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"IOT AND CIRCULAR ECONOMY: HOW FIRMS CAN EXPLOIT DATA GENERATED FROM IOT TO ACHIEVE SUSTAINABILITY GOALS"

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Abstract

Nowadays, circular economy and sustainability are the key to reversing the social, economic, and environmental trends that so far have led us to abuse from our resources and foster a linear model of consumption and production. In this regard, there are several tools that can support circular transition processes. The aim of the present work is to analyze the interrelationships between the Internet of Things (IoT), Big Data, and their role in the transition towards circular economy (CE) and sustainability. The research question is whether companies operating mainly in the business-to-consumer (B2C) field are able to use the vast amounts of data generated from IoT connected devices to support CE and sustainability. To answer the research question, the author made use of a literature review for the theoretical background and case studies in support of the theoretical framework analyzed.

Introduction

The relationship between circular economy, big data and IoT is complex and interdependent. Circular economy (CE) refers to an economic system aimed at minimizing waste and maximizing resource efficiency by closing the loop between production and consumption. IoT (Internet of Things) is about a network of physical devices, vehicles, home appliances and other items that are embedded with sensors, software, and connectivity, allowing them to collect and exchange data. Big Data refers to a massive volume of structured and unstructured data that is generated and collected by organizations and can be analyzed for insights and business value. In the context of circular economy, IoT and Big Data can work together to create a more sustainable and efficient system by enabling real-time tracking and analysis of resource usage and waste generation, as well as facilitating the optimization of resource allocation and reuse. Moreover, by leveraging the vast amounts of data generated by IoT devices, businesses can optimize their processes and systems, promoting a more sustainable and closed-loop economy.

Nowadays, sustainability and circular economy are at the core of discussions of all kinds, starting from the academic world and ending with politics and economics. In particular, the economic meaning that the two terms take on is increasingly important in a context such as the one we are experiencing today. We live in a hyperconnected and volatile world in which there is always an object (or a service) ready to satisfy our need whether it is primary or not. This has led us to live in a world where the linear model of production and consumption is predominant. This has caused a massive exploitation of natural resources, an increase in non-recyclable waste and a rise in pollutants into the atmosphere. Therefore, implementing principles and strategies related to CE and sustainability is vital for our planet to achieve a balance again between what is consumed and what can be regenerated. For these reasons, it is vital that everyone take an active part in the transition toward a more sustainable and circular model of production and consumption. We, ordinary people, should change our daily habits, this of course is only possible if there is full support from institutions and companies that constantly meet our needs. In this regard, technological evolution can prove to be a useful toll in supporting sustainable and circular practices especially as far as companies are concerned, whether they operate in the B2C or B2B sector.

In this respect, the aim of the present work is to analyze the interrelationships between the Internet of Things, Big Data, and the role of the latter in the circular and sustainable transition. The question that arises is: are companies able to leverage the huge amount of data generated from IoT connected devices to implement and support CE and sustainability? In particular, our

focus will be on companies operating mainly in the business-to-consumer (B2C) field that propose IoT connected devices to their customers.
To answer this research question, the author proposes a study divided into four chapters.
In order to find all the material needed for the development of the study, it was necessary to conduct a review of existing literature on several key topics: circular economy, Internet of Things, Smart Products, Industrial Internet of Things, Big Data, CRM and ERP systems, sustainability and business models. About 70 journal articles, scientific papers and books were retrieved from Google Scholar, Scopus and Galileo Discovery (the tool provided by University of Padua for finding all its resources, both in print and electronic format, with a single search). The work was also supported by real and actual data retrieved mainly on the Statista website but also from specific websites belonging to companies and associations (Ellen MacArthur Foundation and United Nation). Lastly, the author conducted an interview to present a case study and implement the theoretical background acquired thorough papers, articles, books and data.

Based on the material resulting from the research, the present work is structured as follow:

- The first chapter presents a theoretical framework on the concepts and definitions that characterize the Internet of Things. This is followed by the evolutive process related to IoT and an analysis on the various benefits and challenges that emerge from the use of it. In addition, a brief distinction is made about the world of IIoT versus IoT. The first chapter concludes with a series of data covering IoT at the global, European, and Italian levels.
- In the second chapter, a focus is made on the relationship between IoT and Big Data. In particular, a distinction is made between Big Data and Smart Data. Next, the definition of connected objects (mainly related to the B2C sector), their evolution process, and their role in reshaping industry sector is discussed. Finally, the relationship between Big Data, IoT, enterprise resource planning systems and customer relationship management tools is analyzed.
- Chapter number three gets to the heart of our research question. In fact, concepts related to circular economy and sustainability are defined. Next, we look at how IoT can prove to be an enabler for the circular economy and how companies can leverage data generated by IoT devices to achieve circular and sustainability goals.
- The last chapter is focused on the application of real cases based on a sample of companies identified from different sources. In this regard, the relationships that exist between companies operating in the b2c sector that through their connected products

seek to leverage data to achieve sustainability and circularity goals are analyzed. In this chapter, the case of the startup Huna is presented, which through its Home Buddy system seeks to support sustainable development and implement circular economy principles.

In conclusion, we can say that most companies working in the B2B sphere, especially in the manufacturing sector, have a greater propensity to exploit data (in this case generated by IIoT applications) not only to improve the company's decision-making, production, and organizational processes but also to implement strategies related to the circular economy and sustainability. On the other hand, companies that operate in direct contact with end users struggle to leverage the data generated from the connected products used by customers. In fact, these devices are capable of generating large amounts of data, but they do not always prove suitable to be leveraged by the company for circularity and sustainability goals. Rather, they prove to be more useful to the end user who is supported in a more sustainable consumption journey.

1. The Internet of Things: Theoretical Framework

In this chapter the author will present a theoretical background for what concerns the IoT world. This will give valuable insights for the reader better to understand the next chapters of the present work.

In section 1.1 we will discuss about several definitions of IoT. Section 1.2 is about the evolution of the Internet of Things world. Section 1.3 tells us which are the main field of IoT application, and which are the most widespread technologies that enable IoT devices. In section 1.4 we will present differences and similarities of IoT and IIoT. In section 1.5, we will analyze the key challenges and benefits that IoT addresses. In the last section, we will present some data and evidences at global, European and Italian levels.

1.1 What is IoT: definition and concepts

In the past decades, the word Internet acquired a particular importance in several industries and in everyday life. As time passed, we saw the term Internet being associated with physical objects, with "things".

Even if there is no clear path of who coined the term "Internet of Things", the literature suggests that Kevin Ashton, a British technology pioneer, was the first. In his interview with the RFID Journal, he stated that he was the first to use the term "Internet of Things" during a presentation at P&G in early 1999 about RFID technology and supply chain management (Ashton, 2009).

Later, the IoT concept reached its widespread meaning thanks to the article published on the Scientific American in 2004. In this journal article the authors link the term IoT to the concept of "Internet-0" (I0) as the process of giving everyday objects the ability to connect to a data network in order to reach a higher level of benefits. I0 is seen as a compatible layer below the existing Internet. (Gershenfeld et al., 2004)

Nowadays, everyone talks about IoT, but there is no standard and common definition for it. For this reason, in this section, we will introduce some of the most cited and well-known definitions so far. The International Telecommunication Union (ITU) in its report (2005) defines the IoT as an extension of the the world of information and communication technologies (ICTs). According to the ITU, the IoT is composed of three dimensions of connectivity: anytime, anyplace for anyone and anything. In the literature, different authors gave their own definition of IoT on the basis of their studies. Vermesan et al. (2022) define the IoT as "a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities, use intelligent interfaces, and are seamlessly integrated into the information network.” Atzori et al. (2010) complete the previous definition by adding that things should operate through unique addressing protocols. Thanks to this, objects can interact with each other and collaborate to achieve a common objective. On the other side, Smedlund et al. (2018) focus their definition more on the physical aspect of the IoT side. In fact, they state that “the IoT is a distributed network of connected physical objects” where the greater the data exchanged without intermediaries (among objects), the higher the chance to develop new business opportunities. Wang et al. (2021) state that “The Internet of Things (IoT) is an extended and expanded system network based on the Internet, and its ultimate goal is to achieve real-time interaction among things, machines and humans through various advanced technological means”. They expand their view adding the human component to the two main elements of IoT which are the physical and the purpose ones. To conclude, Dorsemaine et al., (2015) define the IoT as “group of infrastructures interconnecting connected objects and allowing their management, data mining and the access to the data they generate.” They focus their definition on the physical and employment part of the IoT.

Hence, based on the previous elements, a definition of IoT could be: a network of things connected through the Internet by hardware and software elements, which are able to generate data and communicate among themselves, with the objective to make humans’ life and work easier and more innovative.

As we have seen there are several key factors that are common in some or almost all definitions. In the following table, we summarized all the definitions cited so far, trying to classify them according to their content based on three key elements:

1. The physical aspect related to objects, structure and processes employed in the IoT field;
2. The purpose of IoT applications;
3. The “human” component;

Table 1 - Definitions of IoT

Author	**Definition**	**Year**	**Content of definition**		
			Physical	**Human**	**Purpose**
Gershenfeld et al.	Process of giving everyday objects the ability to connect to a data network in order to reach a higher level of benefits.	2004	✓	✗	✓
ITU	Global infrastructure for the Information Society, enabling advanced services by interconnecting	2005	✓	✗	✗

	(physical and virtual) things based on, existing and evolving, interoperable information and communication technologies				
Atzori et al.	The basic idea of this concept is the pervasive presence around us of a variety of things or objects which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals.	2010	✓	✗	✓
Dorsemaine et al.	Group of infrastructures interconnecting connected objects and allowing their management, data mining and access to the data they generate.	2015	✓	✗	✓
Smedlund et al.	The IoT is a distributed network of connected physical objects. As these devices exchange data with each other instead of through an intermediary, the IoT increases the complexity of business ecosystems and opens up new business opportunities.	2018	✓	✗	✓
Wang et al.	The Internet of Things (IoT) is an extended and expanded system network based on the Internet, and its ultimate goal is to achieve real-time interaction among things, machines and humans through various advanced technological means.	2021	✓	✓	✓
Vermesan et al.	Dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication	2022	✓	✗	✓

	protocols where physical and virtual “things” have identities, physical attributes, and virtual personalities, use intelligent interfaces, and are seamlessly integrated into the information network.				

(Source: author processing)

Moreover, in their work, Atzori et al. (2010) present alternative visions and perspective of the Internet of Things. In fact, they converge three different visions into the IoT paradigm:

1. “Things”-oriented vision which is mainly related to the hardware side of the IoT;
2. “Internet”-oriented vision, on the other hand, is more focused on the software side;
3. “Semantic”-oriented vision is based on the architectural and environmental part of the IoT.

These three perspectives are more specific and hinge on the technical rigidity of the various definitions.

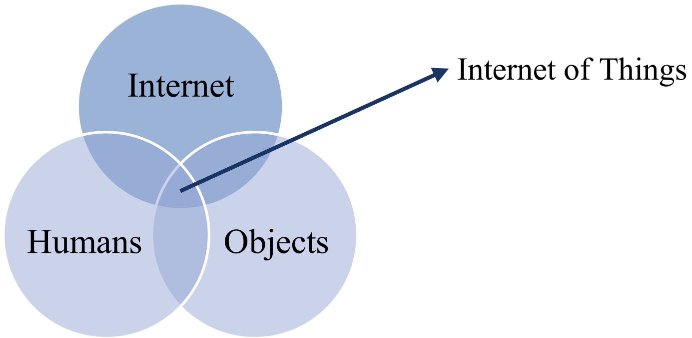
This non-homogeneity of definitions inspired some authors in the literature, in particular Sorri et al. (2022), which in their work present three reasons why there should be a unique definition of IoT:

1. It can be assumed that growth in both the literature volume and the subject areas diversification has led to vagueness and more variety as to what constitutes the IoT. Having a standard definition will help us weave together the core concepts and technologies that should be seen as fundamental to the IoT,
2. Several synonyms or terms describing a similar concept have emerged during the past years.
3. IoT utilization seems to be expanding at a slower pace than earlier estimations.

This could be a starting point for future research, but this is different from the focus of the present work. Another key aspect we did not consider in this section is the role of the human being in the IoT world.

The figure below represents the interconnection between the Internet, humans and objects that create the so-called Internet of Things.

Figure 1 - Interconnections of IoT



(Source: author processing)

Several key elements characterize the Internet of Things. In particular, Vermesan and Friess (2014), listed the main constructs of IoT:

1. Interconnectivity. IoT allows any device to be connected with the Global information and communication infrastructure. This can be considered the most important characteristic of IoT because having connected products allow users and manufacturers to implement the use of the product but also the strategies related to its commercialization.
2. Things related Services. The IoT is capable of providing thing-related services within the constraints of things, such as privacy protection and semantic consistency between physical things and their associated virtual things. Because this occurs, both the physical and IT technologies will be reshaped.
3. Heterogeneity. IoT is able to connect devices that present different characteristics in terms of both hardware, software and networks. In fact, products can interact with each other, with users and service platforms through different networks.
4. Dynamic changes. The state of devices changes dynamically, e.g., sleeping and waking up, connected and/or disconnected as well as the context of devices including location and speed. Moreover, the number of devices can change dynamically. This characteristic allows companies to speed data collection and analysis processing.
5. Enormous scale. The number of connected devices will grow more and more as technology progress. Moreover, these devices need to be managed from the point of view of the number of communications they process but also from the point of view of the data they generate and their interpretation for application purposes. This relates to semantics of data, as well as efficient data handling.

If Vermesan and Friess exposed the pillars sustaining IoT, Krotov (2017) in his article “The Internet of Things and New Business Opportunities” presents what he defines a “socio-technical” perspective to give the reader a holistic understanding of what IoT is and what trajectory it can achieve.

He developed a three-level framework of analysis:

1. Technological environment that concerns all the hardware, software, platforms, data and network related to the IoT.
2. Physical environment is about the context in which the IoT takes place. For example, human and non-human objects and the physical surrounding.
3. Socio-economic environment that includes consumers, entrepreneurs, governments and legislative bodies. The socio-economic environment embeds the physical and technological environment in a sort of ecosystem in which every single actor has its own role in order to achieve a common goal.

In the table below Krotov summarized his socio-technical perspective about the IoT world.

Table 2 - Socio-technical perspective about the IoT

Technological Environment	Hardware	Various wireless devices (e.g., wireless laptop computers, smart phones, RFID tags, wireless censors, RFID readers) used to connect human and non-human objects to the IoT and enable communication and interaction among these objects via a ubiquitous wireless network.
	Software	Front-end software applications developed to create value for a particular group of customers and various utility applications (e.g., middleware or server-side software) supporting execution of end-user IoT apps.
	Networking	Various networking technologies and hardware enabling wireless communication among IoT nodes and connecting these nodes to the internet.
	Integrated platforms	An integrated, cloud-based platform (e.g., Microsoft Azure) that enables integration and seamless interoperability of various hardware, software, and networking elements of the IoT.
	Standards	Various technical and operational standards outlining the design of various IoT elements and ensuring their interoperability. Standards are developed by industry associations.
	Data	Massive volume of data generated by IoT nodes constantly broadcasting their properties via the network (e.g., a temperature sensor broadcasting room temperature every 2 minutes) or by engaging in transaction with other IoT nodes.
Physical Environment	Human objects	People directly interacting with the IoT with the help of various wireless devices (e.g., laptop computers, smartphones, RFID tags, health sensors).
	Non-human objects	Physical objects (e.g., cars, fruits, packages) and animals that can connect and communicate via a network.
	Physical surrounding	The physical space (e.g., room, building, park, city) or a physical substance (e.g., air, water, soil) that human and non-human objects are embedded in or interact with.
Socio-Economic Environment	Consumers	Individual consumers or organizations targeted by specific IoT applications.
	Legislative bodies	Organizations responsible for formulating, disseminating, and enforcing various laws and regulations related to IoT.
	Industry associations	Various organizations comprising for-profit companies and non-profit institutions responsible for setting standards and guidelines that facilitate IoT adoption and ensure interoperability of IoT technological elements and security of the overall IoT infrastructure.
	Consumer privacy groups	Formal and information organizations advocating for consumer rights and protecting consumers of IoT applications and related technology from security and privacy violations.
	Entrepreneurs	Entrepreneurs and leaders of existing businesses or non-profit organizations engaging in entrepreneurship and intrapreneurship using IoT.

(Source: “The Internet of Things and New Business Opportunities”, Krotov, 2017)

We can deduce that the Internet of Things is a very broad concept. For example, consumers can connect different devices in their homes (such as: washing machine, light bulbs, virtual assistant...) and control them with an app; they made their home smart.
On the other hand, firms can connect their machinery with software and hardware components. This allows firms to make their production process more efficient and make the best use of their machines, this implies cost reduction, efficient production and less waste as well.

1.2 Evolution of IoT

Before the IoT revolution, there are several steps we must consider. IoT is a result of an evolutionary process which includes not only technological progress, but also cultural and economic.
Khanna and Kaur, (2019) in their work present us a linear framework of the evolution of IoT during time. First of all, they identify the "Pre-Internet phase" in which people communicate through fixed-line telephones and Short Message Service (SMS). Going on, we have the "Internet of Content phase". People are now able to exploit the potential of Internet surfing the net, sending emails, online entertainment (e.g., ARPANET). The third step is the defined as the "Internet of Services phase". We see the birth and evolution of the e-commerce platforms (such as Amazon and E-Bay) e-productivity online auction, retailing, ads. In the fourth phase "Internet of People", people start making use of the Internet to socialize. Social media are becoming widespread. We see the rise of LinkedIn, Myspace, Skype, Facebook. Sharing platforms such as YouTube and Google+ appear for the first time. The last phase is the one we are experiencing: the "Internet of Things phase" in which products are connected through the Internet and generate data.
The figure below summarizes the key steps of the evolution of the IoT in a linear perspective.

Figure 2 - The evolution of IoT

(Source: author processing)

In addition to that, IoT technologies (e.g., chips, sensors, wireless technologies) place themselves in a hyper-accelerated innovation cycle. This is the reason why they evolve more rapidly than the typical consumer product innovation (Lee and Lee, 2015). This evolution process is supported by several and huge investments, not only from the private sector but also from governments. In the next section, we will take a closer look at the data IoT generates, not only in economic terms.

The cultural evolution of people also supports the development of IoT. Of course, countries with a higher level of education and wealth have a higher chance to adopt IoT technologies not only for industry purposes but also as everyday life tools to improve their everyday routine (e.g., smart watches, Amazon Alexa, Google Home…).

1.3 IoT Application and Communication Technologies

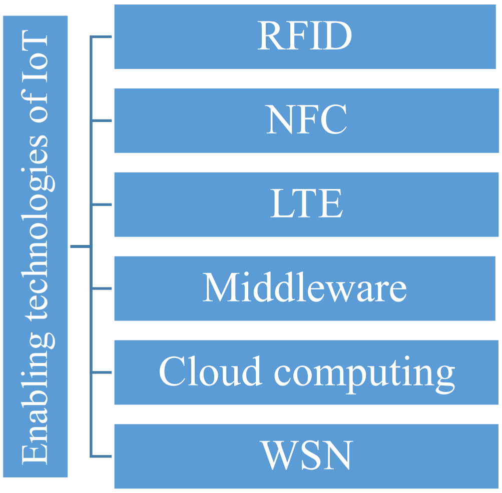
The functioning of IoT-based product and services is strictly linked to both software and hardware technologies. These technologies enable peculiar functions that allow devices to interact among them and exchange a significant amount of data. In this section, we will explore some of them in order to have a clearer outline of the topic we are discussing about.

Things are linked to the Net via Radio-frequency Identification (RFID), Bluetooth, Long Term Evolution (LTE), Wireless Sensor Networks (WSN), Near-field communication (NFC), cloud computing, IoT application software, middleware (Khanna and Kaur, 2019; Lee and Lee, 2015).

- RFID uses radio-frequency electromagnetic fields to transmits data. Each item has different tags which can be read by RFID readers (Khanna and Kaur, 2019).
- LTE is a standard wireless communication protocol for high-speed data transfer between mobile phones (Khanna and Kaur, 2019).
- WSN are defined as "spatially distributed autonomous sensor-equipped devices to monitor physical or environmental conditions and can cooperate with RFID systems to better track the status of things such as their location, temperature, and movements" (Atzori et al., 2010).
- Middleware is a software layer interposed between software applications to make it easier for software developers to perform communication and input/output (Lee and Lee, 2015).

The main technologies that enable IoT devices are grouped in the figure below.

Figure 3 - Enabling technologies for IoT



(Source: author processing)

With the evolution of IoT-related technologies, IoT-based products and services have seen their application in different fields and sectors. IoT is spread at both B2C and B2B markets.
In their papers, Khanna and Kaur (2019) and Lee and Lee, (2015) present several sectors and uses in which IoT has seen its rise in the past decades: healthcare, manufacturing, retailing, home appliances, agriculture and breeding, logistics, heavy equipment and airlines.
They both state the benefits of adopting IoT technologies that are concrete and easily measurable. In particular, Lee and Lee (2015) show two different methods to evaluate the feasibility of an IoT-based project:

- Net Present Value (NPV) approach which results to be inappropriate and tends to under evaluate the potential of a project;
- Real Option approach (the right to undertake an action over a period of time) evinces to be more suitable for high uncertainty and risky investments. Thanks to this method, managers have the chance to carefully consider the real value of a project over a continuous period.

IoT allows people and firms to monitor and control connected devices. In this way, it is possible to take track of energy use, environmental conditions, equipment performance in real-time and basically everywhere. For example, in the smart industry field, it is possible to take track of the status of the machines, schedule and distribute their tasks, generate data and analyze them. In the smart home context people can control the light, heating, and safety system by using an app on their phone. In smart city projects we can see traffic remote monitoring, smart lighting systems. The smart health sector saw its rapid growth thanks to the Covid-19 pandemic. IoT helped medical doctors to trace their patients without being physically present in the room and

give them the right medication at the right time through a complex, but intuitive, system of software and objects connected (Singh et al., 2020).
In particular, Lee and Lee (2015) in their paper identified three main IoT categories for business applications:

1. Monitoring and control systems of the machines;
2. Big data and business analytics to improve the decision-making process to analyze market and consumers behavior;
3. Information sharing and collaboration between people and machines to avoid mistakes and information bias;

It can be argued that IoT is becoming a widespread technology, this is the reason why it is possible to see its application in different domains. Atzori et al. (2010) grouped IoT applications into four macro categories: (i) transportation and logistics; (ii) healthcare; (iii) smart environment; (iiii) personal and social domain. This perspective is enriched by the works of Lee and Lee (2015) and Khanna and Kaur (2019) who also mention: manufacturing, retail trade, finance and insurance, information services, public safety and environmental monitoring, agriculture and breeding.
We can conclude that basically there is no field in which IoT does not find and application. It is becoming a technology that is "embedded" in the everyday life of firms and people.
To sum up, IoT finds application in a huge variety of fields such as: smart home systems, smart health, smart mobility, smart agrifood, wearable devices, smartphone, smart energy systems, smart cities, smart grid and meter, smart security systems, monitoring and control and smart contracts. We will analyze some of these fields in a more detailed manner in chapter two, section 2.2.

1.4 IoT and IIoT

In the first section of the present chapter, we presented the Internet of Things in general. In this section we will take a closer look at the Industrial Internet of Things (IIoT) and present a comparison among the two terms. As the term IIoT suggests us, it refers to the use and employment of IoT technologies in an industrial setting.
As previously seen for the definition of IoT, also for IIoT occurs the same, there is no unanimity. Boyes et al. (2018) give their own definition of IIoT basing their outcome on two key elements: (i) the type of technologies employed in an IIoT setting and (ii) the objectives and purposes of these applications. Hence, the Industrial Internet of Things is: "A system comprising networked smart objects, cyber-physical assets, associated generic information technologies and optional cloud or edge computing platforms, which enable real-time, intelligent, and autonomous access,

collection, analysis, communications, and exchange of process, product and/or service information, within the industrial environment, so as to optimize overall production value."
In addition to that, Sisinni et al. (2018) state that "the IIoT is about connecting all the industrial assets, including machines and control systems, with the information systems and the business processes." From the two definitions that have been reported, it is possible to deduce the essential characteristics of IIoT: industrial asset connectivity through hardware and software components, data generation, processes, and analysis for the optimization of assets and overall production value.

IIoT can be considered as an evolution, or an extension, of the Internet of Things world. It has a machine oriented communication model and has a structured connectivity, while IoT is more human-centered and its connectivity is ad-hoc made (Sisinni et al., 2018).

To conclude, it is possible to assess that IIoT is an extension of the Internet of Things, and its use is exclusive of the industrial sector. Moreover, IIoT is a central enabler for machine efficiency, especially in the manufacturing field.

1.5 Benefits and Challenges

This section presents benefits and challenges that the IoT world brings with itself. As mentioned in the previous section, IIoT is an extension of IoT. Hence, we will discuss about benefits and challenges linked to both IoT and IIoT. For this reason, we will consider the broadest meaning of IoT which includes the IIoT characteristics as well.

Most of the literature reviewed so far is more focused on benefits related to the industrial sector. Concerning the challenges, it seems to be a general affair related not only to the industrial sector but also to final consumers (individuals).

1.5.1 Benefits

The role of IoT devices is the one of facilitating the connection between humans and objects. This is the reason why IoT presents several benefits that we will discuss in this section. In the literature so far analyzed, we found that authors o mention, more or less, the same advantages that will be mentioned in the following lines.

Data generated from IoT helps firms to improve their operational processes through predictive and preventive maintenance, this also helps firms to reduce costs and increase revenues and productivity. In the healthcare field, IoT helps hospitals to improve their patient care. In this way it is possible to reduce human mistakes thanks to more accurate and reliable processes and information that are collected and shared among devices (Gilchrist, 2016).

According to Espinoza et al. (2020), IoT has a positive impact on firms' productivity. Moreover, it fosters economic growth in general thanks to its ability to generate and enrich information along the value chain of production.

IIoT, in particular, contributes to the creation of a collaborative environment and ecosystem thanks to the nature of connected objects and machines within the firm. In addition to that, it also contributes to enhance safety conditions for employees (Sisinni et al., 2018). In fact, workers are more stimulated to collaborate among them if they can use shared data and tools to carry on their duties; machines results to be more efficient (Shukla, 2022).

More in detail, Singh et al. (2020) in their work, present us a case study on the relationship between Covid-19 and benefits of adopting and using IoT related technologies. Thanks to connected hospital and patient tracking through internet-based network, it was possible to exploit IoT technologies to reduce human mistakes and expenses, make a more accurate diagnosis in less time and organize in a more efficient and effectively treatments needed by patients.

It can be argued that benefits from IoT regard for the most the industrial sector, in particular the manufacturing and healthcare ones.

1.5.2 Challenges

It is easy to imagine that in a hyperconnected, world a small error is fatal for the function of a whole system and can create huge problems and consequences if it is not detected in advance, especially if this mistake regard security. On the other side, IoT presents some ethical implications mainly related to privacy and security issues In their paper Lee and Lee, (2015) advice firms working in the IoT field, to reduce the complexity of connected structures, enhance the security and standardization of the processes and, of course, guarantee the privacy and security of the users, which are the key issues in today's world.

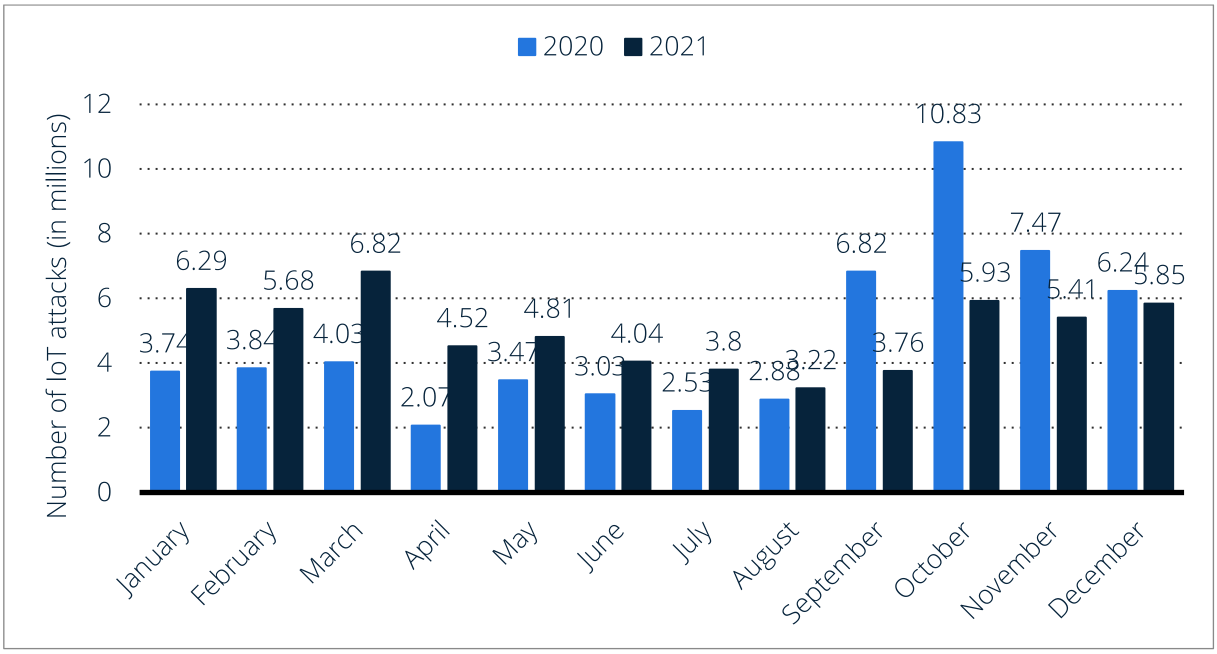
Privacy issues occur at two different levels: data collection and data encryption or anonymization (Sisinni et al., 2018). According to Dey (2019), while designing the architecture of privacy systems, it must be considered that data are not exposed to non-authorized users, that each action is authorized and the connected devices must be identified. On the other hand, for service providers, it is unprofitable to protect users' privacy because of new privacy legislation and the high gains related to the sale of data to third parties. For this reason, trust in IoT is strictly linked to protecting users' privacy (Lee and Lee, 2015). If firms and people do not trust IoT privacy settings, it is difficult for them to adopt these technologies. This causes a slowdown for IoT, especially if we talk about fields in which privacy is a big concern, such as the pharmaceutical industry. In addition to that, users usually pay no or little attention to the privacy policies of their IoT connected devices which generate and share personal information such as: location, health status, purchasing preferences, financial status. Moreover, Vermesan and Friess (2014) present some privacy implications that arise from the spread of IoT devices:

- Preserving location privacy, where location can be deducted from things associated with people, this can also be a security problem if we think about wearables used by military forces during their training, if hacked, these devices contain sensible information that can be used to program attacks or for cyber spying operations.
- Prevention of personal information leakage that people would wish to keep private.
- The use of decentralized computing help keeping information as local as possible avoiding leak of data from one and only workstation.
- The use of soft identities, tailored for each user's application, will help revealing unnecessary information that may lead to privacy breaches.

Strictly linked to the privacy issue there is the security problem. Since these objects are connected through the Net, we can say that they are more vulnerable to cyber-attacks from the outside world.

As shown in the graph below, we can assess that in 2020 about 57 million cyber-attacks were carried on, while in 2021, more than 60 million IoT attacks were detected. We can see peaks mainly in winter months, during summertime there is a decrease in cyber-attacks.

Chart 1 - Number of IoT cyber-attacks



(Source: SonicWall. "Number of Internet of Things (Iot) Malware Attacks Worldwide from 2020 to 2021, by Month (in Millions)." Statista,)

Several issues that can be related to security and IoT for example: insufficient authentication, security configuration, insecure web interface, inadequate software protection, data integrity (Atzori et al., 2010; Dey, 2019; Lee and Lee, 2015). We should also add that IoT devices can also be attacked physically and not only through the Net. In this case, cloud computing can be considered as a valid tool to prevent these attacks.

These threats may be overcome by data encryption that enables protected data to be stored, processed and shared without the information content being accessible to other parties, biometric or two-factor authentication, confidentiality and integrity of the network used to connect devices (Sisinni et al., 2018; Vermesan and Friess, 2014). This helps companies and users to prevent attacks and have a proactive approach with respect to cyber-attacks. Moreover, Voulgaridis et al. (2022) in their work present some security requirements that may prevent data breaches and data misappropriation:

- Data confidentiality is the process in which data are protected by passive attacks. Of course, data encryption is the most critical tool to prevent these attacks.
- Source authentication. Having systems able to truly authenticate the source of transmitted data improve data security.
- Data integrity. It is important to verify the data collection process and the users that have access to the editing and mining processes.
- Availability. Ensuring the availability of the interconnected node system for data transmission and communication with the rest of the unified network, even during denial-of-service attacks

A study from Nemec Zlatolas et al. (2022) on the security perception of IoT devices in smart homes reveals that users are unaware of the security issues that may concern them. Moreover, the main barrier to the adoption of IoT devices results to be the cost related to these objects and not the risks linked to security that may occur during their utilization. It is possible to argue that there is misinformation on real risks and challenges and that people are not well informed on devices they use every day. This also holds for firms that, step by step, are improving their security systems thanks to external providers.

Another key aspect to consider is the data management and data mining theme. In fact, IoT sensor and devices generate a huge amount of heterogeneous data which are difficult to process and store. For this reason, firms try to prioritize the data obtained and discard the ones they think are unnecessary to pursue their objectives. For what concern data management, firms are still unable to correctly store, analyze and employment of the data they obtained (Lee and Lee, 2015).

Another point of view is given by Heppelmann and Porter (2015); before the advent of smart connected devices, the people in charge of security in firms were employed in the IT sector, which duties were to protect firms' datacenter, networks, business systems and computers. Later on, with the introduction of connected devices, security issues are no more limited to IT centers, but are spread across all functions within the firm. This results because every smart product may present a weakness that can be exploited by hackers in order to mine the security of the entire system. Of course, IT centers are still a vital element of the firm and will continue carrying on their duties on security even if all employees must be trained too. A crucial role is also given to end users, who must be trained to understand and control the type of data devices can collect and be transmitted to the cloud.

To sum up, benefits deriving from IoT adoption are always more significant than challenges and risks, which can be mitigated if the proper procedure is applied and also thanks to the technological development. For example, IT centers of firms are always working on new software that prevent attacks, if not so, firms can delegate this function to specific providers that have high standard of security and develop ad hoc solution for every customer. We can also say that as technology related to smart connected objects evolve, also knowledge and habits are rapidly developing.

The table below summarizes the main challenges and benefits related to the adoption of IoT connected devices.

Table 3 - Benefits and challenges of IoT

Benefits and challenges deriving from IoT	
Pros	**Challenges/Risks**
Enhanced productivity and economic growth	Physical attacks
Improvement of operational processes in firms	Cyber security issues
Human mistakes reduction	Privacy challenge
Cost reduction for firms	Data mining issue
Big Data analytics for firms' productivity and efficiency	Data management problem
Time optimization	
Resources efficiency	
Waste management optimization	

(Source: author processing)

1.6 IoT: Data and Statistics

In this section, we will take a closer look to data generated by the IoT world in a threefold perspective: (i) global, (ii) European and (iii) Italian, focusing the analysis on spending, revenues and the number of connected devices.

1.6.1 Global Context

According to the Statista report "Internet of Things – statistics & facts" in 2023 the global spending for IoT technologies will reach 1.1 trillion USD. In 2016 157 billion USD were spent on IoT, the amount raised up to 686 billion USD in 2019; in 2020 the Covid-19 pandemic accelerated investments by 9.2% reaching 749 billion USD. In fact, in 2020, IoT could generate about 181 billion USD of revenues globally while, in 2021, it saw an increase of about 19%, touching the 213 billion USD mark. From the data, we can deduce that IoT follows a positive trend and will grow steadily in the future.

Table 4 - IoT spending

IoT spending	
Year	**USD (billion)**
2016	157
2019	686
2020	749
2023 (forecast)	1.1 (trillion)

(Source: author processing)

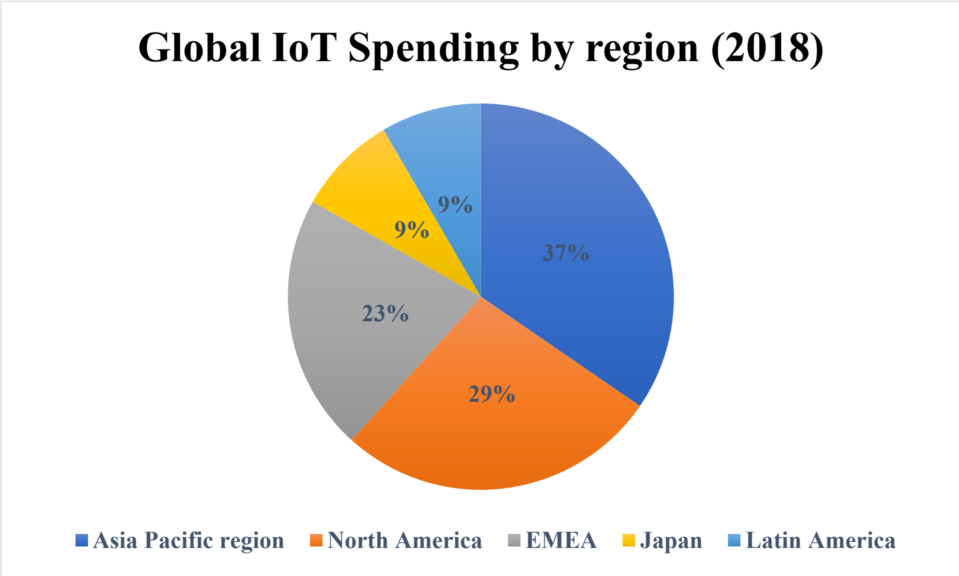
Table 5 - IoT revenues

IoT revenues	
Year	**USD (billion)**
2020	181
2021	213

(Source: author processing)

As we can see from the chart below, back in 2018, the Asia Pacific region had the 37% of global IoT spending followed by North America at 29%, EMEA (Europe, Middle East and Africa) at 23%, while Japan and Latin America share the same percentage (9).

Chart 2 - Global IoT spending by region



(Source: author processing)

In 2019 there were about 8.6 billion connected devices, mainly in the electricity, gas, water supply and waste management field (1,047 million), followed by government (366 million), logistics (183 million) and retail and wholesale (136 million). In 2020 the number of connected devices shot up to 9.76 billion, a 13.5 % increase, with no change in the most employed fields with respect to 2019. In 2021 there were 11.28 billion of connected appliances with an increase of 31.2 % with respect to 2019.

Generally, we saw an increase in both IoT investments and IoT connected devices. Moreover, the Covid-19 pandemic resulted in being one of the main drivers for IoT growth, especially in retail and healthcare, which saw rapid technological development.

1.6.2 Europe

In the European context, the Internet of Things market revenue is worth 4.8 billion USD only in 2021. Considering that in 2016 the revenue stream from IoT was about 1.6 billion, it is possible to state that it has increased by 22 percentage points in a five-year period only.

Revenues from IoT are estimated to grow up to 7.8 billion by 2026, a 62.5% increase with respect to 2021. Moreover, as previously mentioned, the Covid-19 pandemic increased revenues by 50% in one year only, from 2020 to 2021.

Table 6 - IoT market revenues

IoT market revenues	
Year	**USD (billion)**
2016	1.6
2017	2
2018	2.5
2019	3
2020	3.2
2021	4.8
2026 (forecast)	7.8

(Source: author processing)

The industries with the most IoT connections are: automotive, smart buildings and cities, followed by retail and healthcare sectors (Statista Research Department, 2022).

In addition to that, the European Union, allocated several funds (100M €) to IoT related projects within its "IoT European Large-Scale Pilots Program". In 2016, the EU commission launched a strategic investment in the IoT to accelerate the process of digitalization of industries, with the goal to improve not only citizens' quality of life but also the growth of new industries and business processes and, above all, a creation of a safe and sustainable European IoT ecosystem. We can assess that the European scenario is rapidly growing, and it is aligned with the global trends exposed in the previous paragraph.

1.6.3 Italy

The IoT Italian market grew steadily between 2015 and 2021. It worthen about 8 billion euro in 2021, while in 2015 it accounted only for 2 billion euro. As previously seen globally and for Europe, the Italian IoT sector also flourished due to the Covid-19 pandemic. Smart metering and smart asset management result to be the industries with the highest market value in Italy, followed by smart car, building and logistics. Nowadays, there are more than 110 million of connected devices in 2021, 37 million of these connections are cellular IoT.

In addition to the European funds for IoT projects and investments, Italy will also benefit the PNRR (Piano Nazionale di Ripresa e Resilienza) program: about 29 billion euro will be allocated in IoT related activities. More in detail, 14 billion will be used for smart factories, 4 billion for assisted living and healthcare industries, 5.9 billion for smart city (including preventive maintenance for natural disasters and plumbing system) ("Internet of Things in Italia," n.d.). We can conclude that also the Italian IoT market is following the positive trend we highlighted in the two paragraphs above.

As we were able to ascertain, it was not possible to ascribe to a single definition of IoT since there are different meanings for the same term in the literature. We defined the evolutionary process affecting the Internet of Things and analyzed which technologies are needed to create connected products and machines. In addition, the application areas of IoT are countless: healthcare, smart home systems, manufacturing, retail, transportation, energy, agriculture and smart city systems. This makes IoT nowadays a well-established technology not only in business processes (in this case we talk about IIoT) but also in those related to the daily lives of individuals. IoT presents several benefits for firms and users. In fact, it enhances productivity of companies, reduces costs and waste, improves employees' overall efficiency, enables Big Data collection and analytics and allows a better management of the time factor. Of course, it also presents some drawbacks mainly linked to privacy and security issues as we have seen in section 1.5. Lastly, thanks to the data and statistics collected, it is possible to assess that the IoT sector is experimenting a significative growth in terms of the increasing number of connected devices, investments and revenues generated. This trend follows a similar path at global, European and Italian levels.

2. IoT and Big Data

In this chapter, we will make a focus on the relationship among connected devices, data they generate and their use. More in detail, we will see how Big Data are employed to implement Enterprise Resource Planning (ERP) systems and Customer Relationship Management (CRM) tools and practices. It is also analyzed the definition of smart connected products (hence mainly related to the B2C sector), their evolution process and their role in reshaping the industry sector.

2.1 Big Data and Smart Data

IoT connected devices are able to generate a vast amount of data that companies can exploit for their own interests; we are now questioning ourselves: is it possible to use this data to improve firms' sustainability processes? We will answer in the next chapter of the present work; now we will take a closer look at the evolutionary process from Big to Smart Data.

The concept of Big Data was first spread in early 2000 in the computer science and econometric field respectively by Weiss and Indurkhya in 1998 and Diebold in 2000 (Diebold, 2021). According to Iafrate (2015), Big Data can be defined as a phenomenon derived from digitalization. Big Data is about processing, analyzing, and valuing a great amount of heterogeneous data. The role of Big Data is the one of facilitating firms in their decision-making process (in its broadest sense).

Of course, when in the early 2000 and late '90s, the academic world (and not only) started to talk about Big Data, and there were also several issues to investigate. There were some difficulties in understanding how to process, store and interpret these data.

Doug Laney, in his report written for Meta Group in 2001 (now part of Gartner), identifies the three "V" characteristics of Big Data:

1. Volume: a considerable amount of data is acquired through the Net, also thanks to the IoT. This significant amount of data must be stored and as technology evolves, the price for data storage decreases. We can say that Big Data are characterized by the vast amount of information they collect.
2. Velocity: the Net never sleeps, which means that data are continuously generated. For this reason, data must be processed in "real time" because of the volatility of these data.
3. Variety: data are not always structured. This means that data processing systems must be able to analyze, not only a great amount of data, but also data of different natures.

In addition to this, Iafrate (2015) in his book "Form Big Data to Smart Data", adds the fourth "V":

4. Value: a piece of data finds its value in its use. Of course, nowadays, it is difficult for firms to use all the data they have to generate value, but they can use some data to improve their business (in its broadest sense), their relationship with customers or other commercial partners.

Hence, Big Data are a vast amount of heterogeneous information that are continuously generated and processed. These data are a source of gain for firms that can grasp helpful information in order to improve the operability and business strategies of companies. Because of the great amount of information, it is challenging for firms to choose the relevant ones and elaborate them for their purposes.

According to the Oracle report "Big Data Use Cases" (one of the foremost providers of Big Data and analytics software), Big Data are beneficial for several purposes. In the following table, we summarized the most common use of data divided according to their field of application, taking into account the above-mentioned report:

Table 7 - Big Data use examples

Manufacturing	**Retail**	**Healthcare**	**Oil and gas**	**Telecommunications**	**Financial Services**
Predictive maintenance	Product development	Genomic research	Predictive equipment maintenance	Optimize network capacity	Fraud and compliance
Operational efficiency	Customer experience	Patient experience and outcome	Oil exploration and discovery	Telecom customer churn	Drive innovation
Production optimization	Customer lifetime value	Claims fraud	Oil production optimization	New product offerings	Anti-money laundering
	In-store shopping experience	Healthcare billing analytics			Financial regulatory and compliance analytics
	Pricing analytics and optimization				

(Source: author processing)

According to the Statista report on Big Data, in 2021 and 2020, about 45% of organizations used big data analytics as a research method worldwide. This means that Big Data is gaining more and more importance within firms, but it is still not an ordinary practice for the majority of them. Of course, the number of users in the following years is expected to overgrow.
In addition to that, thanks to a technological breakthrough, we are now seeing the rise of the so-called Smart Data which can be defined as a set of technologies and processes in which different data sources are brought together and correlated. These processes enable the value originated from the collected data. Of course, firms must be equipped with a suitable Business Intelligence system to implement and make use of Big and Smart data (Iafrate, 2015). Hence, thanks to smart algorithms, Big Data can be processed and transformed into Smart Data which are easily readable and interpretable since they are transformed into actionable insights.
Smart Data, thanks to their nature, are a crucial tool for managers at all levels of the organization. This helps them make more appropriate evaluations while running their duties and streamline the decision-making process among different hierarchical levels of the business. Moreover, because of the massive amount of data, a single unit within a firm cannot control, store, and process all this information. For this reason, businesses are creating specific data groups that allow a better collection, analysis and aggregation of data. They are also in charge of making data and insights available across different business units (Heppelmann and Porter, 2015).
Hence, we can deduce that smart connected devices produce a vast amount of data that are classified as Big Data because of the characteristics we mentioned before. These data are then transformed into semi-structured Smart Data and release quick insights to end users. Lastly, firms are transforming their way of processing these data. They are creating ad hoc methods and business units in charge of delivering, analyzing and processing all the information they receive from smart connected objects.

2.2 B2C Connected Devices

In this section, we will focus on all the connected devices that belong to users. Users are people who own devices such as: smartwatches, smartphones, smart home systems and all the items that can be used in everyday life from ordinary people.

2.2.1 Smart Connected Objects and Data

As it was mentioned in the previous section, smart connected objects are able to generate a vast amount of information. In this section, we will see more in detail which kind of information smart objects create with a focus on what we call B2C connected devices. We will consider B2C devices all the items sold by firms to people with the purpose of making everyday life smarter and easier. We will now see some examples of smart connected products:

- Amazon Alexa, Google Home are able to transform our home into a smart home. They are smart devices, connected via Wi-Fi technology, able to "speak" like humans, they interact and listen to us. We can talk to them, ask for information, set them up for specific tasks. They can in turn communicate with other smart devices such as smartphones, smartwatches, security systems and smart lighting systems. Because of their ability to communicate with people and connect themselves with several and heterogeneous smart objects, they can elaborate, transform and generate a considerable amount of information quickly. For example, they know if a person is physically home or not, they record conversations, take track of people's or pets' location, they know the humidity and heating levels of the building, they know how much light we need while doing some activities, they can see if our fridge is empty or if we are running out of ink for our printer. These are small examples of what they can do and how much they track us and may help us carrying on some simple tasks or errands in our daily life.
- Smartwatches are small wearable devices mainly connected to smartphones thanks to a Bluetooth connection (or similar technologies). These small objects report to us every activity our smartphone does. Moreover, they transmit useful data not only to our phones but also to specific people if we are in a dangerous situation. Smartwatches take track of our current location, register our sports activities, and monitor our health conditions such as heart rate. The most iconic smartwatch is the Apple Watch, which is becoming more and more sophisticated It can get advanced fitness metrics like stride length, vertical oscillation, heart rate zones and ground contact time to customize your workouts. It is able to detect if you're in a severe car crash and can automatically connect you with emergency services, provide dispatchers with your location, and notify your emergency contacts. It is also able to connect to smart home systems and gather information about lights, security cameras and thermostats.
- Smartphones are the ultimately connected objects. Since their first release, their potentialities were probably underestimated. Nowadays, almost certainly, most people would not be willing to live without a smartphone. We can state that they can be considered the beating heart of smart connected objects. All connected devices use a smartphone as an enabler for its core functions.
- Smart Home Systems can be considered as an ecosystem of connected devices generally headed by a single application. In this ecosystem, every object has its own role and it

allows the others to express their functionalities to the fullest. Some examples are: intelligent thermostats, security systems, smart lighting, smart appliances. Smart Home Systems tell us how often we do the laundry, make the dishwasher, open the fridge and how full/empty it is.

- Smart Car Systems, as it was mentioned for Smart Home Systems, can be considered as an ecosystem too. Nowadays, the latest car models are equipped with the most sophisticated technologies: diagnosis and parking sensors, built-in GPS, digital radio. These equipment allow cars to communicate not only with other vehicles but also with infrastructures. Thanks to this, cars are able to generate data that for example, may help other drivers to avoid traffic jams and car accidents. Also, mechanics can take advantage of these data: they can see in advance which is the problem and try to prevent or solve it in half of the time. The repairing systems will be much more efficient and simpler.

As seen so far, these are just the most glaring examples of smart connected objects we use daily. They originate a vast amount of data that can be useful for several reasons for example, a smartwatch is able to detect if you are in danger and call itself emergency services, smart GPS systems in vehicles suggest to drivers the smartest way to avoid traffic. On the other side, this data generation has some severe implications in privacy and security issues, as discussed in the previous chapter. In the following table, we will summarize which are the primary data that smart connected products can generate:

Table 8 - Types of data generated by IoT devices

Smart Devices/Field of application	**Data generated**
Smartphones	Users' location, preferences in terms of purchasing behavior, health data, physical activities such as the number of km walked.
Smart watches and wearables in general	User location, heart rate, users' accidents
Smart home systems	Humidity and temperature of the environment, data on the use of the products connected, data on the routine of the users (e.g., when the user gets up, when he/she has lunch/dinner and what the user eats)
Smart mobility systems	Data on traffic and accidents, use and status of vehicles, data on users' location.

Smart health systems	Status of the patient to cure a disease, data on how the body is reacting to the prescribed medications and pills, data on the patient in order to prevent some disease (e.g., blood glucose level, blood pressure, cholesterol levels, heart rate, blood oxygen level)
Smart agrifood	Data on the status of the soil, level of fertilizer used or needed by a specific plant, temperature and humidity if crops are located in a greenhouse, data on the status of the crops to prevent diseases and parasites that will harm an entire plantation.
Smart cities	Data on traffic and accidents, data on energy overload that may cause fires or blackouts, data on public transportation systems (e.g., peak hours, number of passengers, prevention of misuse of vehicles, status of the vehicles in circulation), data on the lighting system, data on the water system of the city (e.g., bacteria level, inflow into the sewage system, maintenance status of manholes

(Source: author processing)

It is interesting to see how Mühlhäuser (2008), in its work, focuses on three different types of data that smart objects can collect for analysis:

1. Data about itself, for example, its features and functions, dependencies, product history, status;
2. Data about its potential and current environments, in particular perceived possibilities to adapt to and cooperate with these environments and their constituents;
3. Data about its users, based on elaborate user models that consider dynamically changing user knowledge (learning/forgetting) and distinguish the different user categories reflected in the lifecycle plus each individual user herself.

These different types of data set are extremely useful to understand, not only the status of a specific object, but also the external environment they operate in.

So, we can state that there is a twofold use of connected devices:

- Internal use: collect information on the physical status of the object itself
- External use: gather information about Smart Products' users and the context they are placed in.

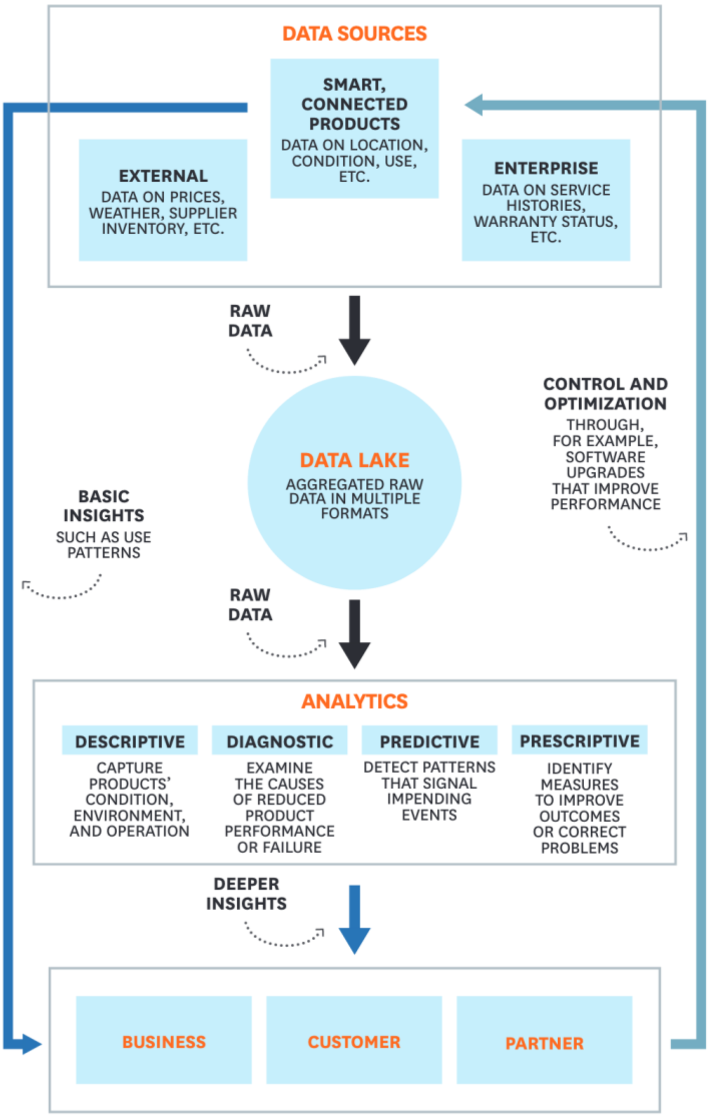
Heppelmann and Porter (2015), in their work, propose a flow chart to explain the potentialities of generating value with data from smart connected products. In the figure below it is possible to see how data and users interacts and which is the process that transform raw data into useful insights. We can analyze figure n. 4 in four key levels:

1. Data sources. In this first step, we have three different actors: (i) smart connected products, (ii) enterprises (iii) the external environment. Smart Products create data on the condition, use, location, health status. These are data based on the use of the object itself. On The other hand, the external environment provides data on prices, suppliers, inventory that are mainly related to the context in which smart objects operate in. Lastly, enterprises have data on service histories, warranty status, development processes, these kinds of information are useful to take track of the process of implementation of smart products.
2. Data lake. All the information processed by the abovementioned actors, in the form of raw data, flow into the so-called "data lake" in multiple formats. Once the data are collected are divided according to their nature and sent to the next phase.
3. Analytics. In this phase of the process, raw data are sent from the data lake and are ready to be processed according to a specific purpose. Heppelmann and Porter, (2015) identify four main purposes for data analytics:
    a. Descriptive. This function gives insights on the products' condition, the environment, and the operations they carry on.
    b. Diagnostic allows users to understand the products' performance or failure.
    c. Predictive. Data take track of the patterns that may report in advance events that can be dangerous for the product itself and users as well.
    d. Prescriptive. This phase process data to improve the outcome of smart products and correct problems when they arise.

    Once the data have been processed, they are transformed in deeper insights that users can easily understand.
4. Users (business, customer and partners) are the last step of the process. They are the one in charge of enhancing the proper value of the information they receive after the analytical process.

This process, described in four steps, allows end users to gather deeper and more complex insights about smart connected products. Of course, these objects are able to generate also basic data, which are ready to read and can be easily interpreted by end users. Once these information reach businesses, customers or partners, they can use the insights obtained to optimize the products' performance through software upgrades, hardware improvement and more adequate employment of the product itself.

Figure 4 - Data transformation process



(Source: Heppelmann and Porter, 2015))

2.2.2 A step backwards: from traditional products to Smart Products

Traditional products are all those physical objects that do not have embedded software able to connect the object itself to a network. Hence, they are not part of the IoT system and pursuit their function without any possibility to take track of their operation through smart systems. An example could be a simple pen that allow the writer to take notes, draw. Of course, a simple pen can be transformed into a smart product if it is equipped with sensors and software applications and it is able to generate data of its usage, conditions.

On the other hand, we have Smart Products, that as the word itself suggest, saw their rise with the Internet of Things. According to Kahle et al. (2020), Smart Products can be defined as an artifact that, besides its physical components, contains digital technology – in the form of, for example, sensors, software and micro-chips – and therefore has capabilities to collect, monitor, control and optimize data from different sources and that may also interact with other products and perform tasks without human input. Moreover, according to Heppelmann and Porter, (2015a), Smart Products are characterized by three core elements:

- Physical components such as mechanical and electrical parts;
- Smart components such as sensors, microprocessors, data storage, controls, software, digital user interface;
- Connectivity components, for example, ports, protocols and networks that enable communication between the product and the product cloud, which runs on remote servers and contains the product's external operating system. In addition to that, connectivity takes three different forms that are: (i) one-to-one, (ii) one-to-many or (iii) many-to-many

These characteristics differ from the ones of simple objects, which do not need sophisticated components. In addition to that, Smart Products need a different technology infrastructure and a different ecosystem of application. We can define an ecosystem as a connected environment in which every component has its own role that is vital for the functioning of the whole ecosystem. Being part of an ecosystem allows member to achieve benefits derived mainly from the interaction with other members (Nambisan and Baron, 2021). Having said that, Kahle et al. (2020) in their work, presents us six dimension of innovative ecosystems strictly related to Smart Products:

- Context that comprises three components: the mission, the drivers and the barriers of the ecosystem.
- Construct dimension is about the structure and infrastructure of the ecosystem; for example, the financial assets, the overall backbone and other resources needed to support the ecosystem and the interaction among the actors.
- Configuration takes into consideration good and well-established external relationships of actors and how do these connections work together.
- Cooperation, which includes all the governance systems and the coordination mechanism of the ecosystem.
- Change dimension considers the actors' ability to deal with changes and how open their culture is to those changes.
- Capability dimension is related to technological features needed for Smart Products.

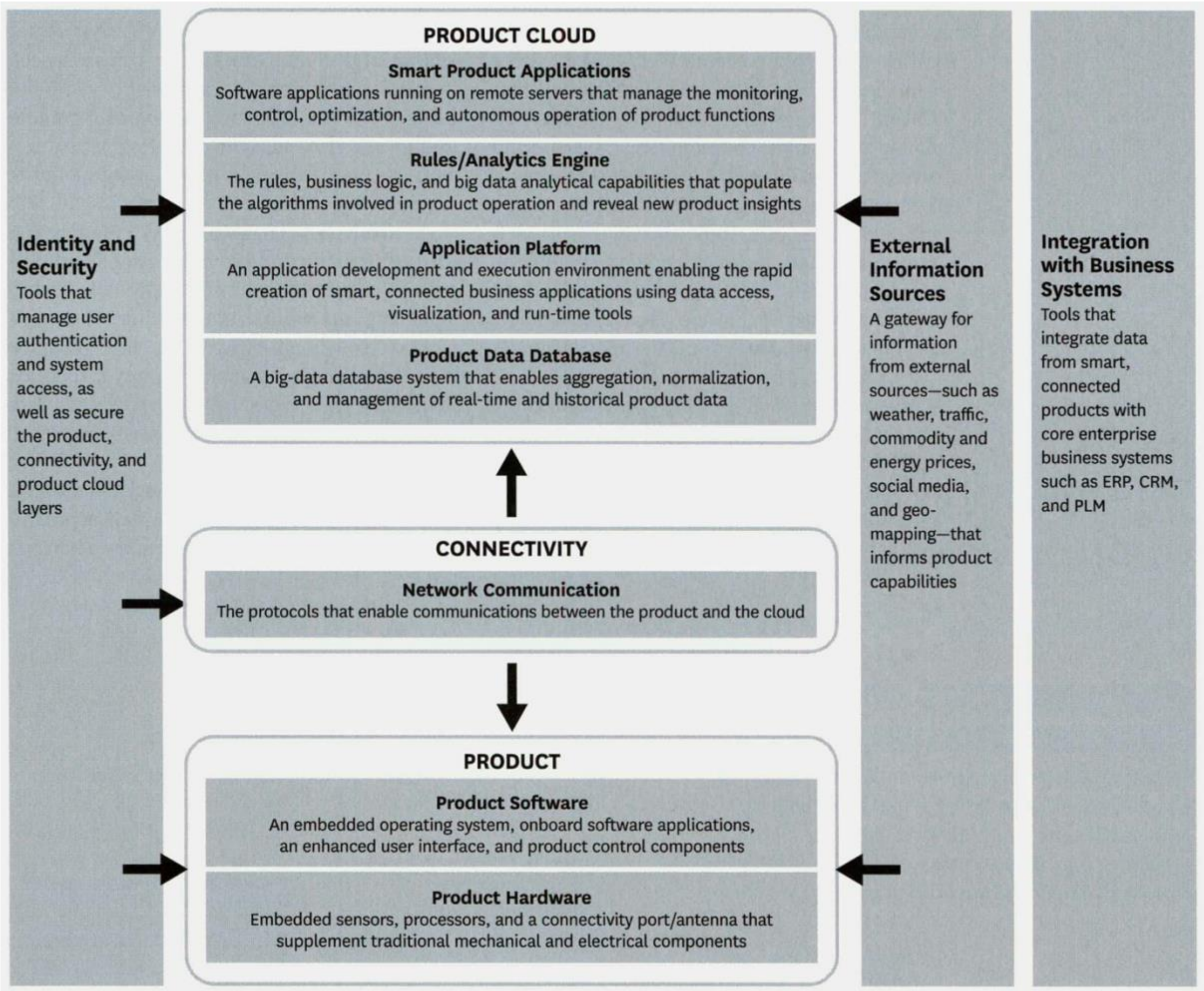
These six dimensions are useful to better define the general outlines in which Smart Products are first idealized and then put into practical framework.

Heppelmann and Porter (2014b), presents us a more complete framework in which Smart Products find their development. In fact, Smart Products need a new technology infrastructure that must be tailored from companies. As we can see from the picture below, we can deduce three key components of the framework:

1. Product that is divided into software and hardware part
2. Connectivity which is based on network communication and it is the key element that links the product part with the cloud one.
3. Product cloud is defined set of tools, such as database, application platform, analytics engine, Smart Products applications, that enable the smart function of the product itself.

These three elements are supported by security tools to implement the overall reliability of Smart Products. On the other hand, they are influenced by information from external sources that impact product capabilities.

Figure 5 - Key components of Smart Products



(Source: Heppelmann and Porter, 2014)

In addition to that, Heppelmann and Porter (2014) presents us four core functionalities that Smart Products have to be such. Each function is the enabler for the next one.

1. Monitoring allows users to take track of product use and misuse

2. Control allows users to enable Smart Products even if they are not physically close, for example turning on the heaters by simply using a mobile application installed on our smartphone.
3. Optimization derives from adequate monitoring and control phases. For example, optimization concern preventive maintenance and remote intervention which allow firms and users to reduce the on-site time intervention and reduce also costs for both sides.
4. Autonomy is a result of combined monitoring, control and optimization processes, which allow Smart Products to self-coordinate with the environment they operate in, to learn from their operations, to run self-diagnosis and send the proper information to the parent company that will be able to control the status of the products they sell.

2.2.3 How Smart Products are Reshaping Industry structure

To understand the effects of Smart Products on the industry structure we must first define the context in which we will operate in. We will make an analysis on the bases of Michael Porter's five competitive forces that shape industry competition.

Figure n. 6 Represents the five forces theorized by Porter that affect industry competition and describe the different types of interactions that occur in an industry. Taking into account the competition that derives directly from existing competitors, according to Porter, (2008) it is possible to identify four more causes that mine competition:

1. Threat of new entrants. Newcomers acquire market share. This is the reason why prices and costs are subjected to transformation. On the other hand, entry barriers work as deterrent for new entrants. Some examples are, economies of scale, customer switching costs, high capital requirements, incumbency well established quality or cost advantages, restrictive government policies, or expected retaliation that may occur against potential entrants by incumbents.
2. Bargaining power of suppliers. Suppliers with high level of influence on the market can leverage their power by boosting prices, limiting services or quality or transfer some costs to other actors within the industry. What makes suppliers dominant are forms of imperfect competition such as monopoly or oligopoly, their specific knowledge that makes it difficult for business to switch to different suppliers.
3. Bargaining power of buyers. Influential purchasers exploit their power to leverage down prices, pretend more services and higher quality products with the consequence of increasing costs for firms. Of course, if firms decide to not accomplish buyers' requests, the latter will switch supplier even if this is translated into a cost for the buyer itself.

4. Threat of substitute products or services. New products and services undermine incumbents in a specific industry sector. Some new products or services may result from innovation or technological processes, in this case, the substitution process is an indirect one because it is due an evolutionary step of something already existing. Of course, substitution can occur also from brand new products and services that enrich the offer of other firms. The threat of substitution is higher the lowest the switching cost for the buyer is.

Rivalry among existing competitors is directly proportional to the number of firms operating in a specific industry: the higher the number of competitors, the higher the competition. Competition can take different aspects such as, prices war, service improvement, high quality advertisement campaign. Rivalry depends on two factors: (i) intensity of competition and (ii) the basis on which firms rival.

In his model, Porter assumes that the industry structure is robust and companies operate in a long run perspective.

Figure 6 - Porter's five competitive forces

(Source: Porter, 2008)

According to the nature of the industry in which the firm operates in, these forces can be more or less intense. The key aspect that drives competition and profitability is the industry structure. According to Porter, (2008) the economic condition of the country, business cycle, regulations and maturity are not considered to be factors of influence for competition and profitability.

Several years later, with the advent of smart connected products, Porter analyzed how smart products affected and influenced the five forces' model.

The industry structure is influenced by the five forces that determines the level of industry competition and profitability. In particular, for what concern smart objects, they affect structure in several industry, mainly the manufacturing one.
Since the production of smart connected devices requires huge fixed costs due to complexity of product design, newcomers find it more difficult to enter that specific industry sector unless they have a solid investment system that allow them to sustain these costs. On the other hand, smart products may be a threat for incumbents if they are resistant to their adoption, in this case new entrants, which have invested in smart products and IoT, take advantage of the resistance if incumbents that will be overcame by newcomers.
Smart, connected objects will transform the bargaining power of suppliers by shifting from hardware to software commercialization. Thanks to this, the number of varieties of physical components will be reduced in favor of embedded operating systems, data storage, analytics software, sensors' providers. Greater power is given to suppliers which are able to manage, store and process data with high security standards.
Because Smart Products drive companies to make more sophisticated and customized products that have prices that are set to capture the maximum value from them. Additional services are added to extend and reinforce the value of connected devices. For these reasons, buyers are less willing to switch from one supplier to another, the cost of the transition is much higher now. Buyers' loyalty has strengthened because now firms are able to create much more deep and close relationship with customers thanks to the customization processes, additional services, after sale ad hoc programs.
Moreover, Smart Products are a great threat as substitute for traditional products because of their superior performances, their high degree of customization and their competition on prices. Lastly, we analyze how these products reshaped the rivalry dynamics among competitors. From one side, smart products contribute to increase rivalry among competitors in the moment they become part of a broader systems of products such as all the devices that can be part of a smart home system; this increase competition among producers of the same item. On the other side, competition can be mitigated when the level of customization of smart products is very high. (Heppelmann and Porter, 2014; Porter, 2008)

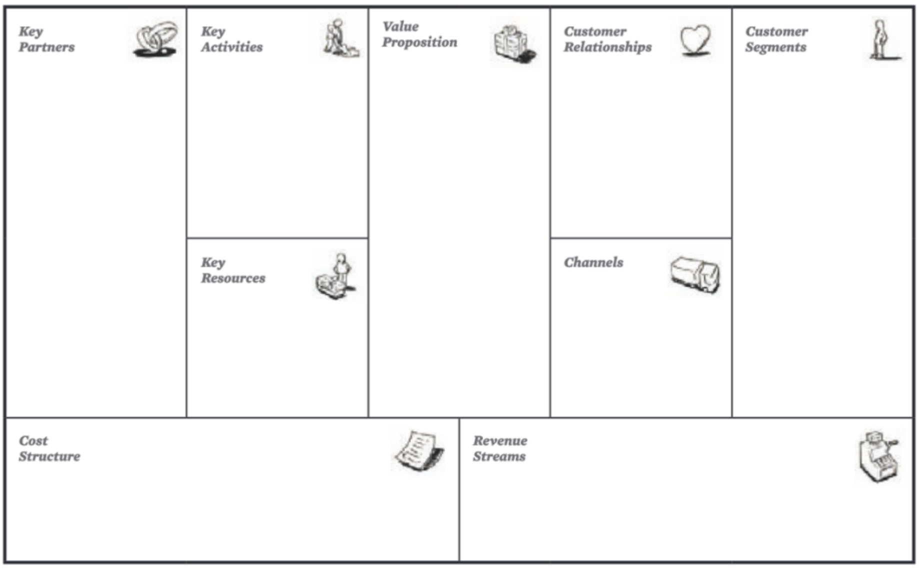
New business models emerged from the adoption of IoT technologies and intelligent products. According to Amit and Zott (2001), a business model describes the step that are performed from a firm to complete transactions, it is the extension of a strategic network and help businesses to identify their process of value creation, delivery and capture. In addition to that, Venkatraman and Henderson (1998), define a business model as a coordinate plan to design strategy along three vectors: customer interaction, asset configuration and knowledge leverage. Hence, a business model can be defined as set of tools and actions that point out the process of value creation, delivery and capture of firms on the basis of three key components: customers, assets and knowledge. Years later Osterwalder and Pigneur (2010), theorized the Business Model Canvas which represent in a graphical pattern nine elements derived from previous studies (Osterwalder, 2004):

1. Key partners. In this building block the company describes its network of external network of supplier and partners useful for the optimization of their business, risk reduction and/or resources acquisition. Some examples of partnership are: coopetition between competitors, joint ventures and strategic alliances among non-competitors.
2. Key activities are those actions that a company must carry on to achieve its goals and operate successfully. Their function is very similar to the one of resource, in fact, activities are needed to maintain customer relationship, earn revenues and sustain the value proposition. Of course, the type of activities differs according to the business model of the company.
3. Key resources are the tools that a firm need in order to deliver its value proposition, reach new market segments and earn new revenues. Of course, different types of resources are needed according to the type of business model. The nature of resources can be of different kinds such as financial, human, physical (assets), knowledge.
4. Value proposition is about the description of the products and/or services offered by the company. In the value proposition there are stated the benefits that the firm offers to a specific group of customers.
5. Customer relationship describes the type of connections that a company establish with his segmented group of customers and severely influence the entire customer experience.
6. Channels are the tools used by the company to communicate the customers they segmented their value proposition. Companies may use their channels or delegate to third parties. Moreover, they can employ direct or indirect channels to drive and support customers in all their phases: awareness, evaluation, purchase, delivery and after sale.
7. Customer segments represent the different types of customers the business wants to address to. We may have niche customer or a wide public. Customers are segmented also according to their sex, age, commercial preferences. Once the firm identify the targeted group of reference start a process of production that respect the characteristics they choose for the targeted audience.

8. Cost structure is the results of all costs that a firm must sustain in order to run its business. Costs vary according to the type of business the firm is carrying on, they can be fixed or variable, firms can take advantage of economies of scale and of scope too.
9. Revenue streams represents the cash that each company is able to generate from customers' interactions. Revenue streams can be generated from different pricing mechanisms such as usage fee, assets sales, subscription programs, licensing. According to the type of pricing mechanism, revenues may be recurrent or limited to a single transaction only.

The picture below, known as Business Model Canvas, summarizes the nine above-mentioned elements, grouped and represented by Alexander Osterwalder & Yves Pigneur in their book "Business Model Generation" (2010).

Figure 7 - Business Model Canvas



((Source: Osterwalder and Pigneur, 2010)

The Business Model Canvas helps companies to have a more complete and clearer framework of their overall economic activity taking into account different aspects that are all strictly linked one to each other. It is a useful tool to carry on activity and be focused on the duties and tasks that must be performed to achieve specific targets.

Smart, connected products, influenced the process of innovation of some business models (BM) that saw their evolution. For example, some smart products replace the traditional concept of ownership, this led to the reduction of the overall demand for a specific product because users can rent the product for a determined period of time or can pay a fee of subscription for its utilization. This type of process is described in the product-as-a-service business model that is described as a provision of marketable set of products and services, designed to be economically, socially, and environmentally sustainable, with the final aim of fulfilling customers' needs (Annarelli et al., 2016). In this type of business model users pay a fee that allow them to use the product rather than buy and owner it. This allows users to be more flexible and decide whether to continue to pay for the use of the product or switch to another provider or supplier. Moreover, this can be translated into a saving for the customer and allow firms to reduce the number of resources needed to build a product.

A similar BM is the one based on sharing activities such as bikes, electric scooter, cars. In this specific context, customers pay only for the time they are using that specific product or service. This allow them to share the cost of the use among different users and permit firms to maximize the use of the product they are temporarily landing to users. Thanks to embedded sensors and appropriate software, firms can track the use of the product and extend is lifetime value by repairing and preventing damages due to intense utilize. Examples of firms that adopted this business model are Mobike, Helbliz, Enjoy, Lime, BlaBla Car.

From the theoretical background we analyzed so far, we can deduce that Smart Products reshaped the way buyers, suppliers and competitors interact among themselves, creating new benefits and challenges for all the actors that operate in an economic context. For example, it is easier for firms to create more customized products and services thanks to the data they obtain from smart products; customer care services are more efficient; users

On the other hand, competition increased among firms that in the previous economic phase were not competing, so new entrants are forcing companies to generate high customized, higher quality and more valuable products and services.

For what concern business models, basically Smart Products contributed to the evolution, improvement and innovation of existing BM mainly reshaping the interactions that occur between firms and customers improving efficiency and operability of products and services offered thanks to the IoT.

2.3 Enterprise Resource Planning and IIoT

So far, we discussed about smart connected objects mainly related to B2C services, in this section we will make a focus on what we call B2B connected devices: the Industrial Internet of Things (IIoT) and their role within the firm. In the literature analyzed, the term IoT is often used as a broader term that includes the meaning of IIoT too. For this reason, in this section we will use both terms, which refer to B2B and industrial sectors.

2.3.1 Theoretical framework

In the 1990s ERP systems were developed to meet the requirements of new user organization, in particular the supply chain processes to implement the flow of information deriving from suppliers. Enterprise Resource Planning (ERP) is a specific designed software, employed by companies, that perform different economic and business activities, such as financial, manufacturing, logistics, cost accounting, purchasing, distribution, customer relations, cash flow, warehouse management, human resources, material management, electronic banking, quality control, with the support of information technology. In particular, it integrates all businesses' departments and functions into a single computer system. Moreover, it plays a critical role in streamline process and also in the improvement of business operation across different industries (Chorafas, 2001; Paksoy et al., 2020; Stojkic et al., 2016; Tavana et al., 2020).

An ERP system is designed on a database layer that is able to process and store different types of data and information. It can be considered as a central location for storing distributing and sending information in several areas of the firm (Paksoy et al., 2020; Prakash et al., 2022)

Hence, Enterprise Resource Planning systems are a set of ad-hoc designed software for companies that are able to process and manage a vast amount of information in a unique platform that is able to communicate across all business units or functions of the firm. Because of the heterogeneity of information ERP systems contain, they are extremely useful for the overall optimization of the production processes of the firm.

2.3.2 Integrating ERP and IoT

With the rise of IoT with all its benefits (discussed in section six of chapter one of the present work), also ERP systems benefitted the adoption of IoT related technologies. IoT, huge data influxes triggers new implementation for ERP systems and as a consequence produces new opportunities for firms (Tavana et al., 2020)

ERP effective application can optimize the business process, rationally allocate resources, improving economic benefits and enhancing the core competitiveness of enterprises. (Su, 2022)

ERP implements operational activities, managerial and strategic processes and decision-making, IT infrastructures and organizational procedures and activities (Paksoy et al., 2020)

Companies may benefits from solutions provided by the IIoT but companies have to redesign their operation to data-driven process to exploit all the benefits (Romeral Martínez et al., 2020)

Some benefits deriving from integrating ERP systems with IoT technologies (Prakash et al., 2022; Tavana et al., 2020):

- Harmonization of communication allowing more precise and efficient data analysis

- Efficient monitoring of each production cycle thanks to the identification of inefficiencies and potential criticalities
- Predictive maintenance helps preventing downtime and balance the workload of machines and systems.
- Real-time information availability. IoT generates real-time data that flow into the ERP system, which processes the data and provides a clear understanding of the situation, in this way it is possible to always have a constantly update framework in which the company is operating in.
- Improved operational efficiency. If the company sells its products through dealers, it can be difficult to keep track of the data generated by end users. Thanks to IoT integrated with ERP, companies enable to products to communicate with their customer right after they are initiated.
- Cost savings, which can be seen in three different forms: reduce upfront expenses, lower operational costs and transparency of the total cost of ownership.
- Flexibility, agility and scalability. Firms are now able to quickly adapt their production systems to changing and rapidly evolving markets and better employ their resources with less and more efficient maintenance.
- Improved business productivity due to the possibility of automating services, processes and procedures.

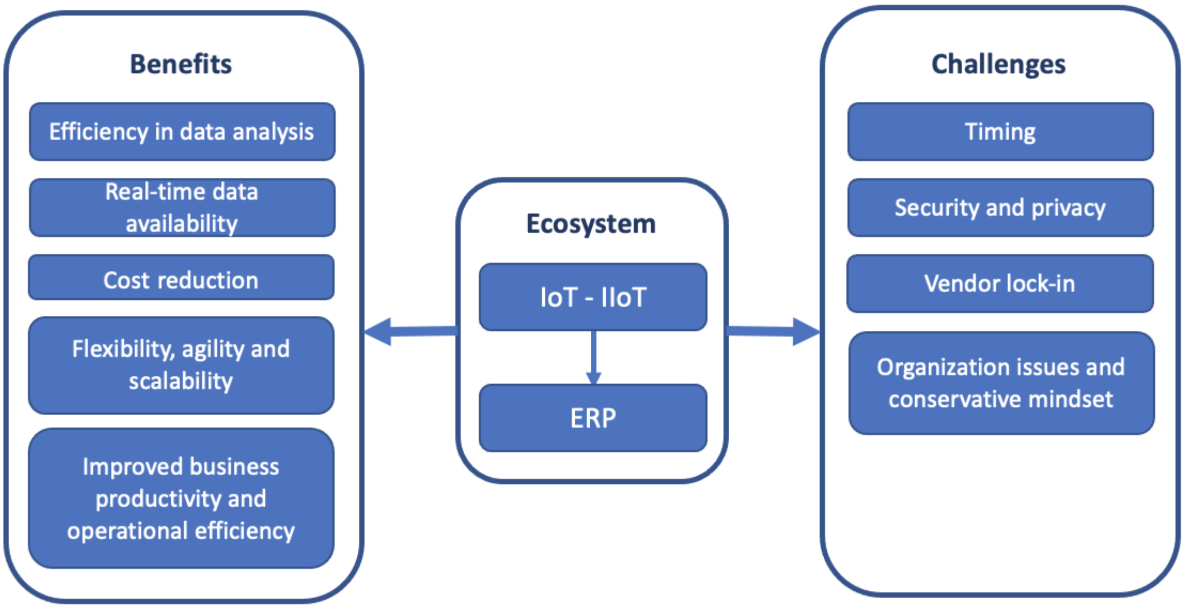
Of course, there are also some drawbacks to consider (Prakash et al., 2022; Romeral Martínez et al., 2020):

- Timing. Time can be considered an ambiguous element. Considering the right timing it is not an easy task and implementing ERP systems when the firm is not ready to embrace the change or is too late can be harmful for the entire organizational system.
- Security and privacy issue. If firms decide to develop ERP solutions with third parties, sometimes it can happen that sensitive data stored by the cloud or database are also shared with third parties. Moreover, if all the data are stored in a single database, a single attack, physical or cyber, can harm the whole system.
- Vendor lock-in that occur when the cost of shifting to another supplier is too high to sustain. Since ERP systems (based on IoT too) require a high level of customization and trust among companies and suppliers, this interdependence may create resistance for companies that wants to change their supplier.
- Organization issue and conservative mindset. Reshaping and implementing ERP systems through IoT imply a change in existing assets and structure of the firm such as staff skill set, infrastructures, and strategies. In addition to that, a conservative mindset

can slow down the adoption of these new technologies and place the firm in a disadvantage position with respect to its competitors.

Figure n. 8 illustrates how the IoT influenced ERP systems, and which are the main implications from a benefits and challenges approach.

Figure 8 - How IoT influences ERP systems



Source: author processing)

2.4 Customer Relationship Management and IoT

In this section we will analyze the relationship that arises between Customer relationship management tools and data generate by connected devices. In detail, we will see how firms can improve their operability, efficiency and relations towards (potential) customers.

2.4.1 Theoretical framework

In the literature there is room for a big variety of CRM definitions, as seen for IoT and IIoT there is no unique definition but it is possible to identify the key and common aspects that are stated in the different statements.

The concept of CRM has been around since decades, in the last two decades it has gradually assumed a more important role within companies, especially at middle and low management levels (Zare and Honarvar, 2021). Moreover, CRM saw its implementation when a shift was made from the traditional “marketing mix”, known as the “4Ps” (product, price, promotion, place), to the relationship marketing, which embed the concept of relationships’ dynamics to the actors involved in the marketing process. In addition to that, other trends helped CRM to emerge. For example, the recognition from firms that customers were not mere economic transaction but also valuable assets to exploit; the advance of IT systems that generated the first data, so firms understood the importance of data analytics and the proactive use of these new technologies for marketing purposes as well; the development of "one-to-one" marketing strategies (Payne, 2008).

Customer Relationship Management (CRM) is an enterprise approach to understand and influence customer behavior through significant communications in order to improve customer acquisition, retention, loyalty and profitability. Hence, it an iterative process designed to collect data from customers insights and transform these interactions into positive customer relationship and specific marketing activities. Through CRM tools firms improve the process to communicate with the right customer, providing the right offer, at the right time and through the right channel (Swift, 2001). Hollensen (2003), in his book "Marketing Management: A Relationship Approach" define CRM as an integrated information system with the purpose of facilitating customers' interactions with the firm through different tools. CRM systems are programmed to plan, schedule and control activities before and after sales in the firm. Customer Relationship Management is about using customer knowledge to better understand and serve them. It is an umbrella concept that places the customer at the center of an organization (Bose and Sugumaran, 2003). A most recent definition of CRM is given by Stojkic et al. (2016) that assess that CRM may be defined as a strategy of management and communication with customers aimed at collecting information about customer. This information is used for increasing customer satisfaction and loyalty, in order to have better, longer and more profitable relationship with them. Yeas before, Payne (2008) introduced another key aspect in its definition of CRM, the one linked to IT and data analytics. According to Payne, CRM is a strategic approach, which combine the strategies of relationship marketing and the potentialities of IT in order to generate profitable, long-term relationship with customers.

We can deduce that the core element of CRM is the customer and how companies are able to create, retain and consolidate a long-lasting loyal relationship with them using different tools and approaches. Hence, CRM is defined as an approach, an integrated system, a set of strategies with a focus on customer relationship to grasp their knowledge, which aim at specific actions such as marketing, profitability, accessible and easier customer interactions with the firm.

Moreover, Zare and Honarvar (2021) in their work identified what they define as "key components of CRM":

- Customer orientation: customers are the core element of the firm and must be put on top. It is essential to grasp their needs in order to generate value for them. This is a beneficial action aimed at long term investment in relationship.
- Loyalty: is considered the most important component of CRM and is one of the greatest achievement a firm has about its customers and it pays off all the effort made by the firm to attracting and retaining clients.
- Understanding demands: only a firm able to perceive customers' needs and expectations can correctly deliver value to its targeted customers.
- Interactions can be considered all the touchpoints that arises between the company and its (potential) customers. Different channels, such as networks, advertising campaign, customer services, are the key enables for interactions.
- Quality of service: good quality products and services make it easier for firms to offer valuable insights to their customer and, of course, customers' choice will be based on solid characteristics that project the relationship into a long term and durable one.
- Flexibility is about the ability of the company to work in a dynamic environment and consequently the firm's capability to adapt the production to a volatile and highly competitive market. Flexibility also includes the concept of customization that can contribute to the creation of a sustainable and competitive advantage for the firm itself.

These peculiar components of CRM should coexist because it will allow companies to exploit CRM potentialities at their maximum. Of course, some components are easily achievable while others may require a greater amount of time. This depends on internal and external factors: for example, the firm's characteristics, the economic context in which the company operates in or the level of competition that exists among firms.

In the literature, some authors identified different types of CRM that companies adopt in the pursuing process of their strategies (Buttle, 2012; Payne, 2008; Yerpude and Tarun Kumar Singhal, 2018):

- Strategic CRM is based on the customer-centric business strategy with the aim to generate and deliver value for customers trying to overcome competitors. A customer-centric strategy is built upon customers' information retention and satisfaction.
- Collaborative CRM takes place when two or more firms, normally operating in different processes of the supply chain, decide to align their tactics and strategies to attract and retain customers in a more profitable approach. In this case valuable information are shared along the supply chain among partners firms.

- Operational CRM is about all the software application a firm possess or uses in order to better manage customers (potential or not) and the information they generate. Some examples can be: sales-force automation, marketing automation or service automation.
- Analytical CRM concern all the data that regard customers. These data can be collected in several ways: through IoT devices, market analysis, feedback from customer services, economic transactions. All these data generate valuable insights that companies can exploit to create a sustainable value proposition and competitive advantage.
- Social CRM is specifically designed to include the customer as an active part of its retention and attraction process through feedbacks opinions and ideas sharing.
- e-CRM specifically refers to the use of e-business tools or e-channels. It can be also considered as an extension of operational CRM.
- Partner relationship marketing (PRM) refers to all the activities that a firm delegate to specific partners that have specific knowledge and competencies in the different aspects involved in CRM practices. Some examples could be: platform partners, software developers, content creators.

Firms can exploit the potentialities of the different type of CRM according to their objectives in terms of customer relationship. This implies that more than a type of CRM can be employed to create a specific and customized set of tools, skills and knowledge that companies rely on for the achievement of their strategies.

In addition to that Payne (2008), proposes a three levels division for CRM:

1. In the first level, CRM is the tool to implement peculiar technology solution project.
2. In the second level, CRM is the result of an evolution and implementation of several series of customer-oriented technology solutions.
3. Lastly, it can be considered as a strategic approach to manage customer relationship to generate and sustain shareholder value.

According to the type of firm or company, they can decide in which of the three levels where to position their strategic approach to CRM. Firms are free to decide how to apply their knowledge to develop sustainable customer relationships.

On the basis of prior knowledge, we can state that CRM practices help companies to achieve higher competitive advantage, better and long-lasting relationship with customers, higher profits, optimize their resources, employ the data they obtain from smart products. Moreover, firms can decide whether to use their internal resources, delegate some aspects to third parties or partner with other firms positioned along the same supply chain.

2.4.2 The role of IoT and Smart Products

Nowadays, CRM strategies and approaches are supported by specific platforms that help companies to achieve their goals in terms of customer centricity. An example of a leader firm in the CRM software industry is Salesforce, which follow a software-as-a-service business model. Salesforce allow its users to pay a fee for a monthly or yearly subscription. It includes in one platform several tools to manage, process and implement customers' relationships.

Software provided by companies such as Salesforce or Gartner are full of data that will be then transformed into useful insight to leverage the relationship with customers. In this section we will analyze the relationship that exist among, IoT devices, users and firms and how the advent of IoT reshaped CRM approaches and tools.

IoT connected devices are redesigning the way people interact with object and the way firm collect data about customers. Smart Products are able to generate a huge amount of information in real time and knowledge. Firms should be able to process them in an effective manner in order to foster their one-to-one relationship with their customers. In fact, firms exploiting CRM strategies built ad hoc for IoT devices are able to collect a vast amount of information that allow them to customize and personalize products and services tailored for their targeted customers, consequently this led to a process of customer satisfaction and retention. Since nowadays, every new object is somehow considered connected to the Net, for this reason, companies with well-established CRM tools are at an advantage over those with limited CRM capabilities. This is true because CRM platforms are embedding new tools able to process all the knowledge grasped from smart products and generated by users. (Yerpude and Tarun Kumar Singhal, 2018)

Since customer are used to interact with IoT devices, for them is more difficult to realize the impact that their actions have and how big is the change in the way firm elaborate their data and information. Smart devices significantly impacted the conventional shape of customer-centric approaches; in fact, thanks to IoT it was possible to accelerate the marketing process and increase the number of chance companies have in order to leverage touchpoints and strategies to reach a wider audience of customers and retain the old ones. (Hashem, 2021).

IoT influences some fields that are implemented through CRM practices (Hashem, 2021):

- Decision making capabilities of the company. For decision makers it is easier to make more informed choices because of all the data they dispose of that concern their products, warehouses, customers. This allows companies to reduce the room of mistakes or consequences resulting from bad decisions. Of course, IoT is only a tool that helps decision makers who still have the responsibility of making the right decision at the right time.

- Data collection. IoT accelerated the process of data collection and contributed to the creation of a framework that supports knowledge and information flows in different application and stores. This helped companies to collect data on customers but made firms aware of privacy issues too.
- Marketing management. IoT collects data that can be specifically addressed to marketing purposes, for example by feeding the machine learning matrixes that have the task to analyze and process the behavior and preferences of customers in order to elevate the content of the information.
- Customers experience that can be fostered by more customized products and services in less time than before, thanks to IoT and smart devices.

Shorter time of data collection and big data analytics enable firm to sustain or create their competitive advantage thanks to IoT that interacts with CRM tools. In addition to that, all these processes implemented by IoT technologies, help companies to enhance customer loyalty, create new long-lasting relationships based on personalization, manage all customers on the basis of the same starting point, create a sense of membership towards the firm in the customer.

2.4.3 New customer relationships

The rise and affirmation of IoT devices and the implementation of CRM techniques and platforms lead to a change in the type of relationship that occur between the customer and the firm.

Customers become "connected customers" that increase their level of interaction not only with products they purchase, but also with the firm itself (Subramaniam, 2022). In fact, the nature of Smart Products allows customers and manufacturer to have a direct and ongoing dialog; this constant series of interactions make the company aware not only of the potentialities that can arise form customer interaction but also of the information that the product gives to firm, that is now seen ad window into the need and satisfaction of the customer. Moreover, the customer is often part of the value creation of the smart products he/she buys. (Chouk and Mani, 2022; Heppelmann and Porter, 2015)

As we could see from the theoretical background concerning CRM and ERP systems, it is possible to assess that IoT, and in general Smart Products, transformed the way how companies perceive data, customers' relationship and also the role of the firm in a competitive environment.

3. IoT and Big Data for Circular Economy

In the present chapter, the concepts of circular economy and sustainability are defined. We will analyze the relationship between IoT and circular economy, in particular to what extent IoT can be considered as an enabler for circular economy. Lastly, we will answer the research question on how firms can exploit data generated from smart products, hence enabled by the IoT, to achieve sustainability goals and circular economy principles.

3.1 Circular Economy and Sustainability: Theoretical Framework

In this section we will present a theoretical framework that will help the reader to have better and clearer understanding of the concepts that are at the bases of our analysis.

3.1.1 Circular economy

Nowadays, circular economy (CE) is everywhere, and a growing interest has been shown not only by scholar and researchers but also by policy makers and associations/foundations; but what is exactly circular economy? The very first approach to CE was theorized by Boulding, (1966). In his article he talks about a future in which there will be a closed economy called the "spaceman" economy. He hypothesized that the earth is similar to a spaceship whit limited reservoirs, either for extraction or for pollution, and people must find their place in a cyclical ecological system which is able to continuously regenerate material. Moreover, new output produced in the "spaceman economy" should be minimized rather than maximized, this because resources are limited and everything should be transformed rather than being generated as new. One of the most well-known definition of circular economy, it is the one given by the Ellen MacArthur Foundation (2013) that defined CE as: "a systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution. It is based on three principles, driven by design: eliminate waste and pollution, circulate products and materials (at their highest value), and regenerate nature".

Since in the literature there is no common definition for CE, we will base our work on the definition given by Kirchherr et al., (2017). In their work they analyzed a total amount of 114 CE definition with the aim of giving a homogeneous perspective of what CE is and which are its principles and mechanism. This is the first study conducted with this aim regarding CE. In this regard Kirchherr et al., after analyzing all the definition in question, according to a coding framework, defined CE as "as an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers."

It is possible to consider this definition a complete one; it includes the context in which CE sees its application, the "R" framework (we will explain it in the next lines), and the operating levels of CE: micro, macro and meso. As said before, in this definition there are mentioned the words "reduce", "reuse," "recycle" and "recover" concepts that are included in the "R" framework. Even for the "R" framework there is no a specific and unique theoretical background in the literature but, there are similarities among the various definitions. More or less, the word included in the "R" framework are always the same but the number may vary from the "3-R" to the "10-R" framework.

One of the first examples of the expansion of the "R" model in the literature can be attributed to Sihvonen and Ritola, (2015) that in their work introduced the concept of "ReX". The ReX model consist of the "3R" basics components: reduce, resuse and recycle with the addition of recover. These four components are then split into additional phases that take into account the life-cycle of products: (i) pre-use phase that involve the "reduce" component, (ii) the use phase that involve the "reuse" component and the (iii) post-use phase in which are involved the "recycle" and "recover" components. In the literature there are analyzed different "R-frameworks": the 3R (Brennan et al., 2015; King et al., 2006), the 4R (Yang et al., 2017), the 6R (Jawahir and Bradley, 2016), the 9R (Potting et al., 2017; Van Buren et al., 2016), or even the 10R (Fornasari, 2022; Kirchherr et al., 2017). For this study we will take into account the ones presented by Fornasari, (2022) and Potting et al. (2017) that, in a sense, embedd all previous studies.

Potting et al. (2017) propose a "9-R" framework in which all the principles listed are ranked according to their degree of circularity from high to low. On the other hand, we have the "10-R" framework proposed by Fornasari (2022), which principles follow a time based logic and also the lifecycle of the products.

Table 9 - "R" framework comparison

	Potting et al. (2017)		**Fornasari (2022)**		
	Principle	**Definition**	**Principle**	**Definition**	
R0	Refuse	Make product redundatn by abandoning its function	Reuse	Think new products with components that	R1

		or by offering the same function with a different product.		can be reused in other contests.	
R1	Rethink	Make products use more intense, for example using a product for multiple purposes.	Repair	Build products easy to repair you don't need to replace them in case of failure.	R2
R2	Reduce	Preventing activities before a product become waste.	Reduce	Weighted onsumption of energy and materials during the life cycle of the product.	R3
R3	Re-use	Disassemblement of a product with the purpose of reuse its components in a different way.	Recycle	Use recyclable materials for new products and design them easily to recycle at the end of the life.	R4
R4	Repair	Involves a partial diassemblemt of the product for its restoring process.	Refuse	Replacce dangerous substances with eco-compatible one.	R5
R5	Refurbish	Repair components or parts of a product with the aim of enanching its quality and functionalities.	Rethink	Think products to use them in a more efficient way and serve diifferetn purposes.	R6
R6	Remanufacture	The product is restored and labeled as "like-new" and its core identy remain the same.	Refurbish	Recontidion prodocts or components to meke them look new again.	R7

R7	Repurpose	The use of the same product (with no intervention) for new purposes.	Remanufacture	Rebuild a product using a combination of reused, repaired and new components.	R8
R8	Recycle	Diasassembly of the product in different components to satisfy different purposes.	Repurpose	Find a new use for the product, which was not compared to the original one.	R9
R9	Recover	Incineration of material with energy recovery.	Recover	Restore a product to become functionl again and find its lost purpose.	R10

(Source: adapted from Fornasari, 2022; Potting et al., 2017; Sihvonen and Ritola, 2015)

As we can see from the table, autors gave different interpretation of some of their "R" principles. Some of them are more concerned with the material part of the products while others are more focused on the principle that states behind that specif action. Also the way they listed the "R" principles is different. As we said before, Potting ranked the strategies according to their degree of circularity in which "refuse" and "rethink" are considered high circularity strategies that decrease the consumption of natural resources and materials used involved in the production process, while "recycle" and "recover" are considered low circular strategies more in line of what we can consider a linear approach to the economy.

The apllication of a circular economy perspective allowed the transition from a linear consumption model, based on the "take-make-dispose" principle, to a circular apllication of of natural resources and materials in the making and use processes of products.

Before making a comparison between the two models, it is necessary to enanche the principles that states behind CE according to the Ellen MacArthur Foundation (2013):

1. Circular economy aims at reducing to zero waste. In this perspectiv the design of products must be focused on optimization for disassembly and reuse.
2. Ce introduces a substantial difference between consumable and durable components used in the production process of objects. Consumables are made of compostable, biological, organic and non-toxic ingredients that can safely return to the biosphere once

they are dismissed and disassembled. In this wat the "waste" produced can be used for new purpose. Durable, such as engines, laptops, smartphone should be made in a way that their components could be easily disassembled and used for a new purpose. Of course, these products are made of technical components, which are not suitable for the biosphere.

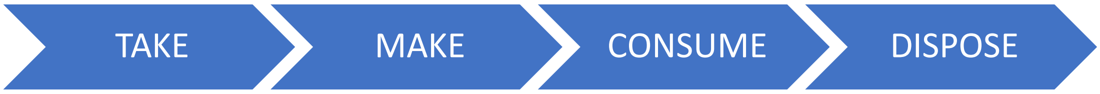
3. For the production processes it is required the employment of renewable energy (e.g., solar panels, wind turbines, biofuels) to decrease resources dependence and increase system resilience.

In addition to that, according to the report on circular economy vision for a competitive Europe (Ellen MacArthur Foundation and McKinsey Center for Business and Environment., 2015) the three principles of circular economy can be translated into six business action that are summarized in the ReSOLVE framework, which helps companies in generating circular strategies and growth initiatives:

1. REgenerate refers to the change from nonrenewable to renewable energies and materials. Waste is converted into sources of energy and raw materials surplus are used in other production chains.
2. Share refers to the actions of sharing the product among multiple users, extend its lifetime value through maintenance and repairing systems and design the product in order to be durable and easily disassemble for recycling purposes.
3. Optimize is about increasing the ration among performance and efficiency of a product; reduce at minimum the waste in the production and supply chain processes; leverage big data, automation, remote sensing, and steering (in this regard, in the next section, we will see how IoT can be an enabler for CE).
4. Loop is about keeping materials and components in a closed loop of production and consumption.
5. Virtualize refers to the service-focused strategy, hence the process of virtualization of utilities (e.g., e-books, streaming services for music, e-commerce).
6. Exchange model implies transferring non-renewable materials and goods into renewable once thanks to the application of new technologies, products and services (e.g., 3D printers)

The three pillars and the ReSOLVE framework can be considered as enables for the switch from the linear model of consumption and production to the circular economic model. The linear model, based on the "take-make-dispose", consists of acquiring huge quantities of raw material to produces different products with several purposes that, once their functions are expired, are reduced into simple waste. In this way products lose their value as soon as they are thrown away.

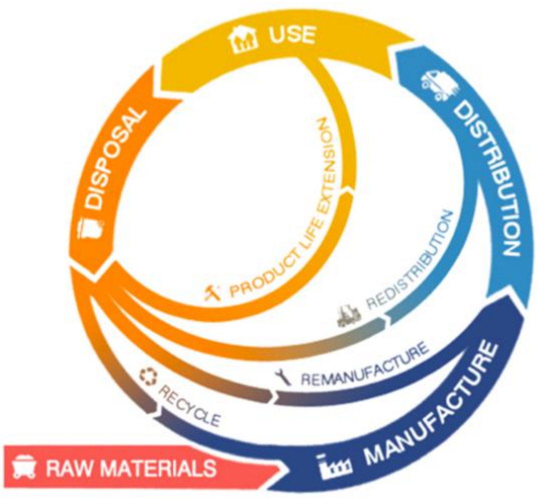
Figure 9 - Linear Model of Production and Consumption



(Source: author processing)

On the other hand, the circular model state that the material to build a new item must be taken from, organic, renewable resource and from components that were embedded in other products that now are employed for other purposes. The energy employed must come from renewable sources and once the product is coming to its end it must be disassembled and its part reintroduced in the production process of another item. The circular model also involves the use of waste produced from an industry, into a completely different production process of a diverse field of application. This closed loop system allows raw materials, components and products to not lose value along the production process (Elisha, 2020; Ellen MacArthur Foundation, 2013).

Figure 10 - Circular Model



(Source: Askoxylakis, 2018)

The Ellen MacArthur Foundation (2013) report on Circular Economy presents the main building blocks for CE in order to create a "winning" environment for all the actors involved in the process:

A. Skills in circular product design and production. It is important to choose the material optimized for the circular setup. The design of products must be durable in time. In addition, modularity and standardization help the process of substitution in case of failure of some components. This method of building also makes easier to disassemble products in preparation for their next round trip

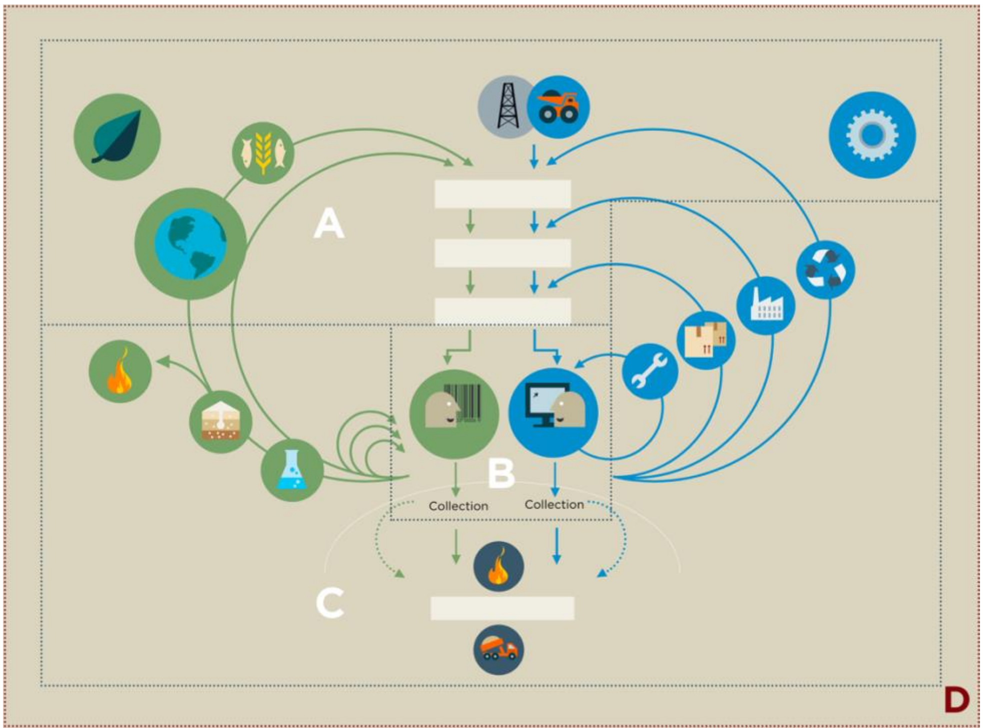
B. New business models: the shift from a classic production model to the one based on long lasting and highly efficient products, creates the basis for new business models focused on usage and performance-based payment models. For example, leasing, hiring, pay per use or performance, sharing systems.

C. Skills in building cascades and/or reverse cycle. At this regard collection systems must be user-friendly, located in accessible areas by customer and must be capable of maintaining the quality of the materials reclaimed to minimize the leakage of components and materials out of the circular system.

D. Enablers to improve cross-cycle and cross-sector performance. Joint product development and infrastructure management are facilitating factor for circular systems. This is also true for favorable investment climate and the education system, which can be considered as a vehicle to increase awareness in young generations. Governments and policy makers play an important role in creating a favorable environment to implement and enhance CE.

In the picture below there are represented the framework we described above. Moreover, it is an extended representation of the circular model of production and consumption.

Figure 11 - Circular Economy building blocks



(Source: Ellen MacArthur Foundation, 2013)

According to the Ellen MacArthur Foundation (2013) we can present a win-win framework for the actors involved in the CE processes economies, companies and users/consumers:

- Economies adopting a circular economy perspective will first of all, reduce the amount of raw material used, this is translated into cost savings that shifts down the cost curve and companies can mitigate price volatility and supply risks. CE, if mainly applied in the service sector, will foster innovation, employment and capital productivity. Moreover, externalities are reduced as the volume of material and products are reduced. Lastly, the circular approach allows well established economies to be more resilient, hence their dependency on the resource market is reduced and the exposure to price shocks and environmental costs are reduces as well.
- Adopting a circular approach, companies may achieve short and also long-term cost benefits and strategic opportunities. The cost for materials will be reduced and also the cost related to warranties will be mitigated thanks to the nature of a circular product "built-to-last". Hence, products are less complex and their lifecycle is more manageable. Customer relationship shift from "consumer" to "user"; this allows companies to improve their customers' interaction and loyalty as well.
- Consumer and users present several benefits. First of all, thanks to the extended durability of products, they will see the total ownership cost decrease. Secondly, products components are customized for users, this led to convenience and greater freedom for choice. Lastly, since circular products are optimized, they do not absolve only a specific function but can be used to pursuit different objectives, for example a flower vase that act as air purifying.

These threefold perspectives allow us to understand the benefits that CE can bring into an economic system and how the actors relate among them to obtain advantages.

Nowadays, climate change, excessive exploitation of natural resources, misappropriation of natural ecosystems, extinction of some species of flora and fauna are all consequences for the massive human attack to the resources this planet has given to us. Having said that, it is important to have some economic models such as the circular one to change direction towards a more sustainable model for us and the planet. In this regard, later on, we will briefly analyze the concepts of sustainability and sustainable development.

3.1.2 Data on Circular Economy in Italy

In this section we will analyze some data regarding CE and its impact on people and economic systems in general. More in detail, we will analyze data at Italian level.

The Circular Economy Network (CEN), Italian association of all the actors involved in the process of the CE in Italy, every year since 2019 releases a report on the state of Circular Economy in Italy in a European framework.

The Circular Economy Network develops its report on the basis of five categories:

1. Production of circular products/services
2. Consumption of circular products/services
3. Waste management
4. Secondary raw material market
5. Occupation and investments

From 2019 to 2022 Italy was the first country in Europe for circularity. This can be seen as a good news but the fact is that the gap that divide Italy from the other European countries, it has critically reduced. France, Poland and Germany, experimented a significant growth in circularity achieving high goals in about a year.

In 2021, the European recycling mean was 57%, Italy was above the mean with 68% of recycling share. In 2022, the percentage for Italy remained stable while the European one reached 35%. This data shows us that during the years influence by the Covid-19 pandemic, CE progression experimented a significant slowdown at European level, while Italy remained stable with no significant growth rate. In the two years interested by the pandemic, globally there was a countertrend: the use of raw materials increased, hence the higher demand of raw materials shook the market, caused uncertainty and fostered companies to increase stocks in their warehouses.

From these data we can deduce that Italy is proceeding in the right direction and can be considered as an example to follow at European level. Of course, the path to achieve higher goals is still long and tough but Italy presents solid bases in order to achieve higher objectives.

3.1.3 Sustainability and Sustainable Development

Sustainability, and more in deep sustainable development, is strictly linked to circular economy. Even though, the causality among the two concept is still no clear at all. It is quite impossible to state if sustainability in an enabler of CE or if the contrary holds. Nevertheless, we can hypothesize that the two concepts are somehow connected and necessary one for the other.

In the dictionary we can find the definition of sustainability as the characteristic of a process to remain constant in a certain level for an undefined time horizon. In our specific work we will analyze the three dimensions of sustainability (Goodland, 1995):

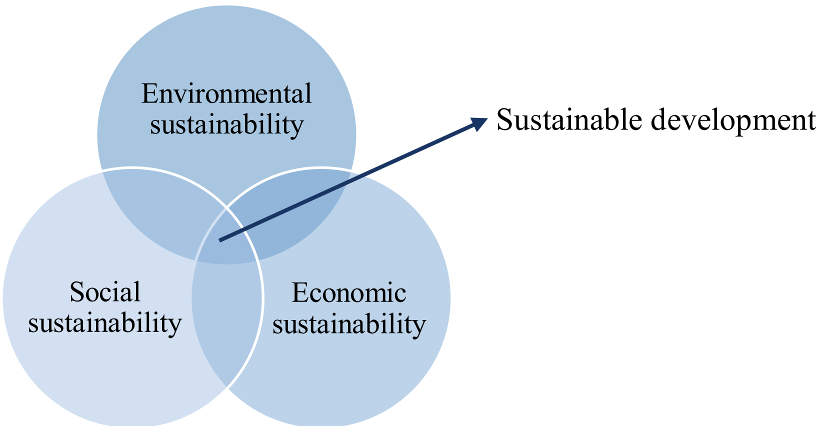
1. Environmental sustainability is intended as "maintenance of natural capital". It is considered as a set of constraints to regulate the scale of human economic subsystem:

the efficient use of renewable and non-renewable resources, on the resource side, and pollution and waste management on the sink side. This means that the natural resources available should be used in a way that will not compromise future generation to make use of the same natural resources.

2. Social sustainability is mainly related to practices aimed at implementing ethics, shared values and equal rights in human communities.
3. Economic sustainability is intended as “keeping capital intact”. Economic sustainability is considered as the ability of an economic system to systematically generate occupation and income.

The three dimensions of sustainability are considered the enablers for a sustainable development. The definition of sustainable development was first mentioned in the Report of the World Commission on Environment and Development (Brundtland, 1987), which state that is: “…development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. Very often in the literature the terms “sustainability” and “sustainable development” are used as synonyms (Johnston et al., 2007).

Figure 12 - Three dimensions of sustainability



(Source: author processing)

Of course, sustainability and hence sustainable development must be supported by some actions and principle that help the system to switch form a non-sustainable to a sustainable model that drives CE as well. In the literature, Kazancoglu et al. (2021), propose us a framework of principles that are necessary for a sustainable transition:

- Interoperability that refers to the ability of smart devices to interact and be connected across the entire organization.
- Virtualization such as digital twin technologies enable workers and management to intervene at the right time with the right technical preparation. In fact, digital twin allows

the 3D virtual reproduction of the object connected and allow workers to practice on it before doing the intervention on the real machine. This of course reduce human mistakes and machines/objects are optimized.

- Decentralization has a higher potential to deal with customized products and complex environment since the is no centrale control mechanism.
- Real-time capability is the key factor for enabling IoT technologies. In fact, thanks to the vast amount of data that can be processed in real time, it is possible to implement various stages of the production processes.
- Service orientation allow the coordination of information in a linear way and the transmission of the latter in real time.
- Modularity refers to flexibility. In fact, with modular systems a company can easily adapt its production systems to the changes occurred in the external and internal environment firms operate in.

As we can see these principles require the support of IoT technologies, digitalization and more in general of Industry 4.0 tools, in the next section of the present chapter we will analyze more in detail the role of IoT in the CE transition.

In addition to the definitions of sustainability and sustainable development, for our work it is important to see which are the sustainable development goals set by the United Nation in the 2015 report: Transforming our World: the 2030 Agenda for Sustainable Development (Organizzazione delle Nazioni Unite, 2015). The report sets 17 goals and 169 targets with the aim of realizing human rights, reaching gender equality and women empowerment. The goals and targets set are integrated and indivisible for balancing the three dimension of sustainability we above-mentioned: economic, environmental and social. Moreover, the goals and targets were set in order to foster intervention in some crucial areas for humans and the planet: people, planet, prosperity, peace and partnerships. Hereunder we will analyze in detail the 17 goals:

1. End poverty in all its forms everywhere
2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture
3. Ensure healthy lives and promote well-being for all at all ages
4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5. Achieve gender equality and empower all women and girls
6. Ensure availability and sustainable management of water and sanitation for all
7. Ensure access to affordable, reliable, sustainable and modern energy for all

8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10. Reduce inequality within and among countries
11. Make cities and humans settlements inclusive, safe, resilient and sustainable
12. Ensure sustainable consumption and production patterns
13. Take urgent action to combat climate change and its impact
14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institution at all levels
17. Strengthen the means of implementation and revitalize the global partnership for sustainable development

The picture below summarizes all the 17 goals set by the UN. The goal of this picture is to allow people to easily recognize the goals and the firms, association, educational institutions, and policy makers that are collaborating to achieve some of them. In fact, visiting websites of some firms it is possible to see which goals they are working on through their effort.

Figure 13 - The 17 Sustainable Development Goals (SDGs)

(Source: "THE 17 GOALS | Sustainable Development," n.d.)

As seen in this section we analyzed a theoretical framework for circular economy, sustainability and sustainable development. It is possible to deduce that the three elements are strictly linked one to the other. We can say that the circular model aims at sustainability and in some sense, sustainability is supported by circular strategies and models.

3.2 IoT as enabler for Circular Economy

In this section we will analyze the relationship between IoT and circular economy. We will try to understand how the Internet of Things can be considered an enabler for CE. Moreover, we will see that most of the cases are related to the industrial sector, only few are related to B2C products, in fact, in this field, IoT is still in an early stage.

First of all, we will see which are the types of CE transitions according to the use of technology in products chains (Potting et al., 2017):

1. Radical innovation in core technology. The transition is fostered by a radically new technology. Socio-institutional change is needed to give the new technology a place in society (e.g., bio-based materials)
2. Incremental innovation in core technology and centrality of socio-institutional changes. In this case technological innovation plays a minor role or no role at all. In fact, this type of transition is based on the adaptation of existing technologies within existing innovation systems (e.g., packaging-free shops).
3. The third type of CE transitions is characterized by a strong socio-institutional influence, facilitated by enabling technology. An example is the transition to what has become known as the sharing economy. This transition from owning a product to purchasing its services primarily involves a socio-institutional change, but this is not possible without IT to link service providers and users.

These three types of transition help us to understand how IoT can be considered a useful tool to implement circular strategies and designs and create new technological architectures. The key roles, in all the three types of transition, are played by the degree of commitment of the socio-institutional environment and the technological shift. For technological shift, it is also intended the role of IoT into the upgrading process.

From one side we have IoT that connects products and machines through a network in order to generate data and optimize the use of physical objects, this streamlines human and economic processes; on the other side we have circular economy that, through the circular model, previously analyzed, it is able to reduce the consumption of raw materials and waste production. These two paradigms are somehow interconnected and present the right characteristics to be one the compensation and enabler of the other. The interaction among the two, of course, are going to reshape the nature of services, products, business models, and ecosystems (Askoxylakis, 2018).

On one side, there are some implications we should take into account when we talk about integration of CE and IoT (Antikainen et al., 2018):

- Requirement of financing funds to drive new ideas into successful business models that will help the shift from product-oriented to service-oriented mindset.
- Regulations on data sharing, ownership and privacy among competitors and actors. As we have seen in Chapter 1, privacy and security are still an open issue for the actors operating in Industry 4.0.
- Training costs for operators to implement the process of ICT and sustainability related competences. When integrating the two systems, it is necessary that all the actors involved in the integration processes are able to understand which are their duties and roles in the process. Moreover, there is the need for a correct management of the tools and resources produced.
- Collaboration among different partners, combining the best of each (e.g., technologies, knowledge, skills) to reach sustainability goals.

These implications can be defined as challenges for the shift from the linear to the circular model of consumption and production with the integration of IoT technologies. Once the process has started it is of vital importance that the actors involved have the right tools to overcome the abovementioned challenges.

On the other hand, we analyzed some papers from the literature (Pagoropoulos et al., 2017; Pardo, 2018; Rizvi et al., 2021; Voulgaridis et al., 2022) and summarized the main benefits deriving from the integration of CE and IoT technologies:

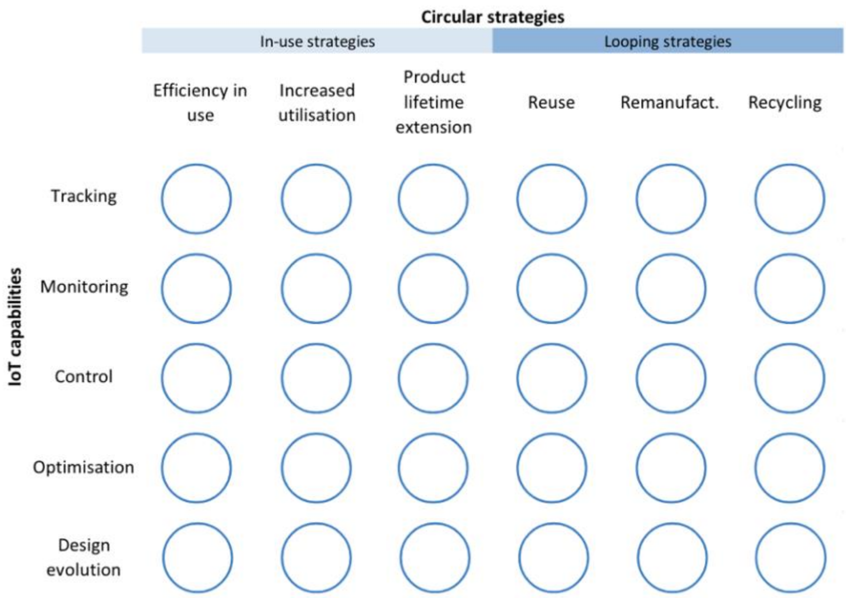
1. Data collection, analysis and integration. These processes are vital in the supporting process and system optimization for CE transition.
2. Promotion of decentralized manufacturing and enterprise systems. Thanks to IoT and IIoT it is possible to remotely follow the processes of production, this allow firms to have more plants and function can be spread across different locations.
3. Predictive maintenance that is possible thanks to sensors embedded in the product/machines delivering real time data on the use and state of components. Thanks to this data it is possible to prevent downtimes and repair or substitute damaged components hence, reducing the amount of waste produced.
4. New business models rise and implementation such as product-as-a-service, sharing economy.

5. Enhancement of more sustainable consumption patterns. It is possible to exploit IoT to obtain information about products and services, implement the sharing economy processes that allow consumers to make more informed choices about the products/services they buy or use.
6. Better management of recycling and recovery of materials (resource efficiency). Through IoT technologies it is possible to implement the management of resources and waste optimizing principles of disassembly and reuse of materials. Moreover, IoT is one of the key enable for reverse logistics processes which are a core element for closing the material loop enhanced by the circular model.
7. Quality improvement. As a consequence of better use of resources and raw materials, it is possible for firms to focus on the quality of products, services and processes. Products are now designed to last longer and can be easily processes for maintenance. Moreover, also the quality of labor increase since some functionalities are now digitalized.

We can say that the above-mentioned benefits can be considered as “direct” ones. IoT has several benefits on CE processes also through “indirect” approaches. For example, reducing the demand for cotton through new business models based on clothing rental, second hand and swapping systems, causes a decline in the amount of land needed to grow cotton thus freeing areas to restore ecosystems and biodiversity. The same process occurs for the marine areas, in fact, IoT can monitor fishing boat and prevent the massive exploitation of the marine stocks allowing the system to maintain its equilibrium and restore itself (“How the Internet of Things can help the circular economy,” n.d.).

For what concern real cases application, Ingemarsdotter et al. (2019) in their work built a matrix presenting from one side IoT capabilities (tracking, monitoring, control, optimization and design evolution) and on the other side circular strategies divided in “In-use strategies” and “looping strategies” (reuse, remanufacturing, recycling, efficiency in use, product lifetime extension and increased utilization) that applied on a sample of 40 relevant cases. The 40 cases cover a variety of products and industries, targeting different customer groups, hence it is an heterogenous sample of companies.

Figure 14 - Matrix of IoT capabilities and circular strategies



(Source: Ingemarsdotter et al., 2019)

The result obtained show that current implementation of IoT-enabled circular strategies mainly supports “efficiency in use” and “product lifetime extension”; on the other hand only few companies showed IoT-enabled “looping” and described “design evolution” for circular economy. Of course, this is only a single study, but it can be useful to have a clearer view of how firms and CE principles interact among them and which processes are more influenced by CE.

As we have seen from the literature so far analyzed, IoT is a valid enabling tool for the transition towards a circular model. Nevertheless, it is less clear the causality that link the two paradigms. Almost certainly, we can assess that circular economy without IoT implementation will exist but the management of the enabling circular processes will be harder. On the other hand, IoT can exist without the application of CE but, if we carefully think about IoT processes, we can agree that these processes indirectly and implicitly support some CE principles. For example, a manufacturer (not very keen on sustainability or circular strategies) implements its machines with IoT technologies with the purpose of increasing machines’ efficiency, reduce downtime, prevent maintenance, track the use of machine in order to repair only some mechanism and not the whole system, reduce use and waste of raw material he employs in the production processes and lastly energy efficiency to reduce costs; even if the manufacturer is not interested in circular strategies and principles, implicitly he is applying IoT to reduce waste, consumption and implement efficiency, all these actions recall some circular principles.

For the reasons we stated above it is quite hard to assess the causality relationship among the two, surely we can state IoT is an enabler for CE and helps the latter to achieve its principles; for this reason there is a positive relationship among the two.

3.3 How to exploit Data for Circular Economy and Sustainability Goals

In this section we will take a closer look at the relationship that occur between data generated thanks to IoT (Big Data), circular economy and therefore sustainability.
In this regard, it must be done a useful distinction between data generated by B2B connected machines and objects and B2C smart products. Even if firms and customers may generate some similar data, their application for CE principles may be different. Data generated in the B2B sector, hence thanks to IIoT applications, are the ones obtained thanks to connected machines. These data are mainly employed within the firm to implement the overall efficiency processes of companies linked to production systems, organizational issues, value delivery processes, management of resources (physical, capital and human), hence CE principles must be adapted to the required context of application. On the other hand, data generated by smart products, (B2C sector) not only help firms to empower their products or services but help also customers to satisfy their needs. In this regard, data have a twofold purpose: help companies and customers; while, in the B2B sector the purpose of data is linked to the empower companies.
On the basis of the literature analyzed and the knowledge cited in the above chapters and paragraphs, we will build a framework to better understand the relationship between circular economy and Big Data. The table below propose a framework of analysis in which there are summarized the relationship between data and circular economy principles and strategies. CE principles listed in the table are based on the ReSOLVE model and "R" framework already analyzed in section 3.1.1 of the present work.

Table 10 -Relationship between Big Data and Circular Economy principles

	Big Data	
CE principles and strategies	**B2B**	**B2C**
Reduce	Thanks to IIoT it is possible to take track of the material used and also the previsions of market demand are more accurate, hence surpluses are reduced, and the production	Smart Products deliver useful insights on users' preferences; hence companies can exploit this data do adapt their production and produce only necessary items to satisfy a specific number of requests.

	system results to more efficient. Consequently, waste is reduced.	
Reuse	During the production process some waste is produce. Thanks to IIoT companies are aware of the amount of waste produced and these quantities can be used for another production process or can be sold to companies operating in a different industry.	In this case, data generated from Smart Products may be used by consumers to transform the primary purpose of the object into a different one. In this case it is possible that companies can take the product back and use it for other purposes.
Recycle	Data on material and components help companies to correctly disassemble their waste or surpluses resulting from the production processes.	In the recycling phase consumers can exploit data generated by their products to implement the management process of disassembling.
Regenerate	Data on energy consumption help companies to reduce their impact on the environment and help them to switch from nonrenewable to renewable energy sources.	The same process occurs for customers.
Share	Data of all types stored on cloud may be shared among different actors working and cooperating in the same value chain, this acts as integration and allow companies to share and consequently reduce the amount energy used to store, process, and analyze data (e.g., industrial symbiosis)	In this case there is not direct correlation between data and Smart Products, but IoT enable a series of tools for end users to allow them to share the use of a single product hence, costs are reduced, and also possible pollution is spread among users.
Optimize	Data on the status of connected machines helps companies to apply principles of predictive and preventive maintenance implementing the efficiency of	Data on use of smart product allow customer to optimize the use of their objects and allow companies to intervene promptly before the item is broken.

	machines and avoiding buying brand new machineries.	

(Source: author processing)

From the table we can assess that Big Data directly support CE processes in the B2B sector while they are an indirect support for what concern the B2C sector.

To conclude we can say that data play a significant role in the circular transition. For this reason, they are a useful resource for companies to implement not only their circular strategies but also achieve some of the 17 Sustainable Development Goals (set by the Agenda 2030) that we mentioned above, in particular goal n. 9 which aims at building resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation, goal n.11 and 12 which aims at building sustainable cities and communities and foster responsible and sustainable production and consumption processes, lastly goal n. 13 which is directly linked to concrete and real actions to fight against climate change.

4. IoT, Circular Economy and Big Data: Real cases application

The relationship between circular economy, big data and IoT is complex and interdependent. The integration of big data and IoT into the circular economy allows for a more accurate and efficient use of resources, enabling organizations to make better decisions, reduce waste. By leveraging the vast amounts of data generated by IoT devices, businesses can optimize their processes and systems, promoting a more sustainable and closed-loop economy.

In this chapter, after reviewing the theoretical background to get a more complete framework of analysis, we will present an example of a B2C company that through the use of IoT devices and the data they generate, seeks to achieve goals related to circularity and sustainability. We will base our qualitative analysis on an interview with the CEO of Huna, Santo Lico, and helpful material and information contained in the company's website.

4.1 Methodology

To support the theoretical implication of the present work, we decided to analyze the work of a company operating in the B2C industry. Hence, this implies that the selected company must satisfy some criteria:

1. Operate in the B2C market (or if mainly B2B companies, have at least one business unit dedicated to the B2C sector).
2. Offer at least one Smart Product or a system for smart connected objects through the implication of the use of IoT technologies.
3. Be willing to actively sustain circular and sustainable goals.
4. Be an Italian company or a foreign company with operating offices in the Italian territory.

No particular standards were set for the size of the company not only in terms of volume of sales and revenues but also in terms of human capital and economic status of the firm (SME, start-up, new entrant, incumbent).

Three different sources of information were taken into account to choose the company that would be the subject of this research. More in detail, three websites were considered:

- Confindustria (https://economiacircolare.confindustria.it/ch/). Confindustria is the main representative organization of Italian manufacturing and services enterprises, grouping together on a voluntary basis more than 150,000 enterprises (Confindustria, n.d.). As part of its promotion of new projects aimed at supporting circularity initiatives, Confindustria initiated a competition to identify best-performing companies in the circular economy with the aim of providing information, examples and tools to size the opportunities offered by the circular economy and the impact it can have on businesses and the entire economic-productive system. In the section “Case History” of the website are listed all the companies that achieved sustainability and circular goals. It is a sample of 113 companies listed in the database in the appendix.

- IoTItaly (https://www.iotitaly.net/esempi-internet-of-things-casi-di-sucesso/). IoTItaly is a nonprofit association whose purpose is to represent the interests of companies that have activities in Italy related to the Internet of Things. The association acts as a meeting point between companies producing IoT technologies and companies interested in future implementation. Through networking and evangelism, the association wants to help write the future of the Internet of Things in Italy (IoTItaly, n.d.). In the section “Esempi Internet of Things” there are presented 7 case studies about firms implementing their strategies through IoT. Not all of the companies listed achieve sustainability and circular goals, we will see it more in detail in the selection process explained below.
- Smau (https://www.smau.it/). Smau is an independent and dynamic platform that, thanks to its many events, gathers around it companies, startups and big players; in particular, all those realities that are working with passion and energy to revitalize the Italian economy and Made in Italy branded innovation (smau, n.d.). On the website dedicated to the 2022 Paris edition a total of 33 startups were listed (https://www.smau.it/paris/).

The total number of companies resulting from the three surveyed websites is 153. From this starting number, companies that did not meet the above requirements were gradually eliminated. In detail, we will see the process of selection of the companies that were chosen as potential case studies for the present analysis. All the firms taken into account are Italian or, if foreigners, with a production plant based in the Italian territory.
On the basis of our sample of companies, we built a database (Appendix A) in which every firm was categorized according to some requirements; figure n. 15 shows the labels and parameters analyzed for the sample of companies.

Figure 15 - Labels from the author's database

Company's Name	Industry	Source	B2C		B2B		IoT/IIoT			
							Yes	Not mentioned	No	Sustainability & CE

(Source: author processing)

First of all, we identified the company’s name, then we specified in which economic sector the selected companies belong to. A great number of economic sectors emerged but the most recurring ones can be classified as follow: energy, service, waste management, food and agriculture, packaging, textile, building material and chemistry. In the "source" label it is mentioned in which sub database the company was found: Confindustria, smau or IoTItaly websites. For each company, it was analyzed the website in order to understand which was the reference market for the products or services they provide. After this further investigation it was possible to state if the company operate mainly in the B2C, B2B or in both spheres. Once established the application field, it was taken into account the presence of IoT or IIoT technologies in three different ways:

- "Yes": the company presented some IoT technologies regardless their application in the production or delivery processes of products or services. Afterwards, we proceeded to check whether the IoT technologies they possessed were in any way related to circular and sustainability issues.
- "No": the company did not make use of IoT technologies.
- "Not mentioned": there is no explicit reference from the company that it might make use of IoT technologies. We might assume that such technologies are being used in some production processes, but we do not know it for sure.

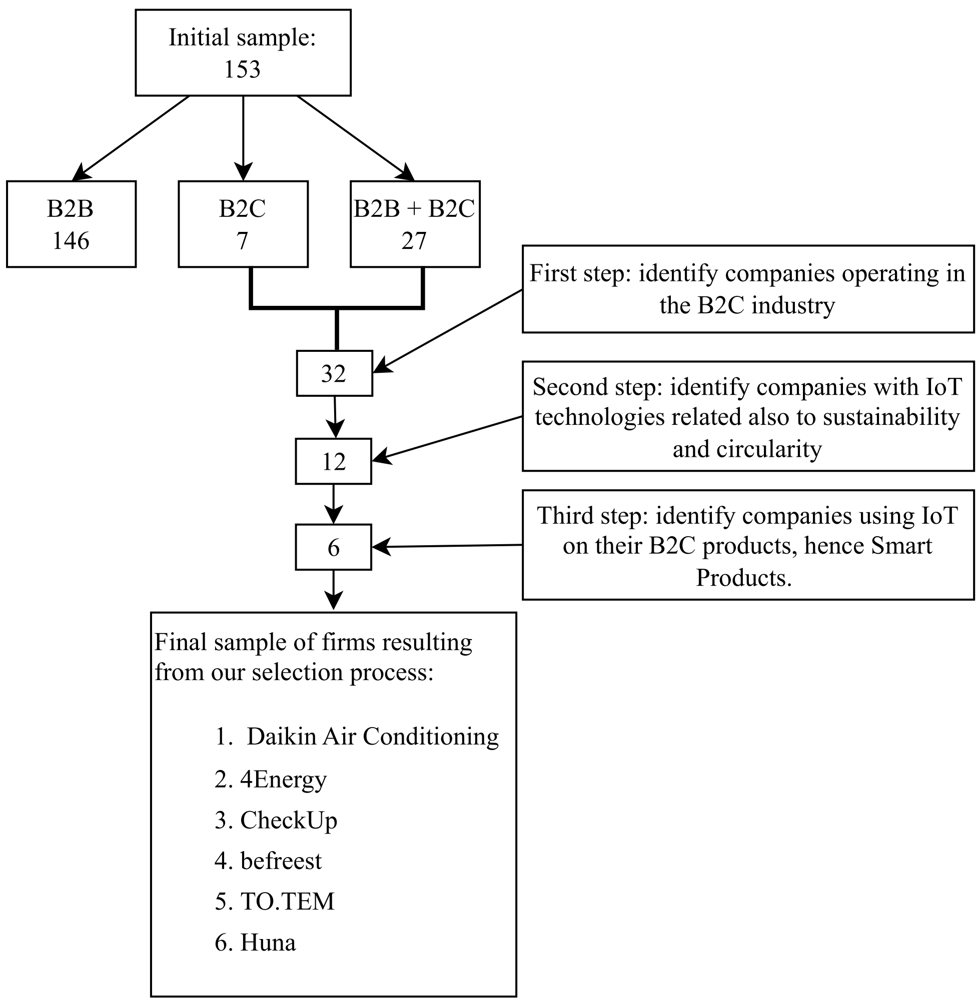
Lastly, we tried to understand if the application of IoT technologies were an active part in reaching sustainability and circular economy principles. In the following section, we will see in detail the selection process that was carried on in order to identify the probable companies subject to our study.

4.1.1 The selection process

A total number of 146 out of 153 companies resulted to operate in the B2B sector, hence only 7 of the sample operate only in the B2C market. Moreover, it must be outlined that 27 companies operate in both B2B and B2C sectors.

First of all, companies working only in the B2B sector were excluded, our sample is now reduced at 34 firms. From these 34 companies we had to see if they used IoT technologies and if these technologies were related to sustainability and circular goals. It emerged that only 12 of them applied IoT technologies; in detail, half of the companies applied IoT technologies in the B2C sector for sustainable and circular purposes; the other half presented some IoT application but were mainly related to production processes and not all of them had sustainability and circularity as main target. Some of these B2C companies that apply IoT to their production processes, used IoT to produce more sustainable items such as bioplastic products, eco cleaners, clothes with recycled fabrics, but in these cases, the products that reach the end customer are not connected objects (even though part of their production process was made possible through the implementation of IoT technologies).

Figure 16 - The selection process



(Source: author processing)

The six companies resulting from our selection process are the following:

- **Daikin Air Conditioning**. Daikin was founded in 1924 in Osaka with no more than 15 employees. In the late 50s it grown and had about 3,000 employees. In 2014, Daikin became a global company operating in more than 145 countries with more than 60,000 employees all over the world. Nowadays, Daikin is one of the leading companies in the air conditioning equipment (Daikin Global, n.d.). Daikin is a company that aims to contribute to sustainable growth for the world by solving social problem and providing society with new value. Is actively supports the Sustainable Development Goals (SDGs) set by the Agenda 2030, more in detail, Daikin aims at delivering affordable and clean energy (goal n. 7), fostering innovation industry and infrastructure (goal n. 9), building sustainable cities and communities (goal n.11), ensuring responsible consumption and production patterns (goal n. 12) and lastly, being an active actor in the climate change challenge (goal n. 13) (Daikin Global, n.d.). Daikin offers solutions to both firms and customers (end users). For what concern our analysis, the focus is on B2C products implemented with IoT technologies in order to enable sustainable and circular processes. In this regard, Daikin developed a set of applications for smartphone that users can download from the app store and are then able to manage their home conditioning system. More in detail, we will see the "ONECTA -Daikin Residential Controller" that enables users to set operational schedules and monitor energy use in their home. Moreover, the app is directly linked to the Daikin cloud which provides predictive maintenance services, this allows Daikin to prevent breakdowns and intervene promptly to solve the problem. Of course, this allows the company to substitute only one part of the system and not the whole object, this reduces waste and increase efficiency (Daikin Global, n.d.). It was impossible to understand if the company uses recycled material for the production processes of its products and smart products. Moreover, the disposal of product at the end of their life cycle and the utilization of production waste are not clearly defined in their sustainability and circular objectives.

- **4Energy** is a company in the renewable industry, it installs solar panels but only in a restricted Italian area: Marche e Abruzzo regions. They offer solutions to both firms and customers in the residential areas. The IoT solution they propose it is a sort of cloud that allow the monitoring of the system. This monitoring system periodically send information to the company, which is then able to prevent downtimes and real time intervention when needed (4Energy, n.d.). This is still a newborn application that need further improvements. Of course, installing a solar panel system will reduce energy consumption and CO_2 emissions too. Also in this case, it is not possible to understand which kind of material are used to produce solar panels and if these panels are produced by external firms or not. This implies a bias in our study because the circular and sustainable objectives are pursued only in the final part of the production process that is the installation of solar panel to use and produce green energy and monitor the system through an IoT device. Hence, circularity is enabled by the promotion and use of renewable energy source and resources optimization thank to preventive and predictive maintenance systems.
- **CheckUp** is a company operating in the design and furniture business. It was born in 1991 with the idea of creating "objects with life inside" as stated in their payoff. Their starting process begins with the identification of customers' needs translated into a design process of the thought solution. They present a wide range of smart products in

their catalogue, but not all of them pursue sustainability and circular principles. Concerning the focus of our study we will consider a specific smart product: ItAir. ItAir is an integrated air purifier that allows users to improve air quality of indoor spaces. It is designed in the form of a smart vase that uses plants for the mitigation of pollutants in soil, water and air. It works as a filter and through forced mechanical ventilation, the system increases the airflow inside the plant and amplifies its effectiveness exponentially. A smart, integrated air regeneration system connects via Wi-Fi to common devices (smartphones, tablets, etc.) through a dedicated app. ItAir guarantees a user experience in real time; using the app the user is able to (CheckUp, 2021):

- Monitor the real presence of pollutants in the air that is being breathed;
- Program the ON/OFF function depending on the level of pollutants detected or at the user's discretion;
- Monitor the temperature and humidity, fundamental parameters for guaranteeing a good level of environmental comfort.

From a sustainable point of view, the smart vase uses the power of plants to eliminate air pollution form indoor spaces. This allows people to have a significant impact in the reduction of energy waste and consumption and less waste is produced with respect to regular air cleaning system that once broken are difficult to correctly disassemble and recycle or upcycle in different production systems. Even in this case it was hard to understand which kind of material were used and how the product is disassembled once broken.

- **befreest** is a startup that produces smart systems to monitor the air quality and reduce the risks of pollutant attacks in indoor environments. Their smart system "nose" can be applied not only in private homes but also in offices, schools and universities, sport facilities, public transportation, hospitals and industrial plants. This smart object is able to take track of CO_2 emissions, fine dust that represent the set of microscopic particles dispersed in the air we breathe in the form of dust, smoke, microdroplets of liquid substances, radon (a naturally occurring, colorless, odorless radioactive gas. It is generated by radium decay, which is the process by which a radioactive substance spontaneously transforms into another substance, emitting radiation), temperature and humidity of the air. The system is connected through a wireless technology to the cloud; the cloud elaborates all the data received by the system and then it sends signals and commands to the "nose" in order to refine the right settings to clean the air (befreest, n.d.). In this case, the company does not specify how the customer accesses the cloud, there is no specification if it occurs through an app or if an extra connected devices is needed. In this case, circularity is pursued by the reduction of pollutants and a more efficient use of resources.

- **TO.TEM** is a startup company operating in the smart mobility business. Their core business is the production of e-kickscooters, which are smart, agile, and equipped with collision warning systems. This new transportation system is called sustainable because it has zero CO_2 emissions and recharges with a minimal amount of electricity. In addition, it becomes smart the moment the users download the dedicated app directly to their cell phone, this allows users to turn their smartphones into a real control panel for the vehicle. The app allows the user to monitor the speed, km covered, GPS system and status of the vehicle. If the app detects any failure in the scooter's system, it is possible to access the "spare parts" section in the app (and also on the website) where it will be possible to purchase only the spare part that was causing the malfunction of the vehicle. In this way, it will be possible to extend the product's life cycle and help the company produce less waste due to its disassembly (TO.TEM, n.d., n.d.). The company does not mention which are the raw materials employed in the production process of the e-kickscooters and, yet again, the sustainability is implied in the type of alternative vehicle used but it was not possible to identify some specific circular purposes in the overall production and delivery processes of the company. On the other hand, circularity of the product itself is enhanced by the use of long-lasting materials and material optimization through preventive and predictive maintenance systems that allow the user to regenerate the product without buying a brand-new one if something brakes.
- **Huna** is a startup company with the aim of developing innovative technological solutions to improve the energy management of urban settings, facilitating their digital transformation. For the focus of our work, Huna developed a solution called “Home Buddy” which is an IoT based product able to manage the smart build system related to private homes. Of course, this system allows the reduction of energy consumption and increase the efficiency of the overall smart building system (“Huna | Home Buddy,” 2018; “Huna | Smart Up The City,” 2018). Huna is the firm that we choose for the "case study” section of the present work. For this reason, in the next section, we will see more in detail how this solution works and how data generated are useful not only for the company but also for users to reach sustainable development goals (SDGs) and circular economy goals.

The table below summarizes the IoT devices’ characteristics and their relationship with circular economy principles produced by each of the selected companies:

Table 11 – Relationship between IoT devices and CE principles of selected companies

Company	**IoT devices**	**Circular Economy**
Daikin Air conditioning	"ONECTA - Daikin Residential Controller" app which is connected to the heating system of the customer's home. It can be used only with Daikin products.	• Resources optimization through preventive and predictive maintenance systems. • Waste reduction.
4Energy	Monitoring system for solar panel to integrate in the customer's smartphone.	• Renewable energy sources utilization. • Resources optimization through preventive and predictive maintenance systems.
CheckUp	ItAir smart vase connected via app to the customer's smartphone to improve the air quality in indoor spaces.	• Waste reduction. • Use of renewable and material for the IoT devices (plants).
befreest	"Nose" smart system (connected via app or extra device) monitors the air quality and reduce the risks of pollutant attacks in indoor environments.	• Employment of long-lasting materials for the device. • Energy optimization. • Waste reduction.
TO.TEM	Smart e-kickscooters with preventive maintenance system manageable by an app.	• Resources optimization through preventive and predictive maintenance systems. • Employment of long-lasting materials for the device

Huna	Home Buddy hub is able to connect the whole home's energy system through a small box connected to an app. It is compatible with all smart products and devices in the home.	• Renewable energy sources utilization. • Recycled material used to produce IoT devices. • Repairing process for faulty components. • Waste reduction. • Resources optimization through the use of existing equipment in the home.

(Source: author processing)

As we have seen, all six companies aim not only for sustainability but also their connected products seek to support the circular transition process. However, some IoT devices turned out to be more comprehensive than others from a functionality and data collection point of view with a focus on circularity and sustainability. For this reason, our attention fell on the last company analyzed: Huna. This reality presents an IoT device that compared to the others appears to be the most consistent with circularity goals. Moreover, the company bases its operations not only on principles of environmental sustainability, but also ethical and economic sustainability.

4.2 Case study: Huna

To enrich and support the theoretical framework analyzed so far, in this section it is presented a case study linked to our topic of discussion. A case study is a research method in which a detailed investigation of a single individual, group, or event is conducted. It can involve collecting data through various methods such as interviews, observation, and examination of documents, and can provide insights into a particular phenomenon or situation. Concerning our specific case of application, we made use of the interview and data collection from the company's website.

The focus of this case study is, through the analysis of an IoT device, to understand which kind of data this product can generate and if these data are useful for the company, and the customer too, to achieve sustainable development goals and circular principles.

4.2.1 Motivation

As case study for our work, we selected the company "Huna". The reasons behind this choice are multiple. First of all, among all the companies it was the one that, according to the objectives set, better employed its knowledge to reach sustainability and circularity goals. Secondly, it is not a multinational company like Daikin it was easier to obtain an interview with the CEO or employees. Thirdly, the data that Huna's systems can collect are more impactful on sustainability and circularity with respect to the one proposed by the other companies as it can be seen in table 11. Moreover, Huna does not operate in a limited Italian territory, so its IoT devices had the chance to be tested much more times and in different conditions and environments. Moreover, Huna clearly states its will to actively sustain environmental, economic and ethic sustainability towards its economic activity.

Thanks to the interview we obtained it was possible to obtain key information on how the product is realized, which kind of material are used and how the company perceive its product sustainable.

4.2.2 Who is Huna

Huna is a startup, based in Milan and funded in 2018, that operates in the energy efficiency sector, not only in the B2B but also in the B2C sphere with the aim to improve the quality of urban areas and infrastructure by simplifying their management, increasing their potential and reducing their costs, with the aim of making cities cleaner, more resilient and inclusive by implementing and experimenting with new technologies. Their vision is to create a sustainable and stimulating environment to live in for businesses and citizens. At the core of their sustainability policies, we find the corporate social responsibility that is a key and determining factor for the success of their future projects ("Huna | Chi Siamo," 2018).

According to the SDGs, Huna actively sustain gender equality and social sustainability (goal n. 5), affordable and clean energy, decent work condition and sustainable economic growth, build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation (goals n. 7, 8 and 9). Moreover, it tries to make cities and humans settlements inclusive, safe, resilient and sustainable through the development of smart lighting systems, as a consequence it ensures sustainable consumption and production patterns and takes active part in the climate change challenge, trying to reduce its impact on the environment (goals n. 11, 12 and 13).

Concerning products (IoT devices) and services, Huna studies, designs and implements advanced remote control and facility management technology solutions: starting from the initial designing planning, up to the implementation and maintenance of the system. Thanks to

continuous activities of upgrading, improvements and R&D activities, the quality of their services, systems and IoT devices is constantly increasing ("Huna | Servizi," 2018).
According to the IoT definitions and the classification we made on the basis of three key factors (physical components, IoT purpose and human components), the IoT devices proposed by Huna embed all these three principles. IoT devices rely on RFID sensors and tag systems which communicate and cooperate thanks to the Wireless Sensor Network (WSN): sensor-equipped devices that monitor the physical or environmental conditions and can cooperate with RFID systems (Atzori et al., 2010). These technologies are supported by the cloud computing which allows the firm to make the data collected usable and interpretable by the customer too. Once that the IoT device is set, it is ready to be used and this is the moment in which it starts to generate data, more in detail Big Data that, as we have seen in chapter number two, are characterized by "volume", "velocity" (data are continuously generated), "variety" (not always data are structured) and lastly "value". Huna can process all the data obtained from its IoT devices and give value to them. In section 4.2.4 we will more in detail how the company is able to give value to the data and how to exploit them to achieve CE and SDG goals.

4.2.3 B2B Products

Concerning the B2B sector, Huna developed several solutions mainly to support municipalities and companies, in detail:

- "Light Touch" is an integrated solution, software and IoT devices that operates in the smart lighting system of a specific municipality. Thanks to the cloud that support this system, it is possible to manage and remotely control the street lighting systems. It integrates the functions for the management of signals and maintenance and also the Geographic Information System (GIS) software designed ad hoc for outdoor lighting structure. Through an IoT device and a mobile app that thanks to artificial intelligence is able to recognize the type of lighting fixture or objects farmed by the camera. In this way, users can take track of the whole lighting systems, are able to intervene promptly in case something does not work as planned and are able to implement the energy efficiency of the lighting system because the app identify which type of light bulb is more appropriate in terms of sustainability and energy saving more in detail, the devices are able to optimize the operating hours of the systems and the brightness level of the lamps. In this way, savings of up to 50% can be achieved compared to traditional LED systems. Thanks to the management and maintenance module of the app, users can access tailormade data based on their role and functionalities. Users can report on the virtual map, through documents or picture, the crucial points in which something is not working as planned. Since Huna expressly state that this is an integrated system, “Light Touch” allows the integration of third-party devices and software within a single platform in order to optimize processes and resolution times (“Huna | Light Touch,” 2019).

- “City Sense” is a system of connected sensor that through the “Light Touch” platform process and generates data about air quality. This allows decision-makers to build and ad hoc environmental policy measures and tailor these policies to the needs of specific points of cities. “City Sense” is an expansion of the “Light Touch” platform that can be monitored in the same mobile app (Huna, 2019b).
- “Eye Light” is an under development system that aims at building a complete suite for traffic flow and vehicle parking management. This system does not require the installation of sensors because the software works exclusively by analyzing the images in real time. Through video analysis it is able to recognize and analyze the vehicles present. It can be applied in urban areas in general, shopping centers, supermarkets and airports. These are only some field of application. “Eye Light” allow municipalities and companies to gather data from traffic flows and parking slots, then they can make this data available for citizens thus allowing them to reduce the amount of time spend looking for a car park and in traffic jams, reducing the consumption of fuel and of course reducing the CO_2 emissions in the environment (“Huna | Eye Light,” 2020).

4.2.4 B2C Products – Home Buddy

Concerning the B2C sector, hence the focus of our study, Huna developed an IoT device called “Home Buddy”, which can be integrate in the “Light Touch” platform. It is a home automation solution for private homes management. “Home Buddy” allows users to manage all the installations remotely, keep track of the consumption generated by each device, save and optimize energy consumption and improve the environment.

In order to collect more information on the product, its functioning and its impact on circular economy and sustainability, we interviewed the CEO and co-founder of Huna Santo Lico.

The software component of the “home buddy” system is entirely produced in-house. On the other hand, for what concern the hardware part, needed to connect the whole system, Huna tries to use commercial hardware or if this is not possible, the hardware part is designed from an external company and is then produced. According to Santo Lico, in the installing phase, they try to optimize all the hardware components that already are in the house, this allows economic savings from one part and sustainability from the other side because it avoids the release of brand-new material. Moreover, Huna tries to use as much as it can recycled material. In addition to that also in the production process if some devices fail the test phase, the company keeps these devices and tries to regenerate, recycle or disassemble them for other purposes.

The combination of hardware and software give birth to the Home Buddy hub which is kind of a small box that must be placed close to the electrical panel or can be disassembled and placed within the same electrical cabinet. Once the hub has been placed it must be connected through a stable and ongoing Internet connection and configured with the existing home system. The Home Buddy hub is able to interact and be integrated with a vast amount of other smart products that can be found in people's houses such as: thermal energy meters, single-phase Energy Meter, three-phase Energy Meter, Z-wave thermostat, air quality sensors, curtain actuators, general purpose actuators and smart plugs.

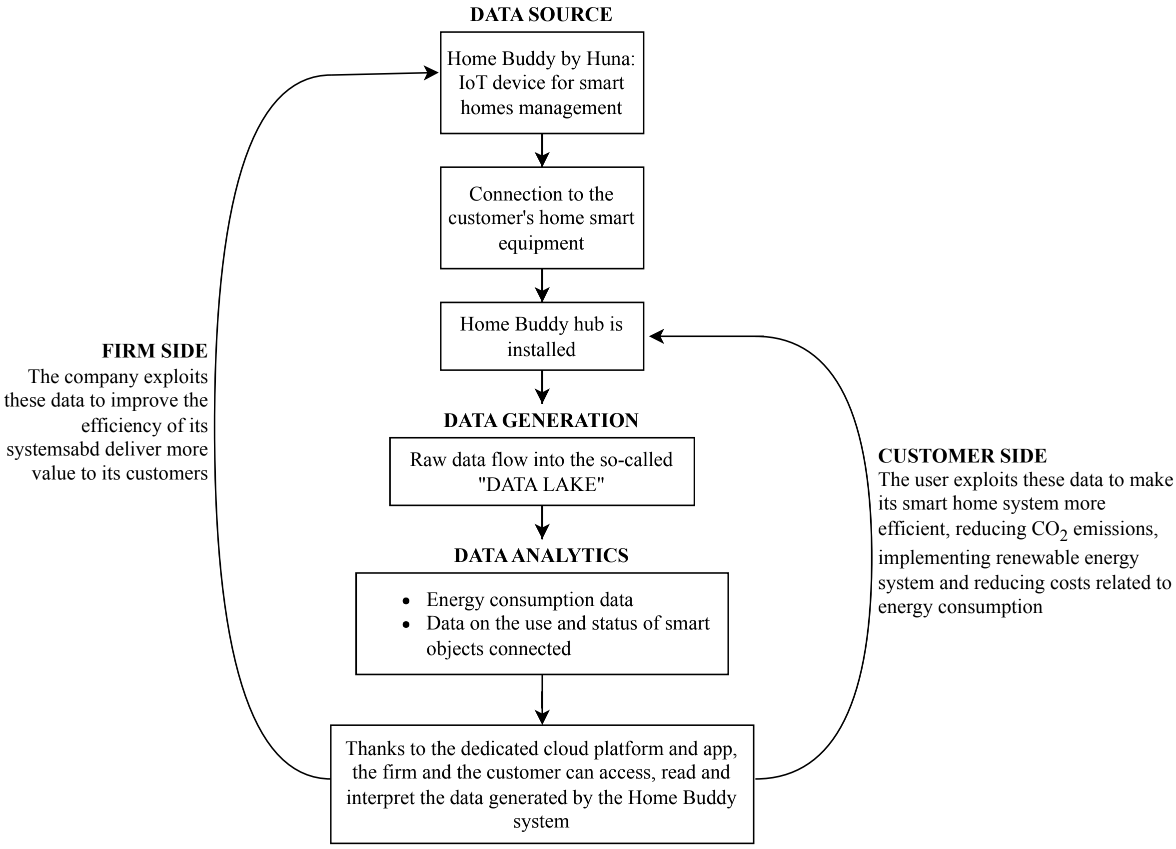
Once the Smart Buddy hub is installed, it starts to process information, which are uploaded to the Huna cloud. Users can access the cloud through the dedicated app, which is essential for exchanging information with the Home Buddy hub that, in turn, communicates with devices in the home: from smart appliances to the boiler and energy and temperature meters. Of course, these connected devices generate a vast amount of data. In particular, Home Buddy collects mainly data related to energy consumption such as: reactive energy, photovoltaic output (if the home is equipped with solar panels), energy exchanges with the power grid so whether the user is giving away energy or buying it, voltage levels and streams of electricity.

All these data are processed and showed to the user who is now able to quantify its energy consumption and see the gain from a more efficient way of managing his/her smart home system. This is translated also into a reduction of the environmental impact of users that decide to invest in more efficient and sustainable management systems for their homes. For the company, having the energy data allows the optimization of devices activations and exploit the most of what is renewable energy or use the heating system at times when energy is cheaper. Huna can exploit all the data collected from the Home Buddy system to improve the efficiency of its products and services updating further versions of the systems sold. Moreover, the company is collecting data to build a system which is able to predict and prevent possible downtimes or breakdowns of connected devices. This will implement the circularity of the company because it will increase the lifetime value of devices that can be repaired in advance rather than being substituted from brand-new products. This process supports the recycle and reuse principles of circular economy.

The Home Buddy solution features a hybrid sales system. It is not entirely marketed as product-as-a-service, but the customer has to pay for the hardware component, in this case the hub, and then a monthly subscription fee is due in order to get access to the platform and the data it generates. Of course, the price of the solution varies according to the home's square meters.

According to the data transformation framework proposed by Heppelmann and Porter (2015), analyzed in section 2.2 of the present work, we will build a similar framework for the Home Buddy system in which the relationship between data, company, customers and data analytics is explored.

Figure 17 - How Smart Buddy works



(Source: author processing based on Heppelmann and Porter (2015))

In the figure above it is graphically explained how data, customer and firm interact among them. First of all, the IoT device is connected to the customer's smart home equipment and the Home Buddy hub is installed and configurated. At this point, Home Buddy is ready to collect and generate data which, in their raw form, flow into the "data lake". From the "data lake", data are analyzed and release information on the energy consumption (reactive energy, photovoltaic output, energy exchanges with the power grid, voltage levels and streams of electricity) and the use and status of smart objects connected. Later on, these data are translated into the dedicated app through the use of the cloud. From the app, the firm and the customer can access, read and interpret the data generated by the Home Buddy system. At this point the path is divided into:

- Customer side. The user exploits these data to reduce its CO_2 emissions, implement the use of renewable sources of energy and reduce the costs related to energy consumption.
- Firm side. On the other hand, the company exploits these data to improve the overall efficiency of its system to generate greater value from its customers. These

improvements, of course, help the company to work on the reduction of energy consumption and the optimization of renewable sources of energy.

As we can see from figure n. 17, data generated flow again in the Home Buddy hub to generate more data; and into the company to implement operational and production processes.

In the next section we will see more in detail how these data are helpful to reach, support and implement SDGs and circular economy principles.

4.3 Findings, Discussion and Conclusion

Not all companies perfectly embody the principles of sustainability and circularity that were the subject of our study. However, it was possible to identify some companies that best approximated what is the goal of our work: understand how the relationships between IoT and Big Data are able to implement sustainability and circularity goals. These companies are the ones listed in the section "Methodology".

As we were able to ascertain, for most of the companies it was not possible to understand what types of materials were used to produce the connected devices, what energy sources were used to carry out the production processes, what the waste disposal process is, and the use of waste from the production process. On the other hand, the targeted companies are striving to find more sustainable solutions for their customers, this is possible thanks to the use of data generated from IoT devices that customers use. In this way, the purpose of the connected products is more likely to be related to sustainability goals such as:

- Reduction of CO_2 emissions and impact on the environment through the use of alternative transportation and energy sources actively supporting the battle against climate change (goal n. 13 of SDGs)
- Contribution to the creation of sustainable systems within cities through systems for the efficient management of energy resources (goals n. 9 and 11 of SDGs)
- These smart products educate consumers about a more sustainable lifestyle and make them more aware of their daily actions and consumption processes (goal n. 12 of SDGs).

According to the Huna case study, we can state that circularity is achieved through the use of recycled material for the production of the hardware components of the system and through the recycling or repairing processes implemented from discarded items and material in the test pahse. While sustainable development goals, thanks to the use of Big Data, are achieved through the reduction in the CO_2 emission thanks to the effciently utilisation of energy systems.

In the table below there are summarized the main findings obtained by the interview. It is represented how the Home Buddy system, also thanks to the supportr of Big Data, is able to implement circular strategies and support sustainable development goals (SDGs) not only for the company but also for the customer.

Table 12 - Circular and SDGs principles enabled and supported by Home Buddy

	Circular Economy	SDGs
Company Perspective	Reuse and recycle principle: utilizaation of regenerated and recycled material or components for the hardware part.	Thorugh the sale of its systems, Huna, creates sustainable management systems for smart cities (goals n. 9 and 11)
	Exploitation of existing resources principle: make maximum use of the hardware systems already installed in the customers' home.	Huna fosters and promote a more sustainable use and consumption of energy not only from renewable sources but also from nonrenewable ones (goal n. 7)
	Waste reduction: Huna thanks to the application of the reuse and recycle principle is able to reduce the amount of waste produced by the production process of its devices.	Huna supports sustainable consumption processes of its customer through the sale of its systems (goal n. 12)
Customer Perspective	Renewable sources of enegies: if the customer's home is equipped with solar panels, Home Buddy will implement the management of the system generating and processing data for a better use of renewable sources.	Environmental sustainability: data on the use of the system allow the customer to reduce its impacto on the environment, reducing CO_2 emission. In this way he/she takes an active role in fighting against climate change (goal n. 13)

(Source: author processing)

To conclude, as we can also see from the table, data generate from Home Buddy have a marginal role for the company for what concern the support of circular economy principles. The contrary holds for sustainability goals (SDGs) for which data play a foundamental role. In fact, without these data it would be impossible to have metrics on the impact of this solution from a sustainable point of view. In general we can say that the company is try to optimize these data and implement their system in order to grasp as much as possible information. For exapmle they are collecting data to build a system of preventive and predicitive maintenace. In this way the resources employed by the firm will be optimized, the use of new raw material will be reduce as well as waste. We can assess that data are important but companies are still trying to understand how to leverage them at their full potential. This means that companies are still studying how best to employ their tools, in this case IoT devices, to get as much data as necessary for them to take a key role in supporting circular transition.

Through the analysis of this case study, it was possible to see that in the world of B2C, data produced by connected products are countless and of considerable importance, but only a few of them can be truly leveraged to achieve sustainability and circularity goals. Of course it depends also on the nature of the smart objects taken into consideration. In our case, it is about a smart connected product focused on sustainability but its implementation is necessary to leverage more useful insights for both the company and the customer.

In general we can say that companies are taking steps in the direction of sustainability and circular economy, driven not only by ethical issues but also by the growing demand from consumers who are an increasingly active part of the transition process. As we saw in Chapter 3, IoT can be of great help in this process. While B2B companies are better able to leverage IoT technologies to improve their production systems in both output and input phases, companies in B2C sectors that sell connected products to end consumers still struggle to find ways to leverage the data generated by smart objects to make not only their production system but also the objects they sell more sustainable.

Conclusion

Throughout this study we have seen that it has not been possible to give a single definition of IoT because of the multiple meanings that exist in the literature. What is more, this field has been shown to be continuously growing at the global, European and Italian levels.

We have seen how Big Data, obtained mainly from IoT and IIoT applicationi are able to influence processes, systems and practices related to Enterprise Rersouce Planning (ERP) and Customer Relationship Management (CRM). In particular, it emerged that Big Data can be used to analyze customer behavior, preferences, and purchase history, allowing organizations to tailor their interactions and offerings to meet the specific needs of each customer. Big Data improve customer segmentation allowing for more targeted and effective marketing and sales effort. Firms can predict customer customer behavior and purchasing patterns, through the analysis of data, and can proactively address customer needs and improve their satisfaction. Organizations can gain a deeper understanding of their customers and use this information to improve their engagement and build stronger relationships. Lastly, organization are now able to make more informed decisions that improve the overall customer experience. On the ERP side, Big Data can be used to track and analyze supply chain data, such as supplier performance, inventory levels, and shipping information, allowing organizations to optimize their supply chain processes and reduce waste in a circular and sustainable perspective. Organizations can gain a deeper understanding of their operations and use this information to make informed decisions about resource allocation, process optimization, and risk management. Predictive and preventive maintenance is now possible and help companies to predict when equipment is likely to fail, allowing organizations to proactively schedule maintenance and reduce downtime. Resource allocation is improved by Big Data, allowing companies to implement the efficiency of resource utilization or better waste management practices are applied. Overall, Big Data has the potential to greatly improve both ERP and CRM practices and systems by providing organizations with the insights and data needed to better understand and serve their customers, optimize their operations and make more informed decisions. As we have seen, some practices linked to ERP and CRM optimization are strictly linked to principles of sustainability and circular economy; in detail, resource optimization allows companies to reduce waste, predictive analysis proactively contribute to reducing the environment impact of the machinery employed, supply chain management is implemented allowing companies to reduce their waste, product designed is improved so that companies produce more durable and easy recyclable objects in line of what consumers' need are, lastly big data are employed to track materials and products throughout their lifecycle, allowing organizations to establish closed-loop supply chains and waste reduction processes.

A brief theoretical introduction was made to better understand the concepts related to circular economy and sustainability. It emerged that also for circular economy there is no unique definition, and it is strictly linked to sustainability. Moreover, it was presented the so called "R" framework which allowed us to have a clearer outline of the circular economy scope.
We have seen the relationships that occur between IoT, sustainability and circular economy and how this interconnection can influence both B2B and B2C industries. Sustainability and IoT are related in several ways. IoT technology can help increase sustainability by enabling the collection and analysis of data that can inform decision making and drive more efficient use of resources. For example IoT devices can be employed to manage energy consumption, waste processes and enable supply chain transparency to monitor the entire supply chain and make the necessary changes to drive sustainability. In relation to that, we have identified the role that business-to-business (B2B) and business-to-consumer (B2C) companies have in the transition towards a circular model of production and consumption:

- B2B companies can promote circular economy principles by designing and manufacturing products that are designed for repair, reuse, and recycling, and by establishing closed-loop supply chains. B2B companies foster circular economy by collaborating with other companies and organizations to develop circular business models and share resources and information. With the help of IoT and IIoT technologies all the above-mentioned processes result to be more manageable and give an essential support to companies in their transition processes towards circular economy.
- B2C companies can participate in the circular economy by offering products and services that promote circular principles, such as product-as-a-service models and leasing arrangements. B2C companies can also encourage circular practices by promoting product reuse and recycling, and by designing products that are durable and long-lasting. The connection with IoT connected devices (hence, Smart Products) is of crucial importance. In facts, these objects are able to generate a vast amount of data that companies may use to implement their circular strategies.

In conclusion, both B2B and B2C companies play a key role in promoting and supporting the transition towards circular economy.

To provide support for the theory analyzed so far, a research was conducted on a sample of 153 Italian companies (or foreign companies with at least one operational location on Italian territory) to understand how their production processes were affected by the IoT and whether or not the IoT supported principles related to sustainability and the circular economy. More in detail, our focus was on B2C companies, specifically on the relationships between their connected products (enabled by IoT technologies), data production, and the exploitation of data to achieve circularity and sustainability goals. We narrowed our sample down to six companies that proposed IoT connected devices at direct use of final consumers. More in detail, we presented a case study on a startup company operating in the energy management industry: Huna. In detail, its system Home Buddy, which is an IoT device that can be connected to the customer's home and allow the remote management of installations, the reduction of energy consumption and the improvement of the overall efficiency linked to the management of smart home systems.

The analysis of our case study showed that the connected product can generate a large amount of data, but only some of this data can be used by the company to create long-lasting products and with recycled, recyclable, and sustainable materials. In addition, it was highlighted that some data is more useful to the end consumer to make its consumption path more sustainable and less impactful for the environment.

In this regard, we can say that, in the B2B sector, data generated by IoT and IIoT devices turn out to be more usable by companies to achieve sustainability and circular goals. As we saw earlier, they are able to design long-lasting products, improve and streamline waste and energy management, enable supply chain transparency processes, apply predictive and preventive maintenance to their machinery's fleet, improve resource allocation, enhance customer experience and leverage customer relationship in general.

On the other hand, data produced by connected devices mainly related to end consumers (B2C sector) are found to be of marginal importance for companies in terms of sustainability and circularity. In fact, companies can exploit only a small amount of data. In contrast, these data can be exploited by consumer to make them more aware of what their impact on the environment is.

Appendix

Appendix A

Database of companies

Company's Name	Industry	Source	B2C	B2B	IoT/IIoT			
					Yes	Not mentioned	No	Sustain ability & CE
100% Campania	Packaging	Confindustria		x		x		
2A SPA	Iron and Steel	Confindustria		x		x		
ABS - Acciaierie Bertoli Safau	Iron and Steel	Confindustria		x		x		
Acqua & Sole S.R.L.	Renewable energies	Confindustria		x		x		
AD Compound spa	Raw material suppliers	Confindustria		x		x		
Alfa Acciai S.p.A.	Iron and Steel	Confindustria		x		x		
Arix S.p.A.	Personal care and cleaning items	Confindustria		x		x		
Bartoli SPA (Naturanda)	Sustainable products	Confindustria	x	x		x		
BASF	Chemistry	Confindustria		x	x			
Buzzi UNICEM	Building material	Confindustria	x	x		x		
Calabra maceri e servizi s.p.a.	Energy and waste management	Confindustria		x		x		
Cancelloni food service spa	Food	Confindustria		x		x		
Carlsberg Italia	Food	Confindustria	x	x		x		
Carrara Marble Way	Raw material	Confindustria		x		x		
Cartiere di Trevi spa	Paper industry	Confindustria		x	x			
Caseificio Elda srl	Food	Confindustria	x	x			x	
CHI.MA Florence spa	Textile	Confindustria		x		x		
Colacem spa	Raw material production	Confindustria		x		x		

Cooperativa Social Quid	Textile	Confindustria	x			x			
Corneli srl	Building material	Confindustria	x	x		x			
Daikin Air Conditioning	Energy	Confindustria	x	x	x				
Dal Maso Group srl	Waste management	Confindustria		x		x			
Dalma Mangimi spa	Feed Industry	Confindustria		x		x			
Decomar spa	Hydraulics industry	Confindustria		x	x				
Demus Spa	Food	Confindustria		x		x			
Di Mauro Officine Grafiche spa	Packaging	Confindustria		x		x			
Duerf srls	Chemistry	Confindustria		x		x			
Eambiente srl	Energy	Confindustria		x		x			
Eco Pets Italia	Personal and Pet care and cleaning items	Confindustria		x		x			
Ecopartner	Energy and waste management	Confindustria		x	x				
Ecopneus scpa	Waste management	Confindustria		x	x				
Ecosuntek spa	Energy	Confindustria		x	x				
Ecotec	Waste management	Confindustria		x		x			
Edilmag srl	Building material	Confindustria		x	x				
EGAP	Raw material extraction; Waste management	Confindustria		x		x			
Egea New Energy	Energy	Confindustria		x		x			
eKoala srl	Bioplastic products	Confindustria	x			x			
Endura spa	Chemistry	Confindustria		x		x			
EPTA spa	Refrigerating systems	Confindustria		x	x				
Fattoria della piana	Food	Confindustria	x	x			x		
Federalpi Siderurgica spa	Iron and Steel	Confindustria		x	x				
Ferrarelle spa	Beverage	Confindustria		x	x				
Fiam Italia srl	Furniture Industry	Confindustria		x			x		

Finstral spa	Building material	Confindustria	x	x		x		
Fonderie di Montorso	Iron and Steel	Confindustria		x		x		
Fratelli Guzzini spa	Design	Confindustria	x			x		
Getra spa	Energy	Confindustria		x	x			
Gruppo Società Gas Rimini spa	Energy	Confindustria	x	x		x		
GUSBI	Manufacturin g	Confindustria		x		x		
Holcim	Building material	Confindustria		x		x		
I.M.A. srl	Energy	Confindustria		x		x		
ICMA srl	Textile	Confindustria		x		x		
ILSA spa	Chemistry	Confindustria		x	x			
Imbal Carton srl	Packaging	Confindustria		x		x		
Italcementi spa	Building material	Confindustria		x		x		
Itelyum	Chemistry and waste management	Confindustria		x	x			
IVAR	Manufacturin g	Confindustria		x	x			
Jcoplastic spa	Plastic industry	Confindustria		x		x		
Krill design	Design and furniture industry	Confindustria	x		x			x
Lavanderia Americana	Industrial Laundry	Confindustria		x		x		
Laziale Distribuzione spa	Logistics	Confindustria		x		x		
Liomatic spa	Service industry	Confindustria	x	x		x		
Logicompany3 srl	Logistics	Confindustria		x		x		
Lucart spa	Paper industry	Confindustria		x		x		
Lucy Plast spa	Packaging	Confindustria		x		x		
Magaldi Power spa	Energy	Confindustria		x		x		
Maire Tecnimont Group	Energy and Chemistry	Confindustria		x		x		
Mapei	Building material	Confindustria		x		x		
Marazzato Soluzioni Ambientali srl	Waste management	Confindustria		x		x		

Marchon Italia	Eyewear	Confindustria	x	x		x		
Minerali Industriali	Mining	Confindustria		x		x		
neoruraleHub	Secondary material supplier	Confindustria		x	x			
Nial Nizzoli srl	Energy and waste management	Confindustria		x		x		
Novamont	Chemistry	Confindustria		x		x		
O-I Italy spa	Packaging	Confindustria		x	x			
Officine di Cartigliano spa	Food and Leather industry	Confindustria		x		x		
Pandora Group Srl	Building material	Confindustria		x		x		
Pasell	Manufacturing	Confindustria		x		x		
Peikko Italia Srl	Building material	Confindustria		x		x		
Phase Motion Control spa	Engineering	Confindustria		x	x			
Plados Telema	Furniture Industry	Confindustria		x			x	
Polycart spa	Packaging	Confindustria		x		x		
Prima Industrie spa	Manufacturing	Confindustria		x	x			
Progeva srl	Secondary material supplier and waste	Confindustria		x		x		
R.ED.EL	Energy Industry	Confindustria		x		x		
RdiciGroup	Textile and Chemistry	Confindustria		x		x		
Rainoldi Legnami srl	Building material	Confindustria		x		x		
REA impianti srl	Energy and waste management	Confindustria		x		x		
Reno De Medici spa	Paper industry	Confindustria		x		x		
Rete Sand	Building material	Confindustria		x		x		
Ricci spa	Building material	Confindustria		x		x		
Rodolfi Mansueto spa	Food	Confindustria	x	x		x		
Roelmi HPC	Health and personal care	Confindustria	x	x		x		
Salvagnini	Engineering	Confindustria		x	x			

San Colombano Costruzioni Spa	Building material	Confindustria		x		x		
Saxa Gres spa	Building material	Confindustria		x		x		
Semataf srl	Special waste management	Confindustria		x		x		
Serveco	Waste management	Confindustria		x		x		
Servizi ospedalieri spa	Service industry	Confindustria		x	x			
Sfregola Materie Plastiche	Packaging and secondary material suppliers	Confindustria		x		x		
Simpatico Network srl	Electronics	Confindustria	x				x	
Simpool srl	Logistics	Confindustria		x		x		
Sirap Gema spa	Packaging	Confindustria		x		x		
Sofidel spa	Health and personal care, Paper industry	Confindustria		x	x			
Spirit srl	Chemistry	Confindustria		x		x		
Stemin	Secondary material supplier	Confindustria		x		x		
Sumus Italia srl	Paper and recycling	Confindustria	x	x	x			x
Tardioli alfredo srl	Secondary material supplier	Confindustria	x	x		x		
Tarkett	Building material	Confindustria	x	x		x		
TM Italia srl	Furniture Industry	Confindustria	x			x		
VDP Fonderie	Smelter	Confindustria		x		x		
Whirlpool Emea spa	Manufacturin g	Confindustria	x	x	x			x
YMA - Industrie Meridionali Alimentari	Food	Confindustria	x	x		x		
Armal	Manufacturin g	IoTItaly		x	x			
Biglia spa	Turning industry	IoTItaly		x	x			
Olivetti	Service industry	IoTItaly	x	x	x			x
4Energy	Energy	IoTItaly	x	x	x			x

Dedagroup Business Solutions	Service industry	IoTItaly	x	x	x			
Pianca spa	Furniture	IoTItaly	x	x	x			
CheckUp	Design and furniture	IoTItaly	x	x	x			x
Aryel	Service industry	smau		x	x			
Axyon Ai srl	Service industry	smau		x	x			
B-PLAS	Bioplastic products	smau		x	x			
BBB srl	Healthcare	smau		x	x			
Beam Digiral	Service industry	smau		x	x			
befreest srl	Health and personal care	smau	x	x	x			x
BePooler	Service industry	smau	x				x	
Builti	Service industry	smau		x	x			
Enismaro	Service industry	smau		x	x			
ESGeo	Service industry	smau		x	x			
Exporium srl	Food	smau		x	x			
Farzati Tech	Service industry	smau		x	x			
Foto Virtuali	Service industry	smau	x	x			x	
Green Independence	Service industry	smau		x	x			
huna	Service industry	smau	x	x	x			x
I'M OK	Service industry	smau		x	x			
Incubatore Campano	Service industry	smau		x			x	
Innovation Engineering	Service industry	smau		x	x			
Keet srl	Service industry	smau		x	x			
M2D Tech	Service industry	smau		x	x			
MaCh3D	Service industry	smau		x	x			
NDG Natural Development Group	Agriculture	smau		x			x	
NTSG	Software and engineering	smau		x	x			

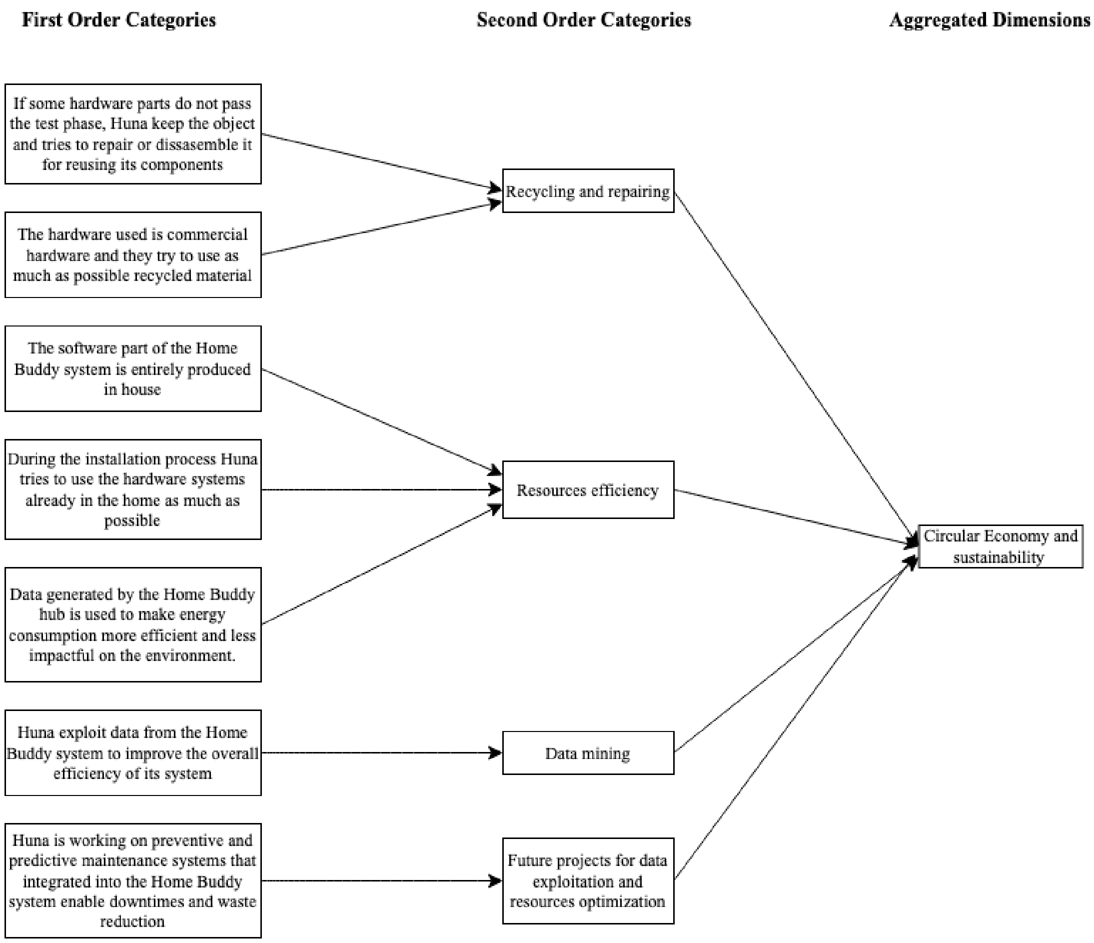
Safer Smart Labels	Service industry	smau		x	x			
sma-rty	Service industry	smau		x	x			
SoftMining srl	Software	smau		x	x			
Strategix	Software	smau		x	x			
Tilebytes	Service industry	smau		x	x			
To Be srl	Software	smau		x	x			
TO.TEM srl	Smart Mobility	smau	x	x	x			x
Vedrai spa	Service industry	smau		x	x			
Wel	Service industry	smau		x	x			
zero3	Energy and waste management	smau		x	x			
153			34	146	61	83	9	9

Appendix B

Codified interview

Interviewee: Santo Lico CEO and Co-founder of Huna

Date: 23/01/2023



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