tool for companies to create value for their customers. Another very topical theme is that concerning the environmental issue: the worrying alarms raised by scientists regarding the state of health of the planet have placed the ecological question in the foreground and the evident climate changes have made it impossible for institutions and citizens to ignore the problem. The current linear economic model is no more feasible moving thoughts towards new circular solutions.

The aim of this thesis is to analyze the relationship between these two macro themes, the servitization and the circular economy, demonstrating how the implementation of a servitized business model could be a successful strategy also to achieve the principles of the circularity. All this mediated by the use of new digital technologies that represent the enablers for the realization of both strategies that have the final purpose of pursuing the economic growth reducing, at the same time, the impacts on the environments.

The first two chapters of this thesis will separately deepen the concept of servitization and the circular economy, highlighting their definition and characteristics, advantages and limitations, the help given by digitalization and the possible applications on business models. The third chapter will instead focus on the analysis of the relationship between the two themes, going to deepen the role of Product Service System as a link between the two theories, the importance of digital technologies and the strategies' potential as response to the crisis caused by the pandemic. In the last chapter, will be presented the empirical analysis based on a questionnaire to four different companies that have implemented different form of circular service-oriented business models.

1. SERVITIZATION

In this chapter, we will focus on the increasingly widespread concept of servitization and how companies can implement servitization strategies in order to make profits. All this in the context of the fourth industrial revolution and the new digital technologies capable to enhance the service offerings.

1.1. Industry 4.0: new technologies and opportunities

The name is Industry 4.0 the new horizon of production and distribution, which is becoming more and more smart, fast and efficient. Thanks to a technological mix of information, automation and integration, that is giving rise to a change in the cultural and technological paradigms, involving the manufacturing system in all its aspects, the Industry 4.0 introduces new concepts of development and way of doing business in a perspective of digital transformation, often synonymous of disruption.

The suffix 4.0 reflects a precise phase of an evolution that had characterized the last centuries of our history. In order to understand the Industry 4.0 phenomenon and the following chapters of this thesis, it is important to describe briefly the four evolutionary steps of the industrial world.

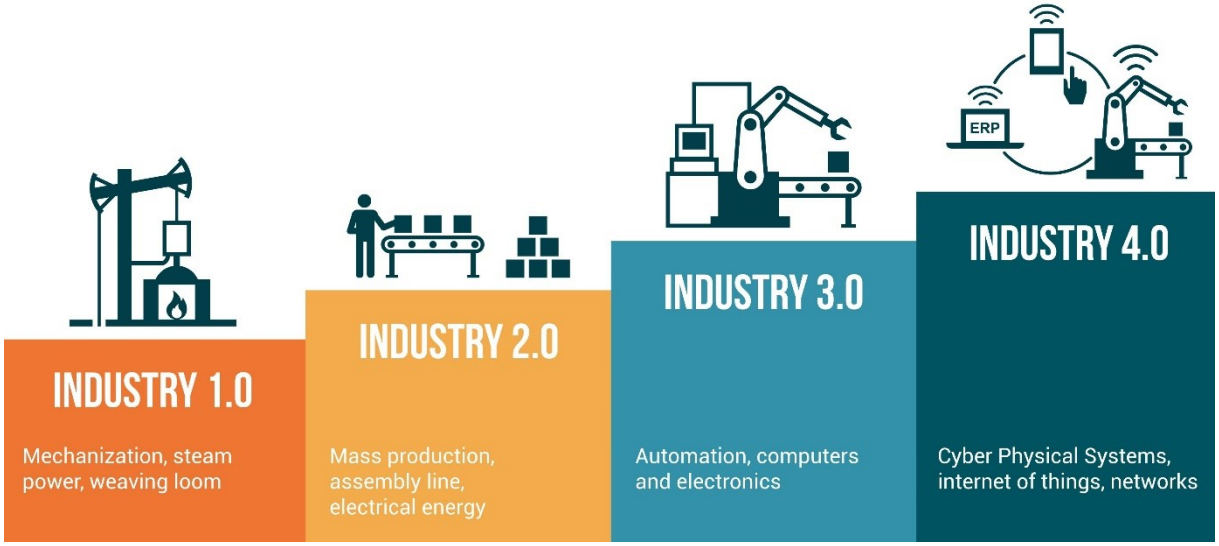

Figure 1: Industry 4.0 as fourth industrial revolution
Source: Adaptation from HBS Digital Initiative's website

The Industry 1.0, from the second half of the 18th century, corresponds to a completely new revolution in the manufactory: the steam engine's invention and the weaving loom allowed factories to abandon the mills and to introduce production mechanization that guarantees higher

speed and power. Then, the introduction of electricity and oil as new sources of energy and the starting of the assembly line's use to implement a mass production, characterized the Industry 2.0 from the 1870s. Industry 3.0, also called "the digital revolution", symbolically starts around the 1970s with the invention of the personal computer, summarizes the application in the factories of the first-generation ICT that further increase the level of automation and trigger the digital transformation not only in the production systems but also at the organizational level. The fourth industrial revolution or Industry 4.0, that is taking place right now, is represented by the combination of technologies that facilitate an industrial production completely automated and interconnected. The term "Industry 4.0" was used for the first time in 2011 at the Hannover Messe as the name of an innovative project from which started intensive teamwork that in 2012 presented to the German federal government several key initiatives for the implementation of the Industrie 4.0's strategy.

Based on the findings from the literature review, Hermann, Pentek and Otto in their paper of 2015 "Design Principles for Industrie 4.0 Scenarios: A literature review" define Industry 4.0 as follows: a collective term for technologies and concepts of value chain organization. Within the modular structured Smart Factories of Industrie 4.0, CPS monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, CPS communicate and cooperate with each other and humans in real time. Via the IoS, both internal and cross-organizational services are offered and utilized by participants of the value chain (Hermann, Pentek & Otto, 2016, pp.11).

The definition appears quite complicated; hence, it is important to explain the Industry 4.0 components in order to fully understand the phenomenon. First of all the Cyber-Physical-Systems (CPS) defined as transformative technologies for managing interconnected systems between its physical assets and computational capabilities (Lee, Bagheri & Kao, 2014). Therefore, CPS represents the possibility of a fusion of the physical and virtual world. The second component is the Internet of Things (IoT) that refers to a networked interconnection of everyday physical objects that interface with each other to share information and take actions. Given the definition of CPS, the IoT can be explained as a network in which CPS cooperate with each other through unique addressing schemas (Hermann, Pentek & Otto, 2015). Another component of Industry 4.0 is the Internet of Services (IoS) that consists of participants, an infrastructure for services, dedicated business models and the services themselves. Enabling service vendors to offer their services via the Internet, various suppliers combine them into value-added services; they are communicated to users as well as consumers and are accessed by them via different channels (Buxmann, Hess & Ruggaber, 2009). The last component is the concept of Smart Factory described as a factory that context-aware assists people and machines

in the execution of their tasks. This is possible thanks to systems working in the background, the so-called Calm-systems, which represent the hardware of a Smart Factory, that are able to take into consideration context information like the position and status of an object, interacting with the environment.

Within Industry 4.0, we are facing a paradigm shift and this was possible thanks to the nine main technologies concerning this revolution. These technologies, also known as pillars or tools of the Fourth Industrial Revolution, are nowadays used to improve all areas of production processes leading to a massive increase in efficiency and a change in the traditional production relationships among market players, as well as between human and machine.

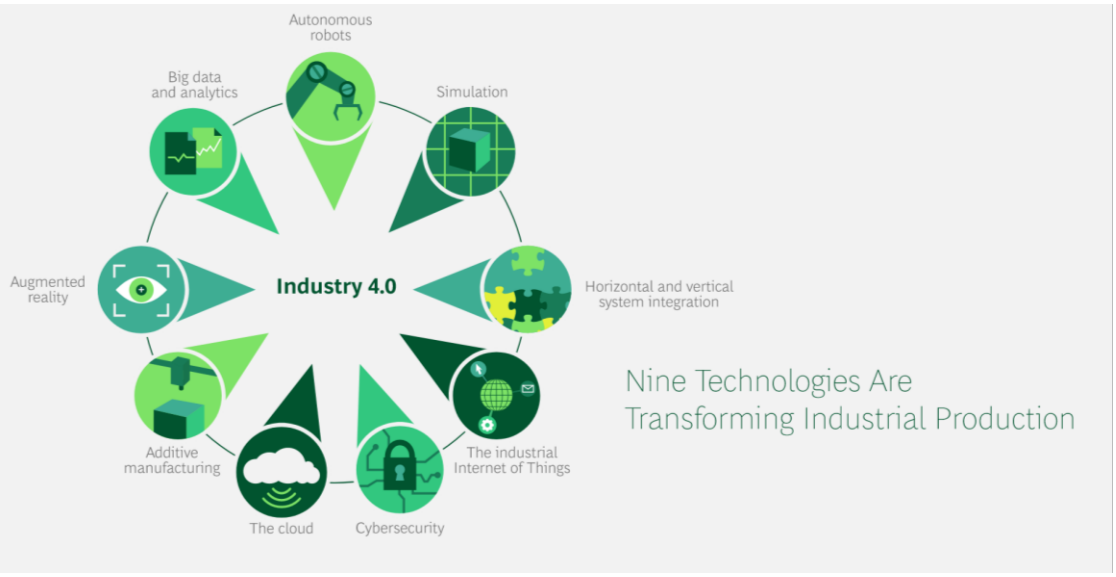

Figure 2: Nine technologies transforming industrial production
Source: BCG analysis

According to the classification performed by the Boston Consulting Group (BCG), one of the main global management-consulting firm, the nine enabling technologies of Industry 4.0 are:

- Big Data Analytics
- Autonomous Robots
- Simulation
- Horizontal and Vertical Integration
- The Industrial Internet of Things
- Cybersecurity
- The Cloud
- Additive Manufacturing
- Augmented Reality

Big Data Analytics consists of the collection and comprehensive evaluation of huge volumes of data from many sources: not only externally from customers but also from production equipment, systems as well as enterprise. Autonomous Robots are high-technological robots able to interact with one another and work safely and together with humans learning by doing from the latter. Simulation is another enabler because permits to leverage real-time data and mirror the physical reality in a virtual model. This allows users to test the new product in a virtual world before the physical changeover, lowering costs and increasing quality. System Integration means the greater integration among companies, departments, functions and capabilities leading to an increasingly immediate exchange of information. Vertical and horizontal integrations refer to the internal and external systems of integration supervised by the firm. Internet of Things, as mentioned before, implies that more devices are enriched with embedded computing, communicating and interacting between each other and the environment. The increase in connectivity and data flow means, at the same time, the fundamental need to protect critical industrial systems and manufacturing processes from cybersecurity threats. Consequently, is essential to guarantee the secure and reliable exchange of information as well as sophisticated identity and access management of machines and users. The Cloud Computing consists of the offer of data-driven services via the Internet bringing down the barriers between different companies and sharing data in a few milliseconds. Additive Manufacturing, such as 3D printing, is now a widespread technology used mostly to prototype and produce individual components. The latter has allowed a decrease in costs, complexity in the construction and lead-time and the development of a more lightweight design. Augmented Reality means a system that combines real and virtual worlds with real-time interaction and an accurate 3D representation of virtual and real objects.

These enabling technologies constitute a big potential for value creation, especially in terms of speed, flexibility, cost reduction, productivity, quality and customer orientation. They form the basis for a digital transformation of firms and sectors; in fact, they represent the front door into a new world made of innovative products and services that are smart and interconnected.

Industry 4.0 and the nine technologies imply also some key principles that can support companies in identifying and implementing new strategies for change. These principles are interoperability, which means the connection and communication between humans and smart factories, virtualization, decentralization thanks to embedded computers in CPS allowing them to make decisions on their own, real-time capability, service-orientation and modularity. Service orientation and the big theme of servitization are one the topic discussed in this thesis and in the following paragraphs will be analysed in more detail.

1.2. Business models innovation: service-oriented business models

The nine key enabling technologies constitute the current technological scenario and represent the driver for a deep shift in the business's strategies, especially towards a service-oriented business models implementation. They redefine the ontological space within which it becomes possible to exploit all the potential of a business, leading to a change in the products and services offered, in the nature of players and the relations between them, and the organizational culture. Among the group of these technologies, discussed in the paragraph before, the IoT and in particular the Industrial Internet of Things has a leading role in helping manufactures to unlock the value of machines and in encouraging the development of service-based offerings (Ehret & Wirtz, 2017). In fact, IoT is fundamental to transform normal and stand-alone objects into smart and connected products, providing firms with the possibility of real-time data, analysis and processing. In this way, it allows customer information and data to be integrated within the firms' information systems and strategic planning (Dalenogare, Benitez, Ayala & Frank, 2018) and the opportunity to monitor, optimize and automatize products' functions, remotely and globally (Porter & Heppelmann, 2014).

Industry 4.0 technologies can help to improve the design of innovative product-service systems and can influence value propositions, up and down in the value chain, affecting the business models themselves and the entire value ecosystem. This new industrial paradigm is transforming the current ways of value creation since it involves changes in the technical and production operations, which in turn has brought extensive organizational consequences and opportunities (Arnold, Kiel & Voigt, 2017). Thanks to a digital network of products and systems, a constant information flow and a real-time capability, this new scenario offers various pretexts for transforming and innovating the business model. The transformation could involve, for example, the rethinking of products or new solutions, the optimization of customer segmentation, the positioning in the market and the pricing strategies, the improvement of customized production, the introduction of new services pre and post-sale, and the development of capabilities to adapt dynamically to market requirements. Digital technologies can radically affect firms' business models, posing significant challenges to their various interlinked elements (Amit & Zott, 2012) and they can make existing business models obsolete and no more competitive. Therefore, IoT and the other enablers pose the basis for a completely new set of threats and opportunities that companies are not able or prepared to face with their actual business models, giving birth the need of Business Model Innovation.

First, it is necessary to define a business model. A business model describes the rationale of how an organization creates, delivers and captures value (Osterwalder & Pigneur, 2009) and, following the Canvas model, it is formed of nine building blocks. These are customer segments

(groups of people or organizations a company aims to reach and serve), value proposition (products and services that create value for a specific customer segment), channels (company's interface with its customers), customer relationships (types of relationships a company establishes and maintains with specific customer segments), revenue streams (revenue a company generates from each customer segment), key resources (assets required to offer and deliver the previous elements), key activities (activities involved in offering and delivering the previous elements), key partnerships (a network of partners and suppliers that support the business model execution) and cost structure (costs incurred when operating a business model). The Business Model Innovation (BMI) theory considers the Business Model (BM) concept in a transformational way as a tool to address change and innovation in the organization, therefore, it occurs when a company improves or modifies at least one of the building block. It could be considered as a process through which firms realize ad hoc changes in the activities and functions within their BMs and explore new architectural designs (Foss & Saebi, 2017): this implies, for example, navigating new opportunities of value creation, distribution channels and customers' relationships.

Industry 4.0 scene and its technologies may have disruptive effects on business models: the redefinition of customers segments served, the offering of completely new value propositions, the reconfiguration of internal and external processes and channels, a more intensive customer orientation, a totally different type of revenue stream and pricing models, the implementation of new capabilities, new collaborations and a redesigning of the cost structure. Considering the key principles of Industry 4.0, it is possible to identify the main drivers of BMI and the consequences for the companies embracing this new paradigm, as summarized in the figure below.

Main Features of the Industry 4.0	Main issues affecting traditional Business Model	Main requirements to face digital transformation
Interoperability	Networking and reduction of barriers	Standardization
Virtualization	Flexibility and personalization	Work organization
Decentralization of decision making	Individualized mass production	Availability of products
	Local production	New Business Models
Real-time capability	Low price	Know-how protections
Service orientation	Smart goods and services	Availability of skilled workers
Modularity	Fragmentation of the value chain	Research investment
	Globalization and decentralization of production	Professional development
	V-H integrated production systems	Legal frameworks

Figure 3: Features, Challenges and requirements related to the Industry 4.0
Source: Ibarra, Ganzarain & Igartua (2018)

Within the BMI, in this thesis, I will focus on the emerging service-oriented business models. In recent years, many product-based companies find themselves moving from their traditional business models centred on product sales towards models based on services. Companies are facing not only an increase in product offering with services, but also they are developing completely new offerings where products are no longer necessarily at the centre of the value proposition, or even of the business model (Kindström, 2010). This phenomenon concerns, therefore, the evolution from traditional business models, based on the transfer of ownership, to new usage-oriented business models where vendors retain ownership of the asset and sell utility as a service.

Following the classification made by Adrodegari (2015) in its paper titled "From ownership to service-oriented business models: a survey in capital goods companies and a PSS typology", it is possible to identify five Product-Service Systems (PSS), characterized by a specific configuration of the each Canvas's building block, and divided into two groups: Ownership-Oriented and Service-Oriented.

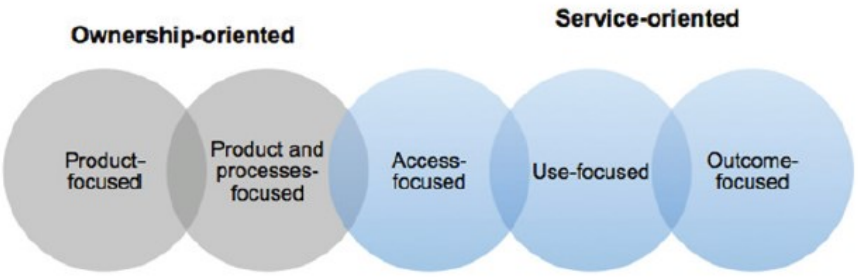

Figure 4: PSS types
Source: Adaptation from Adrodegari et al. (2015)

In the first macro group, product sales are the main revenue stream and services are sold only as an add-on to the product that represents the focus. Services are seen in a transactional way, for example, corrective technical assistance without any contracts, or with a relational approach like maintenance contracts. The Product-focused PSS type is characterized by the delivery of tangible value to customers. The company sells the product or the system and separately sells services during the using phase of the product (e.g. break-fix repair, maintenance agreements). Anyway, services are simple and not customized, with the purpose of improving or restoring the functionality of the products. The Product and processes-focused PSS type does not differ a lot from the previous one. The main difference is that the company offers services both in the pre- and after-sale phases (e.g. consultancy services) with the aim to improve efficiency and effectiveness of customers' operations. The main revenue stream remains that of product sales.

In the second macro group of PSS types, services are the keystone and represent the main source of revenue. An important element here is that customers do not receive the ownerships of the products. The Access-focused PSS type regards the payment of a fixed regular fee to gain access to a product instead of buying it directly. The fee is not related to the product actual usage and can include additional services such as maintenance and assurance costs, given that the company has the responsibility for the product's utilization. In this business model, we assist to a change in the relationship between the company and its customers: from a transaction-based interaction to a relational one, that involves a longer time horizon. In the Use-focused PSS type, clients do not buy the product or system but pay a variable fee that depends on the usage of the product (per-per-use time, pay-per-use unit). The company is responsible for the entire life cycle of products; hence, it is important to optimize the cost structure. Besides, the adoption of this service-oriented business model implies a new revenue stream where the focus is on the definition of new selling parameters driven by customer perceived value (their willingness to pay for services) instead of internal costs and the payback period is often longer than the traditional one. Lastly, in the Outcome-focused PSS type, customers pay a fee that is related to the achievement of a contractually set result in terms of product/system performance or outcome of its usage. Customers can benefit from a reduction in the initial investment and the minimization of operational costs and risks to achieve an expected outcome with product usage. Here, a definition of the right outcome, the right services and the right fee are fundamental for implementing the business model.

In the wake of this orientation towards service-based business models, a further step is happening. The service journey and the digital/technological journey are converging into a digital transformation of business models called advanced service-oriented BM. New digital capabilities, and in particular the nine key enabling technologies, enable deep service and customer insight. These innovative service-based business models relying on IoT technologies, in fact, allow firms to reduce operating costs, generate additional revenue, maintain a long-term business relationship with customers, increase resource utilization, and assess the risks of current product or service provision (Paiola & Gebauer, 2020). The silos mentality[1] dissolves favouring an expansion of the ecosystem and this leads to a series of consequences, advantages and disadvantages, which will be analysed more in the detail speaking about servitization.

[1] Silo mentality is an organizational mindset in which some departments resist to share information and resources with others in the same organization. This hinders the diffusion in firms of a customer-centric and service-based culture.

1.3. Servitization: definitions and drivers

The shift from product- to service-oriented business models is an important phenomenon characterizing manufacturers' strategies in the last decades. Therefore, it is fundamental to define and describe the concept of servitization.

The term was coined in 1988 by Vandermerwe & Rada, who define servitization as: "the increased offering of fuller market packages or 'bundles' of customer-focussed combinations of goods, services, support, self-service and knowledge in order to add value to core product offerings" (Vandermerwe & Rada, 1988, pp. 4). Nowadays the term is widely recognised as the process of creating value by adding services to products, hence, servitization indicates the transformational evolution of shifting from a product-centric business model and logic to a service-centric approach.

The provision of services is different from that of products because services are characterized by four attributes: intangibility, heterogeneity, perishability and inseparability (Roy, Shehab, Tiwari, Baines, Lightfoot, Benedettini & Kay, 2009). Services are intangible because they are represented by a performance, deed or effort, while products are tangible objects. Heterogeneity means that services are never performed in the same way: place, time, recipient, and context always differ. Perishability of services implies that service capacity cannot be restored, saved, returned or resold once rendered to a customer. Lastly, inseparability is the characteristic that a service has which renders it impossible to divorce the supply or production of the service from its consumption.

The paper of Vandermerwe & Rada could be considered a forerunner in the literature around servitization because, from its publication, the economic community has shown great attention on this argument and, consequently, the number of terms used is increased. Another term often mentioned concerning service growth dynamics is "service infusion" meaning the process whereby the relative importance of service offerings to a company or business unit increases, amplifying its service portfolio and augmenting its service business orientation (Kowalkowski, Kindström, Alejandro, Brege & Biggemann, 2012).

The literature suggests three sets of external factors that drive companies to pursue servitization strategies: economic, market and strategic/competitive advantage (Oliva and Kallenberg, 2003; Gebauer et al., 2005).

As regards the economic/financial servitization driver, substantial revenue can be generated from an installed base (IB) of products with a long life cycle and normally services have higher margins than products and they represent a more stable source of income as they are resistant to the economic cycles that influence investments and goods purchases. This can help secure a

regular revenue stream, balance the effects of the saturation of demand in mature markets and withstand an unfavourable economic period.

Second, the market factor: customers are demanding more services. The pressure to downsize to create more flexible firms, narrower definitions of core competencies and increasing complexity that leads to a higher specialization are the main driving force behind the rise of service outsourcing. Moreover, services are fundamental to create customers loyalty to the point where the client can become dependent on the supplier. Services tend to induce repeat-sale and, intensifying the contact between the firm and the customer, can put the supplier in the right position to offer other products or services.

Finally, there is a strategic service growth driver. Products are commoditized and competition proliferates, on the other hand, services, by being less visible and more labour dependent, are much more difficult to imitate and therefore they represent a sustainable resource of competitive advantage.

In addition to the environmental/external drivers, it is possible to individuate some firms' internal motivations for implementing servitization strategies.

Services are an important tool for fully exploiting product and technology capabilities. Manufacturing companies can possess state of the art competences in engineering and technology that can be used to forge new services and further serve the needs of the IB and the market (Ulaga & Reinartz, 2011). Services can create a lock-in effect thanks to a product's design able to obstacle any competitor possibility of serving it or also incorporating service components in the product design process in order to foster the service options. Moreover, as we can see later speaking about digital servitization, the combination of services and technologies allows the analysis and interpretation of customers' processes and product use data. Another internal motivation could be the capacity to better capture customer relationship value. Services help to develop closer and long-lasting customer relations with better understanding: this leads to an increase in customer satisfaction and presumably an increase in cash flows over time. Thirdly, servitization could open new market opportunities towards new service-oriented business models with the possibility of orchestrating new value constellations.

The transition to a firm service-saturated does not occur in one time only but occurs in stages (Oliva & Kallenberg, 2003) due to the fact that servitization has a deep impact on the day by day operations from the development of new capabilities, contracts, pricing strategies, risks and new partners, therefore companies have to adapt slowly (Gaiardelli, 2014).

Following the analysis of Oliva and Kallenberg, the first step regards the consolidation of the product-related service offering. Initially, most manufacturing companies provide services to sell and support their products as an add-on to products. Those services are fragmented within

organizations that, to be successful, have to consolidate their existing service offering under a unique organizational unit. This consolidation has the aim of improving the efficiency, quality and delivery time of the services provided and the possible creation of additional services to enrich the service offering. At the same time, the consolidation of services leads to the development of a monitoring system to control its effectiveness and efficiency, allowing managers to understand the size and the potential of the service market.

The second step consists in entering the IB service market. Thanks to the monitoring system implemented in the previous stage, now it is possible to fully identify and realize the profit potential. There are two major challenges in performing this transition into the IB services. The first one is the cultural effort to switch from a product-centred logic to a service orientation learning how to value services, how to sell, deliver and bill them. The second difficulty is the need to create a global service infrastructure that can respond locally to the requirements of the IB. This necessity involves huge investments that probably will not be immediately profitable and the diffusion of ad-hoc capabilities across the network.

The last step concerns the expansion of the IB service offering and it takes place only when the core functionality of the service organization has been set. This phase occurs through two different dimensions: first, it is necessary to change the focus of customer interactions from transaction-based to relationship-based; then, there is the change in the value proposition from product efficacy to the product's efficiency. Moving along the first dimension, the shift regards the services' pricing strategy which changes from task-specific to a fixed price over a period of time impacting on the firm's risk given that the service provider assumes the risk of equipment failure. Because there is this risk, it is fundamental to develop a new set of organisational skills within the service organization and information gathering capabilities to better deal with it. In this situation, once the service organization is in place, it becomes a fixed cost and, for the provider, the main driver of profitability is capacity utilization. However, manufactures have the advantages of experience that allow them to perfect the infrastructure/organization with practice. The second transition implies that the product becomes part of the offering instead to be the focus of the value proposition. Companies that are successfully moving into this dimension define solution provider as continuous support to improve the utilization and effectiveness of their IB as opposed to new equipment. The main challenge here is to provide services over the entire life cycle of the IB. To do that, the firm should replicate the HR and knowledge management capabilities developed for the service network and, at the same time, needs to create new networks to work with a new distributional channel and different partners.

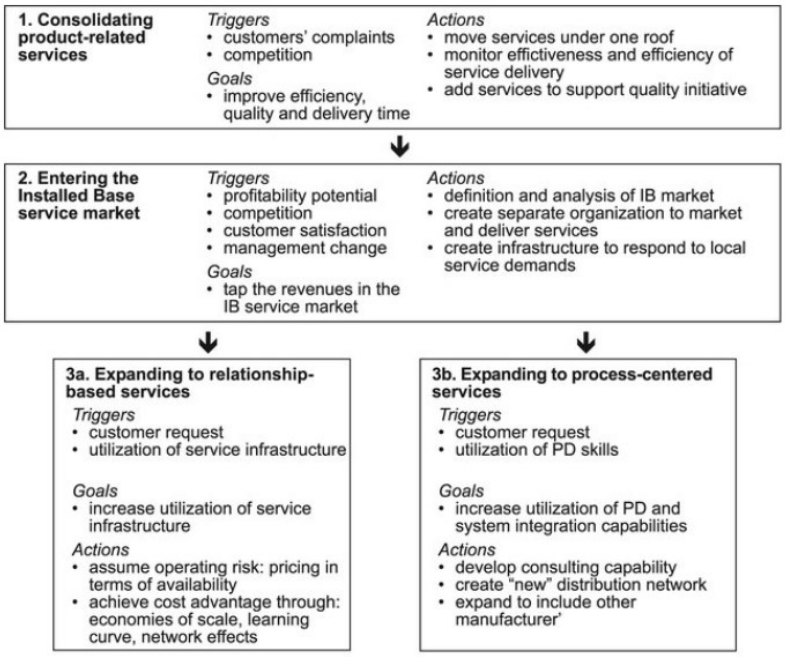

Figure 5: Process model for developing IB service capabilities
Source: Oliva & Kallenberg (2003)

1.4. The development of services in manufacturing: resources and capabilities

Servitization in manufacturing is defined as the process of innovating companies' capabilities and procedures to support the shift from providing products to providing product-service systems. Today, the process of servitization involves a growing number of manufacturing firms that are strategically choosing to couple their traditional product offering with service components. The principal aim for manufacturers is to renew and reorganize the business model to respond better to market demand and eventually increase the market share while boosting the revenue stream.

Ulaga and Reinartz (2011) proposed a model about the different type of hybrid offerings implementable in the BtoB market; in fact, the authors assert "goods manufacturers, unlike pure service providers, find themselves in a unique position to grow revenues through hybrid offerings but must learn how to leverage unique resources and build distinctive capabilities" (Ulaga & Reinartz, 2011, pp. 2). This model identifies four BtoB service categories combining two different dimensions: the nature of the recipient (if the service is directed at the supplier's good or if it is directed at the client's process) and the nature of the value proposition (input-based if there is a promise to perform a deed or output-based if there is a promise to achieve a performance).

Each category implies a different combination of goods and services and differs in key resources, capabilities and success factors.

Nature of the Value Proposition	Service Recipient	
	Service Oriented Toward the Supplier's Good	Service Oriented Toward the Customer's Process
Supplier's promise to perform a deed (input-based)	**1. Product Life-Cycle Services (PLS)** *Definition* •Services to facilitate the customer's access to the supplier's good and ensure its proper functioning during all stages of the life cycle *Examples* •Delivery of industrial cables •Inspection of an ATM machine •Regrooving of an industrial tire •Recycling of a power transformer *Primary Distinctive Capabilities* •Hybrid offering deployment capability •Design-to-service capability *Main Underlying Resources* •Field service organization •Product development and manufacturing assets	**3. Process Support Services (PSS)** *Definition* •Services to assist customers in improving their own business processes *Examples* •Energy efficiency audit for a commercial building •Logistics consulting for material-handling processes in a warehouse *Primary Distinctive Capabilities* •Service-related data processing and interpretation capability •Hybrid offering deployment capability •Hybrid offering sales capability *Main Underlying Resources* •Installed base product usage and process data •Field service organization •Product sales force and distribution network
Supplier's promise to achieve performance (output-based)	**2. Asset Efficiency Services (AES)** *Definition* •Services to achieve productivity gains from assets invested by customers *Examples* •Remote monitoring of a jet engine •Welding robot software customization *Primary Distinctive Capabilities* •Service-related data processing and interpretation capability •Execution risk assessment and mitigation capabilities •Hybrid offering sales capabilities *Main Underlying Resources* •Installed base product usage and process data •Product development and manufacturing assets	**4. Process Delegation Services (PDS)** *Definition* •Services to perform processes on behalf of the customers *Examples* •Tire fleet management on behalf of a trucking company •Gas and chemicals supply management for a semi-conductor manufacturer *Primary Distinctive Capabilities* •Service-related data processing and interpretation capability •Execution risk assessment and mitigation capabilities •Design-to-service capability •Hybrid offering sales capabilities •Hybrid offering deployment capability *Main Underlying Resources* •Installed base product usage and process data •Product development and manufacturing assets •Product sales force and distribution network •Field service organization

Figure 6: Classification Scheme of Industrial Services for Hybrid Offerings
Source: Ulaga & Reinartz (2011)

The first class is Product Life-Cycle Services (PLS) and they refer to the range of services that facilitate the customer's access to the manufacturer's good and ensure its proper functioning during all phases of its life cycle. Some examples are the delivery of industrial cables, the calibration of a gas chromatograph, the installation of a power transformer or the regrooving of a truck tire. PLS are "must-have" services, highly standardized, and directly attached to the supplier's good, therefore, the value proposition derives from the promise to perform a deed on behalf of the customer. Anyway, these services are critical in that they are pivotal in establishing the vendor's reputation and quality as a competent service provider. PLS are considered as a pre-requisite to expand into higher value-added services, the adjacent category.

The second category is Asset Efficiency Services (AES) defined as services provided to help customers achieve productivity gains from their assets. AES are still designated around products sold and rarely are provided as stand-alone services but, differently from PLS, the value proposition focuses on achieving particular performance levels or outcomes. Some examples of this type of services are the on-site preventive maintenance on a ball bearing, the remote monitoring of a high voltage circuit breaker or the uptime guarantee on a pump in a nuclear plant. They are no more considered as "must-have" services thanks to their increasing

customization and differentiation from competitors, and therefore customers show a higher willingness to pay for them.

The third category is Process Support Services (PSS) that are services directed to assist customers in improving their business processes. PSS include, for example, the diagnostics of a welding process, the energy-efficiency audit of a store, the training on new safety regulations or the consulting to achieve cost reductions. These services focus on the customer's process and the value proposition is based on leveraging the supplier's resources and distinctive capabilities to help clients optimize their operations. The supplier makes assessment and gives recommendations about the process but he is not responsible for outcomes and performances: the customer remained solely in charge of deciding on and implementing process changes. PSS are highly customized services and allow a strong differentiation of the supplier in the market, for this reason, customers' willingness to pay tended to be high and generally, they are priced as professional services.

Finally, Process Delegation Services (PDS) is the fourth category. They are a combination of goods and activities that suppliers integrate in order to perform processes on behalf of the customers. Examples include the tire fleet management for a global logistics and supply chain expert, the fly-by-the-hour agreement for commercial jet engines or the operating of the paint shop in a car manufacturing plant. This category represents the most complex type of hybrid solution because the object is not the product but the process and the supplier takes control offering a value proposition based on the promise to achieve process performance. PDS are highly personalized services responding to customers' specific requirements and they imply a certain level of customer involvement. As a consequence, it is fundamental that the interests of both parties are aligned to benefit from the advantages of the collaboration.

When you sell services, you are selling competencies and capabilities therefore the knowledge enclosed in your company. Each category of hybrid offering requires a different combination of critical resources and capabilities for servitization that allows companies to gain a specific competitive advantage.

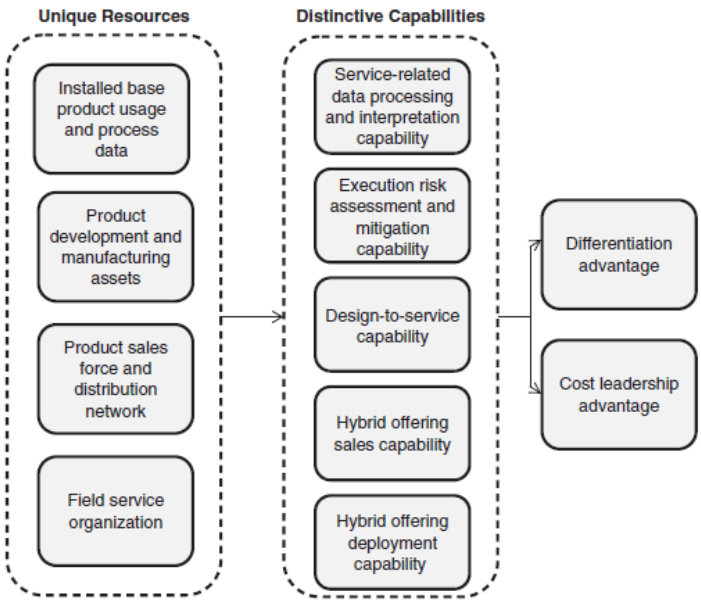

Figure 5: Manufacturer-Specific Resources and Capabilities for Successful Hybrid Offerings
Source: Ulaga & Reinartz (2011)

Resources, in general, are the stocks of available factors owned or controlled by the firm (Amit & Schoemaker, 1993). Ulaga and Reinartz individuated four unique resources for servitization that are the most critical and useful for implementing hybrid offerings:

- Installed base product usage and process data that is the stock of product usage and customer process data collected through a firm's installed base of goods and/or used in customers' operations (Reinartz & Ulaga, 2014). It represents the most strategic asset held by manufacturing firms and it can be leveraged for servicing products for maintenance, repair and revamping, retrofitting and collecting data thanks to the impact of smart technologies.
- Product development and manufacturing assets are the second critical resource and are defined as the stocks of resources invested in a firm's R&D and production infrastructure. These resources are both tangible such as machines, production tools, specific components, and intangible like patents and licenses.
- Product sales force and distribution network assets are the resources linked to a firm's direct sales organization and channel intermediaries to cover sales territory. The privileged access to markets and sales through direct and indirect sales infrastructures is a unique resource but it is important that the sales force be aligned with the service strategy redefining the way of presenting the company on the market.
- Field service organization assets are the resources allocated to a network of specialized technicians (people and resources) aimed at deploying and servicing the firm's installed base. Field services and spare parts secure for manufacturers a big percentage of

revenues and profits could represent an opportunity to propose to customers different types of consulting and efficiency services.

Resources are only one side of the coin and always have to be completed with capabilities in order to be effective. Capabilities concern the firm's capacity to deploy its resources (Amit & Schoemaker, 1993) and, in their model, Ulaga and Reinartz derived five distinctive capabilities for servitization:

- Service-related data processing and interpretation capabilities consist of the manufacturer's ability to analyse and interpret installed base product usage and process data to help customers enhance productivity gains and/or cost reductions. Therefore, the interpretation of data and the consequent transformation into information is the key capability in order to gain unique insights for achieving customer benefits.
- Execution risk assessment and mitigation capabilities are defined as the manufacturer's capacity to evaluate the uncertainty whether contractually agreed-upon outcomes will be realized and to design and implement safeguarding mechanisms to strike a balance between performance commitments and maintaining internal profit targets. Entering into service contract could be risky both in terms of expectation on profit and in terms of expectation on outcomes but if you strong manage this capability, it could represent a powerful resource of differentiation from competitors.
- Design-to-service capabilities are the manufacturer's capacity to develop a hybrid offering where tangible and intangible elements interact synergistically to tap its potential for new revenue generation and/or cost reduction. The purpose here is the collaboration between product and services in the innovation process trying to provide the service as early as possible, and gaining, in this way, a competitive advantage.
- Hybrid offering sales capabilities refer to the specific approach and mindset to adopt when you sell a service instead of selling goods. They are described as the manufacturer's capacity to reach key decision-makers in the customer organization, coordinate key contacts in the customer and vendor firms, sell hybrid offering value through specific documentation and communication tools, and align the sales force with both the field organization and the channel partners to increase hybrid offering

revenues. In fact, the sale process is more complex and longer therefore requires a strong capacity to switch from selling product features to selling value.

- Hybrid offering deployment capabilities are necessary to strike the balance between ensuring efficiency and effectiveness in service production and delivery process. The authors define these capabilities as the manufacturer's capacity to rely on flexible offering platforms that can standardize hybrid offering production and delivery processes while also safeguarding its ability to adapt to individual customers' needs. For efficient execution of the hybrid offering, it is useful to adopt a production-line approach to services in order to achieve repeatability and economies of scale, guarantee modularity of service elements and control the service delivery costs with smart technologies, routine maintenances or training customers.

1.5. Digital servitization

Now is the time to describe how digital technologies, analysed in the first paragraph, play an important role in enhancing the servitization process. The nine key enabling technologies of Industry 4.0 are allowing new forms of services for manufacturers, boosting servitization through digitalization (Coreynen et al., 2017) and opening innovative opportunities for a service-oriented transformation of business models.

Rolls-Royce Plc is one of the pioneering examples of servitization when in 1999 has transformed its business model in order to provide a completely new solution. The latter comprehended the management of engine transport for repairing and overhauling, the handling of auxiliary supplies and the collaboration for the maintenance. To do this, the company implemented a new payment mechanism, the so-called "Power by the hour", based on the actual flight hours performed by the engine. In 2018, almost twenty years later, Rolls-Royce launched the program *Intelligent Engine,* which relies on the same concept but is perfected by the adoption of digital technologies. The initiative was presented with the following vision: *"*with the digital revolution blurring the boundaries between our physical products and the services we provide, we see a future where our engines are connected, contextually aware and even comprehending. A future where we design and test engines digitally, service them remotely and manage them through their digital twin." The connection between engines enables continuous and multidirectional communication between product, manufacturer and third parties who carry out service activities. The intelligence inherent in the engine and in the algorithms that govern it and its capacity to interface with the external environment, allow the self-regulation of some key parameters according to what is detected in the surrounding context. Finally, the ability to

collect, archive and analyse historical data related to internal and external conditions of use, makes it possible to continuously learn and improve performances. Therefore, from the successful example of Rolls-Royce we can understand that digital technologies are important tools for digital servitization and, at the same time, they are a formidable enabler of servitization processes.

Industry 4.0 technologies, and in particular the IoT, constitute the basis for servitization processes thanks to their capacity of efficiently capturing and transferring data; therefore we don't discuss any more about servitization but about digitalization. Digitalization, or digitization, refers to the increasing use of digital technologies for connecting people, systems, companies, products and services (Hsu, 2007) and it represents an important primer for companies to increase their service offerings as shown in the figure below.

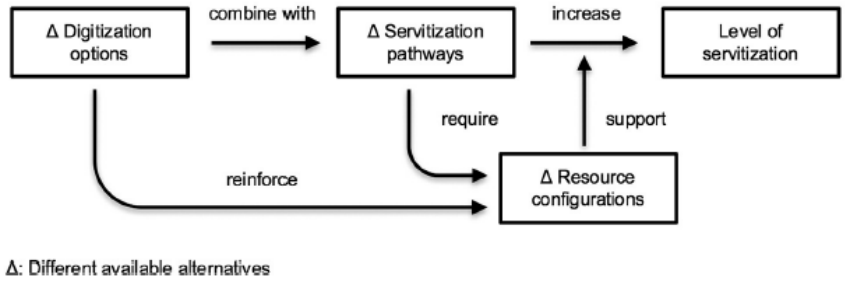

Figure 6: Boosting servitization through digitization
Source: Coreynen et al. (2016)

According to Porter and Heppelmann (2014), new technologies are transforming normal products into "smart and connected products" leading companies to a new set of technological possibilities expanding their boundaries and redesigning their value proposition towards servitization. In order to build a smart and connected product are necessary three types of characteristics: physical (the mechanical and electrical parts of a product), smart (sensors, microprocessors, data storage, controls, software and the operating system able to interface with users) and connectivity (the ports, antennae and protocols enabling wired or wireless connections with the product). These smart and connected products are able to perform new functions and capabilities that define the competitive positioning of the company; and they are grouped into four areas: monitoring, control, optimization and autonomy.

Monitoring capabilities include the capacity of sensors and external data sources to analyse the external environment and to assess the product's condition, operation and usage. Besides, monitoring also enables alerts and notification changes useful to the following area. Control regards the software embedded in the product or the product cloud and can supervise the product functions but also to personalize the user's experience. Monitoring and control capabilities permit to generate algorithms capable to optimize product operation and use.

Optimization enhances product performance and allows predictive diagnostics, service and repair. Lastly, combining monitoring, control and optimization capabilities allows the creation of autonomy capabilities. These comprehend the autonomous product operation, the self-coordination of operation with other products and systems, the autonomous product enhancement and personalization and the self-diagnosis and service.

Nowadays smart and connected products are widespread among firms and constantly increasing thanks to technological advancement, so much that digitization is becoming the "new norm" (Hinsenn, 2010).

The fundamental question is whether the digitization and servitization are the same concept or whether they have similar foundations. Vendrell-Herrero et al. (2017), analysing the concerning literature, affirmed that "whilst it is possible to move towards service without digitizing the offer, and it is possible to digitize an offer without offering it as a service, the interaction between digitization and servitization is considered very strong" (Vendrell-Herrero, Bustinza, Parry & Georgantzis, 2017 pp. 71). Digitization can facilitate the development of cost-efficiency operations and is an activator of service quality through better allocation of resources and better information sharing between the boundaries of the firm (Kindström & Kowalkowski, 2014). Given that, a great number of researches start to speak about "Digital Servitization" defined it as the provision of IT-enabled services relying on digital components embedded in physical products.

According to Vendrell-Herrero et al, digital servitization is different from servitization in three main aspects. First, the marginal cost of digital services is near zero, thanks to the high use of technologies there is an opportunity to avoid, in this way, the servitization paradox since services are labour-intensive. Second, digital services have the possibility to be substitutes of traditional products, while normal services usually are considered only complementary. Third, the presence of digital technologies opens new business opportunities for many innovative firms that would enter the market (new service-oriented business models).

Digital servitization pulled by smart and connected products, therefore, reshapes the level of competition in the market but also redefines the industries boundaries. The basis of competition shifts from the functionality of a discrete product to the performance of the broader product system, in which the firm is just one actor. The manufacturing companies now can offer a package of connected equipment and related services that optimize the overall results (Porter & Heppelmann, 2014).

In their research, Coreynen et al (2017), highlight that there are three potential pathways for companies to increase their service offerings depending on whether digitization is implemented

“back-end” or “front-end”: industrial servitization, commercial servitization and value servitization.

Industrial servitization means that the provider translates knowledge acquired from internal process optimization into tangible value-added services for the end customer. Information and communication technologies here are fundamental resources in order to control workflows leading to faster production and delivery of customized offerings. An important capability to develop in this pathway is the ability to continuously adapt to different customer needs, given that the passage from products to services requires a different sales approach. Industrial servitization is only the first step of digital servitization; in fact, not always can guarantee a sustainable competitive advantage, since this strategy is likely to be imitated or copied by other companies.

In commercial servitization, the company aligns its value creation routines with the customer’s internal process developing new forms of interaction. Digital technologies allow companies to provide services that support customers in the control of their processes. This pathway is favoured by capabilities that support customer linking, channel bonding and technology monitoring in order to manage constantly the front-office customization and the back-office production and delivery processes (the so-called hybrid offering deployment capability by Ulaga & Reinartz, 2011). Commercial servitization strategy is characterized also by the scalability and flexibility of digital solutions that allow the addition of customized features and functionalities with minimal economic expenses. Moreover, companies gain the ability to capture customer needs, analyse them and create new ideas for products, the so-called interpretation capability (Kindström & Kowalkowski, 2014).

Last but not least, there is value servitization defined as “a fundamental renewal of the current value chain through the creation of new digital products that impact customer processes and provide a more disruptive impact on provider-customer relations” (Coreynen, Matthyssens & Van Bockhaven, 2017, pp. 8). As the previous path, in this strategy companies create a closer and long-lasting relationship with customers as these are involved in the development of products. Nevertheless, value servitization implies a more dynamic and innovative service orientation and, consequently, requires more radical resources and capabilities.

Another interesting research is that of Nicola Saccani, Associate Professor at Brescia University, in which he affirms that it is possible to conceptualize the role of digital technologies in the servitization process through the DIKW model (Data-Information-Knowledge-Wisdom). This model develops on three main levels:

- Information and Cloud: simple actions of data processing such as selection, arrangements, aggregations and classification generate the information. These operations allow answering questions about "Who? What? When? Where?". In the smart connected products panorama, it is the Cloud computing that supports the transformation of data into information, because it enables remote data storing and ensures the access to computational resources able to enter, visualize and elaborate information.
- Knowledge and Analytics: knowledge becomes synonymous with analytics when it comprehends the storage and combination of information, which are integrated and permit to increase the learning and experience, leading to insights, know-how and decision support.
- Wisdom: the last level regards the capacity to discern the reasons why in certain circumstances it is necessary to do specific actions, combining information and the generated knowledge of previous levels with the personal judgement, ethical considerations, aesthetic opinions or social problematics. At present, this level resides exclusively in human capacities, in particular in the entrepreneurial ability to discover new business opportunities. The next step could be represented by artificial intelligence.

Therefore, "new technologies, in various form, are helping to blur boundaries between manufacturing and services" (Dinges, Urmetzer, Martinez, Zaki & Neely, 2015, pp. 13): the cloud computing, big data, social media allow manufacturers to reimagine their service businesses to create greater value for the stakeholders in a new system.
Concluding, digital technologies offer a rich new set of value creation and growth opportunities for companies, in particular in respect of services; hence in next paragraph will be examined the major advantages and challenges for companies implementing these hybrid strategies.

1.6. All the advantages and challenges of servitization

Servitization replaces "sell and move on" commercial relationships with a model that has demonstrated the ability to improve product availability and reduce the cost of ownership by linking a provider's compensation to the output value of the product generated by the clientele. For companies that decide to implement servitization strategies, there are many advantages and opportunities.
First, any servitization relationship includes incentives for the supplier to reduce costs. Especially using the digital technologies, from the beginning, manufacturing firms experience

an improvement of internal processes regarding the management and maintenance costs, as well as in terms of services' quality perceived by the market, all this to the advantage of brand equity. Moreover, there is the possibility to share risks with the customer, in particular the financial risks, basing the relationship on achieving the best performance possible. Another advantage of servitization is the strengthening of the relationship and collaboration with customers and increasing customer satisfaction. In fact, occurs a loyalty enhancing effect of client and user, given that the relationship with the supplier does not conclude with the purchase of the good but continues in time. Manufacturers, therefore, can create long-lasting, secure relationships with their customers, even to the extent of shutting out competition. If a company establish a multi-year contract with customers, involving regular and planned support at no extra cost, there is no easy opportunity for others to level their way in. Digital servitization permits also the possibility to improve product functionality without having to replace it. If we consider a smart and connected product able to generate data and to transmit them to the operations centre, the company can extract valuable information concerning the way customers employ the product, providing accordingly tips on how to optimize its use in order to improve its performance, security and duration. The last but not least benefit for manufacturers offered by servitization is the opportunity to hypothesize new business models, to be developed as a function of insights coming from smart products and from a deeper knowledge of usage experience of customers. As a result of all these advantages, companies see its profits generated by services increase and often new revenue streams are created. These revenue streams are highly reliable and with a long-term horizon, and are not reliant on the potential market crisis or new product sales.

Assuming the customers' perspective, servitization allows clients to obtain tangible benefits such as the increase of efficiency, productivity and quality of products and services. Moreover, a servitization relationship is characterized by the absence of a heavy, upfront charge that must be either financed or come from the purchaser's pockets. In fact, customers have the possibility to access and use the product or service without having to bear the expense to buy it and, not having the ownership, do not suffer the product's obsolescence. Clients are involved in the creation of value and they too can benefit from a long-lasting relationship with the supplier leading to better performance for both. Lastly, thanks to formulas such as pay for the use or pay for the performance, customers have the guarantee to actually have what they paid for.

Besides all these advantages, there is also an environmental and social matter from which we all benefit: it is the chance to implement with different servitization strategies a circular economy. We will discuss this later in the next chapter.

Despite the great potential of servitization and numerous examples of success, many cases give evidence that it is difficult to achieve the expected revenues, profits and customer satisfaction

(Kowalkowski, Gebauer, Kamp & Parry, 2017). Gebauer and Friedli (2005) have defined this phenomenon "service paradox", specifically, where investment in service growth fails to generate corresponding returns or shareholder value. Through empirical studies, the authors have identified a U-shaped relation between servitization and performance. In the case of a low level of services, typically add-on services, a company in the first phase of investment, is able to obtain an increase of profit margins, given that it improves the value of its offer without incurring a significant expense. A medium level of services, on the contrary, requires huge investments and structural changes that can destabilize the equilibrium of the company and that can strongly affect the financial statements. Instead, when a company manages to stabilize its new business model providing a high level of services to a wide audience, can benefit from scale economies that compensate the initial investments and assure high margins.

To avoid the service paradox, a company that decides to follow a servitization process must be prepared to face some hurdles emerging with the transformation of the business model.

The first obstacle regards the passage from a product-centric mindset to a service-centric and customer-focused one. Services are intangible and difficult to design, produce and sell, therefore it is necessary a change in the work routine but also a redesign of the marketing strategy in order to transmit the value and enthusiasm of the new company philosophy. The fixing of specific, realistic and measurable objectives can help the transitional phase (Fliess & Lexutt, 2019), giving the possibility at the beginning to focus on small concrete targets. Moreover, services need a shift of the attention toward outcomes and for this reason, the pricing of them is more difficult.

In order to fully benefit from the opportunities arising from servitization, companies must transform normal products into smart products: objects with embedded sensors and intelligence, connected with data processing platforms. Companies are required to enter in the IoT dimensions, data analytics and Cloud to manage the information flows useful to extract customer insights. Many companies underestimate the value and potential of customers' data and are not inclined to do extensive investments for the digital transformation.

Another hurdle of servitization concerns the increasing complexity of the relationship with the customer. In fact, the rapport does not conclude with a simple economic transaction but imply a collaboration during the entire life cycle of the product. The service offering means also an increase in customer touchpoint and, consequently, in the number of employees who relate with acquirers. Companies, in this sense, have to provide adequate training to their staff improving the relational skills and the ability to understand customers' needs. In addition, most business services require some form of customer participation as active involvement in the design and delivery. Therefore, "the client plays an interesting complex role in the service organizations,

since he not only receives and consumes the service but also serves as a component in its production and delivery. Thus, in a service business, clients must be selected and managed as carefully as employees" (Pistoni & Songini, 2017, pp. 42) and the loss of control over the process represents a challenge for firms.

Together with the evolution of customer's relationships, also the relations within the supply chain require an upgrade. Regardless of the investments made and the owned competencies, companies, at least at the beginning, need external expertise and an active collaboration with suppliers in order to sell the new offering. The level of vertical integration adopted by organizations and the choice of the distribution channels will be influenced by the complexity of the servitization strategy and by the desired autonomy that the company want to maintain.

2. CIRCULAR ECONOMY

In this chapter, we will analyse the concept of the circular economy, its huge potential and its limitations. In particular, we will focus on the need for change towards a more sustainable model, the business models inspired by this concept and the role of digital technologies in enabling their implementation.

2.1. From a linear model to a circular model

The economic growth model that has characterized the last century is defined "linear economy", an industrial and market economy, based on the extraction of constantly new raw materials, on mass consumption and the waste production at the end of the product life cycle. This model follows the "take-make-dispose" pattern: companies extract materials, apply energy and labour to manufacture a product and sell it to the end consumer, who then discards it when it no longer serves its purpose. This approach relies on the idea that resources are unlimited and always available; therefore, companies are encouraged to design life-limited products to keep constant the flow of the sale. The linear model is also called "cradle-to-grave" meaning that products are designated just for their function, without taking into account their potential at the end of their life.

The ever-growing demand and the related volumes required started to put into discussion the linear approach highlighting the need for urgent action. Few facts: during the 20th century the use of natural resources increased at about twice the rate of population growth (UNEP IRP, 2017; in the last decade in order to revive the economic growth were used more materials per unit of GDP; to meet the functional needs of the society, per year, are extracted over 84 billion tonnes of materials and only 9% of them are recycled (Circle Economy, 2018, The Circularity Gap Report, An Assessment of the circular state of the global economy); some studies have estimated that in 2050 there will be more plastic than fishes in the ocean(World Economic Forum, Ellen MacArthur Foundation, 2016); and it was demonstrated that pollution was responsible for more than 9 million premature deaths in 2015(The Lancet, 2017).

This critical trend pushed companies to be more aware of their production processes and sustainability issues, starting to shift to models where fewer resources are wasted. To develop an alternative growth model to the linear economy, important intellectuals as the architect Walter Stahel, the physicist Amory Lovins, the green economist Nicholas Georgescu-Roegen and many others, have elaborated different ways to stop the waste of materials and the pollution from fossil sources supporting the efficient production, the recycling and the use of renewable

sources. The result of years of researches and studies for a more sustainable world merged in the concept of "circular economy", an economic model based on the reduction and removal of waste and on the idea of maximizing the use-value of products lengthening their life as much as possible.

The Ellen MacArthur Foundation, one of the most active realities in the promotion of this alternative economic model, defines the circular economy as an approach to redefine growth, focusing on positive society-wide benefits: "it entails gradually decoupling economic activity from the consumption of finite resources, and designing waste out of the system. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural, and social capital."

The circular economy is meant for being able to regenerate by itself. For example, we can think about a spacecraft where an astronaut has limited resources and he must try not to generate waste because he is unable to eject it. The theory of circular economy claims to consider the earth as a huge spacecraft and for this reason, it is based on the principle of decoupling economic growth from the consumption of resources and the generation of waste.

The idea of a circular circuit of materials was presented for the first time in 1966 by the economist Kenneth E. Boulding in his article "The Economics of the Coming Spaceship Earth". In 1976, Walter Stahel and Genevieve Reday proposed to the European Commission a report titled "The Potential for Substituting Manpower for Energy" highlighting the circular economy vision and its impact on job creation, resource-saving and waste reduction. Then, in 2006, with the 11° Chinese five-year plan, the promotion and feasibility of implementing a circular economy have augmented. Finally, from 2010, the Ellen MacArthur Foundation, an independent body, strongly carry on this model and recently it has delineated the economic opportunity of circularity.

The circular model distinguishes between technical and biological cycles. Consumption occurs only in biological cycles, where food and biologically-based materials reintegrate into the biosphere through processes like composting and anaerobic digestion. Technical cycles, instead, are designated to recover and restore products, components and materials thanks to choices like reusing, repairing, remanufacturing and recycling.

According to the Ellen MacArthur Foundation, three principles are the foundations of this new system:

- Design out waste and pollution. Waste and pollution are the results of decisions made during the first stage of the product's creation. Starting from the design phase,

companies have the possibility to reduce them consistently, thanks to a change in the mind-set and the exploitation of new materials and technologies.

- Keep products and material in use. Given that it is unsustainable to keep wasting resources, it is necessary to start designing products and components that we can reuse, repair and remanufacture with little effort. Otherwise, we should be capable to get the materials back so they do not end up in landfill and we can reintroduce them in the production cycles.
- Regenerate natural systems. The principal concept is that everything is food for something else. Therefore, giving back to the soil the nutrients that the economic activity discards, we can enhance our natural resources.

A circular economy aims to restore every type of capital: financial, human, manufactured, social and natural. By designing out waste and pollution, keeping products and materials in use, and regenerating natural systems we can reinvent everything. The diagram below shows the continuous flow of technical and biological materials through the "value circle".

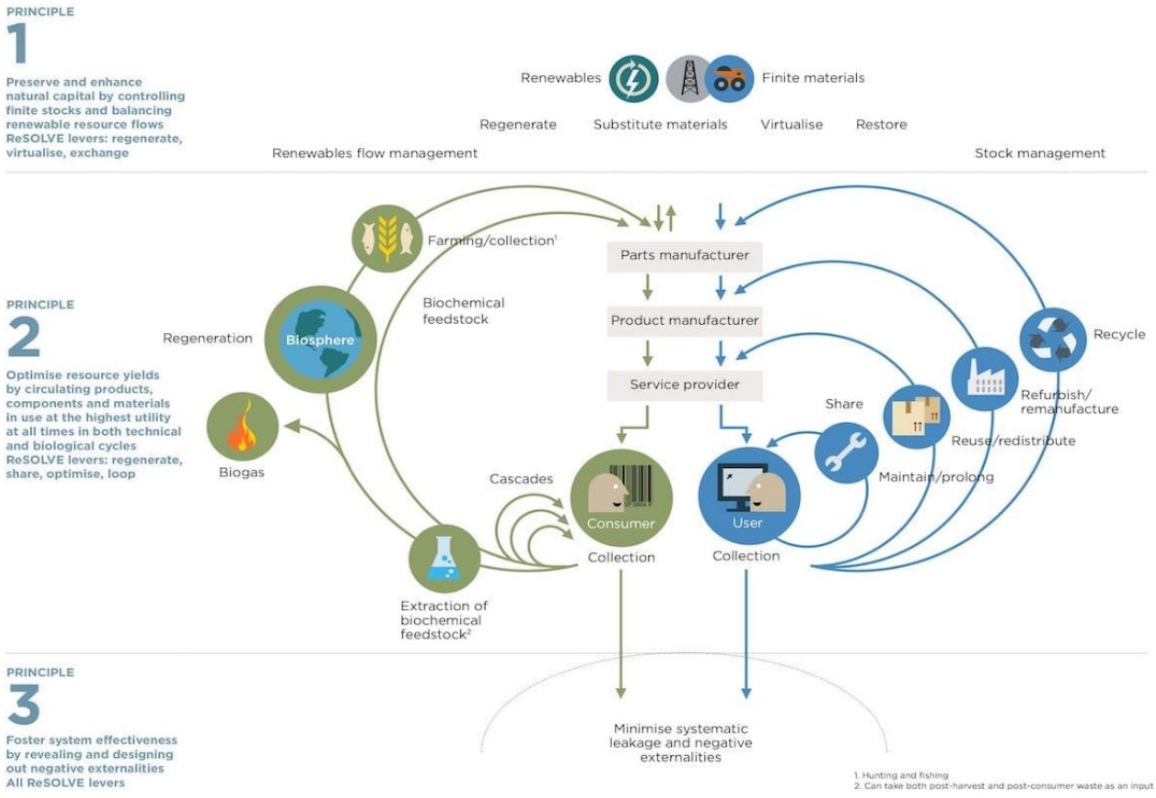

Figure 7: Circular Economy System Diagram
Source: Ellen MacArthur Foundation

The circular economy can be explained also with the concept of "cradle-to-cradle" (C2C), developed by Braungart and McDonough (2010), which contrasts with the "cradle-to-grave" of the linear model. This approach, applied to systems design, tries to adapt the industrial models to nature, which means converting the production processes in a manner so that they regenerate, assimilating the materials used with the natural elements. The eco-effectiveness is privileged over the eco-efficiency. The theory, in fact, affirms that the industry has the task of preserving and enhancing the ecosystems while maintaining the economic cycles, creating, in this way, systems that are not only efficient but are compatible with the environment. The idea is to have a positive impact on the world around us, and no more only less negative effects.

2.2. How circular economy works

A circular economy is a systemic approach to economic development designated to benefit businesses, society, and the environment (Ellen MacArthur Foundation). The application of this paradigm, to be efficient, must be based on an informative network of all the players engaged in the supply chain. A transition towards a circular economy is by nature a systemic path that affects different actors in a shared belief that everyone can and must do his part. First of all, the circular economy involves firms, and the productive world in general, that can gain economic benefits such as the cost-cutting, the reduction of supply risk and the improvement of the corporate image. Even services are protagonists of this structural change because they offer possibilities linked to new service-oriented business models based on the product's access instead of merely ownership. It involves citizens because they are called to make choices and decisions about responsible and sustainable consumption. The financial world plays an important role in terms of resilient, sustainable and especially forward-looking investments and the role of research is equally key speaking about technological innovation. Finally, public institutions are involved in the circular economy process with reference to the smarty city, the urbanization, and the co-housing.

Therefore, all the active players have available four main strategies to put in place the circular economy transformation. These strategies are also called the "4 R":

- Reduction. The first axiom of the circular economy is the reduction of consumptions in terms of used resources, materials and sources of energy in the entire supply chain. This, for example, can be done through energy efficiency measures or a detailed plan of raw material focused on avoiding waste.

- Reuse/Redistribute. Products at the end of their life and materials can be reused multiple times and redistributed to new users in their original form or with little enhancement or change (reconditioning). eBay is an important example of marketplaces where this approach is already well established and well-functioning.
- Refurbishment/Remanufacturing. This consists of the regeneration of components, restoring their value, when the reuse is no longer feasible. When a product is remanufactured means that it is disassembled and rebuilt to create a new product with the same warranty. Instead, remanufacturing concerns the reparation of products as much as possible giving them a "better look", usually without the replacement and the dismantling of components.
- Recycling. The recycling of materials is the process in which a product is reduced in all its basic material levels, allowing those materials to be remade into new products. This strategy is considered as the last resort because implies the use of labour and energy, the costs to reproduce entirely a new item, and the inevitable material losses.

Adopting a circular approach means reviewing all stages of the product life cycle (from the design to the collection) and paying attention to the entire supply chain involved in the production. This attention passes through the respect of some basic principles, which the Ellen McArthur Foundation has identified in five fundamental criteria:

- Systemic approach. This means thinking holistically, being careful with the whole system and considering the cause-effect relationships between the different components. Understand underlying relations if there is a critical point when we want to improve the system to avoid worsening the situation.
- Ecological design. From the beginning, it is important to design products thinking about their use at the end of their life, therefore with characteristics that will allow them to be disassembled or regenerated. Forecasting the specific use of every material used in the production gives the opportunity to reuse and recycle the components more easily and more effectively.
- Renewable resources. Relying on energy produced from renewable sources is a fundamental criterion of the circular economy that tries to abandon the old energy model based on fossil sources.
- Modularity and versatility. Give priority to the modularity and versatility of the product lead to better adaptability in case of changes in external conditions. Products should be designed for upgradability and easy repair so that it is simpler to remove

only some components, lowering the costs of switching parts when damaged. Moreover, modular products have a higher level of customization and can be innovate based on market demand.

- "Waste is food". This means the zero waste objective promoting the replacement of virgin raw materials with secondary raw materials coming from recovery chains that preserve their quality. Biological wastes are compostable, while technical ones are reused with minimum energy consumption.

2.3. Business models inspired by circularity

The circular economy, briefly, regards the creation of new value chains that decouple growth from the use of scarce and linear resources. This can be achieved in several ways. Circular business models are "business models that are suited for Circular Economy by incorporating elements that slow, narrow, and close resource loops so that the resource input into the organization and its value network is decreased and waste and emission leakage out of the system is minimised" (Geissdoerfer, Morioka, de Carvalho & Evans, 2018, pp. 3). A circular business model, therefore, articulates the logic of how an organization creates, offers, and delivers value to its broader range of stakeholders while minimising ecological and social costs. If a company decides to transform its business model for circularity has to consider three major pillars: a sustainable value creation, a more pro-active management of more comprehensive set of stakeholders, and a long-term perspective (Geissdoerfer et al., 2016).

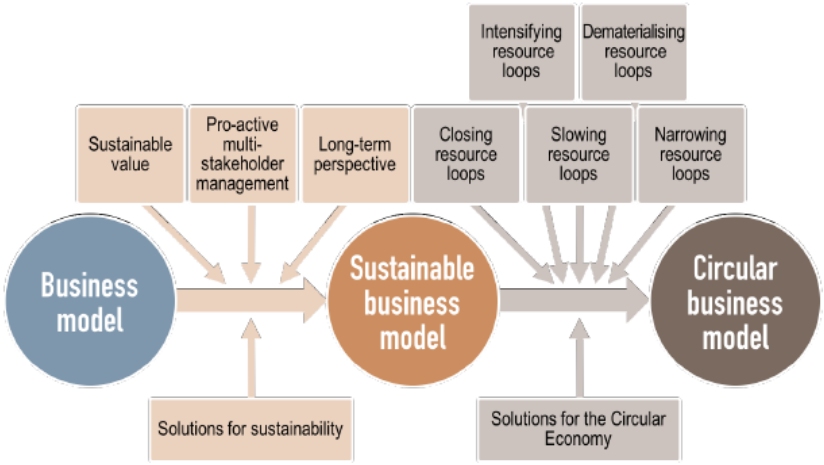

Figure 8: Comparison of traditional, sustainable, and circular business models
Source: Geissdoerfer et al. (2016)

As shown in the figure, the evolution towards circular business models is not immediate and requires a great commitment at all levels of an organization. Nevertheless, circularity has inspired many companies to think about new ways to create value for clients, completely free from the constraints of the linear model. Regardless of the specific strategy chosen by the firm, it is necessary to think and create a product that is designed from the beginning with the purpose of extending as much as possible its life. According to Bocken et al. (2016), in this context, there are some requirements to follow in the design of a product among which the main ones are: the "design for attachment and trust" that indicates a good created aesthetically pleasing also in the long-term so that it is resistant to trend changes; the "design for maintenance and repair" that means a product easy to fix; the "design for standardization and compatibility" that has the purpose of creating products with compatible elements with others; the "design for durability" that concerns the resistance to external changes.

Peter Lacy and others analysts of Accenture, one of the biggest multinational professional services company in the world, in a research on 120 case studies, has identified five underlying business models that companies are implementing, in the idea of circular innovation. Firms can put in place individually one of these business models or a combination of them. The benefits of implementation are many such as massive resource productivity, an improvement in the differentiation and customer value, the reduction of costs and risks.

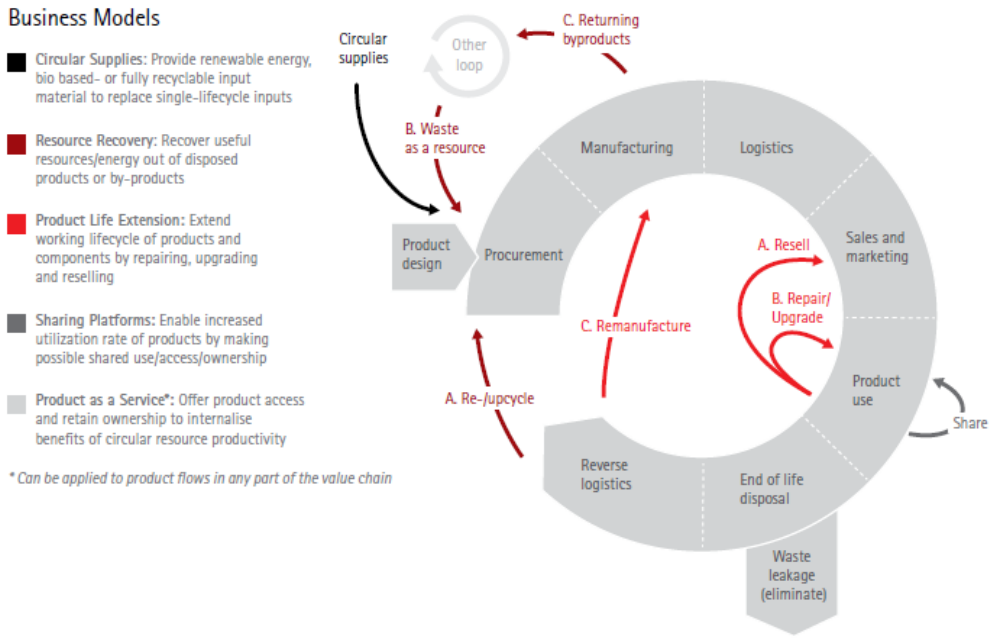

Figure 9: The five circular business models
Source: Accenture (2014)

The first business model is “Circular Supplies” and is based on supplying fully renewable, recyclable or biodegradable inputs that start the circular production and consumption systems. This model ensures the elimination of scarce resources and the cut of waste supporting the entire supply chain with the removing of inefficiencies since the beginning. Circular supplies model is suitable especially for companies dealing with scarce commodities or ones with a major environmental footprint.

“Resource Recovery” consists in the recovery of embedded value ate the end of one product lifecycle to feed into another. This approach facilitates the return chains and considers waste as a big potential for recycling/upcycling and industrial symbiosis. The recycling/upcycling concerns the reuse of waste by the company that generated them, while the term industrial symbiosis means the process by which wastes of a firm become the raw materials for another. This model is a good strategy for companies that produce large volumes of by-products, allowing them to eliminate material leakage and maximize the economic value of product return flow.

Then we have “Product Life Extension” that regards the extension of the lifecycle of products or assets thanks to actions like maintenance, repairing, upgrading, remanufacturing and remarketing. This model is particularly useful for most capital-intensive B2B segments and B2C companies that serve markets where pre-owned products are common, helping them to maximize the economy.

While the previous business models are characterized by a revolution in terms of production methods, the following two ones are focused on trying to explore new innovative and sustainable ways for satisfying the customer’s needs.

The “Sharing Platforms” business model supports the idea of a strong collaboration among product users, either individuals or companies. The model offers an alternative to the sporadic use of certain goods, giving the possibility to use them only for the time necessary and at a lower cost. Companies with a low utilization or ownership rate of their products or assets should put in practice this approach in order to benefit from an increase in utilization.

Lastly, the “Product as a Service” business model regards the abandonment of traditional “buy and own” approaches in favour of evolution towards services. Here, companies maintain the ownership of products and offer them with arrangements like leases or pay-per-use. With this approach, product longevity, reusability and sharing are drivers of revenue streams and are able to reduce cost substantially. This model is attractive to firms whose products’ cost of operation share is high and that have an advantage relative to customers in managing the maintenance of goods. The idea of “Product as a Service” in the circular economy is comparable to the Product

Service Systems (PSS) of servitization and in the next chapter, we will analyse the conjunction of these two theories and how services can help in enhancing a circular development.
Concluding, circular businesses no longer have the objective of profit maximization or cost-cutting improving the efficiency in supply chains, factories, and operations. Rather, they are focused on redesigning and restructuring Product-Service-Systems following a bottom-up approach to ensure the future viability of business activities and market competitiveness.
To support the transition to the circular economy, companies with their business models play an important role. Circular business models, in fact, allow the retention of an asset at its highest value over time and support enhancement of natural capital (Ellen MacArthur Foundation, 2016). The embracement of these new models will bring enormous and tangible benefits such as greater control of resource streams through the value chain so the added value can be identified and captured, the emergence of new players specialized in waste handling, refurbishment and reverse logistics, an increase in the cooperation within the supply chain among all actors and the creation of new services.
According to Peter Lacy and the Accenture research, in order to succeed in these business models and enjoy the benefits of their implementation, companies must develop new circular capabilities:

- At the highest level, it is necessary a change in business planning and strategy to be able to manage complex and collaborative circular networks instead of simply focusing on core business. It is important to consider all the circular chain in order to understand where and how value is created and therefore concentrate activities around that.
- In the circular economy, we assist the shift from designing for single-use to designing for many life cycles and users. This implies a different approach toward innovation and product development. In the design phase, firms are called to rethink products to generate revenues not only at the point of sale but also during use and with costs for return chain and reprocessing that are minimum.
- Another capability regards sourcing and manufacturing. Companies must pay more attention to material inputs that have to be renewable or fully restorable and about the production process that has to be efficient in terms of waste and environmental impact.
- Sales and marketing abilities of organizations play an important role in the success of business models. Sales and marketing have the objective of generating revenues from the use of products and services instead of the purchase of them. Moreover, they need to develop new ways to attract customers towards service-based models where the ownership is no more of clients and they need to strengthen the after-sale services to

support the entire lifecycle of products. It is also fundamental to transmit the values of circular economy embraced by the company.

- At the end of the process, capabilities in terms of reverse logistics and return chains are critical. They have the task of reducing logistics and waste management cost, retain customers with good return programs, and comply with government regulations.

Circular business models are disrupting industries around the world and if in the past the disruption was driven by start-ups, nowadays also large multinationals are supporting the change. We can think about BMW and Cisco Systems that are extending the life of used products through refurbishment and resale, Amazon with its formula of the textbook as a service or Philips offering light as a service, or even H&M that promotes the collection of garments in all its stores to close the textile loop. And these are just some example of paradigm-shifting that we are living.

2.4. Enabling circular economy through the use of digital technologies

Most of the circular business models highlighted before would not be possible without the support of new technologies, named the Industry 4.0 technologies. Digitalization can be seen as one of the enablers of the circular economy due to its building visibility and intelligence into products and assets. Digitalization boosts the circular economy business models by helping to close the loop, slow the material loop and narrow the loop with increased resource efficiency (Antikainen, Uusitalo & Kivikytö-Reponen, 2018).

One the one side, the circular economy is considered a new industrial paradigm for decoupling economic growth from finite resource constraints by providing opportunities for companies in terms of new ways of value creation, revenue generation, cost reduction, resiliency and legitimacy (Manninen et al., 2018). On the other side, Industry 4.0 with its rapid digitalization of economy and society thanks to new digital technologies, is helping companies to increase competitiveness and efficiency, by reaching time reduction, flexibility, cost reduction, productivity and quality. Even if these two models have been historically considered as separated roads for economic growth, the increasing pace of production and consumption that is led by Industry 4.0 might indicate an obligation for both paradigms to co-evolve (Ünal, Urbinati & Chiaroni, 2018). The synergies between cyber-physical systems, Big Data, data analytics, IoT and innovative circular business models could provide greater opportunities towards more sustainable industrial value creation and value capture in the context of the circular economy.

Bressanelli et al. (2018) pointed out that digital technologies have the potential to enable and facilitate the circular economy transition. In particular, they identified eight functionalities: improving product design, attracting target customers, monitoring and tracking products, providing technical support, providing maintenance, optimizing the product usage, upgrading the product, enhancing renovation and end-of-life activities.

One of the "4 R" of the circular economy is reduction. Digitalization of industry allows using fewer resources more efficiently leading to a reduction in energy consumption, logistics routes and waste for example. Moreover, circular economy involves multiple players that must cooperate in order to achieve the best results. This implies a large number of data streams. Digitalization means an improvement in traceability and transparency of data throughout product lifetime and smart connected products allow suppliers to monitor, control, analyse and optimize product's performance and collect valuable usage data. If a company knows the location of the product in real-time, has the possibility to increase product accessibility and the chance of collecting, refurbishing, remanufacturing and recycling it at the end of its cycle. Knowledge of the product condition permits predictive maintenance, advanced diagnostics and prognostics that increase the product reliability and availability. This encourages longer life for products and further remanufacturing with lower costs. The use of digital technologies allows also the promotion of shared use through digital platforms and virtual distribution channels, leading to a reduction in waste and environmental impact.

A powerful example is Michelin that has recently implemented IoT technology to connect its tires and collect data about them (such as temperature, wear, pressure) in real-time. This has allowed Michelin to reduce fuel consumption, improve maintenance activities and enable new business models inspired by circularity. Thanks to the IoT and Big Data, the company is able to offer its tires through an "as a service" business model, where you pay for the miles travelled but not the tire itself. Furthermore, the introduction of digital technologies has favoured the remote control activities decreasing the overall environmental footprint of Michelin.

It is possible, therefore, to speak about Circular Industry 4.0 defined as "a democratized platform of managing strategic value creation and capture based on given context (in production and services) while exploiting digital enabling technologies, which stimulate competitiveness and flexibility for a regenerative economic growth decoupled from resource use and social impact" (Ünal, Urbinati & Chiaroni, 2018, pp. 6).

Following the research of Ünal, Urbinati and Chiaroni, they highlight the relationships between Industry 4.0 pillars and two of the process embedded in a circular business model: value creation and value capture. Value creation concerns the degree a company leverages its key resources, activities and partners to enhance the circularity of its system; while value capture

regards the degree to which a firm makes visible to customers its compliance to the principles of the circular economy.

		Circular Economy business model	
		Value Creation	*Value Capture*
Industry 4.0 pillars	*Cyber Physical System*	-Resource, energy and capacity efficiency -Sharing data through partners among supply chain to enhance skills and capabilities	-Supporting the service models for customers through highly integrated physical goods with smart algorithms
	Cloud manufacturing	-Effective collaboration through value chain for design, assembly and manufacturing while capturing new skills	-Enabling active customer engagement in Circular Economy activities -Active e-commerce enabled promotion of circularity
	Internet of Things –IoT	-Better communication and exchange of data through value chain	-Enables the service models through collecting real-time information on location, condition and availability of assets
	Additive manufacturing	-Facilitating the DfX practices for CE (design for disassembly, recycling etc.) -Resource, energy and capacity efficiency -Friendly material usage as a substitution to mainstream toxic ones in the market	- Unique parts-solutions that can't be produced with conventional methods for sale of single products as well as service -Enabling active customer engagement in Circular Economy activities as the parts are tailored for specific customer

Figure 10: Deployment of Industry 4.0 on Circular Economy business model
Source: Ünal, Urbinati & Chiaroni (2018)

The first technological pillar considered is Cyber Physical System and is an important enabler of the circular economy because permits the integration of cyberspace, physical processes and objects. In this way, machines and devices in the production lines are all connected as a network allowing the constant monitoring and control of processes, giving real-time feedbacks and data. Physical processes respond to these feedbacks and adjust so that the loop continues; besides, the availability of real time data support instantaneous decisions about maintenance needs, prioritization of orders, energy efficiency and reduction of waste.

Cloud manufacturing technology allows the creation of a virtual and global space in which a shared network of manufacturing resources and capabilities is promoted. It is a service-based tool, where supplier and customers have the possibility to interact with exchanging services rather than physical products. Therefore, as well as encourage the collaboration of all actors among the entire value chain, this technology is crucial for e-commerce, an important aspect of circularity.

Big Data and IoT can allow the monitoring, analysis and control of product's data in order to support their lifecycle and extend their replacement along the entire supply chain. IoT can be considered a digital enabler of the circular economy because of permits system optimization models, real-time measurement, big-data analysis and process control, smart integration of tools and methods, which help to quantify resource efficiency (Reuter, 2016). Moreover, Big Data,

thanks to their characteristics[2], facilitate the circular economy transition because are able to support information flows and the collection and share of data among the stakeholder network. Lastly, additive manufacturing technologies can be used in circular business models to sustain the design phase of products. In fact, they allow the production of modularized and customized products easy to disassemble and reconstruct. In this way, manufacturing of products becomes decentralized and allows lower distribution costs and raw materials savings (Nobre & Tavares, 2017).

Thus emerges that the integration of circular economy and Industry 4.0 is powerful and indispensable for economic growth and prosperity decoupled from resource and social impact. Despite this, there are some barriers and challenges for companies implementing digital technologies for a circular economy-based supply chain.

Antikainen, Uusitalo and Kivikytö-Reponen (2018), analysing the literature, have identified four types of obstacles: financial barriers regarding the substantial investment for new technologies and the quantification of financial benefits; structural barriers in terms of the possibility of missing exchange of information and the unclear responsibility distribution; operational barriers concerning the change in the infrastructure and the supply chain management; and attitudinal barriers concerning the shared perception of sustainability and the risk aversion. Moreover, the authors affirmed that even if digitalization has increased the amount, accuracy and speed of information, currently there are problems related to them such as the underdeveloped availability of information, increased transaction and search costs, and lack of knowledge.

Another interesting study regarding this theme is that of Rajput and Sigh (2019). According to them, the first obstacle in the adoption of 4.0 technologies in the circular economy is represented by the need to integrate Cyber Physical Systems since they use different computing models and collect huge amounts of data that must be analysed and managed together. In addition, could result difficult to integrate automated systems required by the circular economy without scarifying the flexibility characterizing smart factories. Other challenges regard the design, compatibility and infrastructure standardization necessary for the application of smart products and the integration of processes. The geographical location of the production could also represent an obstacle for the device connection and integration since they require cloud storage, privacy and security support, computational activities, compatibility among systems, which must be as much improved and under control as possible for an efficient remote

[2] Big data have four main characteristics: volume, velocity, variety and veracity. These characteristics find applicability in the ReSOLVE framework for circular economy. ReSOLVE states for Regenerate, Share, Optimise, Loop, Virtualise, Exchange.

connection. Another barrier regards the achieving of automated synergy, which requires a centralized model of evaluation for collecting data, standardize and analyse them accurately for eliminating errors and maximize efficiency.
All these obstacles are of primary importance to overcome in order to guarantee a fluid interaction between humans and machines and to facilitate the management of automated systems that offer real-time solutions on operational processes. The successful win of these challenges permits to benefit from the conjunction of disruptive technologies and circular economy values.

2.5. How does circular economy create value?

The circular economy is a model for production and consumption which involves sharing, leasing, repairing, refurbishing, remanufacturing and recycling existing materials and products as long as possible in order to extend the life cycle of products. The European Commission recently estimated that the transition towards a circular economy could create 600 billion euros annual economic gains for the EU manufacturing sector alone, while also reducing total annual greenhouse gas emission by 2-4% (COM, 2105). These data already make us understand why the circular economy has been gaining traction with both business and government leaders.
Bressanelli et al. (2018) highlighted three ways through which circular economy creates value: increase in the utilization index of products and their general efficiency thanks to approaches like sharing and pay-per-use, the extension of the life cycle and gain from the residual value. These three benefits can greatly improve the positive impact of adopting circularity in line with sustainable environmental, economic and social development.
More in detail, the macroeconomic benefits of shifting to a circular economy are:

- Economic growth. The combination of increased revenues from new circular activities and lower-cost production derived from the more productive utilisation of inputs can boost the overall economic growth. It is estimated that an increase in resources' productivity of 30% by 2030, could raise the GDP by almost 1% (McKinsey, 2017).
- Material cost savings. If raw materials are recycled or the components of products are reused, fewer expenses are needed for buying them. It is estimated that, in the sectors of complex medium-lived products in the EU, the annual net-material cost savings opportunity could be up to 630 billion dollars. While, for fast-moving consumer goods, there could be potential for material cost savings of about 700 billion dollars in the world (Ellen MacArthur Foundation).

- Job creation potential. The birth of new circular activities such as innovative design, research, new service-base business models, recycling, remanufacturing, will require a new workforce. This impact on employment is principally due to increased spending in fuelled by lower prices; high quality, labour-intensive activities and higher specialized jobs especially in remanufacturing. It is estimated that with the implementation of the circular economy there could be created more than 170,000 direct jobs by 2035 through the measures on waste management alone (European Commission, 2020).
- Innovation. The transition towards a completely effective circular economy requires a not insignificant level of innovation. This new model represents a huge creative opportunity. The advantages of a more innovative economy consist of higher rates of technological development, improve materials, labour, energy efficiency and wider profit opportunities for organizations.

Successful circular economy contributes to all the three dimensions of sustainable development: economic, social and environmental. That is way circular economy is also considered a win-win-win model where the environment, companies and individual can benefit from its implementation.

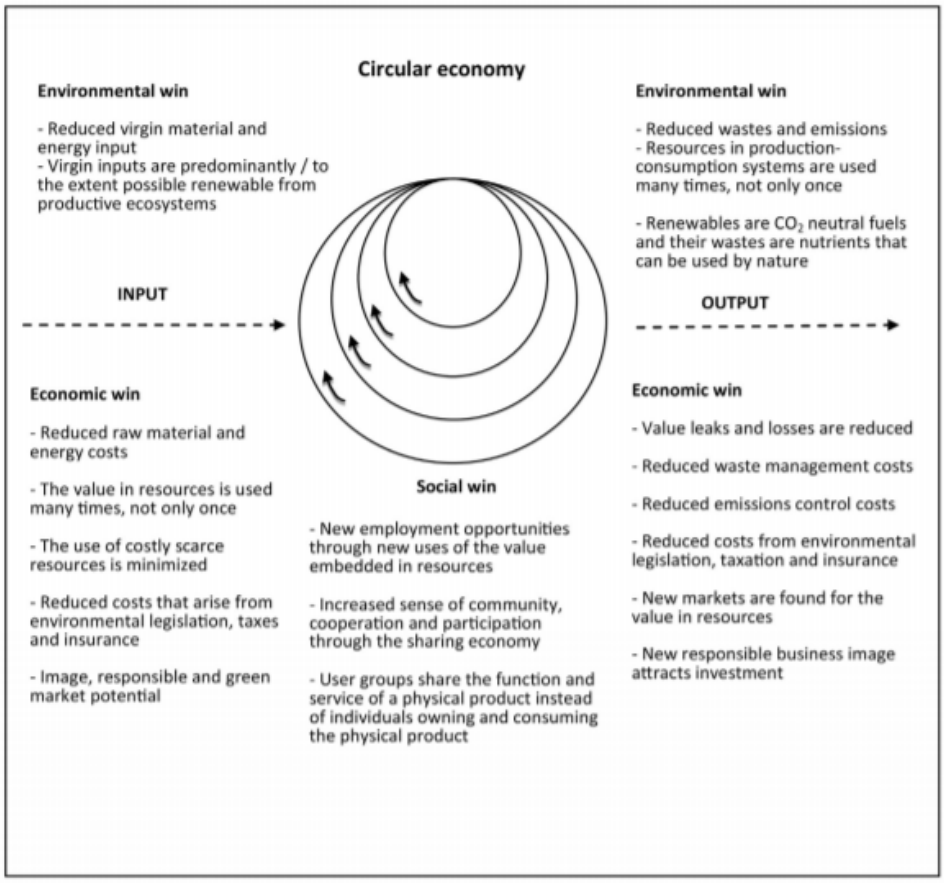

Figure 11: Circular economy for sustainable development. The win-win-win potential of circular economy. Source: Korhonen et al. (2018)

By designing out waste and pollution, keeping products and materials in use and regenerating natural systems, circular economy means a strong tool for achieving global climate targets. The first positive impact on the environment is the reduction of carbon dioxide emissions relative to today's levels across mobility, food systems and building construction. It is estimated for Europe a reduction of carbon emissions by 450 million tonnes by 2030 (United Nations, 2020); moreover, specific analysis has identified that the UK, keeping organic waste out of landfills, could decrease greenhouse gas emissions by 7.4 million tonnes per annum (Ellen MacArthur Foundation). Another environmental benefit regards the primary material consumption: the implementation of the circular economy, in fact, can lead to a reduction in material consumption of 32% by 2030 (EEA, 2015). Lastly, thanks to the full compliance with the principle of regeneration, there is a benefit in terms of land productivity and soil health. Higher land productivity, less waste and the return of nutrients to the soil will increase the value of land and soil as assets. Returning biological resources back into the soil will reduce the need for replenishment with additional nutrients allowing to save almost 40 billion dollars annually worldwide in land deterioration.

For the business world, the circular economy represents an opportunity to turn waste into value taking advantage of new profit opportunities, lower costs due to lower virgin-material requirements, and stronger relationships with clients. Companies have the possibility to reduce costs and create new profit streams; for example, some studies found out that the cost of remanufacturing mobile phones could be reduced by 50% per device or that if the firm decides to lease washing machines instead of selling them, they would earn roughly a third more (Ellen MacArthur Foundation). By using fewer virgin materials and more recycled inputs in the production, companies can benefit from a reduction in the exposure of volatility in raw materials prices and from an increase in the resiliency of supply chains. This because the circular economy helps to create supply chains that are short, transparent, redundant and flexible. As mentioned before, a circular economy would open roads to new business models, in particular towards new business services opportunities. This new demand for business services includes, for example, the collection and reverse logistics companies that support the reintroduction of products into the system, the product remarkets and sales platforms that promote higher utilisation of goods, the need of specialised knowledge and services for the remanufacturing and refurbishment of products. Finally, yet importantly, circular solutions offer new possibilities for including customers and establishing longer-term relationships. For instance, the increase of touchpoints due to the implementation of business models like rentals

or leasing, allows companies to interact more with its customers, gain unique insights into usage patterns, and benefit from loyal and greater satisfied clients.

The third winners are the individuals that will be provided with more durable and innovative products that will increase the quality of life and save money in the long run. It has been researched that the circular economy has the potential of increasing the disposable income of the average European households. Mainly due to a decrease in the cost of products and services, the average disposable income for EU households would rise by 3000 euros by 2030 (Schulze, 2016). Customers have can benefit from a more inclusion in the supply chain, from better customization of products, and from the sense of well-being conferred by the purchase of sustainable products. Another advantage for individuals is linked to the reduction in the obsolescence: total ownership costs are lowered, and there are fewer problems and hassles associated with repairs and returns of products. Circular economy improves also the living conditions and the related health effects because its effective implementation allows significant reductions of antimicrobial, air pollution, water contamination, foodborne diseases. It is estimated that a circular economy for food could save 290,000 lives otherwise lost to outdoor air pollution per year, by 2050 (Ellen MacArthur Foundation).

2.6. Limits of circular economy and best practices

Despite the benefits that the circular economy can bring, the model is not free from inefficiencies and issues. An increasing number of policy measures and initiatives supports the transition; however, political, social, economic and technological barriers persist. In fact, while many in business and policy circles have proclaimed their support for the circular economy (European Commission, 2008), its implementation still appears to be in the early stages. China may be the only notable exception with its "Circular Economy Promotion Law of the People's Republic of China" representing a forefront of circular economy adoption.

Hence, the question is what are the main inefficiencies and barriers that slow down the transition towards a circular economy?

The Green Economy Observatory in 2015 identified that the inefficiencies derive from the centrifugal forces generating wastes, which characterized the circular model: a substantial input flow of raw materials gradually gets thinner due to the leakages of materials. These leakages represent the inefficiencies arising from waste materials and garbage that never go back in the economic cycle and therefore generate a loss in value. This explanation gives a more realistic representation of the circular economy model as shown in the figure below.

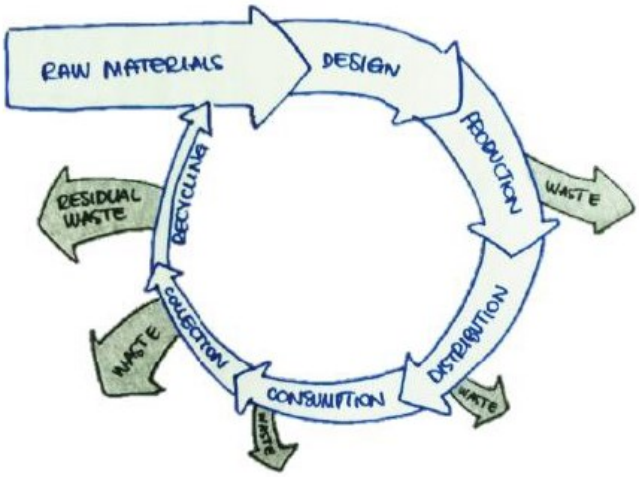

Figure 12: Efficiency lost due to centrifugal forces in the circular economy model
Source: The Green Economy Observatory (2015)

These centrifugal forces, as in physics, are the consequence of a series of inactions and limits: cultural, technological, institutional, economic, and only with the overcoming of them, it is possible to fully realize the circularity. This loss of efficiency can be attributed to different causes:

- Market barriers. These regard mainly the price bias given that the products' prices are not able to reflect the costs related to the environmental impact. Therefore, most polluting companies face lower fixed and variable costs (transferring them to the community) that allow lower and more competitive prices for their products. Moreover, the shift to a circular business model requires high upfront investments that most companies are not willing to pay because considered complex and risky.
- Cultural barriers. Traditionally companies' strategies are focused on short-term targets and not on objectives with a wider range of action like an improvement in environmental performances, thus, the change in firm's culture and mindset is very difficult. In addition, businesses often lack the awareness, knowledge or skills to put circular economy solutions into practice. On the other hand, customers not always are willing to change their consumer habits. Consumers prefer new products instead of recycled ones because they consider second life goods having lower efficiency, and often they change their mind too quickly giving limited chances to circular products.
- Geographical barriers. The geographic dispersion of the supplier network leads to a situation where it is difficult to not lose waste along the value chain. Moreover, the globalization hampers the application of reverse logistics, which implies backwards handling of products in the supply chain.

- Regulatory barriers. The political signals towards a circular economy are not sufficiently strong and coherent. It is not uncommon the setting of some regulatory limitations that hinder the circularity such as the constraints on the use of second raw materials.
- Technological barriers. Having the relevant technology in place is a prerequisite for the circular economy transition but always is easy to manage or obtain.

To overcome these limitations, we need effort and a global vision. According to Geng, Sarkis and Bleischwitz (2019), a global strategy for the circular economy should include the following. First, the development of a global database in order to collect information about resources' use, with indicators on global flows, production costs and market trends. Second, the creation of a global platform with experts and organizations for sharing knowledge and learning about the circular economy. Third, there is the need for international alliances for large-scale experimentation especially about governance and financial innovations. Fourth, the development and harmonization of standards regarding performance measurement, reporting and accounting with the aim of reducing gaps between sustainability strategies. Fifth, the introduction of dispute settlement and sanctions on an international scale, with a reputational risk for business, in order to motivate their commitment to the circular approach.
Concluding, the linear economic model is no more sustainable and a structural change is necessary in the entire world. The circular economy could be a valuable alternative but it must be implemented with a method and with global cooperation.

3. THE CONTRIBUTION OF SERVITIZATION IN CREATING CIRCULARITY

The aim of this thesis is to highlight the role of services in boosting circular strategies, all this in the panorama of industry 4.0 and digital technologies. In this chapter, we will try to converge the servitization and circular economy theories into one concept also showing their potential as response to post Covid-19 situation.

3.1. Circular service-oriented business models

The implementation of service-oriented business models, as we saw before, is one of the possible solutions for enabling the circular economy into companies. Moving towards a servitized business model (such as the pay-per-use, sharing, or leasing) can represent a great tool to enhance competitiveness and promote sustainability. The client goes from being a "consumer" of a product, to become a "user" of the service, with a substantial reduction of the CO2 emissions, for example (Tukker, 2004).

In particular, we consider the Product Service Systems (PSS) defined as "a mix of tangible products and intangible services designated and combined so that they are jointly capable of fulfilling final customer needs" (Tukker & Tischner, 2006, pp. 1552). In this type of business model occurs a shift from selling products to selling the utility, therefore, companies have an incentive in manufacturing products with longer life in terms of services, products that are easy to use and reuse and that are also efficient relating to total cost and materials employed. By definition, a PSS is not a circular business model but there some similarities between PSS and circular economy and some shared principles. For example, both have the objective of satisfying users' needs in an effort to radically lower environmental impacts (Lewandowski, 2016), both carry on the idea of efficient utilisation of products, and both are supported by digital technologies. Digital technologies, in fact, are key enabling factors for servitization strategies and, at the same time, for the implementation of circularity.

Regarding this theme, an interesting study is that of Bressanelli, Adrodegari, Perona, and Saccani (2018) in which they analysed how new digital technologies, especially IoT, Big Data, and analytics, help in the adoption of usage-focused business models to achieve the fundamental circular economy value drivers. These latter are: increase resource efficiency, extend product lifespan, and close the loop (Ellen MacArthur Foundation, 2016).

Following the classification of PSS elaborated by Tukker, the authors described each business model highlighting the aspects in terms of services and their potential contribution in meeting the three circular economy drivers:

- Product-focused BMs. In this category, the tangible value embedded into products is the centre and it refers to the four P's of the marketing mix: price, product, promotion, and place (Kujala, Artto, Aaltonen & Turkulainen, 2010). Here services have a low level of customization and normally concern the maintenance and repair of products sold. Product ownership, in fact, is transferred to purchasers and the company can sell additional add-on services. Therefore, in this type of business model, firms have no or lower responsibility for product lifecycles and transactions are often single and independent from each other (Barquet, de Oliveira, Amigo, Cunha & Rozenfeld, 2013). All things considered, product-focused BMs are not the best vehicle to achieve circular economy objectives, since they do not care about slowing, narrowing, and closing loops.
- Usage-focused BMs. In this class of business models, the ownership of products is not transferred to customers that, instead, pay a fee in order to have access to them. Therefore, services became crucial and more customized. Companies are responsible for all the lifecycles of products providing services such as maintenance, repair, and control. In addition, companies have an incentive in creating products efficiently, meaning products easy to maintain, with components easy to reuse, and easy to upgrade. Usage-focused BMs, through pay-per-use and sharing mechanisms, aim to achieve a longer life for their products and to increase resource efficiency, by adhering, in this way, to circular economy principles.
- Result-focused BMs. Here, the customer does not buy the product or system but pays a variable fee that depends on the achievement of a contractually-set result, in terms of product/system performance or outcome of its usage (Tukker, 2006). The value is delivered to clients through a mix of integrated products and advanced services; therefore, a field service network is necessary. The company is responsible for the entire lifecycle of products, hence it is encouraged to design durable products, to extend as much as possible the product lifespan, and to close the loop collecting back products and re-entering them in other cycles. Thus, result-focused BMs allow reaching all the circular economy value drivers.

Result-focused business models appear to be the most effective strategy to move towards a circular economy. However, it is generally difficult to measure outcomes and results in term of

product/system performance, and reach an agreement between customer and supplier in this regard (Bressanelli, Adrodegari, Perona & Saccani, 2018). Nowadays, usage-oriented BMs are becoming increasingly widespread in both B2B and B2C sectors, especially thanks to the growing popularity of the sharing paradigm. Therefore, the authors decided to focus the analysis on this type of servitized business model, to point out how digital technologies applied to them help in achieving the fundamental circular economy criteria.

First of all, it is important to specify the main possible alternatives in a usage-focused BM which are: pay-per-use, rental and leasing. The pay-per-use type means that customers buy an output instead of a product based on some indicators or KPIs achieved (kilometres travelled, number of printers, data transferred, hours of use) causing non-exclusive and non-individual access. The rental implies that customers buy the ability to use a product for a long period with exclusive and individual access. The leasing means that clients purchase the ability to use a product for a shorter period of time with non-exclusive and non-unlimited access.

The literature acknowledges that, among the Industry 4.0 technologies, IoT, Big Data and analytics play a transversal role in the implementation of service-oriented business models and the transition towards a circular economy, as we have seen in the previous chapters.

The authors started identifying eight functionalities of digital technologies in usage-focused business models: improving product design, attracting target customers, monitoring and tracking product activity, providing technical support, providing preventive and predictive maintenance, optimizing the product usage, upgrading the product, enhancing renovation and end-of-life activities. These functionalities permit to fulfil one or more principles of circularity as shown in the figure below.

ID	Usage-Focused BMs Functionality	Digital Technologies		Product Life Cycle Stage	CE Value Driver [20]		
		IoT	Big Data & Analytics		Increase Resource Efficiency	Extend Lifespan	Close the Loop
1	Improving product design	X	X X	Begin of life		X	X
2	Attracting target customers	X	X X	Begin of life	X	X	X
3	Monitoring and tracking products activity	X		Middle of life	X	X	
4	Providing technical support	X	X X	Middle of life		X	
5	Providing preventive and predictive maintenance	X	X X	Middle of life		X	
6	Optimizing the product usage	X	X X	Middle of life	X		
7	Upgrading the product	X		End of life	X	X	
8	Enhancing renovation and end-of-life activities	X	X X	End of life			X

Figure 13: Conceptual framework highlighting the role of digital technologies in enabling the transition towards CE
Source: Bressanelli, Adrodegari, Perona & Saccani (2018)

The first functionality regards the possibility for companies of improving products' design to better satisfy the customers' requirements. This is possible thanks to the collection of usage data through the IoT and the analysis of them by the use of adequate analytics. Therefore, improving product design allows extending the product's lifespan thanks to the design of goods that are easier to maintained, upgraded, dissembled and recycled, and permits to close the loop through repair, remanufacturing and recycling.

Second, an elaboration of the information gathered from the products installed base (using all the digital technologies under consideration) about how consumers are employing products allows firms to improve marketing activities with the final objective of attracting new customers. The latter have to be convinced about circular economy values adopted by the company. Moreover, for this functionality, technologies enable to increase resource efficiency, extend product lifespan and close the loop, attaining all the three CE value drivers.

Third, companies thanks to IoT can monitor the product condition, status, location and usage. This function allows extending the product lifespan because it discourages careless users' behaviours that may lead to premature deterioration of products. Besides, monitoring and tracking product activity permits the adoption of sharing business models in which products are shared among several users and the information concerning the location, usage, the condition must be collected and disclosed to every user. This leads to an increase the in product's utilisation, which means an increase in resource efficiency.

The fourth functionality is providing technical support thanks to the analysis of Big Data stored by IoT. This technical support means the provision of additional services such as repair, assistance and spare parts management leading to an extension of the product lifespan.

The use of IoT, Big Data and analytics in usage-focused BMs, entails the provision of preventive and predictive maintenance. The latter permits to extend the lifespan of products achieving the second value driver of the circular economy.

Sixth, companies, by analysing with proper analytics the Big Data collected through the IoT, can offer to their clients customized advice in order to optimize the product usage phase (for example recommendations about how products should be used to reduce energy consumption). In this manner, resource efficiency is increased.

Then, another functionality is upgrading the product. Thanks to the IoT, products become smart and for companies, the remote upgrading is easier because only digital elements have to be replaced like the firmware or software. Normally this allows a reduction in product consumables during the usage phase increasing in this way the resource efficiency. In addition, the second circular economy value driver is achieved since with upgrades the products remain usable and competitive extending their lifespan.

Digital technologies enhance renovation and end-of-life activities given that allow companies to access real-time product information such as geo-localization, status and condition. This permits to perform collection, refurbishment, remanufacturing and recycling operations in an appropriate way. These activities play a fundamental role in maintaining the reliability of products for other lifecycles closing the loop.

Therefore, we have seen that service-oriented companies that employ digital technologies have a huge potential to contribute to the circular economy transition. This because such business can influence how products are used by customers through innovative business models, designated to slow, close, and narrow the loops (Heyes, Sharmina, Mendoza, Gallego-Schmid & Azapagic, 2018).

Servitized business models, in which the supplier retains the product ownership, supported by I4.0 technologies, represent one of the most powerful alternatives to achieve the circular economy value drivers. Despite this, these three topics (digital technologies, servitization, and circular economy), usually, in the literature, are addressed in isolation and only in the last years, some researches started to highlight their interrelationships. Facts, however, show that are emerging more and more innovative business around the world that are succeeding thanks to this trinomial and in the next chapter we will analyse some of them.

3.2. Services and circular economy in response to Covid-19

The Covid-19 emergency has led not only to problems in the health system and society but will also have important repercussions on the global economy. The reduction or blocking of activities, the efforts to restart and the prefiguration of when and how the "new normal" will be characterized are issues and concerns that affect all economic actors in this particular period. On the other hand, one of the most relevant point in this scenario is represented by the possible answers to this situation and both services and circular economy are good candidates.

Some of the main negative effects on the economy are the reduction of the domestic demand especially for the countries most affected, the reduction in the production volumes due to the temporary closure or the decrease in the normal activities, the “disruption” effects on supply chains on the products and service offerings because of branching of global supply chains and the high level of uncertainty that could lead in a decrease of investments.

This period of emergency has highlighted all the vulnerabilities of our current system, starting with globalization, which favored the pandemic but also questioning the linear economy model with the waste of resources and production of waste and environmental emissions.

The circular economy, therefore, comes into play in terms of resilient supply chains that are able to meet the increasing need for security of the people. By using fewer virgin materials and more recycled inputs in the production processes, companies can benefit from a reduction in the exposure of volatility in raw materials prices and the supply risk. With the circular economy, companies can reduce the risk of adverse events thanks to the creation of supply chains that are short, transparent, redundant and flexible. In the first place, the European Commission and the European Council (2020) in the document "A Roadmap for Recovery – Towards a more resilient, sustainable and fair Europe" have outlined the key points to restart after the Covid-19 emergency and among these, there is the need for a transition towards a circular economy. Investing in clean and digital technologies and capacities, as part of a circular economy, will help create jobs and growth and will allow Europe to make the most of the first move in the global race for recovery. The circular economy, in fact, can allow generating green alternatives to disruptions and a powerful example is the smart working that leads to a positive environmental impact reducing, at the same time, the costs for firms.

Another way to respond to this difficult situation is servitization strategies. A survey conducted by ASAP Service Management Forum (2020) on more than 150 Italian companies, shows that who has bet on servitization strategies, especially the digital ones, on one side might have mitigated the lockdown impacts and on the other side might be more ready to restart. The practice and the literature teach us that a structured adoption of new technologies makes it possible to improve the provision of existing services and to develop new ones, thus favouring the creation of new competitive advantages and new sources of revenue that are anticyclical with respect to the crisis. In fact, when sales of new products are slowed down, manufacturing companies must exploit more and better the potential of services on the installed base and their active clients, thus creating value (for customers and consequently for themselves) and long-lasting relationships. It will therefore be essential for manufacturing companies to be able to make the most of the potential of the installed base, using digital technologies to offer smart services that are data-driven, remote, proactive and "augmented". The research has identified two possible ways for servitized companies to face the Covid-19 emergency: first identify how to help more customers, through value-added services that support them in their operational processes; second, adopt more and more technologies to offer smart services.

In addition, it was found that business models alternative to the pure sale were less affected by the crisis. The leasing or the rental and the pay-per-use or pay-per-performance revenue models have resisted without suffering too much the lockdown, this mainly because the supplier remains the owner of the good transferred to the customer decreasing the risk of losing existing

clients. Once again, the trinomial servitization, circular economy and digital technologies represents a successful way of doing business.

As Albert Einstein said: “We cannot expect things to change if we continue to do the same things. The crisis is the greatest blessing for people and nations, because the crisis brings progress”. The Covid-19 emergency could be thought as an opportunity to reconsider the business models maybe towards more service-oriented, sustainable and technological forms, with the aim of creating a “new normality”.

4. EMPIRICAL ANALYSIS

In this last chapter, we will analyse four real cases of companies that have implemented a service-oriented business model in compliance also with the circular economy principles. First, we will take an overview of their businesses in light of servitization and circularity and then we will collect and analyse the answers given to a semi-structured questionnaire.

4.1. Companies overview

The companies selected for the purpose of this thesis are MUD Jeans, Homie, Astrel Group and Energys - Piovan Group. I decided to take into consideration these companies because they are different from each other (different business models, different markets, different clients and products sold) but, at the same time, they embody all the themes of this analysis.

All the companies considered are dealing with services: some have transformed their business in completely servitized ones selling no more products but the access to them, others have incremented their offer of services in order to monitor the product functionality and help promptly their customers. All the companies sustain, at different levels, an idea of a circular economy trying to decrease their impacts on the environment and services are powerful tools to do that. Finally, all the companies have implemented a digital background, in step with new technologies, useful to support their business models collecting and processing data in real-time, monitoring the products' status and the clients' usage, and enabling the servitization and the circularity.

Now we will describe one by one the companies, in particular, explaining them in terms of services and the circular economy.

	Mud Jeans	**Homie**	**Astrel**	**Energys**
Country	The Netherlands	The Netherlands	Italy	Italy
Headquarter	Laren	Delft	Gorizia	Venezia
Sector	Fashion industry	White goods industry	Electronics	Energy service
Legal form	B corp	Start-up	Ltd	Ltd
Foundation	2012	2016	1987	2012
Mai	11	7	35	Not available

Turnover 2018	About 2 ml €	Not available	11.265.654 €	994.662 €
Interviewee	Bert van Son	Colin Bom	Matteo Marchiò	Nicola Piovan
Role	Founder and CEO	Founder and CEO	CFO	President
Date of questionnaire reply	05/10/2020	12/10/2020	10/10/2020	14/10/2020
Interview granted	Yes	No	Yes	No
Day of the interview	05/10/2020	-	08/10/2020	-
Duration of the interview	Half an hour	-	Half an hour	-

Table 1: Companies' summary data

4.1.1. MUD Jeans

MUD Jeans is a sustainable and fair trade manufacturing company based in The Netherlands with its headquarters located in Laren. It works in the fashion industry producing and selling denim products that satisfy the principles of the circular economy. The company was re-launched by Bert van Son, the founder, who in 2012 acquired the brand and proposed a new vision for MUD Jeans. A team of eleven employees with different nationalities (73% are women) forms the company selling its denim products in 300 stores in over 26 countries in the world. The mission consists of promoting the circular production and a conscious consumption for the fashion industry by taking positive action, encouraging transparency and supporting sufficiency. From this mission is based the strategy that splits into three pillars: circular economy trying to make products 100% circular; fair factories seeking to create a safer and healthier working environment; and positive activism trying to inspire other realities to do better for the world.

Regarding the servitization theme, MUD Jeans, with its pioneering "Lease A Jeans" system launched in 2013, is located in the usage-focused PSS type promoting use over ownership. The company started from the fact that the fashion industry is a dirty business, responsible for 10% of annual global carbon emissions and that the trend of fast fashion is no more sustainable for our planet. "A rental model for jeans could be the secret to making fashion more sustainable," says the founder and CEO Bert van Son who strongly believes in the transformation of the business into a product-as-a-service model. A client can lease jeans for a period of one year paying a monthly fee of € 7,50 and an upfront membership fee of € 29 (with which you can lease three pairs of jeans). During the twelve months of the lease contract, customers have three options:

- Switch the current jeans for another type and keep leasing the new pair of jeans for the same monthly fee. With the old pair, MUD Jeans decides whether to recycle it or sell it as a vintage piece depending on its condition.
- Return the jeans without receiving a new pair. The returned jeans will be recycled or sold as a vintage piece depending on its status.
- Keep the jeans for longer. At the end of the contract, the client has the possibility to keep the jeans given that he is the actual owner after the twelve monthly payments. The company, that prefers to recycle the jeans promoting the fulfilment of the circular economy, discourages this option.

Moreover, customers benefit from a free repair service during the lease period (at the time available only in the Netherlands, Belgium and Germany) identifiable in an additional service that enriches the service offering. This allows MUD Jeans to develop closer and long-lasting relationships with clients increasing their levels of satisfaction and presumably increasing the cash flows over time thanks to satisfied customers that are happy to repeat the leasing. "A shift from ownership to paying for the service is good for the environment and for you," we read on the company website. Why? Thanks to the lease system the fast fashion and therefore the waste is discouraged while the recycling and the saving of resources is enhanced. On the other side, customers can pay only for the service and for the product also benefiting from a higher flexibility.

"Lease A Jeans" is a powerful example of use-focused business models in which the ownership of products is not transferred to customers that only pay a variable fee depending on the usage of the product. The company, therefore, is responsible for the entire life cycle of the jeans and for this reason, is incentivized to offer also additional services such as repairing and to create products that from the beginning are designed to be easy to maintain, reuse, upgrade or recycle. Through this approach, MUD Jeans aims to be a pioneer in the fashion industry as regards the circular economy, given the huge social, economic, and environmental impact of this industry. However, even if the principal business model is the product-as-a-service, the company strives to fulfil all the principles of the circular economy dreaming to eliminate the waste and focusing on positive society-wide benefits.

The circular economy drives every decision made at MUD Jeans from the design and production phase to the recycling one. From the beginning, its products are made in such a way that they can easily be deconstructed and reincorporated into production processes, for example, the company replaced the typical leather patch on jeans with a printed label making jeans mono-material hence facilitating the recycling at the end. The production phase is managed by a

simple supply chain, which allows the total transparency and control over products. To produce one pair of MUD Jeans the company uses 577 litres of water that represents less than 10% of the industry standard (7000 litres per jeans) and, in this way, it saved 550 million litres of water until 2019. Another interesting number is the 1,5 million kilos of CO2 avoided until 2019 due to the use of renewable energy in factories and recycled cotton. Besides, the production is determined by market demand ensuring no overproduction and no unwanted stock. As we explained before, then there is the lease phase in which the company carries on the idea of keep products and materials in use and raising awareness among customers about solutions alternative to the fast fashion. Leasing is not the only option offered by MUD jeans that also sells its products but giving a ten euro discount if clients send an old pair of jeans before the purchase. The lease includes a free repair service and at the end of the contract the jeans usually are returned to the factory: in this way, MUD Jeans prevents the creation of waste and preserves products in good conditions. When the jeans go back, the company evaluates their status and if the latter is good, they are fixed and upgraded and added to the vintage collection. With these processes, the products' lifespan is extended potentially allowing a reduction in carbon emissions and water around 20-30% for each pair of jeans. If the returned jeans are no longer in good conditions, MUD Jeans starts the process of recycling. Here the jeans are shredded into fibres and remixed with fresh organic cotton in order to make new yarns. Up until 2019, the company saved 20,000 jeans from landfill and incineration turning them into new usable denim. The goal for the near future is a pair of jeans made 100% post-consumer recycled denim.

For its commitment to circular economy values, MUD Jeans received several awards for its innovative approach in the fashion industry such as B Corporation Best for the World Environment Honoree in 2018, Vegan PETA award in 2015, Sustainability Leaders Awards in 2015 and many others.

At the beginning of the business, customers are confined to a small niche, vegans. Currently, more and more people are wearing MUD Jeans (in 2019 were sold 34,500 jeans) and its clientele is represented by conscious men and women sensitive to sustainability issues. A community that actively share why and what they buy or lease from MUD Jeans and that leads to word of mouth that grows the customer base as well as sharing the story about their vision and mission. MUD Jeans, therefore, is fully consistent with the purposes of this thesis because represents a successful implementation of a service-oriented business model in lines with the principles of the circular economy. It shows how the transformation of the business model towards the servitization could be a key strategy for following the circularity and spreading its values among customers.

4.1.2. Homie

Homie is a young organization that offers domestic appliances on a pay-per-use basis with the principal aim of reducing the environmental impact linked to domestic consumption. Nancy Bocken, Colin Bom (the CEO) and Hidde-Jan Lemstra founded the company in 2016 from a spin-off of the Delft University of Technology. This start-up is based in Delft and its main purpose is to demonstrate that new sustainable business models can contribute to sustainable consumption and a circular economy. A team of five expert people composes Homie and it works in the white goods industry. The company, at the time, does not manufacture its own washing machines or the other devices but rather acquires existing household appliances and adapt them for the pay-per-use model. The goal of Homie is making the white goods sector more sustainable reducing the waste of resources. Promoting the pay-per-use model, the company tries to discourage the inefficient and pollutant use of appliances and at the same time stimulates the sustainable consumption and the creation of long-lasting relationships.

As concerns the servitization theme, Homie is at the forefront of the transformation and adoption of business models fully servitized. The company's products are washing machines and dryers (dishwasher will be available in this autumn) that are commercialized following a pay-per-use business model in which the full service is granted, there is no upfront cost and the installation is free. How does this system work? First of all, a customer orders the appliance online and Homie guarantees a fast response service to schedule the delivery date. The delivery and the installation are free and the company also offers the service to take back the old appliance. The important step here is the connection of the installed household appliance with the client's Wi-Fi network. The Wi-Fi and the digital tracker added in the machine allow monitoring the conditions of the product and controlling its usage. With this model, the customer pays only when the washing machine and/or the dryer is used, there are no hidden costs. Prices depend on whether the client is a heavy consumer or a light consumer; therefore, they vary based on how environmentally friendly the program is. The lower the temperature of the wash, and the lower the dryness level of the drying cycle the cheaper the programme will be. Typically, prices differ by ten cents between light and heavy users. The appliances are linked to a Homie account in which customers have the possibility to view their usage in real-time, understanding, in this way, what are their current costs. Every month, the company sends to its clients a personal usage overview with some advice on how to use appliances in a better and more sustainable way. Besides, Homie offers an endless guarantee that includes free repairing or replacing the broken devices, thus assuming the total responsibility of products.

This start-up promoting the use over the ownership has implemented a service-oriented business model accompanied by strong customer service, as shown before. With this approach,

Homie benefits from the consolidation of long-lasting relationships (and presumably a flow of recurring revenues) with its customers that in turn can enjoy the pleasure of more flexibility, no sunk costs and free maintenance. Choosing Homie, in fact, is cheaper than a lease contract or a new washing machine or dryer. Some reasons, for example, are that more than 50% of the washing machines exhibit defects within five years and the costs for fixing are often quite high; if you consider a second-hand appliance the purchase is inexpensive but typically break down quickly. Homie customers instead are more aware of their washing and drying behaviour and use the machines less and more economically. Thanks to a pay-per-use business model, where consumers pay for the unit of service, it is seen that customers would become more conscious about consumption patterns stimulating the sustainability consumption (Bocken et al., 2018).

This evidence leads us to the second macro-argument of this thesis: the circular economy. Homie stands as a practical example of a company that has adopted the concepts and principles of the circular economy intending to reduce the environmental impacts and sensitize people towards more conscious and sustainable consumption.

First, Homie only offers durable and energy-efficient machines and is committed to providing all the activities in support of the prolongation in good conditions of the appliances. By repairing and reusing the devices, they last much longer (the products' lifespan is extended) and therefore fewer appliances must be produced (no waste of resources). But the company does not only want to contribute to a circular economy, in which products are maintained well, reused, repaired, remanufactured, but it also wants to encourage sustainable usage of devices through the pay-per-use business model. When paying per use, consumers are more conscious about their usage patterns because the price scheme of the pay-per-use model provides opportunities to link the costs to environmental impacts. In the Homie case, by reducing the price per wash for the lower temperature settings, more sustainable washing behaviours are stimulated and consequently, the environmental impact of using the washing machine or the dryer is reduced. The journal paper of Bocken et al. (2018) has demonstrated that the number of washes and the laundry temperature dropped when paying per use leading customers to wash more efficiently: they use up to 25% less energy and water. In particular, the study has shown that Homie users have an average of 12-13 number of washes in a month respect to the European average of 13.5 times monthly; and that the average temperature is around 38.1°C versus the European average of 43°C. At the end of the product lifecycle, if it is no more possible to repair or refurbish the appliance, Homie starts the process of recycling the old machines, putting into practice the last "R" of the circular economy.

The customer base of Homie is composed by environmentally and cost conscious people that have given up to the ownership of products and have preferred to be more flexible and

sustainable. At the beginning, the mission of the company was not shared by many customers but nowadays it has received a lot of attention especially among literates and economists and the customer base is increased rapidly.

Concluding, Homie represents another successful example of a company that combining services and the circular economy has found an alternative way for the economic growth. Product-service systems, as the pay-per-use model, have the potential to break the link between profit and production volumes, to reduce resource consumption and material used, to motivate inclusion of through-life and end-of-life issues, and to lead to enhanced efficiency in use and product longevity (Bocken et al., 2014). Homie embodies all these opportunities.

4.1.3. Astrel Group

Astrel Group is an Italian company, based in the province of Gorizia, specialized in the design and manufacture of electronic solutions for energy and wellness markets in the IoT era. Founded in 1987, the company's fields of competence are Solar PV monitoring & self-consumption, Biomass Heating control, Wellness equipment control, Smart Home devices e Renewable Energy Management. Active for more than thirty years in the electronics sector, nowadays Astrel is involved in the development of devices for the digitalization of living and work environments. In this sense, Astrel, favouring the Made in Italy, carries on all Research & Development and manufacturing activities.

The company, in the last years, has moved its business model towards new forms of digital servitization providing IT-enabled services relying on digital components inside the physical products. The increasing use of digital technologies, in this way, allows the increasing connection and interdependency of customers, the company, systems, products and services.

Astrel carries on its business on smart and connected products that are able to activate the world we live in; in particular, the company aims to transform homes and buildings into smart environments that result more efficient and sustainable. The majority of solutions offered by Astrel are based on the "Rialto Active Products", an integrated system that thanks to the wireless connection and the high network coverage brought the buildings into the IoT world with simplicity (with also an increase in the time-saving).

The heart of the Rialto system is the WhiteBox control unit that allows controlling all connected Rialto devices, up to 32 devices. This system, thanks to its embedded intelligence, can interface with the external environment allowing the self-regulation of some functions according to what is found in the surrounding space. Moreover, it is able to collect, archive and analyse a huge amount of data related to the internal and external conditions of use, leading to a continuous improvement of performances and constant monitoring. This WhiteBox represents a real "smart

and connected product" (with the typical physical, smart and connectivity characteristics) which allowed Astrel, a manufacturing company, to increase its offer with a package of connected equipment and related services that optimize the overall results (Porter & Heppelmann, 2014).

We can categorise the Astrel strategy as a form of commercial servitization in which digital technologies permit companies to provide services that enhance the product sold and support customers in the control of their processes. At the same time, companies can gain the ability to capture customer needs, analyse them and create new ideas for products. As we said before, Astrel focuses on four main sectors: wellness, biomass heating, photovoltaics and smart home, providing solutions that combine services, people, IoT and spaces. The most services are provided as regards the smart home and they consist of a simple system that will turn any home into a smart home accessible to everyone. All the services and devices are available and managed thanks to a single App called "Rialto Active App" through which users can supervise the temperature or the energy usage in their homes, can manage the enlightenment, the window blinds or the watering for the garden. The system guarantees real-time measurement (not estimations) about the energy consumed by connected devices and in this manner consumers can be provided with information and functions that will be helpful in the process of managing energy and saving it too. Therefore, this App allows transforming living areas into spaces that are more comfortable, safe and green.

Astrel offers also an active monitoring IoT system able to detect and monitor danger situations such as water penetration through the roof or an abnormal level of floor temperature. Recognizing this type of situations, the system immediately transmits alarm warnings by phone or email, as well as generating an alert voice message by Alexa. All the services provided by the company can be checked constantly and people can ask for help in a user-friendly portal in which customers are well-taken care for the installation phase or other problems.

Concluding, Astrel is a manufacturing company that thanks to its innovative products connected to the IoT gains the possibility to retrieve data flows during the products' lifecycle. Analyse those data opened opportunities to obtain important information useful to enhance already existing services or to develop new ones (Zambetti et al., 2020).

As regards the circular economy, Astrel believes that environmental protection is one of its primary objectives together with the quality of products, service excellence and the customers' satisfaction. Firstly, the company is committed to the reduction of waste and, in fact, its products are compliant with the WEEE Directive. In order to reduce the volume of waste generated by discarded electrical and electronic equipment, Astrel's products are designed from the beginning so that they can be reused, recycled and recovered.

The use of digital technologies allows the company to monitor and analyse the energy consumption thanks to remote control. This is an example of energy efficiency and cost savings both for Astrel and its customers. Therefore, even for the implementation of circular economy principles, Astrel takes advantages from the opportunities provided by the Industry 4.0.

4.1.4. Energys – Piovan Group

Energys is an energy service company founded in 2012 by an agreement between Piovan and ESCo Veneto and it is officially recognized by the "Gestore dei Servizi Energetici" (GSE). It is based in Veneto and belongs to the Piovan Group, a global leader in the supplying ancillary equipment and services to the plastic industry. Energys is an ESCo that means, following the ENEA definition, an "Energy Service Company" operating through consulting projects on production processes and energy management. Its final objective is to provide solutions for energy saving and the achievement of the white certificates.

Energys offers a full range of services and new digital technologies to perform a thorough analysis of consumptions, identifying all the potential economic and energy savings both at the company level and with reference to the single production processes. It operates on three main areas: the monitoring and analysis of energy efficiency, the energy assessment and the energy audits. The company can rely on a team of expert technicians that follow the whole process of consulting assuming the risk of the proposed energy efficiency solution, removing any burden of organization and investment from the customer. Clients pay at the end of the process and the payment depends on the achievement of a contractual result: it is a form of outcome-focused PSS business model. The company's approach consists of a pre-analysis of the customer's production process, its characteristics and critical parameters in order to collect data and identify the weaknesses in the energy system. Then, an intervention plan is drawn up and presented to the GSE, the body that examines the feasibility of the project regarding the efficiency's recovery. The intervention plan is developed through three steps:

- Fist a software for monitoring and analysing energy consumption is installed. This is connected to a series of measuring instruments able to detect data regarding different physical measures such as power, electricity, thermal energy fluid flow and temperature. In this way, Energys can create a status map of customer efficiency, identifying the areas of inefficiency.
- The law obliges large companies and energy-intensive industries to conduct energy audits. Energys, through energy assessment tools, develops different ways to reduce energy consumption and evaluate an estimation of the potential cost saving.

- Lastly, Energys performs an energy audit, which is a systematic and documented process that allows obtaining a report on the energy consumption of the building or the area in question.

These three passages represent the starting point to individuate the best solutions to reduce costs related to energy supply and, once GSE has approved the plan, the Energys' technicians install a measuring kit capable to monitor and keep under control the energy parameters, typically for a period of five years. The combination of advanced technologies and the expertise of Energys permits to offer a range of services that is constantly expanding and that enjoy a high level of customization.

Therefore, clients and their needs are at the centre of the Energys business model that with the offering of a wide spectrum of services is also able to implement some circular economy principles. As we have seen before, the main area in which the company is committed is energy efficiency and in general the avoiding of resource waste. Energys is an example of how digitalization of processes allows using fewer resources more efficiently leading to a reduction in energy consumption, logistics routes and waste. The end of the intervention of Energys is the acquisition of the white certificates, also known as Energy Efficiency Certificates (EEC) that are tradable instruments giving proof of the achievement of end-use energy savings through energy efficiency improvement initiatives and projects. Each certificate is worth one tonne of oil equivalent saved and according to GSE, Energys's work permits to save 4,347 kWh each year.

Concluding, Energys acting as a service company in the world of energy efficiency is able to reach different values of the circular economy promoting a more sustainable approach for industries.

4.2. Description of the analysis and the results

This thesis starts with a literature review of the servitization and the circular economy in the light of Industry 4.0 and its new digital technologies. The literature analysis was fundamental to understand and deepen the topics in order to identify some real companies that were different but united by a successful strategy of servitization able to fulfil the requirements of the circular economy. After identifying the four cases to take into consideration, an analysis of their business models was done and, combining the theory with the practice, a short questionnaire was drawn up. Firstly, I contacted some key people within companies (the managers) to ask them permission to treat their companies as a case study for my thesis and their availability to answer my questionnaire. Then, I sent them the questionnaire, which they had to access via a

link, because, in this way, I was able to collect and analyse all the answers together. Some of the interviewed said he is available also for a short discussion online meeting allowing me to integrate the answers and to better understand the context.
The questionnaire is structured to touch almost all the themes of this thesis with the aim of comparing the literature with real situations, considering also the particular period we are living. Therefore, now I present questions one by one, their sources, and the relative answers and comments, trying to identify a common direction or conflicting thoughts.

The first question is a double choice question in which I asked if the main source of revenue in the company derives from service offering or product sales. I decided to propose this as the first question in order to contextualize the company and the answers to the following arguments.

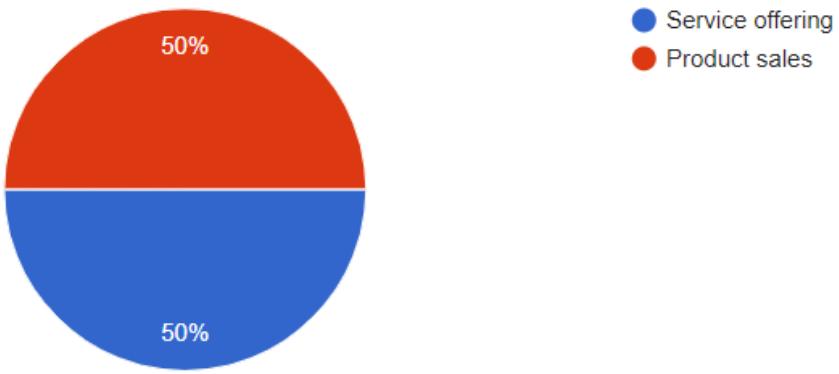

Figure 14: Graph of the answers to the first question

The answers are distributed as expected. The main source of revenue for Mud Jeans now is the product sales with a percentage of 75% of revenues while only the 25% of revenues derive from the service offering meaning the "Lease A Jeans" program. Bert van Son, the founder and CEO, said me that the company is committed to balancing the two percentages in the future years (50%-50%) through a big campaign promoting the leasing model and giving customers incentives if they choose the non-buying option. Astrel Group is the other company that answers product sales as the principal source of revenues. The business model of the company, in fact, is based on the sale of devices for the digitalization of living and work environment, the service offering is, for the moment, a corollary to better satisfy clients. Matteo Marchiò, CFO of the company, confessed that the provision of services is fundamental to maintain the relationships with customers and that in the future is possible that Astrel will increase the services offered. The main source of revenue for Homie derives from the service offering. This makes absolute sense given that the Homie business model is a fully servitized one with the adoption of the pay-per-use approach. The company does not sell any devices but it makes a profit through the utilisation of those devices. Also, Energys answered that the main source of revenue is the

service's provision and this is evident since it is a service company. The service offering, in fact, represents the core business of Energys that provides its experience and professionalism in the energy efficiency sector. Therefore, this is the starting point: two companies with a completely service-oriented business model and the other two companies that have the intention to increase the part of services.

The second question always concern the servitization theme and it is: "Do you think that the service offering could be a source of competitive advantage?". The possible answers were yes or no, and, also in this case, the cumulative result was as I expected.

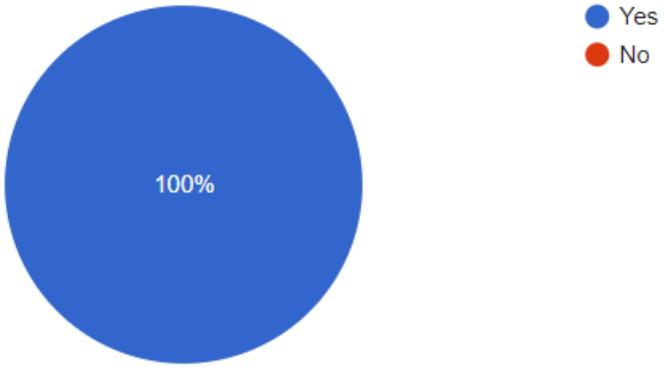

Figure 15: Graph of the answers to the second question

As shown in the graph above, all respondents agree that the provision of services is an important source of competitive advantage. Fully servitized business models or the offering of additional services represent a big opportunity for companies to differentiate from goods and achieve higher customer satisfaction. Services are less visible and more labour-dependent, they are unique and with the possibility of higher customization. They involve the creation of a relationship with clients that usually are called for an interaction with the supplier, leading to situations that are hard to imitate by competitors. Services provide a new source of revenue during the life cycle of products that is more resilient and cyclical respect to the simple product sale. All these aspects imply that service offering could be a sustainable source of competitive advantage and the answers from the analysed companies have confirmed this hypothesis.

The third question concerns the relationship between services and new digital technologies and how the latter could be considered as enablers of servitization strategies. The question has been formulated in this way: "How much do you think from 1 to 5 that the following digital technologies are fundamental for implementing service-oriented business models?". Below I

made a list of the nine key enabling technologies proposed by the Boston Consulting Group and the interviewed had to assign a score to each. Based on the relative importance of the digital technology for the implementation of servitization strategies, a score of 1 represents the lowest level of significance while a score of 5 means “I think that this technology is fundamental!”.

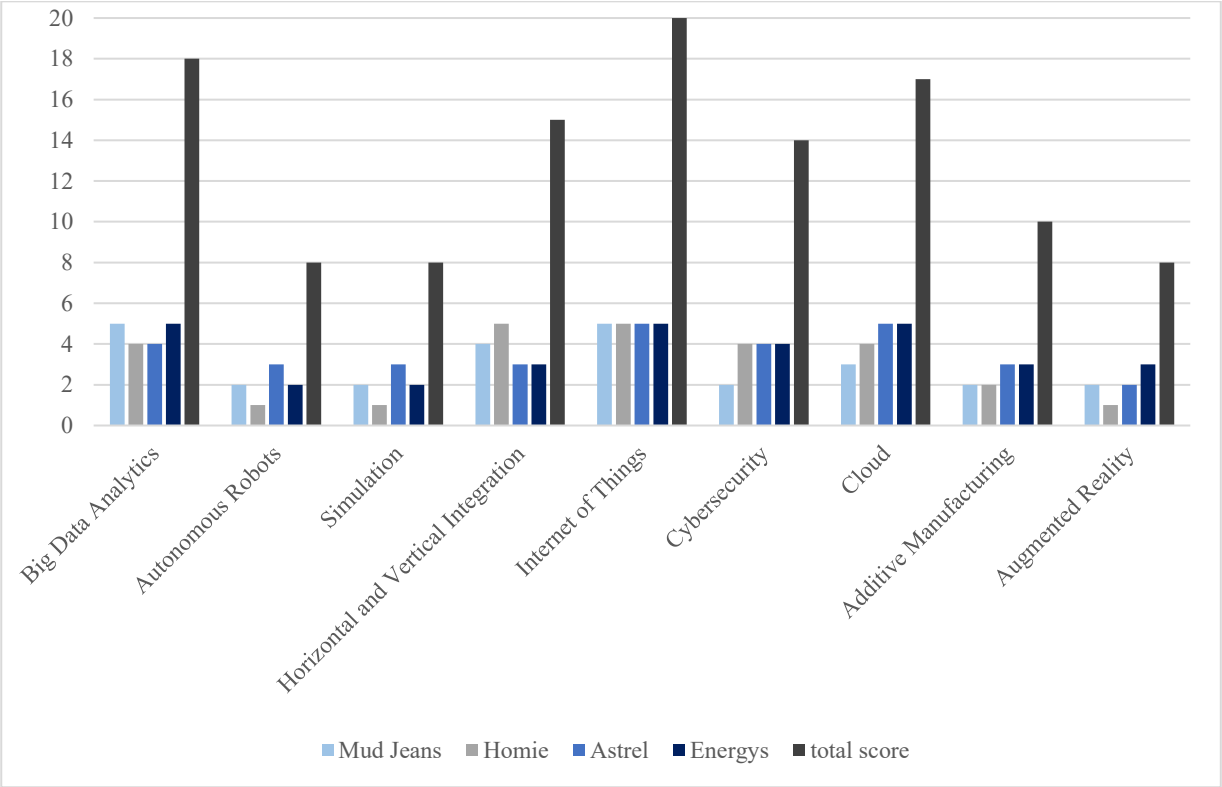

Figure 16: Graph of the answers to the third question

As we can see from the graph above, the technology that has received the cumulative maximum score is the Internet of Things followed by Big Data Analytics and Cloud computing. Industry 4.0 technologies have opened innovative opportunities for a service-oriented transformation of business models and, especially the IoT, have enabled new servitization processes thanks to their capacity of efficiently capturing and transferring data. IoT is also the main technology to transform goods into smart and connected products able to connect people, systems, companies, products and services. I think that these are the reasons for its first place and the maximum score for the importance given by the interviewees. Big Data Analytics has the second place because they permit the storage and combination of information leading to the comprehensive evaluation of huge amounts of data from many sources. The Analytics represent a fundamental tool for the provision of services because allow the control of the products function or the services collecting at the same time many insights useful for the customization and the personalization of users experience. The third place is covered by Cloud computing that thanks to the transformation of data into information permits servitized companies to access easily to

data optimizing the service offered, its performance, the diagnostics and the rapid response. Summing all the scores, then we have in decreasing order Horizontal and Vertical Integration, Cybersecurity, Additive Manufacturing and on par Autonomous Robots, Simulation and Augmented Reality. Analysing specifically each company it is possible to deduce other information based on their overviews in the previous paragraph. In terms of servitization, Mud Jeans considers the most important technologies Big Data Analytics and Internet of Things and immediately after the Horizontal and Vertical Integration. I agree with this classification as regards Big Data Analytics and the Integration given that Mud Jeans has to manage huge amounts of data about the clients who take part in the leasing program and needs to be integrated with its partners and internal departments to operate efficiently and successfully. I was surprised that the IoT received the maximum score because the business of Mud Jeans does not involve this technology directly. Maybe the answer is inspired by the general idea that the IoT is a key factor for the implementation of servitization strategies and not thinking only about Mud Jeans. Colin Bom, CEO of Homie, has assigned the highest score to IoT and Horizontal and Vertical Integration and I think that it is reasonable. The IoT is fundamental for the business of Homie because it allows the transformation of household appliances into smart devices and consequently the company can monitor their conditions and intervene promptly for the maintenance. At the same time, the Integration, the Analytics and Cloud (the technologies with the second highest score) allow Homie to collect data in real time, analyse them and follow customers during the entire utilisation of products. As expected, Astrel thinks that the most fundamental technologies for the servitization in its business are the IoT and Cloud computing. These two technologies represent for the company the fundamental tools for the activities of supervision of temperature, control on energy usage, and generally the transformation of homes into smart livings. The IoT permits the intelligence and connection of products that are able to communicate and interact between each other and the environment, while Cloud allows the transformation of data into information leading to remote data storing. Energys has given the maximum score to Big Data Analytics, IoT and Cloud. I think that these choices are in line with the business model of Energys that consists in the installation of particular systems able to gather data from plants and monitor their functions in order to obtain the white certificates. Therefore, the company has to deal with huge information and has to be capable to store and analyse them efficiently.

The fourth question is structured as the previous one but it takes into consideration the relationship between digital technologies and the implementation of the circular economy. Precisely, the question is: “How much do you think from 1 to 5 that the following digital

technologies are fundamental for implementing the principles of the circular economy?". This question is a parallel of the third one in order to understand the relative importance of technologies with respect to the two macro-themes of this thesis.

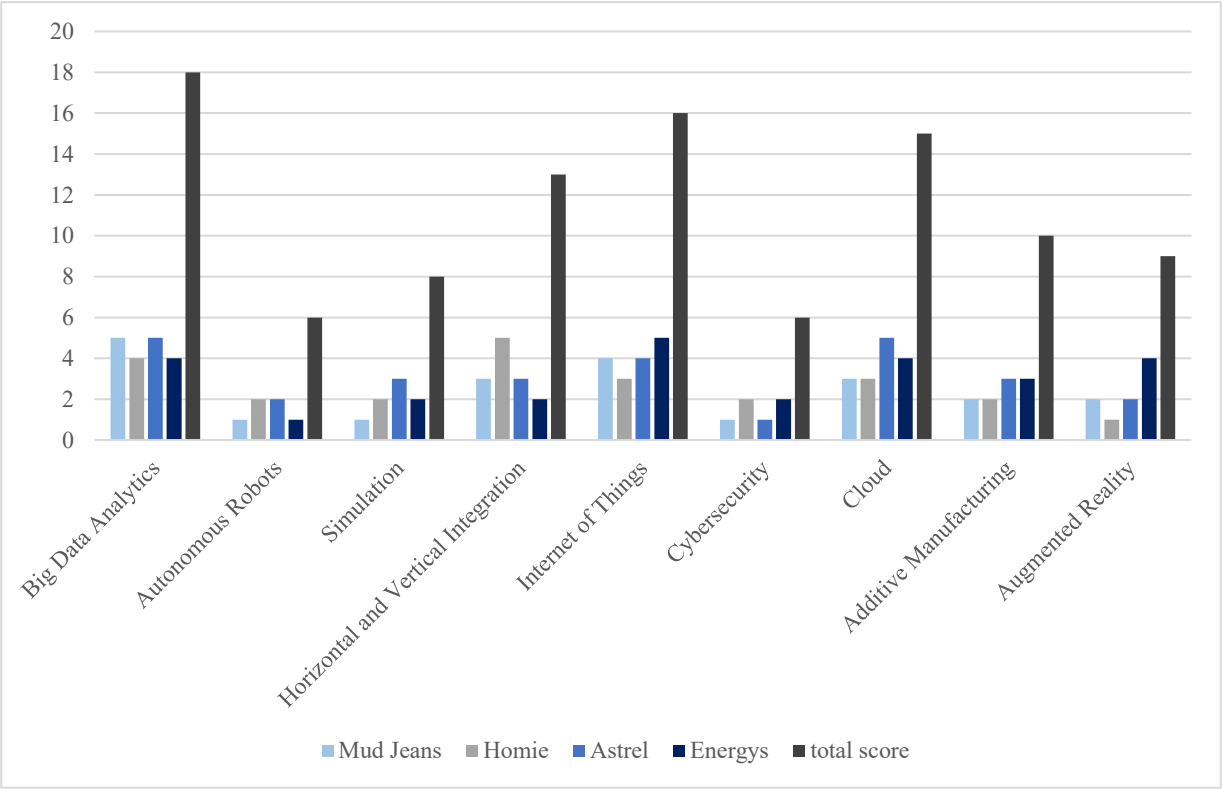

Figure 17: Graph of the answers to the fourth question

As shown in the graph above, the classification following a decreasing order is Big Data Analytics, Internet of Things, Cloud, Horizontal and Vertical Integration, Additive Manufacturing, Augmented Reality, Simulation, Cybersecurity and Autonomous Robots. Therefore, the podium is the same as the technologies most important for servitization strategies and even in this case I expected it. Big Data Analytics allows the monitoring, the control and the analysis of product or service's data to support their entire lifecycle and extend their replacement along the value chain. The IoT permits the optimization of models and systems providing real time measurement and information useful to close the loop or narrow the loop. Digital technologies, in few words, allow the use of fewer resources in a more efficiently manner leading to a reduction in waste, energy consumption and logistics routes. Cloud computing helps the creation of virtual and global spaces in which data are stored with an increase in traceability and transparency and permitting the cooperation between multiple players, a prerequisite of the circular economy. In addition, Additive Manufacturing is interesting to analyse because it represents an important tool in the design phase of products by encouraging the modularity and customization of goods that will be disassembled and

remanufactured with less effort. Going more into detail, Mud Jeans has assigned the maximum score only to Big Data Analytics explaining that it deals with huge data to manage all the processes behind the creation of circular jeans and therefore this digital technology is fundamental to collect information always accessible along the value chain. Homie has given the highest score to Integration technologies because, not being a manufacturing company, needs to have efficient relationships with its suppliers and customers. The circular economy's values have to be shared among all interested parties for the purpose of increasing cooperation. Connected to this, the second technology for importance is Analytics because the company has to collect and analyse many data from the suppliers but especially from the customers' utilisation of devices. Data useful to control the products' condition and consequently offer predictive maintenance to extend their lives. Astrel has classified Big Data Analytics and Cloud in the first place and I think that this choice is dictated by the necessity of gathering and analysing huge amount of date from the smart products in order to monitor their efficiency and guarantee the highest product's performance. Lastly, Energys, as I expected, has given the maximum score to IoT. For the company this technology is indispensable to capture data from machineries and analyse them in real time allowing the prioritization of problems and the management of energy efficiency.

The following question is based on the study of Bressanelli, Adrodegari, Perona, and Saccani (2018) in order to understand for the interviewed which are the functionalities most unlocked by digital technologies, in particular IoT and Big Data Analytics. The answers given to the previous two questions confirm that these two technologies are the most fundamental both for implementing the servitization strategies and the circular economy principles. Therefore, this question is a right consequence. In detail, the question is: "Which of the following functionalities do you think that digital technologies have enabled the most in your business?". Below there were listed the eight functionalities and the respondent had the possibility to choose even more than one answer.

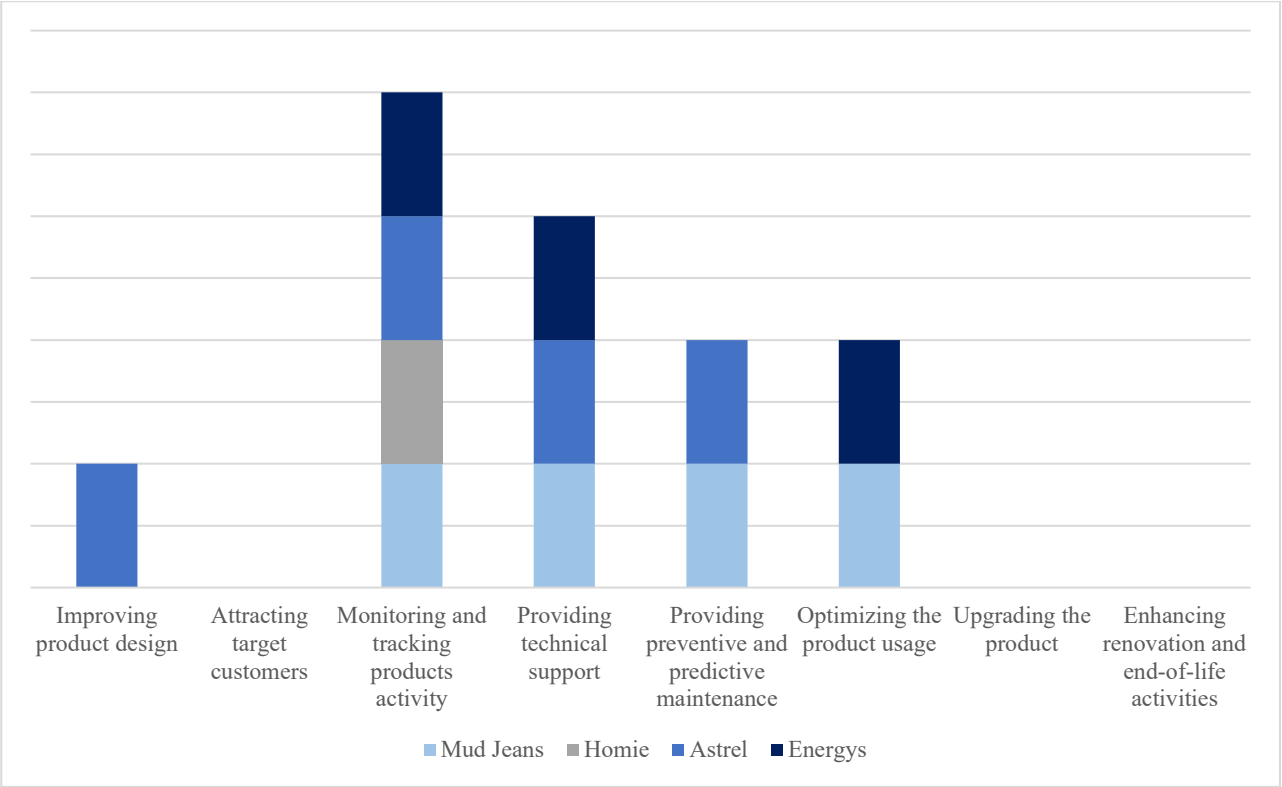

Figure 18: Graph of the answers to the fifth question

All the companies considered for the questionnaire are examples of service-oriented business models (at different levels) and circularity. This question puts in relation a servitization strategy that with the adoption of digital technologies is able to achieve the main principles of the circular economy. As we can see in the graph above, all the interviewed has chosen the "monitoring and tracking products activity" functionality, in fact, every company considered needs to monitor the product condition, status, location and usage in order to operate efficiently. This activity allows also satisfying all the value drivers of the circular economy, as explained in the third chapter. Three out of for companies has selected also the "providing technical support" functionality. Service companies, thanks to the use of IoT and analytics, can provide additional services such as repair and assistance, fundamental to extend the products' lifecycles and increase customers' satisfaction. "Providing preventive and predictive maintenance" and "optimizing the product usage" functionalities have received two votes and only Astrel has selected "improving product design". Notably is that "attracting target customers", "upgrading the products" and "enhancing renovation and end-of-life activities" were not chosen by any companies. It is possible to deduct that the support of the digital technologies mainly needs to increase the efficiency in the utilisation of products, collecting data about their conditions and helping customers to during the use. Interesting is also the fact that all the companies have chosen four or three options while Homie has selected only one answer corresponding with the most voted functionality.

The sixth question concerns the circular economy and its value driver. It is linked to the previous question because takes into consideration the main circular economy principles that in the opinion of Bressanelli et al. (2018) are achieved in a servitized company thanks to the use of digital technologies. The question is "the Ellen MacArthur Foundation says that increase resource efficiency, extend product lifespan and close the loop are the fundamental circular economy value drivers. Which one for your company is the most important to follow?". The interviewed have the possibility to select only one answer and this allows me to understand how the company prioritizes the circular actions.

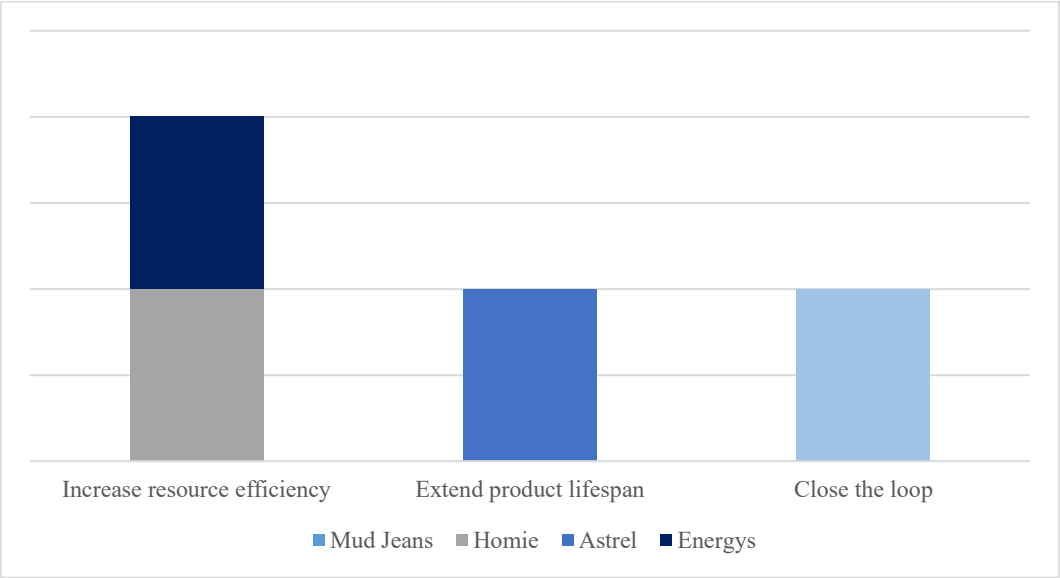

Figure 19: Graph of the answers to the sixth question

Mud Jeans has chosen as answer "close the loop". This is in line with the business model adopted by the company in which the principal purpose is creating the circularity in every phase of the value chain. In addition, the functionalities selected in the previous question are consistent to this answer because by monitoring the products and by providing support and maintenance, the company is able to keep products and materials at the highest value in time, therefore, closing the loop. Homie and Energys have selected "increase resource efficiency" and I think, also in this case, that the answers are coherent with their businesses. The more efficient use of resources for Energys is necessary in order to improve the client's processes in the light of the energy efficiency and achieve ultimately the white certificates. For Homie, instead, the increase in resource efficiency is promoted through price incentives applied on the less polluting washing programs that lead to an improvement in the users' habits and at the end in a reduction of the environmental impacts. Lastly, Astrel responded that the most important

value driver for its company is “extend product lifespan”. This answer is not in line with what I expected because, thinking at its business, I would bet on “increase resource efficiency”. In this question is not possible to make a cumulative comment because the answers are too few to talk about a trend, but it remains interesting understand how companies concretize their efforts concerning the circular economy.

The following question regards always the circular economy theme and it focuses on the implementation of specific circular business models. I decided to insert also this question in order to understand if the interviewed are able to frame their businesses and recognize themselves into one or more already defined business models. The question follows the classification made by Peter Lacy and other analysts of Accenture (2014) that had individuated five underlying business models inspired by the circular innovation. Specifically, the question is “Which of the following circular business models is your company implementing?” and then there were list the five choices with each a short description. The respondents can select even more than one answer.

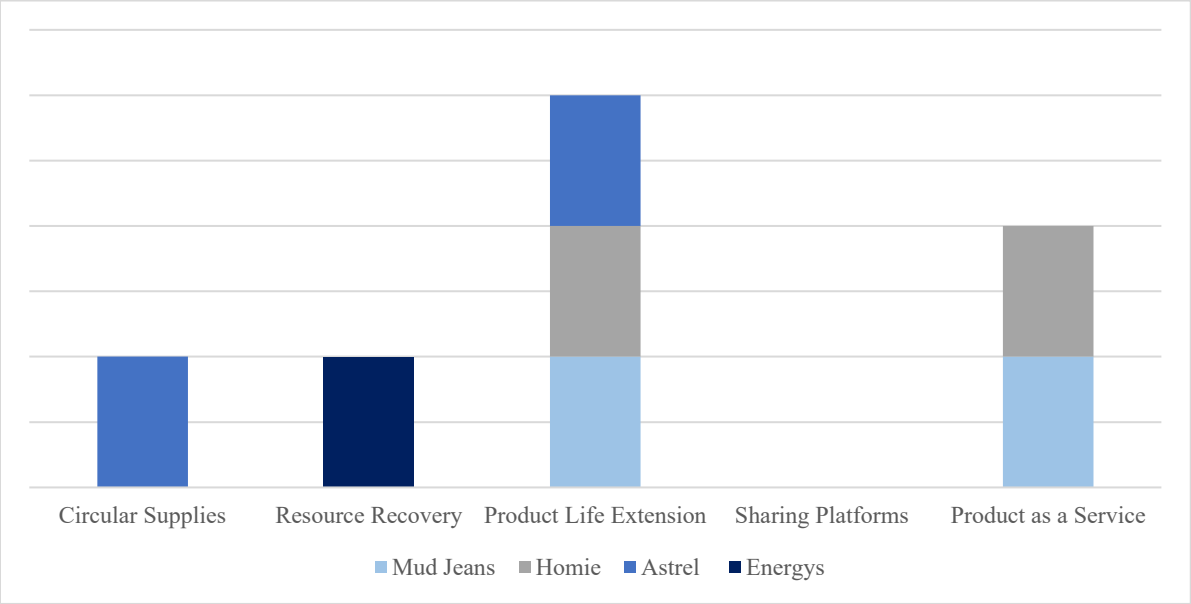

Figure 20: Graph of the answers to the seventh question

Circular Supplies mean the provision of renewable energy, bio-based- or fully recyclable input material to replace single- lifecycle inputs. This option was selected only by Astrel that, developing devices for the digital transformation of living and working environment, focuses on photovoltaic, energy saving, the waste monitoring since the design and installation phases. Resource Recovery implies the recovery of useful resources or energy out of disposed products or by- products. This business model was the only identified by Energys whose job consists in achieving the energy efficiency and issuing the white certificates. Product Life Extension means extending the working lifecycle of products and components by repairing, upgrading and

reselling. Mud Jeans, Homie and Astrel have chosen this option and this is line with their business models in which providing technical support they try to maintain the products in good conditions as long as possible. Sharing Platforms is the business model based on the purpose of increase the utilisation rate of products by making possible shared use, access or ownership. No company has selected this option, maybe in the future Homie and its idea of promoting the shared appliances in buildings could also fit this business model. Product as a Service means the offering of product access and retain the ownership to internalize benefits of circular resource productivity. Even if all the analysed companies are service companies at different levels, only Mud Jeans and Homie are implementing business models based on "product-as-a-service". Mud Jeans through the leasing program for jeans and Homie through the pay-per-use model for domestic appliances.

The next two questions regard the servitization and the most critical resources and capabilities necessary to implement a service strategy. Questions are based on the research of Ulaga and Reinartz (2011) in which they analyse the shift from providing products to selling product-service systems and the relative implications. When you treat services, you are dealing with specific competencies and capabilities that constitute the knowledge of your company. Therefore a company needs to have or develop some critical resources and capabilities for servitization that could represent the source of competitive advantage.
The first question is "How important is from 1 to 5 to possess the following resources that are the most critical and useful for implementing service offerings?". Then are listed the four critical resources with a short explanation and the interviewed had to assign a score to each option. The second question, instead, is "How important is from 1 to 5 to possess the following distinctive capabilities for successful service offerings?". Like the previous question, there is the possibility to give a score to each capability. Below I report the response graphs.

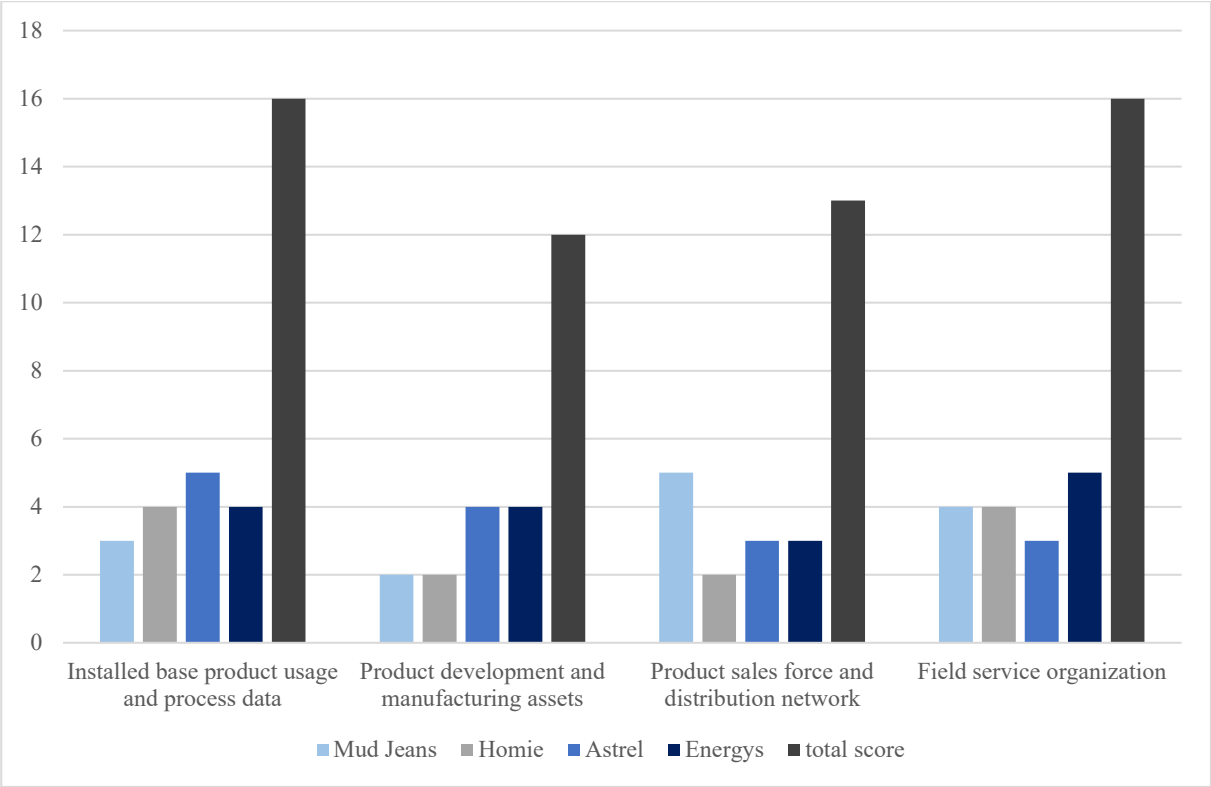

Figure 21: Graph of the answers to the eighth question

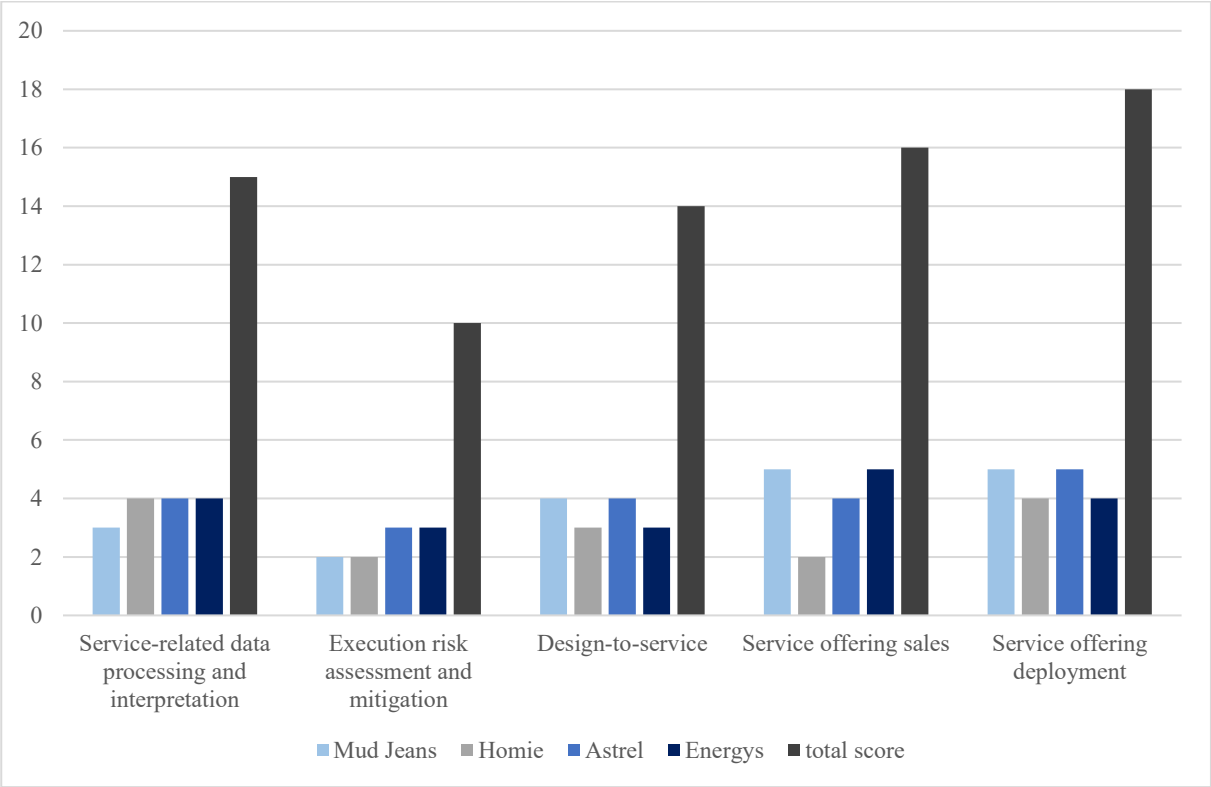

Figure 22: Graph of the answers to the ninth question

As regard the graph of the critical resources for servitization, you see that “installed base product usage and process data” and “field service organization” resources have received the highest scores, meaning that for the considered companies they are the most important to possess. This implies that having data about the product usage and the customer process is considered fundamental in order to manage and leverage the service offering. Such information could represent the key factor in the implementation of different servitization strategies that range from the maintenance and repair of products to the sale of services. Moreover, the questionnaire shows that for companies possess a solid field service organisation is crucial to create customer engagement and lay the groundwork for a long-lasting relationship. Having a field service organisation means having the right workers, skilled and expert, to deliver the value to clients. Specifically, Mud Jeans has assigned the highest score to “product sales force and distribution network” resource that is the level of alignment between the sales organisation and the service strategy. Bert van Son supported this answer by the fact that the company wants to increase the revenues from the leasing program and the related services, meaning that it is important to change the way in which the company present itself in the market. Homie gave its maximum score to “installed base product usage and process data” and “field service organization” resources confirming the company’ need to obtain usage data from products and customers in order to provide consultancy and supporting services. Astrel, instead, selected “installed base product usage and process data” option as the first place because without the collection of useful data about products and processes its service support will be in vain. Lastly, Energys has assigned the highest score to “field service organisation” resource and this was to be expected given that, in quality of a service company, it is fundamental to efficiently manage all the aspects of the service offerings.

Concerning the distinctive capabilities for successful service offerings, the “service offering deployment” capability received the highest score followed by the “service offering sales”. The first capability consists in the creation of a flexible platform for services that permits the standardization but also the customization on the basis of different customers. If a company is able to achieve in this sense the flexibility, it can also reach economy of scale in services and consequently the reduction in costs. The second capability regards the development of a specific mindset to adopt when you sell services instead of goods and the important thing is to highlight their intrinsic value. I think that for the types of companies selected for this research, these two capabilities are fundamental to possess to operate efficiently and effectively and to investigate more and more the passage towards the servitization of businesses. Therefore, the answers are in line with what I expected. In third place, we have “service-related data processing and interpretation” capability consisting in the capacity to interpret and analyse the installed base

product usage and process data to provide support to customers and gain unique insights. This capability is the consequence of the "installed base product usage and process data" and in fact, the points assigned by companies correspond to that assigned to the relative resource.

The following section of questions regards the current theme of how companies have reacted to the crisis caused by the pandemic. I decided to insert also this set of questions in order to have some feedbacks on whether the interviewed think that services and the circular economy are good starting points to restart after this critical period.
The first question is "How much did your company suffer from the lockdown?" in order to understand how the respondents quantify from one to five the difficult situation of the last months.

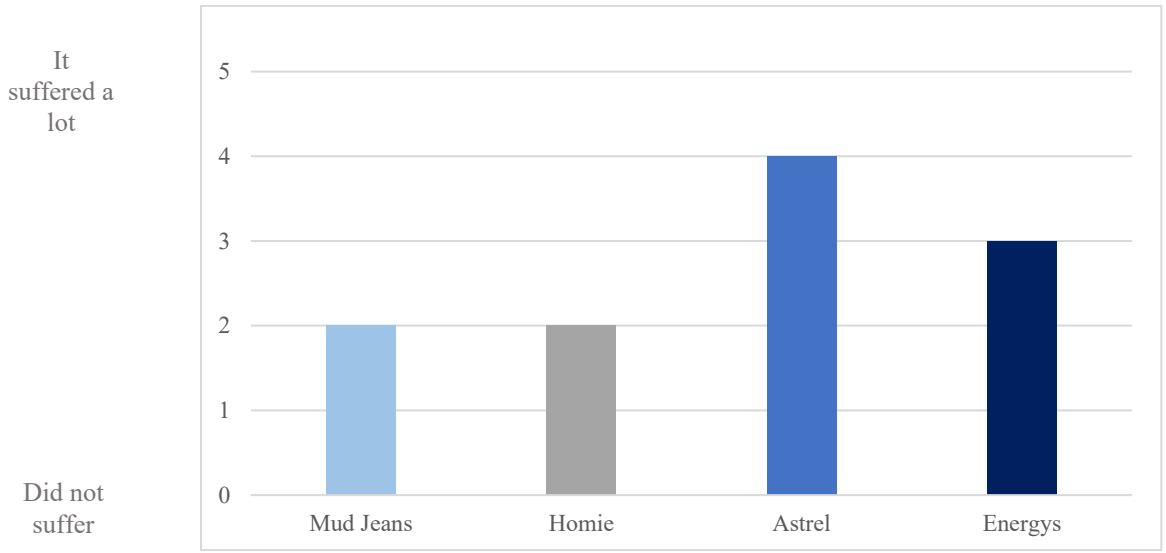

Figure 23: Graph of the answers to the tenth question

The first observation is that the answers range from two to four, therefore, no company was damaged a lot from the lockdown period and no company has not suffered any repercussions. However, it is possible to analyse and comment some differences:

- First, the difference between the two companies based in The Netherlands and the two Italian companies. Both Mud Jeans and Homie have assigned a score of two to this question, meaning that their businesses not suffered a lot from the lockdown and the consequent global crisis. Both the representatives of these two companies, in fact, told me that since the beginning they have received big investments from the Dutch Government. That money mainly was used to cover the fixed costs. The representatives

of the two Italian companies instead did not named the measures taken by the Italian Government in favour of aid for enterprises.

- Second, we can see that companies adopting business models based on the pay-per-use or the leasing approaches have suffered less than the purely service company (Energys) and Astrel, which at the moment offers only add-on services. This evidence confirms the researches made in this context that showed that business models in which the supplier remains the owner of the good transferred to the customer were less affected by the crisis. Principally because the customer does not have to sustain huge initial costs and also there is a decrease in the risk of losing existing customers given that the contract is for a specified period of time. The combination of servitization and the circular economy seems to be effective also to withstand the difficult times.
- Another observation regards Astrel that represents the lowest level of servitization among the companies selected for this thesis and the highest score in terms of lockdown's repercussions. The main source of revenue for Astrel derives from product sale and services, although complex, are considered additional to products. However, I think that the principal reason for its slowdown in economic activity is that it sells expensive products that are unnecessary for an individual. If the level of servitization will be higher maybe the company would have suffered less, but this is only a hypothesis.

The other questions are "How important do you think service provision is to restart after the lockdown period?" and "How important do you think the circular economy and therefore the creation of more resilient value chains is to restart after the lockdown period?". The first question aims to investigate the perception of the interviewed towards the servitization and its positive implications relative to the crisis. The purpose of the second question is a mirror of the first one in order to understand the potential attributed to the circular economy as an innovative strategy in a world that is rapidly changing. The companies had to select a grade from one to five respectively if they consider the service provision and the circular economy as useless or as a good starting point for the economic restart. I decided to ask these questions to figure out how companies committed with services, circularity and digital technologies consider their business models strong enough even in the case of a crisis.

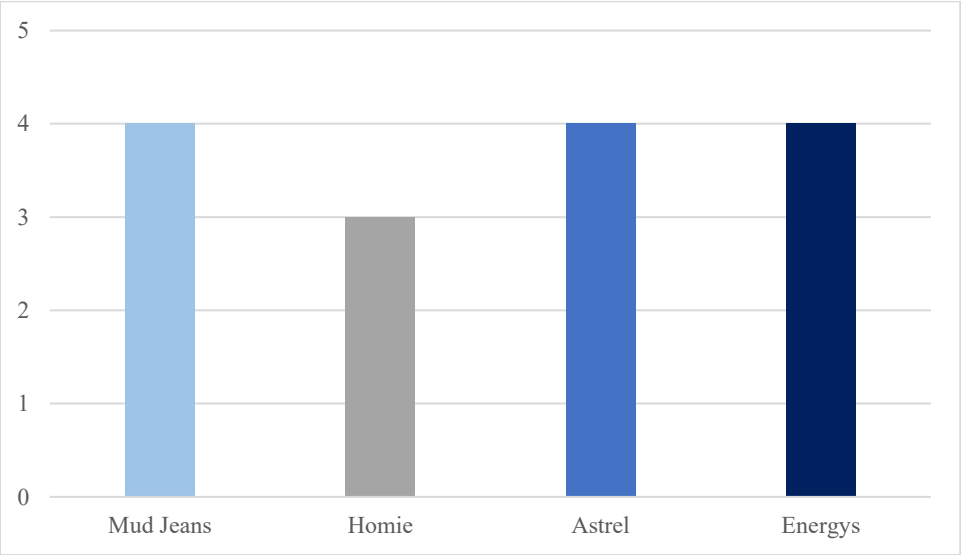

Figure 24: Graph of the answers to the eleventh question

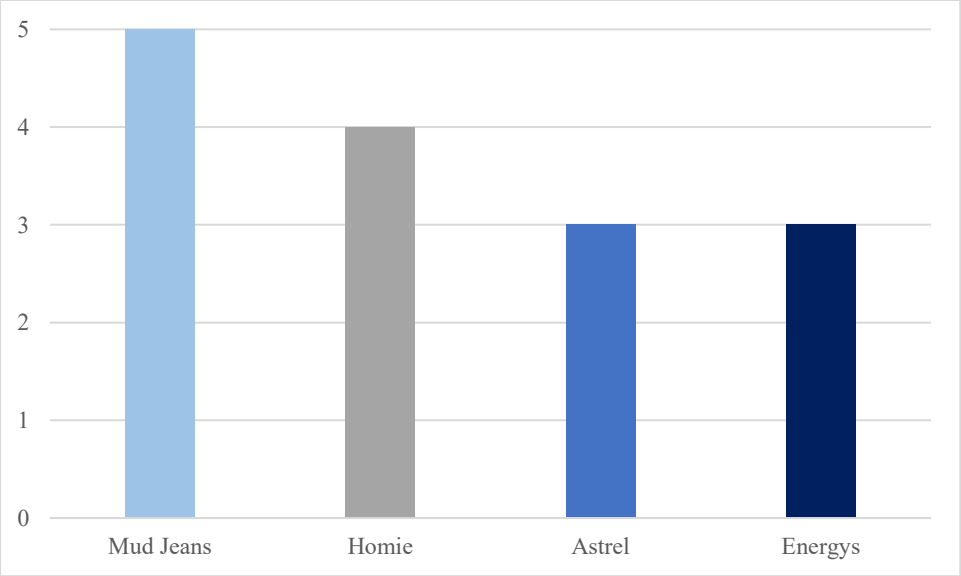

Figure 25: Graph of the answers to the twelfth question

The first thing to notice is that Mud Jeans and Homie assigned a higher importance to the circular economy to restart after the lockdown period, while Astrel and Energys believe that the provision of services could be more successful. The second important fact is that every interviewed has acknowledged a score higher than three both to servitization and circularity, meaning that both the strategies are recognized as powerful.

The circular economy promotes the creation of resilient value chains that are shorter, transparent, redundant and flexible. Moreover, the use of fewer virgin materials and the adoption of recycling processes allows reducing the volatility's exposure in raw material prices and the supply risk. In few words, the circularity approach decreases the uncertainty. On the other side, the servitization implies the development of long-lasting relationships with

customers, the possibility to produce only on demand and to have a source of revenue usually anticyclical with respect to crisis. These are the main reasons for which services and the circular economy could be good starting points in response to Covid-19 and the evidence of the previous question confirms this. Almost all interviewees also affirmed the need for initiatives on the part of the European Union, which must become a driving force behind the transition. In this sense, the strategy of the European Union for the relaunch of the economy after the coronavirus emergency should not only promote collaboration between institutions and companies and transparency of processes, but also should consist of concrete financial aid. Financial aid addressed to increase the level of services as possible and powerful strategy to abandon the linear model and embrace compactly the circular economy model.

Below the graphic representation of all the answers given by each company in order to have a rapid view of the questionnaire.

Questions	**Mud Jeans**	**Homie**	**Astrel**	**Energys**
1. *Main source of revenue*	Product sale	Service offering	Product sale	Service offering
2. *Service offering as source of competitive advantage*	Yes	Yes	Yes	Yes
3. *Main digital technologies for servitization*	Big Data Analytics, IoT	Integration, IoT	IoT, Cloud	Big Data Analytics, IoT, Cloud
4. *Main digital technologies for circularity*	Big Data Analytics	Integration	Big Data Analytics, Cloud	IoT
5. *Functionalities enabled by digital technologies*	Monitoring and tracking, providing technical support, providing predictive maintenance, optimizing the usage	Monitoring and tracking	Improving design, monitoring and tracking, providing technical support, providing predictive maintenance	Monitoring and tracking, providing technical support, optimizing the usage

6. Circular economy value driver followed	Close the loop	Increase resource efficiency	Extend product lifespan	Increase resource efficiency
7. Implemented circular business models	Product life extension, product as a service	Product life extension, product as a service	Circular supplies, Product life extension	Resource recovery
8. Main resources for servitization	Product sales force and distribution network	Installed base product usage and process data, field service organization	Installed base product usage and process data	Field service organization
9. Main capabilities for servitization	Service offering sales, service offering deployment	Service-related data processing and interpretation, service offering deployment	Service offering deployment	Service offering sales
10. Lockdown suffering from 1 to 5	2	2	4	3
11. Important of servitization after the lockdown	4	3	4	4
12. Importance of circularity after the lockdown	5	4	3	3

Table 2: Summary of the answers

Summing up, the empirical evidence emerged from the questionnaire shows us that services are considered by all the interviewed a powerful source of competitive advantage and a possible business model to promote the circularity. This demonstrates the consciousness about the servitization theme and the willingness of companies to take into consideration the possible transformation of their business but at the same time, the difficulties and fears to face. Digital technologies are viewed as fundamental and especially the Internet of Things, the Big Data Analytics and the Cloud are most important tools to possess in order to accomplish the transformation towards forms more servitized and circular. These technologies help the implementation of circular service-oriented business models and in particular are useful to monitor the product or the service conditions and to provide the technical support in real time.

To operate, companies believes that the most important resources to have are the installed base product usage and process data and a solid field service organization. Moreover, are necessary to develop the service offering deployment and the service offering sales capabilities to manage and coordinate the service transformation. Finally, the questionnaire has confirmed that the combination of services and the circular economy represents also a valid strategy to resist and restart after the crisis.

CONCLUSIONS

The present work aims to analyse the relationship between servitization and the circular economy highlighting the potential of service-oriented business models in achieving the circular principles and therefore reducing the negative effects of the economy on the environment.

In the literature, the two macro branches discussed in this thesis, the servitization and the circular economy, are relative new and especially their interrelation and interdependence only in the last decade have been deepened. Given the newness of these arguments, there are still many limitations and problems to solve but also many challenges and opportunities to discover both for academics and companies. For example, one limit consists in the need of huge financial resources and a solid organizational structure to transform the business. This could represent a problem for the existing SME that, even if they have the will, do not possess the sources necessary for the transformation. In fact, usually, the business transformation towards more servitized forms that are also more sustainable is performed by large companies with wide financial resources or by innovative start-ups that, since the beginning, invest in the digitalization and the promotion of specific values.

Digitalization and digital technologies is another theme addressed in this work: their support in the development of servitization strategies is a key factor for the success. Why do we talk about servitization only in recent years? A possible explanation is the Industry 4.0 revolution that with its new technologies has provided the necessary tools to ride the waves of change and start to think about new ways to do business. Digital technologies that are also enabling factors for the circular economy and that, therefore, constitute the digital background of this thesis.

Nowadays environmental problems cannot be overshadowed and therefore the search for business models that also promote the health of our planet is a moral duty. This urgency has given rise to new models such as the pay-per-use, in which the ownership of the products remains with the sellers, who have demonstrated the effectiveness and efficiency of the services in also pursuing the environmental issue. The characteristics of services and their broad applications, in fact, offer many possibilities to exploit for the realization of the circular economy model.

Despite the many challenges posed by the implementation of servitization, there are several roads still to run and the difficulties must not inhibit efforts towards a more sustainable and environmentally friendly economic world. The synergy between services and the circular economy has proven to be successful also to combat the crisis caused by the pandemic, sign of the huge potential of this combination.

The literature regarding the relationship between servitization and circular economy, as mentioned, is in its infancy and the present work represents just a small snippet. The important thing to remember is the role of national and supranational institutions in promoting this transition through financial incentives, campaigns to raise awareness among consumers, and an integrated policy shared between all the states.

APPENDIX

Below the questionnaire submitted to the four companies. The questionnaire was created through “Moduli Google” and here it was adapted for a comprehensive view of the questions.

The contribution of services in implementing the circular economy mediated by the use of digital technologies

Dear interviewed, my name is Chiara Bastianello and I am a magistral graduate student at the University of Padua - School of Business Administration. Thank you in advance for taking part in my analysis, your answers will allow me to gather information relevant for my thesis and will help me finish my course of study as best I can.
For information, curiosity or feedback: chiara.bastianello.1@studenti.unipd.it

Servitization and circular economy

The main source of revenue in your company derives from: *

- ◯ Service offering
- ◯ Product sales

Do you think that the service offering could be a source of competitive advantage? *

- ◯ Yes
- ◯ No

How much do you think from 1 to 5 that the following digital technologies are fundamental for implementing service-oriented business models? *

	1	2	3	4	5
Big Data Analytics	○	○	○	○	○
Autonomous Robots	○	○	○	○	○
Simulation	○	○	○	○	○
Horizontal and Vertical Integration	○	○	○	○	○
Internet of Things	○	○	○	○	○
Cybersecurity	○	○	○	○	○
Cloud	○	○	○	○	○
Additive Manufacturing	○	○	○	○	○
Augmented Reality	○	○	○	○	○

How much do you think from 1 to 5 that the following digital technologies are fundamental for implementing the principles of the circular economy? *

	1	2	3	4	5
Big Data Analytics	○	○	○	○	○
Autonomous Robots	○	○	○	○	○
Simulation	○	○	○	○	○
Horizontal and Vertical Integration	○	○	○	○	○
Internet of Things	○	○	○	○	○
Cybersecurity	○	○	○	○	○
Cloud	○	○	○	○	○
Additive Manufacturing	○	○	○	○	○
Augmented Reality	○	○	○	○	○

Which of the following functionalities do you think that digital technologies have enabled the most in your business? (even more than one answer) *

- [ ] Improving product design
- [ ] Attracting target customers
- [ ] Monitoring and tracking products activity
- [ ] Providing technical support
- [ ] Providing preventive and predictive maintenance
- [ ] Optimizing the product usage
- [ ] Upgrading the product
- [ ] Enhancing renovation and end-of-life activities

The Ellen MacArthur Foundation says that Increase resource efficiency, extend product lifespan and close the loop are the fundamental circular economy value drivers. Which one for your company is the most important to follow? *

- ◯ Increase resource efficiency
- ◯ Extend product lifespan
- ◯ Close the loop

Which of the following circular business models is your company implementing? (even more than one answer) *

- [ ] Circular Supplies: provide renewable energy, bio based- or fully recyclable input material to replace single- lifecycle inputs
- [ ] Resource recovery: Recover useful resources/energy out of disposed products or by-products
- [ ] Product Life Extension: extend working lifecycle of products and components by repairing, upgrading and reselling
- [ ] Sharing Platforms: enable increased utilization rate of products by making possible shared use/access/ownership
- [ ] Product as a Service: Offer product access and retain ownership to internalize benefits of circular resource productivity

How important is from 1 to 5 to possess the following resources that are the most critical and useful for implementing service offerings? *

	1	2	3	4	5
Installed base product usage and process data	○	○	○	○	○
Product development and manufacturing assets	○	○	○	○	○
Product sales force and distribution network	○	○	○	○	○
Field service organization	○	○	○	○	○

How important is from 1 to 5 to possess the following distinctive capabilities for successful service offerings? *

	1	2	3	4	5
Service-related data processing and interpretation capability	○	○	○	○	○
Execution risk assessment and mitigation capability	○	○	○	○	○
Design-to-service capability	○	○	○	○	○
Service offering sales capability	○	○	○	○	○
Service offering deployment capability	○	○	○	○	○

Sevices and circular economy in response to Covid-19

How much did your company suffer from the lockdown? *

	1	2	3	4	5	
It did not suffer	○	○	○	○	○	It suffered much

How important do you think service provision (hence the creation of more long-lasting relationships with customers) is to restart after the lockdown period?

	1	2	3	4	5	
It doesn't help	○	○	○	○	○	It is an excellent starting point

How important do you think the circular economy and therefore the creation of more resilient value chains is to restart after the lockdown period?

	1	2	3	4	5	
It doesn't help	○	○	○	○	○	It is an excellent starting point

BIBLIOGRAPHY

- Adrodegari, F., Alghisi, A., Ardolino, M., & Saccani, N. (2015). From ownership to service-oriented business models: a survey in capital goods companies and a PSS typology. *Procedia CIRP*, *30*, 245-250.
- Amit, R., & Schoemaker, P. J. (1993). Strategic assets and organizational rent. *Strategic management journal*, *14*(1), 33-46.
- Amit, R., & Zott, C. (2012). Creating value through business model innovation. *2012*.
- Antikainen, M., Uusitalo, T., & Kivikytö-Reponen, P. (2018). Digitalisation as an enabler of circular economy. *Procedia CIRP*, *73*, 45-49.
- Arnold, C., Kiel, D., & Voigt, K. I. (2016). How the industrial internet of things changes business models in different manufacturing industries. *International Journal of Innovation Management*, *20*(08), 1640015.
- Arnold, C., Kiel, D., & Voigt, K. I. (2017). Innovative business models for the industrial internet of things. *BHM Berg-und Hüttenmännische Monatshefte*, *162*(9), 371-381.
- ASAP Service Management Forum. (2020). Reagire a Covid-19 – L'importanza dei servizi. Available on http://dt-lab.it/wp-content/uploads/2020/05/Covid-e-Servizi_ASAP-white-paper.pdf
- Astrel website, available on https://www.astrelgroup.com/
- Bagnoli, C., Bravin, A., Massaro, M., & Vignotto, A. (2018). Business Model 4.0. *Edizioni Ca'Foscari, Venezia*.
- Bocken, N. M., De Pauw, I., Bakker, C., & Van Der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308-320.
- Bocken, N. M., Mugge, R., Bom, C. A., & Lemstra, H. J. (2018). Pay-per-use business models as a driver for sustainable consumption: Evidence from the case of HOMIE. *Journal of Cleaner Production*, *198*, 498-510.
- Bonviu, F. (2014). The European economy: from a linear to a circular economy. *Romanian J. Eur. Aff.*, *14*, 78.
- Boulding, K. (1966). E., 1966, the economics of the coming spaceship earth. *New York*.
- Bressanelli, G., Adrodegari, F., Perona, M., & Saccani, N. (2018). Exploring how usage-focused business models enable circular economy through digital technologies. *Sustainability*, *10*(3), 639.

- Bressanelli, G., Adrodegari, F., Perona, M., & Saccani, N. (2018). The role of digital technologies to overcome Circular Economy challenges in PSS Business Models: an exploratory case study. *Procedia CIRP*, *73*(2018), 216-221.
- Buxmann, P., Hess, T., & Ruggaber, R. (2009). Internet of services. *Business & Information Systems Engineering*, *1*(5), 341.
- Coreynen, W., Matthyssens, P., & Van Bockhaven, W. (2017). Boosting servitization through digitization: Pathways and dynamic resource configurations for manufacturers. *Industrial marketing management*, *60*, 42-53.
- Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics*, *204*, 383-394.
- Di Maria, E., De Marchi, V., Blasi, S., Mancini, M., & Zampetti–Legambiente, G. (2018). L'economia circolare nelle imprese italiane e il contributo di industria 4.0. In *Università degli Studi di Padova, Dipartimento di Scienze Economiche e Aziendali "Marco Fanno", Laboratorio Manifattura Digitale e Legambiente*.
- Dinges, V., Urmetzer, F., Martinez, V., Zaki, M., Neely, A. (2015). The future of servitization: technologies that will make a difference. *Cambridge Service Alliance Executive Briefing Paper.*
- Effoduh, J. O. (2016). The Fourth Industrial Revolution by Klaus Schwab.
- Ehret, M., & Wirtz, J. (2017). Unlocking value from machines: business models and the industrial internet of things. *Journal of Marketing Management*, *33*(1-2), 111-130.
- Energys – Piovan Group website, available on https://energys.piovan.com/it
- European Commission (2020). CIRCULAR ECONOMY - Closing the loop: an ambitious eu circular economy package. Available on https://ec.europa.eu/commission/sites/beta-political/files/circular-economy-factsheet-general_en.pdf
- European Council (2020). A Roadmap for Recovery – Towards a more resilient, sustainable and fair Europe. Available on https://www.consilium.europa.eu/media/43384/roadmap-for-recovery-final-21-04-2020.pdf
- European Council. (2020). A Roadmap for Recovery – Towards a more resilient, sustainable and fair Europe. Available on https://www.consilium.europa.eu/media/43384/roadmap-for-recovery-final-21-04-2020.pdf

- Fliess, S., & Lexutt, E. (2019). How to be successful with servitization–Guidelines for research and management. *Industrial Marketing Management*, *78*, 58-75.
- Foss, N. J., & Saebi, T. (2017). Fifteen years of research on business model innovation: How far have we come, and where should we go?. *Journal of Management*, *43*(1), 200-227.
- Frank, A. G., Mendes, G. H., Ayala, N. F., & Ghezzi, A. (2019). Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technological Forecasting and Social Change*, *141*, 341-351.
- Gaiardelli, P., Resta, B., Martinez, V., Pinto, R., & Albores, P. (2014). A classification model for product-service offerings. *Journal of cleaner production*, *66*, 507-519.
- Gebauer, H., & Friedli, T. (2005). Behavioural implications of the transition process from products to services. *Journal of Business & Industrial Marketing*.
- Gebauer, H., Fleisch, E., & Friedli, T. (2005). Overcoming the service paradox in manufacturing companies. *European management journal*, *23*(1), 14-26.
- Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy–A new sustainability paradigm?. *Journal of cleaner production*, *143*, 757-768.
- Geng, Y., Sarkis, J., & Bleischwitz, R. (2019). How to globalize the circular economy.
- Hermann, M., Pentek, T., & Otto, B. (2016, January). Design principles for industrie 4.0 scenarios. In *2016 49th Hawaii international conference on system sciences (HICSS)* (pp. 3928-3937). IEEE.
- Heyes, G., Sharmina, M., Mendoza, J. M. F., Gallego-Schmid, A., & Azapagic, A. (2018). Developing and implementing circular economy business models in service-oriented technology companies. *Journal of Cleaner Production*, *177*, 621-632.
- Homie pay per use website available on https://www.homiepayperuse.com/
- Ibarra, D., Ganzarain, J., & Igartua, J. I. (2018). Business model innovation through Industry 4.0: A review. *Procedia Manufacturing*, *22*, 4-10.
- Iraldo, F, & Bruschi, I. (2015). *Economia Circolare: principi guida e casi studio.* Osservatorio sulla green economy, IEFE Bocconi, Milan.
- Kindström, D. (2010). Towards a service-based business model–Key aspects for future competitive advantage. *European management journal*, *28*(6), 479-490.

- Kindström, D., & Kowalkowski, C. (2014). Service innovation in product-centric firms: A multidimensional business model perspective. *Journal of Business & Industrial Marketing*.
- Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the circular economy: evidence from the European Union (EU). *Ecological Economics*, *150*, 264-272.
- Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, conservation and recycling*, *127*, 221-232.
- Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular economy: the concept and its limitations. *Ecological economics*, *143*, 37-46.
- Kowalkowski, C., Gebauer, H., Kamp, B., & Parry, G. (2017). Servitization and deservitization: Overview, concepts, and definitions. *Industrial Marketing Management*, *60*, 4-10.
- Kowalkowski, C., Kindström, D., Alejandro, T. B., Brege, S., & Biggemann, S. (2012). Service infusion as agile incrementalism in action. *Journal of Business Research*, *65*(6), 765-772.
- Kujala, S., Artto, K., Aaltonen, P., & Turkulainen, V. (2010). Business models in project-based firms–Towards a typology of solution-specific business models. *International Journal of Project Management*, *28*(2), 96-106.
- Lacy, P., Keeble, J., & McNamara, R. (2014). Circular Advantage. *Accenture.[WWW Document]. URL https://www. accenture. com/us-en/strategy-index*
- Landrigan, P. J., Fuller, R., Acosta, N. J., Adeyi, O., Arnold, R., Baldé, A. B., ... & Chiles, T. (2018). The Lancet Commission on pollution and health. *The lancet*, *391*(10119), 462-512.
- Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & information systems engineering*, *6*(4), 239-242.
- Lee, J., Bagheri, B., & Kao, H. A. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. *Manufacturing letters*, *3*, 18-23.
- Lucke, D., Constantinescu, C., & Westkämper, E. (2008). Smart factory-a step towards the next generation of manufacturing. In *Manufacturing systems and technologies for the new frontier* (pp. 115-118). Springer, London.
- MacArthur, D. E., & Waughray, D. (2016). Intelligent Assets: Unlocking the circular economy potential. *Ellen MacArthur Foundation: Cowes, UK*.

- MacArthur, D. E., Waughray, D., & Stuchtey, M. R. (2016, January). The new plastics economy, rethinking the future of plastics. In *World Economic Forum*.
- MacArthur, E. (2013). Towards the circular economy. *Journal of Industrial Ecology*, *2*, 23-44.
- Mastrogiacomo, L., Barravecchia, F., & Franceschini, F. (2019). A worldwide survey on manufacturing servitization. *The International Journal of Advanced Manufacturing Technology*, *103*(9-12), 3927-3942.
- McDonough, W., & Braungart, M. (2010). *Cradle to cradle: Remaking the way we make things*. North point press.
- McKinsey & Company (2017). Mapping the benefits of a circular economy. Available on https://www.mckinsey.com/business-functions/sustainability/our-insights/mapping-the-benefits-of-a-circular-economy#
- Michelini, G., Moraes, R. N., Cunha, R. N., Costa, J. M., & Ometto, A. R. (2017). From linear to circular economy: PSS conducting the transition. *Procedia CIRP*, *64*(2017)
- Morlet, A., Blériot, J., Opsomer, R., Linder, M., Henggeler, A., Bluhm, A., & Carrera, A. (2016). Intelligent assets: Unlocking the circular economy potential. *Ellen MacArthur Foundation*, 1-25.
- MUD Jeans (2019). Sustainability Report 2019.
- MUD Jeans website available on https://mudjeans.eu/
- Nobre, G. C., & Tavares, E. (2017). Scientific literature analysis on big data and internet of things applications on circular economy: a bibliometric study. *Scientometrics*, *111*(1), 463-492.
- Okorie, O., Salonitis, K., Charnley, F., Moreno, M., Turner, C., & Tiwari, A. (2018). Digitisation and the circular economy: A review of current research and future trends. *Energies*, *11*(11), 3009.
- Oliva, R., & Kallenberg, R. (2003). Managing the transition from products to services. *International journal of service industry management*.
- Osterwalder, A. P., & Generation, Y. B. M. (2009). Alexander Osterwalder & Yves Pigneur. *Business Model Generation*.
- Pagoropoulos, A., Pigosso, D. C., & McAloone, T. C. (2017). The emergent role of digital technologies in the Circular Economy: A review. *Procedia CIRP*, *64*, 19-24.
- Paiola, M., & Gebauer, H. (2020). Internet of things technologies, digital servitization and business model innovation in BtoB manufacturing firms. *Industrial Marketing Management*.

- Pistoni, A., & Songini, L. (2017). *Servitization strategy and managerial control*. Bingley: Emerald Publishing Limited.
- Porter, M. E., & Heppelmann, J. E. (2014). How smart, connected products are transforming competition. *Harvard business review*, *92*(11), 64-88.
- Rajput, S., & Singh, S. P. (2019). Connecting circular economy and industry 4.0. *International Journal of Information Management*, *49*, 98-113.
- Rojko, A. (2017). Industry 4.0 concept: background and overview. *International Journal of Interactive Mobile Technologies (iJIM)*, *11*(5), 77-90.
- Roy, R., Shehab, E., Tiwari, A., Baines, T. S., Lightfoot, H. W., Benedettini, O., & Kay, J. M. (2009). The servitization of manufacturing. *Journal of manufacturing technology management*.
- Schulze, G. (2016). Growth Within: A Circular Economy Vision for a Competitive Europe. *Ellen MacArthur Foundation and the McKinsey Center for Business and Environment*, 1-22.
- Tukker, A. (2015). Product services for a resource-efficient and circular economy–a review. *Journal of cleaner production*, *97*, 76-91.
- Tukker, A., & Tischner, U. (2006). Product-services as a research field: past, present and future. Reflections from a decade of research. *Journal of cleaner production*, *14*(17), 1552-1556.
- Ulaga, W., & Reinartz, W. J. (2011). Hybrid offerings: how manufacturing firms combine goods and services successfully. *Journal of marketing*, *75*(6), 5-23.
- Ünal, E., Urbinati, A., & Chiaroni, D. (2018). Circular industry 4.0: an integrative framework.
- Vandermerwe, S., & Rada, J. (1988). Servitization of business: adding value by adding services. *European management journal*, *6*(4), 314-324.
- Vendrell-Herrero, F., Bustinza, O. F., Parry, G., & Georgantzis, N. (2017). Servitization, digitization and supply chain interdependency. *Industrial Marketing Management*, *60*, 69-81.
- Xia, F., Yang, L. T., Wang, L., & Vinel, A. (2012). Internet of things. *International journal of communication systems*, *25*(9), 1101.
- Zambetti, M., Adrodegari, F., Pezzotta, G., Pinto, R., & Saccani, N. (2020). Understanding Data-Driven Product Service System characteristics: a conceptual framework for manufacturing applications. *Industrial Systems Engineering*.