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Industrial Internet of Things: state-of-the-art and directions of future development

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Abstract

Internet of things is one of the technologies that is contributing the most to the digitization of the companies. In particular, the work will focus on the application of this technology for Industry 4.0, analyzing in depth the solutions belonging to Smart Factory, Smart Logistics & Supply Chain and Smart Lifecycle field of application. The aim of the thesis work conducted is to develop a state-of-the-art analysis of the Internet of Things technology for Industry 4.0, in Italy and abroad, and to understand the main directions of future evolution of this technology. In order to answer the first question, it was conducted a census of the projects that have been implemented in recent years all over the world, which contributed to enrich the IoT projects database provided to me by the Osservatorio IoT. From there, an analysis of the projects was developed, focusing on various factors including geographical distribution, trend of number of projects implemented overtime and main application areas. In addition, it was carried out a survey, limited to Italian companies, that was sent to both large companies and SMEs, through which numerous factors belonging to the IIoT world were analyzed. In order to understand future development prospects, a research was performed to identify the most innovative start-ups that have emerged in recent years in the IoT sphere. In doing so, the main developing trends were identified. One of these, the AIoT, was finally analyzed in detail through a dedicated model.

Key-words: industry 4.0; internet of things; industrial internet of things; smart factory; smart logistics; artificial intelligence.

Abstract in italiano

L'Internet of Things è una delle tecnologie che sta contribuendo maggiormente alla digitalizzazione delle aziende. In particolare, il lavoro si concentra sull'applicazione di questa tecnologia per l'Industria 4.0, analizzando nel dettaglio le soluzioni appartenenti agli ambiti applicativi di Smart Factory, Smart Logistics & Supply Chain e Smart Lifecycle. Il lavoro di tesi condotto si pone come obiettivo quello di sviluppare un'analisi dello stato dell'arte della tecnologia dell'Internet of Things per l'Industria 4.0, in Italia e all'estero e quello di comprendere quali siano le principali direttrici di evoluzione future di questa tecnologia. Per rispondere alla prima domanda, è stato in primo luogo effettuato un censimento dei progetti che sono stati implementati negli ultimi anni in tutto il mondo e che hanno contribuito ad arricchire il database di progetti IoT fornitomi dall'Osservatorio IoT. Da qui è stata svolta un'analisi dei progetti su vari fattori, tra cui la distribuzione geografica, il trend temporale e gli ambiti applicativi. Inoltre, è stata condotta un'indagine, limitatamente sulle aziende italiane, inviata sia alle grandi aziende che alle SME, attraverso la quale sono stati analizzati numerosi fattori appartenenti al mondo IIoT. Per comprendere le prospettive di sviluppo future è stata condotta una ricerca volta a identificare le start-up più innovative che sono nate negli ultimi anni nella sfera IoT. Così facendo, sono stati identificati i principali trend in via di sviluppo. Uno di questi, l'AIoT, è stato infine analizzato nel dettaglio attraverso un modello dedicato.

Parole chiave: industria 4.0; internet of things; industrial internet of things; smart factory; smart logistics; intelligenza artificiale.

Contents

Executive summary

Introduction

For a number of years now, we have been witnessing a revolution in the world production system, which precisely goes by the name of the Fourth Industrial Revolution. The industrial world is trying, in increasing measures, to take advantage of the enormous technological progress that has developed in recent years. Resuming the theme of the Third Industrial Revolution, with which industrial automation began to be exploited for the first time in history through the use of computers within industry, we are now aiming for the massive use of digital technologies that can create enormous value through the generation of data. From these, any company can potentially derive a gigantic amount of information that, if well used, will contribute significantly to the creation of competitive advantage. These are some of the factors that characterize Industry 4.0, a term that was first used during the Hannover Fair in Germany in 2011.

PNRR

In this context, the Italian government, recognizing the fundamental importance of promoting the technological development of the companies in its territory, has included the theme of digitization as a protagonist of the Piano Nazionale Ripresa e Resilienza, through the new Piano Nazionale Transizione 4.0 (subsequent to the Piano Nazionale Industria 4.0 developed earlier in 2017). With the new plan, scheduled investments have reached 24.3 billion by 2022 and include, among other things, an increase in the tax credit for R&D-related expenses (from 12 percent to 20 percent) and the transformation of the super and hyper depreciation for innovative 4.0 assets, into a tax credit.

Industrial Internet of Things

In the context of Industry 4.0, one of the technologies that has made a major contribution to the digitization of industry is definitely the Internet of Things (IoT). This strong influence came from its ability to integrate the virtual world with the real world, taking advantage of the massive use of sensors (inside machineries, warehouses, water networks, products and many others), which allow a huge amount of data to be collected and enable all the constituent parts of the factory (operators, machinery, software...), to talk to each other in a smart way. In addition,

another great advantage is its versatility. In fact, IoT can be leveraged in numerous applications including smart factory, smart metering, smart home, smart logistics, smart car, smart building, smart agriculture, smart city, and smart asset management.

Within the wide world of IoT, Industrial IoT (that is the main topic around which the entire thesis revolves) represents an important part. As the name suggests, Industrial IoT consists of applying all the principles and technologies of IoT in the industrial environment. The focus has been placed particularly on three fields of application, which appear to be those most developed in the Industrial IoT field:

Smart Factory: The smart factory concept is based on the use of digital technologies that make it possible to integrate current manufacturing processes. It is based on the use of sensors to monitor machinery and products in the shopfloor. This provides numerous advantages in terms of management such as real-time visibility on the correct status of the machinery, the possibility of implementing preventive maintenance logic (or even predictive maintenance), up to situations in which it is the machinery that autonomously (by analyzing some of the data collected), is able to make decisions regarding its management. As a result, there will be a significant impact on business performance in terms of production, quality and energy consumption.

Smart Logistics & Supply Chain: by leveraging IoT in the supply chain, companies can gain tremendous benefits: increased visibility, increased security (of data and products), information from other value chain participants that is more reliable and easier to share, optimizing routes for transporting products, and streamlining internal company movements. All of these benefits are made possible through the modernization of the current supply chain into data-driven supply chains, which allows to identify in real-time the location of every object in it, making its optimization possible.

Smart Lifecycle: represents the management of the entire product lifecycle (from design to disposal stages), within a digital and interconnected context. It enables valuable information that can be used to optimize the product itself. For example, companies, through IoT, could greatly improve the development process of new products by analyzing historical data of previous versions. Or they could improve the product (in terms of performance/service offerings) by analyzing how customers are using it.

Although there are countless potential benefits that companies would be able to gain from using IoT, there are still different barriers and weaknesses that hinder the large-scale deployment of this technology. Among the most important ones there

are cybersecurity issues, the need to adapt and own infrastructure and invest in new ones to foster integration between IT and OT, the lack of a common standard that would allow easy interconnection between IoT systems from different industries, the large energy consumption due to the permanent activation of the various IoT technologies, and the difficulty in exploiting the maximum potential from the large amounts of data collected.

Research objectives

The primary objective of the research, is to deepen the state of diffusion of this technology in Italy and abroad. The question I will ask during my thesis work is, therefore, the following: *Which is the state-of-the-art of Industrial Internet of Things technology?*
In addition, I will focus on the analysis of the future trends that will characterize the next years of IoT evolution. Specifically, I want to understand which are the proposal of the most innovative start-up, and therefore, which are the proposals that will likely improve the degree of diffusion and effectiveness of IoT technology. The main questions that have been faced are:
Which are the most influential trends that are changing the world of IIoT? How is the theme of environmental sustainability impacting on IIoT development? In what measure are companies focusing on it with their IoT solutions?

Methodologies

Different types of sources were used throughout the entire thesis work.

Literature review: in order to develop the first chapter an analysis of the literature was made. This allowed me to understand and report the fundamental concepts of this paradigm. To do this, the main articles on the subject were analyzed using the search engines of Google Scholar, Scopus and Science Direct. Being the IoT a technology that has witnessed (and is still witnessing) a great development, it has been chosen to select only the most recent sources, avoiding articles that discuss the topic in a context too different from the current one.

Primary sources: the thesis develops around the survey conducted in collaboration with the Osservatorio Internet of Things. Through the survey we investigated the current state of adoption of IoT solutions within the companies interviewed. The questionnaire comprehend 24 questions and it can be consulted in the Appendix.

Secondary sources: in order to analyze the degree of diffusion of IoT in Italy and in the world, one of the objectives of the thesis is to map the projects that have been implemented in recent years. I contribute to expand a database of IoT projects

provided by Osservatorio IoT using the following sources: IoT technology supplier sites, specialized websites in the world of digitalization and corporate sites.

Finally, it has been exploited the website "Crunchbase" to conduct a research of the most innovative start-ups operating in the IoT. Here a total of 43 start-ups have been selected. The start-ups identified were grouped into innovation clusters and for each of them some examples were inserted. In addition, to develop the model regarding the start-up that focus their offer on the technology of AIoT, I select a total of 24 start-up:

Analysis of the current scenario

For the analysis of the current scenario, it has been exploited the database of Interent of Things projects. The first analysis proposed highlights the predominance of Europe over the other continent in terms of number of projects implemented in its territory (71% of the projects mapped). However, the great influence of projects developed in Italy should be considered. Indeed, it represents 44 % of the total sample. A percentage that is undoubtedly affected by the methodologies used for the research of the projects, that bring to a particular focus on Italian cases. Moreover, it is possible to notice a strong trend of growth from the early 2000s to now. Considering projects' application fields, it is possible to see a dominance by the Smart Factory, that represents the 70% of the cases.

Smart Factory

The term Smart Factory refers to the use of various digital technologies within the factory that, by combining with each other, make the operational processes more efficient and flexible, being able to dynamically coordinate processes, people and machinery. In particular, through IoT technology, a large amount of information related to the operation of the entire plant can be obtained, which, after being processed and analyzed, manage to generate a great value for the management of the factory. Four main specific application related to the Smart Factory domain have been identified:

Production optimization: Production optimization is closely linked to monitoring the progress of production processes, with the goal of optimizing key parameters for each company such as time, cost, quality and safety.

Preventive maintenance: Preventive maintenance consists of a precise maintenance policy that is based on performing maintenance intervention before failure occurrence. To do so, the intervention is scheduled according to predetermined intervals of time or units of use, or prescribed criteria, to reduce the probability of failure. All of this is made possible through the exploitation of IoT and data

analytics, which make obsolete an asset management approach based on the "run to failure".

Predictive maintenance: Predictive maintenance can be seen as an evolution of preventive maintenance, discussed in the previous section. The key feature of predictive maintenance is that the interventions scheduling is based on the forecast of trend of one or more parameters linked to the degradation process.

Energy management: This factor is particularly relevant in the manufacturing industry, notoriously the most "energy-intensive" one. There is, therefore, the need to adopt strategies to monitor actual energy efficiency levels. This would make it possible to develop solutions to reduce the various energy wastes present in plants. In addition, energy efficiency is crucial in the context of moving more and more toward sustainable production, a factor that is gaining considerable importance as a result of increasingly stringent regulations in this area.

Smart Logistics & Supply Chain

With the pandemic we are currently experiencing, there appears to be an increasing need to use cutting-edge technologies that enable to obtain more information about logistics flows (generating a better and more responsive decision-making process). Smart logistics solutions are generally based on optimizing all organizational and strategic operations related to the management, storage and destination of goods. To achieve these goals, it is necessary to make logistics processes (internal or external to the company) as transparent as possible, including analyzing the operations of collaborators, partners and suppliers. In this scenario, IoT enables precise and timely monitoring of all objects connected to the system, enabling companies to organize logistics processes in an optimized way.

Traceability along the Supply Chain: The ever-increasing complexity and variability of supply chains, stimulates companies to invest more and more in asset tracking solutions. Through track and trace solutions, companies are able to significantly reduce inventories through real-time visibility of inventory and shipment levels. As a result, there are significant savings in inventory management costs

Traceability of internal warehouse: Also for this specific application, the principles of visibility are considered as the basic point of any project. Companies are able to achieve great results in terms of work safety, efficiency and a relative reduction in costs, all thanks to the tracking of operators, vehicles and assets within the warehouse.

Logistical assets management: One of the most common applications of logistics asset management is in enterprise fleet management. Companies, in fact, by connecting their fleet via IoT sensors, are able to optimize its performance (in terms of safety, energy consumption, productivity), thanks to continuous real-time monitoring.

This possibility is particularly interesting for cold chain management. Some companies, in fact, need to ensure a precise degree of humidity and temperature during the transportation of goods. The ability to continuously monitor these parameters would make management much smoother, optimized and safer.

Smart Lifecycle

In general, the management of the lifecycle of a product (or of an asset), encompasses all those activities of a strategic and operational nature that characterize its production process, which characterize the stages of design, use, market launch, maintenance and finally disposal. IoT would allow companies to develop a holistic view of all phases of the product life cycle. In fact, a connected product would be able to collect data from the creation to the final disposal, which, once analyzed by the company, would be of critical importance in optimizing each of the product's life stages.

Optimization of product development: This application enables companies to make new product development processes more effective. This requires continuous collection of data generated by products (already in the market) connected and equipped with IoT sensors. Some of the main benefits that companies find by using solutions of this type are the reduction of time between product conception and sale (time to market) and the reduction of product development costs. In fact, the goal of companies is to optimize and make more effective the design and development phase of their products by leveraging information from related products already used by customers

Survey analysis

In this chapter, I propose the results of the survey that has been conducted together with the Osservatorio Internet of Things. The survey is composed of 25 questions, and it is inserted in the Annex. The questions proposed, cover a wide range of topic that better explain the relationship of each company with the technologies analyzed. The aspects on which the questions focus on are:
-The effect of the current economic and political instability over the performances of the company.
-How the companies are trying to obtain the funding of the PNRR, and how it has impacted on the investments budgeted by the company.
-The relationship of the company with the IoT technology (if there is a strong awareness inside the company, if the theme is relevant for it and if it has already implemented IoT projects in the past).
-If the company is investing in services as well, together with the IoT solutions. The survey further deepens on who is the provider of this services and on what are the point of weaknesses on outsourcing those services.

-The main driver for the implementation of IoT project.
-The most influential professional figure inside the company for the implementation of IoT projects.
-If and how the company has exploited the data generated by IoT projects (and, eventually, why they have not been exploited).
-The feedback about the project already implemented.
-The main barriers (if any) that prevent from the launch of IoT projects.
-The most crucial phase of an IoT project.
-Future plan regarding the implementation of IoT projects and, eventually, which kind of application of Industrial IoT the company would like to exploit
-The objectives that the company would like to achieve with new IoT projects
-The development of the company in terms of cybersecurity in IT systems.
-The willingness of the company to collaborate with third parties for integrated IoT projects (and, eventually, with which actors).
-The impact that IoT projects implemented had on some specific performances

Directions of future development

To conclude the thesis work I decided to propose an analysis of the future developments of the technology of IIoT by analyzing the main trend that are developing nowadays around this technology. To do that, a research on the website "Crunchbase" has been conducted, with the aim of finding which are the offering of IoT start-ups that developed over the last years. The start-up found during the research were subsequently clustered in the following groups:

AIoT: is the joint use of Artificial Intelligence and IoT, with the aim of creating synergies between IoT tools and AI algorithms. Indeed, the great advantage of using artificial intelligence in data analysis is the ability to generate predictive analytics, which would allow to anticipate problems or possible opportunities for improvement within the factory processes. And thanks to IoT devices, the algorithm will have accurate and reliable data to analyze, which is an essential factor for the effectiveness of AI.
Two sub-groups where then identified, based on the objective for which these solutions are sold to companies. The first one is characterized by the use of the above technologies based on the improvement of the performance of the production process (such as quality, speed, productivity, efficiency). The second, focuses on improving the environmental sustainability of companies that adopt such solutions (through, for example, the reduction of greenhouse gases).

Cybersecurity: with the usage of IoT devices, an additional great level of complexity in terms of cybersecurity is added to companies, due to the integration of the

physical world with the digital one. In fact, the countless devices that are used to exploit the power of IoT (creating a connected and intelligent factory) make companies even more vulnerable to possible threats and violations. For these reasons, the theme is of fundamental importance for enabling a massive spread of IIoT solutions within the factories.
Within the cluster of Cybersecurity start-up, a sub-group of companies focusing on Blockchain technology has been inserted. One of the most important features of this technology, that can result to be critical for the cybersecurity of the companies, is the decentralization. In the blockchain, data is shared across multiple "nodes" that use precise software to ensure that data remains unchanged. As a result, since all information are decentralized, it is more difficult for an attack to be able to tamper with the information.

Metaverse & Digital Twin: The term Metaverse refers to a digital universe that users can access, through the technologies of Augmented Reality (AR) and Virtual Reality (VR) and live virtual experiences. This highly innovative technology can also be used on an industrial level, even if the applications in this field, as mentioned before, are still very limited. In this case we talk about Industrial Metaverse, that uses the technologies of AR, VR and Internet of Things to improve the efficiency and productivity of industrial companies.
If we consider the application at the industrial level, one of the key technologies on which the Metaverse is based is that of the Digital Twin, already developed in some companies. Thanks to digital twins, in fact, it is possible to duplicate any environment and process, allowing to perform experimental and predictive analysis.

Finally, a model was developed with the aim of analyzing more in depth the trend of AIoT, which the most spread among the ones mentioned before. The focus was put on two specific characteristics of the offering of the start-up analyzed, which are:

Scope of the solution: the two main macro-areas of application that emerged are the improvement of the factory's production performance and the increase of the company's environmental sustainability. In the first case, the combination of IoT and AI is exploited to optimize the production process. The predictive logic of AI enables services such as predictive maintenance and improvements in various performances such as quality control, optimization of production scheduling, maximization of machinery utilization, increase in productivity, and increase in occupational safety

Specificity of the solution: the objective is to understand whether the offerings are extremely focused or, on the contrary, can be applied to a broad spectrum of cases. To define that I took into considerations both the number and variety of sectors in which the solution can be used and the number and variety of applications included in each proposal.

Conclusions

Thanks to both the analysis of the database of IIoT projects implemented and the survey conducted, it was possible to understand which is the state-of-the-art of this technology.
With the first analysis mentioned, a trend of growth in terms of number of projects implemented year after year has been highlighted. Moreover, looking at the distribution of the projects considering the application area, it emerged that the Smart Factory is the most spread one, followed by Smart Logistics and finally, by Smart Lifecycle application area.

From the analysis of the results coming from the survey it was possible to highlight some important points. First of all, the awareness of IIoT solutions among Italian companies is growing and the vast majority of the company surveyed has already implemented a project. In this sense, the PNRR has been important considering that 45% of the companies increased their investments in IIoT solution after the implementation of the plan. Considering which are the reason for which companies focus on IIoT, the most selected one was the possibility to reach benefits of efficiency (such as reduction of production costs and time). On the other hand, regarding the barriers met, there are both internal motivations (like the lack of internal competences and expertise) and external ones (like economic instability or lack of raw materials). Regarding the trend towards the servitization, the majority of the company declared to have activated additional services for their projects, with a predominance of information services. Moreover, from the surveys it was possible to highlight the difficulties that companies still have in the exploitation of the value of the data. Half of the respondents is currently not exploiting the potential coming from data analysis (and many of them has not even planned to do that in the near future).

With the research of innovative start-up carried out, it was possible to identify the main trends of development of the IoT technology. It emerged that the two most spread ones are the AIoT and the Cybersecurity. Moreover, a very innovative technology that is developing in the last years is the Metaverse even though, we are still far from a massive adoption of this solutions inside the factory. Finally, with the model proposed to deepen the trend of AIoT, it was possible to highlight that the applications that focus on the improvement of production

performance are still more spread than those that focus on the environmental sustainability of companies. Moreover, it emerges how the latter ones tend to have a high level of specificity being applicable only to specific context. On the other hand, the start-ups that developed products and service for production performances improvement are usually applicable to a great variety of manufacturing contexts.

1 Industry 4.0 and Internet of things

1.1. Industry 4.0

1.1.1. Introduction

The last two years have been extremely complex for the Italian and international manufacturing system. Unavailable manpower, forced shutdown of facilities, impossibility of forecasting highly variable levels of supply and demand are just some of the problems that this sector has been forced to face during this period. However, as often happens, from periods of crisis such as the one we are currently experiencing, great opportunities for change and renewal arise. This is the case of the so-called digital transition, a process that began several years ago but has received a significant boost from COVID-19 due to the need to make the most of the innovative technologies currently on the market. The effects of COVID-19 are considerable, but they are not all negative. The pandemic, in fact, has acted as an amplifier and catalyst for the digital transformation of manufacturing companies, also by changing the mindset and approach of the companies themselves: these previously sought the use of technology and Industry 4.0 solutions primarily for convenience while today having digital operations is a prerequisite on the road to the new normal. By enabling the digital factory paradigm, 4.0 technologies represent one of the most important and powerful levers that business leaders must consider in order to overcome this moment [1]. And that's why, as highlighted by the Deloitte study, companies are continuing to invest in Industry 4.0 despite Covid-19 crise. In particular, 63% of the manufacturing companies surveyed (survey conducted in 2020) confirmed that they have not stopped funding smart manufacturing projects, but on the contrary have increased capital flows, precisely because of the strategic importance that is recognized to the use of technologies in industrial environment. In order to properly understand the meaning of industry 4.0, considered as the Fourth Industrial Revolution, it is necessary to make a brief historical analysis. This will allow to have a complete view of the process of continuous transformation that started more than two-hundred years ago. Over the past few centuries, we have seen four real revolutions that have turned the industrial world upside down.

The *First industrial revolution* began in the 18th century. The major change that took place during this phase was mainly due to the introduction of the steam engine used for mechanized production, leading to the gradual abandonment of the artisan production system based on manual tools in favor of a production system centered on the machine.

Subsequently, towards the end of the nineteenth century, another great invention revolutionized again the production process. This was electricity, which made the advent of mass production possible. Also, during this period, the use of steel, chemicals and oil began. This set of factors characterize what is known as the *Second Industrial Revolution*.

In the second half of the twentieth century there was the birth of digital technology, electronics and IT (information technology) led to the *Third Industrial Revolution*, during which there was for the first time a progressive automation of industrial processes, at the expense of a smaller presence of human operators in the factory.

On the basis of the latter, the process of transformation that is characterizing our days has developed: the *Fourth Industrial Revolution* (which is often referred to as Industry 4.0). The process of automating industries that began last century has been taken up and applied on a significantly larger scale thanks to the enormous technological improvements we have witnessed in recent years. Through the implementation of these digital technologies, the aim is therefore to increasingly reduce the presence of human operators within factories through increasingly pervasive automation, ensuring, among other things, advantages in terms of efficiency, effectiveness and safety.

As will be explained later, Industry 4.0 is based on the massive use of innovative technologies from which companies are able to obtain huge amounts of data, which must be analyzed and transformed into information capable of generating a competitive advantage. The Fourth Industrial Revolution has its centrality in the power and strength of data, in the ability to analyze multiple sources through Big Data, in the real-time management of information with real-time analytics and in the development of predictive capabilities that come from Cognitive Computing, both applied to the behavior of products (e.g. predictive maintenance), and to the behavior of customers (predictive behavioral analytics that integrate directly with the design of new products). Data is now a critical element of business competitiveness and the predisposition to create analytical elaboration processes, with the relative ability to insert these elaborations to support all daily processes, has become a strategic prerogative for any company [2]. Industry 4.0 is often named as the Fourth Industrial Revolution in research papers, i.e., 4IR, as it shows the changes or the revolutions that occur in the production or manufacturing methods followed in traditional industries. These changes have been achieved by enhancing

Industry 3.0, which occurred with the usage of computers in industries. These computers are used more efficiently in Industry 4.0 when IoT was introduced in operational and digital domains, machine learning, and other technologies, to make machines smart, autonomous, or less human-dependent [3].

1.1.2. Industry 4.0 Technologies

"KETs are knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration. KETs can assist technology leaders in other fields to capitalise on their research efforts".

This is how Key Enabling Technologies (KET) has been defined by the European Commission in the tentative to generate a common understanding within Europe about what should be considered as KET.

MISE (Ministero dello Sviluppo Economico) in "Piano Nazionale Industria 4.0" identified 9 main enabling technologies.

Figure 1 MISE – Piano Nazionale Industria 4.0, Key Enabling technologies

Advanced Manufacturing Solutions

The Advanced Manufacturing Solution is a field of collaborative robotics that indicates the integration of techniques and technologies for the optimization of the design and production process and the creation of differentiated, economic and competitive products. The Advanced Manufacturing Solution gives the possibility to make more flexible and effective complex production systems that can be revised and reorganized by overcoming the traditional division between automatic and manual systems, and their fusion into a single system that integrates human and robotic work. The adoption of the Advanced Manufacturing Solution in the industrial sector ensures greater production efficiency thanks to the reduction of errors, time and costs and an improvement in productivity and safety of workers and processes [5]. Automation is key in Industry 4.0 applications, so the tasks susceptible to be automated may be performed by using cobots, robots or Autonomous Ground Vehicles (AGVs). These are used to perform tasks in collaboration with humans; robots are instead able to work independently (without human presence) to automatize tasks; AGVs have the role to transport or search item throughout the factory. [6]

Additive manufacturing

The standard ISO/ASTM52921-1 has defined it as the "*process of joining materials layer upon layer in order to make physical objects directly from 3D model data*". With Industry 4.0, these additive-manufacturing methods will be widely used to produce small batches of customized products that offer construction advantages, such as complex, lightweight designs [7]. It deals with creating layer by layer a three-dimensional object. This technology allows the engineers to realize the things (which they have in their mind) in the shortest possible time [8]. Flexibility and customization are part of the foundations of the Industry 4.0 paradigm. Both features should be provided by a smart factory without increasing the cost of the product. In this scenario, 3D printing allows for manufacturing certain prototypes and low-volume batches at a lower price than traditional manufacturing techniques [6].

Augmented reality

Augmented-reality-based systems can be exploited for different kind of services, like selecting parts in a warehouse and sending repair instructions over mobile devices. For instance, operators may receive repair instructions on how to replace a

particular part while they are looking at the actual system that need to be adjusted. This information may be displayed directly in workers' field of sight using devices such as augmented-reality glasses [7]. It deals with the interpretation of digital pictures or information onto real-world objects [8]. Through AR it is possible to see, directly or indirectly, virtual elements on top of the real-world physical environment. Regarding Virtual Reality (VR), both the environment and the elements are virtual. In the case of industrial environment, where there are certain industrial restrictions such as tough lighting condition, battery life and external protection, it is possible to use the terms Industrial Augmented Reality (IAR) and Industrial Virtual Reality (IVR). Both AR and VR evolved remarkably in the last decade, where they proved to increase productivity and to be helpful in industrial design processes, when manufacturing certain goods or for maintaining specific industrial components [6]. Finally, AR and VR can also play an important role for the product development process, given that it provides a concrete vision of the product assessment. VR can be exploited as a visualization platform for aligning physical production lines with the virtual world (Turner et al., 2016).

Simulation

The aim of simulations is to re-create the physical world in a virtual model (which can be constituted by products, humans and machines), by exploiting real-time data. Operators will therefore be able to optimize in the virtual world (before than in the real world) the setting of the machines (for the following product in line), allowing to drastically reduce machine set-up times and to increase the quality of the production [7]. The information collected by an Industry 4.0 factory can be used to model the behavior of all the entities involved in the production system (e.g., machines, operators, products) by making use of simulation software. Such a software can determine the current state in the real-world of the factory (this is related to the concept of Digital Twin) and then predict future events, suggest mitigation measures to avoid problems, or suggest improvements to reduce costs or to improve quality [6].

Horizontal and vertical integration

Horizontal and vertical integration are essential to automate data exchanges inside factories and to communicate with suppliers and clients. Traditionally, such a kind of integrations have been provided through Manufacturing-Execution System (MES), Product Lifecycle Management (PLM), Enterprise Resource Planning (ERP) and IoT platforms, but Industry 4.0 demands higher integration levels, since the

mentioned platforms may not be shared with other industrial partners or clients (thus requiring additional integrations, which are usually very expensive) [6]. With Industry 4.0, companies, departments, functions, and capabilities will become much more cohesive, as cross-company, universal data-integration networks evolve and enable truly automated value chains [7].

Industrial IoT

As it will be better explained later, Industrial IoT refers to the industrial application of IoT technology which deals with linking any device to the internet. IoT consists of the worldwide network which allows the communication between person-to-person, things-to-things and person-to-things. To do that, all the entities must be provided of distinctive uniqueness. It represents a dynamic global network infrastructure able to self-configure thanks to interoperable and standard communication protocols. Here, both physical and virtual 'Things' are integrated into an information network, being provided of their identities, physical attributes and virtual personalities [14]. Nowadays, just a limited portion of industries have sensors and machines which are networked and use embedded computing. They are typically organized in a vertical automation pyramid in which sensors and field devices with limited intelligence and automation controllers feed into an overarching manufacturing-process control system. But with the Industrial Internet of Things, a greater amount of entities (which can be even unfinished products) will be enriched with embedded computing and connected using standard technologies. This solution will enable the devices on the field to interact and communicate with each other and with central controller, in case of necessity. Finally, IIoT enable real-time responses by decentralizing decision making and analytics [7].

Cloud

With Industry 4.0, more production-related undertakings will require increased data sharing across sites and company boundaries. At the same time, Cloud technologies will achieve shorter reaction time (several milliseconds), thanks to significant performances improvement. As a result, machine data and functionality will increasingly be deployed to the cloud. This will enable an increasing amount of data-driven services for production systems, which may include also monitor and control processes [7]. Cloud deals with the use of computer system assets mainly computing power and data storage [8]. Most modern industrial companies already rely on applications deployed on local or remote cloud computing systems, which allow multiple Industry 4.0 participants to collaborate among them in an easy way.

However, such a kind of system suffer from a major limitation: if the cloud is somehow affected by software problems, high workloads or attacks, the whole system may become blocked to every user [6].

Cybersecurity

With the increased connectivity and use of standard communications protocols that come with Industry 4.0, the need to protect critical industrial systems and manufacturing lines from cybersecurity threats increases dramatically. As a result, secure, reliable communications as well as sophisticated identity and access management of machines and users are essential [7]. Intra and inter-connections are key in Industry 4.0 applications, so it is necessary to protect the systems involved in such connections. In addition, security is essential for industrial critical systems, which have been widely targeted by cyber-attacks in the last years, affecting both complex industrial systems and simpler physical access systems [6].

Big data and analytics

Analytics based on large data sets has emerged only recently in the manufacturing world, where it optimizes production quality, saves energy, and improves equipment service. In an Industry 4.0 context, the collection and comprehensive evaluation of data from many different 3 sources—production equipment and systems as well as enterprise- and customer-management systems—will become standard to support real-time decision making [7]. Big data analytics deals with the processing of large volume data to uncover hidden pieces of information, to establish correlations among collected data, to understand market trends and customers' requirements which can help manufacturers to do effective business planning [8]. As its name suggests, it addresses the analysis of large quantities of data generated by connected equipment, machines, components, products and people.

However, Big Data does not only mean massive volumes of data, but also to all the techniques and tools used to store, organize and process data, to transform them into valuable knowledge [15]. The ideal Industry 4.0 smart factory collects huge amounts of data from many different sources of the value chain (e.g., from plants, suppliers, logistic providers or service providers). This huge amount of data generates a great value for the companies; however, in order to process them, advanced Big Data techniques are required. Moreover, Data Analytics can be exploited also to predict future demand or imminent problems [6].

1.2. Piano Nazionale Transizione 4.0

In the last period, Industry 4.0 is observing a great development also thanks to the investments brought forward by the Italian government in this area with the extension of "Piano Nazionale Industria 4.0" in Piano Nazionale Transizione 4.0". Piano Nazionale Transizione 4.0 (Piano Nazionale Impresa 4.0, Piano Industria 4.0 in the initial versions of 2017) is a national plan prior to PNRR (Piano Nazionale di Ripresa e Resilienza), in favor of Italian companies of every productive sector with the aim of encouraging technological innovation of Italian companies. From 2021 it is financially included within the PNRR itself. The intervention plans are managed by MISE – Ministero dello Sviluppo Economico. The original law, which introduced the criterion of encouraging technological development in companies, is Law 232 of 11/12/2016, i.e., the 2017 Budget Law, which introduced increased depreciation in the budget. Companies could increase their investment costs in the balance sheet and thus reduce taxable profits. The super depreciation was 140% for ordinary assets ("superammortamento" in Italian) and 250% for innovative 4.0 assets ("iperammortamento" in Italian). From the beginning of 2020, the increased depreciation was transformed into a tax credit.
The tax credit allows a total and immediate "availability" of the benefit, regardless of the results of the financial statements, and the possibility to monetize the amount by offsetting any business tax; it also allows the use of the incentive by a number of companies that do not draw up the financial statements, such as farms taxed on cadastral income. To determine the amount of the benefit, the legislation distinguishes between ordinary goods without technological content and "innovative 4.0" goods, i.e., capital goods whose operation is controlled by computerized and digitized systems. Quite different is the incentive: for goods 4.0 is equal to 50%, while for ordinary goods is 10%. The 50% rate is valid until 12/31/2021, then drops to 40 in 2022 and 20 until 2025.
For investments above 2.5 million euros the percentage become respectively 30% until 12/31/2021, 20% in 2022 and 10% until 2025; while for investments above 10 million euros they further reduce to 10,10,5 per cent.

The benefit of the tax credit does not only apply to investments in capital goods but may also concern Research and Development expenses and those for training. Technologically advanced capital goods are set out in Annex A of the original law (Finance Act 2017), which identifies them in detail. In general, they are defined as those able to use the technologies of digitization, interconnection and automation, to ensure better performance for companies from an economic, environmental and productivity point of view; machineries equipped with features such as CNC (Computer Numerical Control) or PLC (Programmable Logic Controller) control

capabilities, interconnection to information systems, interconnection with the logistics system and supply network, intuitive man-machine interface, systemization of collected data; all those equipment whose operation is controlled by computerized systems or managed through appropriate sensors and drives, all systems for quality assurance and sustainability, all devices for human-machine interaction and for the improvement of ergonomics and safety in the workplace. Investments in intangible assets such as software, systems, platforms and applications, specified in attachment B of the same law, are also facilitated.

There are also other fundings for technological development and innovation, again managed by MISE.

Legge Sabatini

It focuses on the purchase of capital goods. The law has been in force for many years, but in its latest version (Nuova Sabatini) it aims to encourage the evolution of production systems in all sectors towards an innovative 4.0 logic. The law is aimed at micro, small and medium enterprises. It intervenes by facilitating access to bank credit. The investment is paid entirely by the adhering bank; the company subscribes to an installment financing plan or a leasing. The Ministry, through a special fund, guarantees the banks 80% of the value in the event of insolvency and it also intervenes with interest rate incentives.

Digital Transformation

This is aimed at micro, small and medium-sized companies and it finances technological innovation and digitalization projects with 10% non-repayable and 40% subsidized financing.

Smart and Start

It finances innovative start-ups with subsidized financing for 80% of expenditure.

There are also sectoral aid plans under the responsibility of the various ministries. For the agro-food sector, for example, there are incentives for innovation and the diffusion of 4.0 technologies, managed by the Ministero delle Politiche Agricole, Alimentari e Forestali (MIPAAF). In the report drawn up by Osservatorio Internet of Things of Politecnico di Milano [12], it emerges how the benefits obtainable thanks to the Plan, are one of the most important factors driving companies to invest in Industrial Internet of Things projects. "In third place among the most popular

drivers, there are the incentives related to the Piano Nazionale Industria 4.0, which in recent years have helped to create a strong awareness in companies, laying the groundwork for the start of projects. On this front, the novelty concerns the new Piano Nazionale Transizione 4.0 recently approved by the Italian Government, which provides for an increase in investments to support companies from 7 to 24.3 billion euros until 2022. Among the main measures of the Plan there are: the tax credit for R&D, which will rise from 12% to 20% with a ceiling of 3 to 4 million euros; the tax credit for technological innovation, which will rise from 6% to 10% with a ceiling of 1.5 to 2 million euros; and finally, the tax credit for green and digital innovation, which will grow from 10% to 15% with a ceiling of 1.5 million".

1.3. Internet of Things

1.3.1. What is and Main Application

As explained before Internet of things is one of the key enabling technologies that allows companies to perform an effective digital transition. It was Kavin Ashton who first formulated the phrase "Internet of Things" in 1999. Since that time there has been a continuous development of this ubiquitous connectivity, which is currently being exploited in various fields including defense, industry, energy, agriculture, medicine, not to mention the importance in the development of cities, homes and smart devices. It is a technology that serves as a link between the physical and virtual worlds. This is made possible through the use of an Internet network to transmit data between them [16]. The IoT can be defined as an ecosystem populated by intelligent devices, which, through the use of sensors, processing technologies and networking technologies, are able to offer smart services to the end users [17].Every object, mechanical/electronic machine, individual, and entity has a unique identifier and, without requiring human-human or human-machine interaction, is able to exchange information within a system.
The fundamental idea of an IoT system is the trade of data between machines which are elicited by cutting edge technologies like WSN (Wireless Sensor Networks) and RFID (Radio Frequency Identification) with usage of sensing devices with effective decision making skills and intelligent algorithms after which an action is performed accordingly. IoT systems are deployed successfully by enabling telecommunication interfaces with the internet in devices like sensors and actuators with storage and processing sections for successful interactions between machines [16].
IoT can be used in a wide range of industries, exploiting its potentially unlimited applications.

Looking at the report developed by Osservatori IoT [11] the most spread applications of this technology are the following:

Smart Factory, greatly incentivize by Piano Nazionale Transizione 4.0. It is mainly linked to real-time monitoring of production and to management of energy consumption. Moreover, one of the most spread applications is preventive maintenance: data coming from connected machines allow a better management of maintenance activities, passing from a corrective logic - in which one waits for the failure to occur - to a predictive approach that anticipates the malfunctioning and optimizes the maintenance activity itself, reducing time and costs related to machine downtime. In fact, real-time monitoring and analysis of the data collected from individual machines allows the supplier to intervene promptly to reduce downtime and thus provide maintenance services with a logic in which the customer pays only for the actual use of the machines

Smart Metering, with the great increase of installation of Smart meter for electrical and gas. This solution gives a great contribution for environmental sustainability if we think, for example, of the installation of connected water meters (Smart Metering water), which allow - thanks to remote meter reading - to have more accurate bills, to reduce fraud and to identify faults in the pipelines. All of this on the one hand translates into economic benefits.

Smart Home, with solutions for increasing the security and comfort and reduce energy consumptions. Moreover, they bring numerous benefits for the frail and elderly in the home, with smart applications for remote control and monitoring of vital and clinical parameters and with emergency response services. Finally, a third area that presents significant opportunities refers to the possibility of stipulating home insurance policies in which the premium varies based on the level of "smartness" of the home.

Smart Logistics, used for the management of company's fleet and for the traceability of goods and assets internally to the companies' warehouses or along the entire supply chain which also considers satellite-based anti-theft solutions.

Smart Car, mainly linked to the highest number of cars connected through SIM or with Bluetooth systems and to GPS/GPRS for localization and registration of driving parameters for insurance purposes. Connection between different vehicles or between vehicles and infrastructure also allows to prevent and detect incidents.

Smart Building, mainly linked to the management of energy consumption in the building and to video surveillance. It consists of automatizing buildings' systems for safety, comfort and energy consumptions reasons.

Smart Agriculture, with the development of connected equipment and machineries and of monitoring solutions of the field, which bring to higher quality products, less resources needed and lower environmental impact.

Smart City, with a great increase of project launched in Italian municipalities, with the aim to monitor all the element of a city, increasing the livability and sustainability.

Smart Asset Management, used to monitor assets from remotely, in order to detect possible failure or to take trace of them. It is mainly used to monitor gambling machine, elevators and vending machine.

Monetization

IoT changes completely the way companies can create and capture value, as mentioned in the article of Harvard review «così l'IoT cambia la creazione e la cattura del valore» [9]. In a world connected by the Internet of Things, you can add value to a product, and derive revenue from it, even after you've sold it to the customer.
Tracking usage behaviors and networking with other products and control centers creates huge new opportunities. The ability to track usage allows the product to be "adapted" to customer behaviors. And of course, products can be connected to each other and provide valuable data that can be analyzed to fine-tune new services, predict demand, optimize processes, and improve the customer experience. And with IoT, for the first time, it is possible to analyze exactly how a customer "lives" the buying experience and the use of the product, and then understand how to improve and enrich that experience by giving it new life.
In addition to value creation, IoT technologies and cloud-based data sharing and analysis also revolutionize the next phase, value capture, i.e., the monetization of the value created for the customer.

In this regard, Capgemini consulting, in its article «Monetizing the Internet of Things: Extracting Value from the Connectivity Opportunity» [10], has identified four main monetization model that can be exploited to extract value from IoT:

Hardware Premium: it represents the simplest and most basic among the forms of monetization explained. It requires companies to offer additional connectivity options to a product (already in the market or a new product) by offering remote device management in the form of mobile applications. Companies will then be remunerated through the premium earned for the functionality of the product sold (improved through a basic level of connectivity and control).

Service revenue: this mode provides a recurring revenue stream. In addition to this, there is the great advantage of establishing a relationship with the customer that persists even after the product is purchased. In this model, companies are able to generate a service from what was their traditional product by tying a recurring pricing model to specific functionality

Data revenue: in this case, companies take advantage of the large amount of data that is generated by sensors within their facilities. Monetization is then based on the ability to capture, package and sell the data collected. After being aggregated and anonymized, they can be sold in their raw state, they can be leveraged to package insights and, finally, they can be monetized through advertising.

Ecosystem building: as mentioned earlier, IoT relies on an ecosystem of connected objects, and the greater the amount of those objects, the greater the benefits and value generated for all the actors involved in the ecosystem. Companies that use this model will not be focus on selling a product/service, but on offering a shared platform to the other protagonist inside the ecosystem (like hardware manufacturers, software developers, service providers). In this way companies (platform promoters) earns from both end customers and other platform users. Platform users pay the promoter for inclusion in the platform while, from the final customer, the promoter receives a share each time a product is sold on the platform.

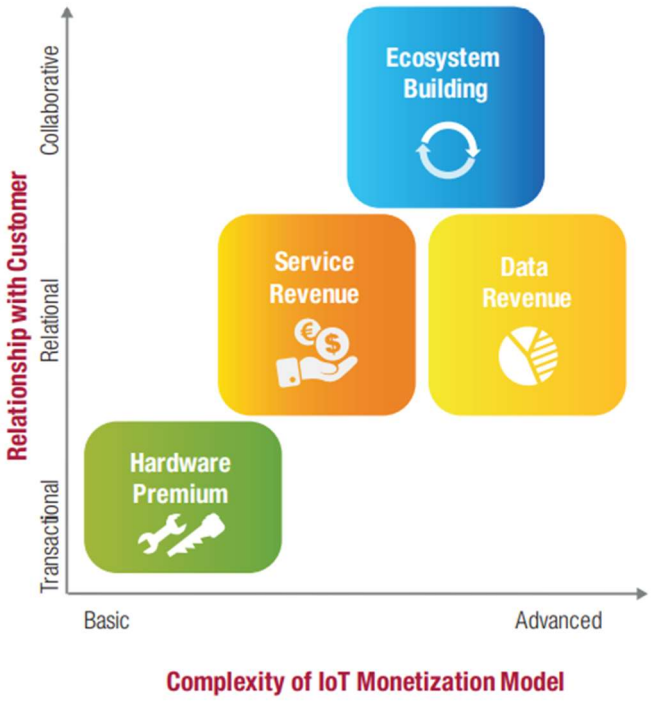

Figure 2 Capgemini consulting, «Monetizing the Internet of Things: Extracting Value from the Connectivity Opportunity».

In a connected world, business is not restricted to the physical sale of products, the amount of which can even be exceeded by other subsequent sources of revenue: value-added services, subscriptions, mobile apps. In this regard, the IoT also helps to increase the possibilities of loyalty, multiplying the options for personalization and contextualization: an effect further amplified in the case of a platform that includes multiple products and services.

1.3.2. The Technology

In the following chapters I will deepen on the technical features of IoT, discussing about the technologies behind Internet of Things. In particular, I will focus on SMART products' characteristics, on the typical architecture of IoT systems and on the most common technologies exploited in IoT projects.

SMART Products

Internet of Things is based on the so-called Smart objects. Following the definitions given by Osservatorio Internet of Things in its report "Il mercato dell'Internet of Things in Italia: applicazioni e trend di sviluppo" [13], a SMART object is characterized by holding one or more of the following features:

- *self-awareness*, which includes identification, i.e., the possession of a unique digital identifier, localization, i.e., the ability to know one's location, and status diagnosis, i.e., the ability to monitor operation and service needs.

- *interaction with the surrounding environment*, which includes data acquisition through the measurement of state variables (sensing) - such as temperature or pollutant concentration - or flow variables (metering) - such as electricity, gas, water and heat consumption - and actuation, i.e., the ability to execute commands.

- *data processing*, which can be basic (e.g., filtering, averaging) or advanced (e.g., statistical analysis, forecasting).

- *connection (wired or wireless)* to carry the collected information locally. Intelligence does not stop at objects but goes right into the nature of the network that interconnects them: use of open technological standards, accessibility to data and reachability of objects, multi-functionality are key properties of the smart network.

Architecture

Considering the definitions given in previous paragraphs, IoT is the set of technologies that allows to connect the virtual and the physical world. As a result, there is the necessity of elements that capture data from the physical world and transform them into virtual data and of elements capable of store all the data and make them readable and analyzable by human operators.
In this regard the Osservatorio IoT has defined (in the same report aforementioned) what is the typical 3-layers architecture of IoT. The three main components are the following:

- *interface with the physical world*: at this first layer a large number of nodes (tags or sensor units) interact with the environment; this is the layer that connects the real world with the digital one, through a wide range of devices, including sensors, actuators, machines and devices.

- *mediation*: the second level units, which include RFId concentrators and tag readers, have the task of collecting information from the first level nodes to convey it to the control centers.

- *control center*: the third level units, which include central acquisition systems and operating rooms, characterized by increasingly flexible architectures that often leverage cloud technologies, have the task of storing, processing and making available the information collected from the lower levels.

Technologies

One of the biggest challenges in the IoT world is connectivity, as it is necessary for the data being generated to be transmitted to the Internet. The ultimate goal of such applications is to analyze and process this data in order to improve the performance of the devices. Therefore, it is necessary to use new technologies for this purpose [16].
The technologies underlying the Internet of Things paradigm are numerous and in strong development. The Internet of Things paradigm encloses under its "hat" numerous technologies, characterized by different degrees of maturity. Eight technology clusters result from this analysis carried out by Osservatorio Internet of Things:

- *Passive RFID* (Radio Frequency Identification): this is the simplest technology with which an object can integrate into the Internet of Things. It groups all the automatic radio frequency identification standards that do not require the presence of a battery on board the object.

- *Active RFID* (Radio Frequency Identification): provides additional functionality compared to passive RFID thanks to the use of a battery, which allows for improved communication performance (reading distance) and enables autonomous operation, without the need for interrogation by the reader.
- *Personal Communication*: groups together standards for communication in short-range networks (PAN - Personal Area Network) designed for consumer applications and characterized by very narrow communication bands (such as Bluetooth low-energy, ANT, NFC13). The diffusion of these technologies has received considerable impetus thanks to their integration with most of the latest generation of mobile devices (smartphones, tablets).
- *Wireless Bus*: these standards (including, for example, Wireless M-Bus, KNX, X10) are proposed as a "wireless" alternative to wired solutions already used for some time in the industrial world. The most widespread technology is represented by Wireless M-Bus, a protocol that supports - among others - the 169 MHz frequency band. The technologies belonging to this cluster do not allow sophisticated communication architectures, since they replicate the principles of field buses.
- *WiFi*: these are protocols that allow wireless access to local broadband networks. Since they have been developed for multimedia applications, which require the transmission of a large amount of data, they have high energy consumption, which implies strong limitations of applicability in the IoT field.
- *Low-Power Mesh Networks* (RMLP): networks formed by low-power nodes and characterized by complex, self-configuring network architectures capable of supporting dynamic data routing and optimized for low power consumption (such as ZigBee, WHart). There is currently a great ferment on these technologies, which are considered one of the cornerstones of IoT development, and a lot of work is being done on protocol standardization.
- *Cellular networks*: these are the usual cellular communication technologies, namely GPRS, GSM (2G), HSPA (3G), no to the recent LTE (4G). In view of the high energy consumption, they find application especially in those cases where it is possible to power the nodes, as well as in combination with RMLP and Wireless Bus for communication between second level devices (concentrators) and control centers.

- *PLC* (Power Line Communication): the transmission of information occurs through the modulation of the electrical signal used for the power supply.

There are both protocols designed for the residential world and for the medium and high voltage network: the main difference concerns the maximum communication distance and the supported data-rate.

1.4. Industrial Internet of Things

1.4.1. What is and Main Benefits

After having introduced IoT technology - analyzing both the technical features, the possible fields of usage and the context in which it is developing - I will focus on a precise application, that is Industrial Internet of Things (IIoT). The term IIoT refers to the use of traditional Internet of Things (IoT) technologies and in industrial environments. Therefore, it implies the massive deployment of industrial sensors, actuators and machines with remote sensing/actuation capabilities in context aware environments [6]. IIoT consists of applying the Internet of Things (that can be defined as the ubiquitous connection of physical objects based on advanced communication and information processing technologies) into industrial systems. Its main objective is to transform industrial operations and roles offering to effective solutions. Additionally, it can be seen as a new combination of physical machines with digital possibilities, where all the entities within the industrial environment (such as machine, computers and people) are networked and in communication with each other [20]. Industrial Internet of Things (IIoT), as a typical implication of Cyber-Physical Systems (CPS) in Industry 4.0 era, has attracted significant attention. Its main goal is to improve production efficiency by optimizing the use of resources in the manufacturing industries. This aim can be achieved thanks to a deep interconnection of physical equipment, an intelligent awareness of environment and automatic control and a wide collection of multi-dimensional data. In a narrow sense, IIoT is considered as a subset of IoT and defined as a communication network with high reliability, low delay and high controllability that provides ubiquitous interconnection for industrial intelligent objects [18]. The spread of Industrial IoT brings intelligence to all areas of enterprises, infrastructure, production systems, products and generates a flywheel effect on Industrial Analytics and the Cloud, supported by the growth of devices and services that enable IoT connectivity both in the enterprise and at customer sites. This transformation leads enterprises to revise not only processes but also products. Thanks to the IoT, products become intelligent, talk to each other and to customers, so it is necessary for companies to put this knowledge to value [2]. As a

result, by applying IoT technologies in Industrial applications, companies are able to significantly increase the efficiency of their production processes, as well as more efficient networking and communication between the machineries and the operators of the plants. Moreover, it would enable companies to be more competitive on the market, thanks to an improvement in the quality control (in terms of a minimization of losses) [25]. It improves the data assembling, productivity of the operation, communication efficiency, and overall manufacturing performance. IIoT is also serves to be a good means for improved and efficient warehouse automation. It allows to select the least routes, making the delivery of products much more efficient and, in addition, to reduce the time used during the management of inventory [3]. Going more in depth, the possible application field and related benefits that have been identified by Fatima et al. are the following:

- *IoT Application in the Business Area*: when discussing different IoT applications, predictive monitoring and maintenance are better discussed as they involve several sensory data, such as temperature, density, vibration, temperature, voltage, and current, using machine learning models. The latter can make predictions on when failure is going to occur, allowing companies to reduce the number of incident and breakdown of their assets. The ML model are trained thanks to all the data generated by the sensors connected to the machines. This will lead to the provision of accurate probability and prediction.
- *IoT in Process Automation*: to increase the efficiencies and the reduce costs of the different processes in warehouses, plants, and factories, companies are trying to automate all those repetitive and mundane tasks in order to free operators, who will therefore be able to focus on high-level activities. The type of automation is strictly dependent to the kind of industry considered (processes can be automated either with robots, IoT and software). In industrial processes, IoT is used to track and monitor the analytics of different machines. In production plants, IoT is used to monitor key parameters (such as temperature and pressure) and to switch different processes on and off, based on the conditions.
- *IoT in Production Testing*: in production testing, IoT is used to test the quality of different products to reduce the time and cost of testing. To test the quality of the product, different sensors with IoT devices are used with the combination of machine learning (ML) models. ML models in IoT identify the object, then test its quality using sensor data and provide quality level feedback of the product to the managers.

- *IoT and the Supply Chain*: IoT is a global platform of internet-connected smart devices that enhance supply chain ICT infrastructure to obtain a better connectivity with both customers and suppliers. Many are the possible examples in that sense: visibility on the storage conditions along the entire supply chain, tracking and tracing of products, processing of payment based on the location and many other possible benefits resulting from the application of IoT in supply chain management.
- *Temperature Monitoring/Controlling System*: the temperature is monitored in the oil and gas industry to ensure the system's overall safety. The temperature is monitored in the food industry to ensure food safety. The sensor communicates with the process station, which collects the temperature data and sends it to the cloud. Some algorithms are used to determine if it is within the required range or not. After that, if necessary, corrective actions are taken.
- *IoT and the Control Systems*: control systems are the main element in factory automation, as the integration of physical systems with the internet requires a collaboration with ICT experts; thanks to algorithms, sensors and actuator can be linked to each other over the internet. This allows to obtain some level of performances; for instance, temperature, pressure and flow sensors can be exploited in a manufacturing process that involves chemical mixing. The controllers are connected to the sensors via Ethernet or Wi-Fi. If the temperature of the chemical used in the process overcome a fixed threshold, then the controller quickly adjusts the power that is given to the heater.

Although the term that the authors used in their study is IoT rather than IIoT, they specifically precise that the discussion is limited to IoT in industrial environment (i.e. Industrial Internet of Things). Moreover, by looking at the report developed by Osservatorio Internet of Things, it emerges that the main drivers for the adoption of the technologies varies depending on the dimension of the company. For large companies, the benefits of efficiency and effectiveness (indicated by 80% and 55% of respondents, respectively) are the priorities, in line with what was already observed in 2019, while SMEs follow more varied objectives, without a clear polarization (most options range between 20% and 25%): this testifies to an underlying uncertainty in relation to the strategy to be followed, also due to less knowledge of the subject. In third place among the most popular drivers, there are the incentives linked to the National Plan Industry 4.0 (already discussed above), which in recent years have helped to create a strong awareness in companies, laying the groundwork for the start of projects. (On this front, the news concerns the new Piano Nazionale Transizione 4.0 recently approved by the Government, which

provides for an increase in investments to support companies from 7 to 24.3 billion euros until 2022) [12].

In the next sections, I will further concentrate on those areas of applications most diffuse according to the latest research and surveys conducted by Osservatorio IoT, which are Smart Factory, Smart Logistics and Smart Lifecycle.

Smart Factory

Smart manufacturing is the foundation of Industry 4.0 and combining IoT technology with manufacturing science is the cornerstone of smart manufacturing. Its goal is to integrate IoT technologies with current manufacturing processes to drive production, changing the traditional workshop management style. Following this approach, Industrial IoT is used to monitor and track goods (and equipment in general) at the workshop, as well as to control in a smart way the production procedure. The smart control of the manufacturing procedure per forms the self-activating decision-making process by utilizing a knowledge base for the decision making, and by storing, analyzing, and processing related manufacturing data [3]. The Internet of Things enables early detection of system failures, design of performance-based services and optimization of technical support. Thanks to IoT, it is possible to significantly strengthen the transition from reactive to predictive maintenance policies, with detailed information on asset histories. By connecting different data sources together, IoT technologies also enable real-time visibility into asset status. For example, a negative variation in the energy performance of a device, can serve as an index of machine or plant performance, so as to generate an appropriate preventive action. Extending this possibility to all elements of a production process means gaining operational and competitive advantages that can make all the difference.
IoT for maintenance management on the one hand optimizes the life cycle of plants and operating performance, and on the other allows a decrease in costs related to inspections and scheduled interventions. Thanks to the historical collection of information and its processing, plants made "smart" by the IoT are able to adapt according to the conditions of use in which they are, defining reactive procedures of predictive maintenance able to anticipate failures. Typically, in the event of excessive stress, the plant can reduce performance levels autonomously by operating at reduced scrap. This adaptive capability is particularly effective in the case of networked plants and machines, where each component acts according to the conditions of the other elements, avoiding conflict [2]. Industry 4.0 represents the next step on the evolution of traditional factories towards actual smart factories, which are designed to be more efficient in terms of resource management and to be

highly flexible to adapt to ever-changing production requirements [6]. Looking at the results provided by Osservatorio IoT [12] the most spread solutions in the field of Smart Factory are linked to product optimization, energy management and preventive maintenance, which are going to be deepen in Chapter 3. The result obtained by Osservatorio IoT (in the previous analysis of year 2021) is shown in the figure below.

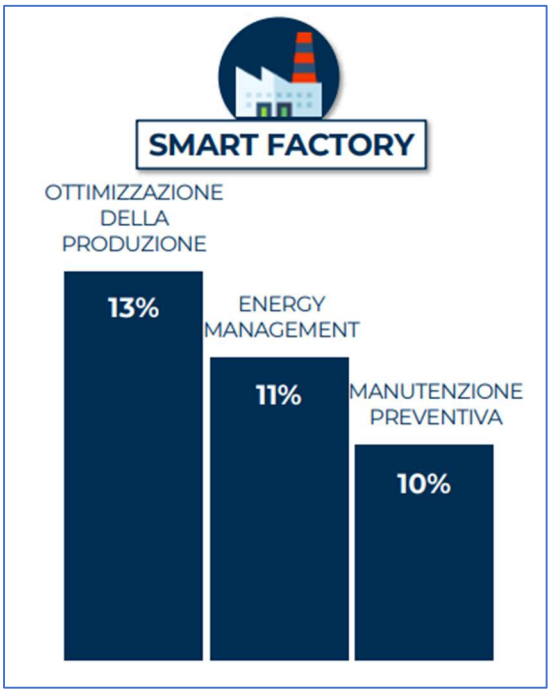

Figure 3 Osservatorio Internet of Things 2020-2021, «Industrial Internet of Things un confronto tra grandi imprese e PMI», Smart Factory.

Smart Logistics & Supply Chain

The supply chain is a series of processes involved in the production and distribution of goods. Generally speaking, the entities of supply chain consist of many stakeholders, such as suppliers, manufacturers, retailers, carriers, and customers. The traditional supply chain is still facing challenges and issues in information sharing, data security, trust, and performance. An ideal supply chain should ensure end-to-end visibility, flexibility, inferred trust, and control of the process [18]. The possibility of assigning an IP address to each physical object enables numerous applications, the most important of which is the tracking of products and their quality. Starting from the data obtained from a precise and punctual monitoring of the connected objects, it becomes possible to organize an optimization of logistic processes: all the plants, devices and systems of a logistic chain can be minimized in order to limit energy consumption and the release of CO_2 into the atmosphere. In addition, in the field of transport, the use of special technological tools based on

IoT makes it possible to optimize routes, avoid unnecessary routes and dead periods. As a result, the exploitation of IoT technology in this environment has also strong influence on the sustainability of supply chain, which is a widely discussed topic nowadays. The amount of data generated by the Internet of Things requires the adoption of a resilient and secure network and cloud infrastructure, capable of making data always available. The combined use of IoT and cloud in logistics enables a whole other set of crucial issues for the industry, including reducing costs associated with last-mile delivery, optimizing transportation capacity, and the need for business diversification and innovation [28]. Intralogistics (intended as a set of logistical flows of goods and materials within a company strongly influenced by the "digital transformation") is evolving to meet the demands of a constantly changing market that no longer requires a standard mass production, but the ability to produce small batches at a time. It becomes then essential to optimize the flow of goods through a proper organization of data by organizing processes and production flows on the basis of stored data. At the same time, new sensors and intelligent systems lead to greater transparency and process control of the entire supply chain. In this vision, logistics, and in particular intralogistics, becomes an opportunity to increase competitiveness and further refine lean production processes. Sensors able to communicate with each other with IoT and RFID technologies transmit identification data of the goods and the environment, reducing the risk of loss or damage [2]. The ability to use wide-ranging IoT devices in the enterprise also allows for supply chain improvements through the analysis of the data derived. We could say that a data-driven supply chain is developing. And the benefits are significant. Indeed, having sensors that are always connected allows you to monitor location, temperature, rough handling and other basic parameters. And all the data can be shared in real time via the cloud. Not only does this allow for immediate problem solving, but it also paves the way for whole supply chain analysis and efficiency on a macro scale because companies can access data on the location of goods in transit and get real-time indications of their condition. IoT solutions combine integrated sensors and cloud-based monitoring to provide supply chain managers with the data they need to perform optimization. First and foremost, they enable improved inventory management. Because it shows exactly where shipments are at any given time (and how long they take to complete each portion of the route), accurate data analysis allows you to arrange targeted increases in safety stock (to meet any fluctuations in demand) or replace stock lost due to damage or unforeseen delays during transport. In addition, with real-time visibility into where and when damage occurs due to temperature fluctuations or rough handling, you can design specific processes to eliminate the root cause of these problems. Understanding the precise timing and routing of each shipment allows you to address problems based on data, not assumptions [29].

The most spread solutions, regarding Smart Logistics & Supply Chain are those that guarantee support to logistic, focusing on the traceability of the products along the whole Supply Chain and internally to the companies' warehouses, together with the management of logistical assets, as shown in Figure 4 [12].

Figure 4 Osservatorio Internet of Things 2020-2021, «Industrial Internet of Things un confronto tra grandi imprese e PMI», Smart Supply Chain.

Smart Lifecycle

Smart Lifecycle is related to the management of all the life cycle of a product, exploiting the digital and interconnected world. It considers all the activities that characterized each stage of product's life (from the very first like designing to the last ones like disposal). With the development of Industrial Internet of Things, companies are able to constantly monitor the products, gathering a huge amount of data related to it, being able to optimize its management. For instance, companies can improve the development process of a new product by exploiting older versions of connected products. Or producers can gather data to understand how the client use it and what are its main requirements, in order to develop always more improved versions of the product. You can't talk about Smart Lifecycle without referring to Product Lifecycle Management (PLM). The term PLM is given, today, a double meaning; PLM is both the product lifecycle management process and the software used to implement the process [30]. Product Lifecycle Management (PLM) is the business activity of managing, in the most effective way, a company's

products all the way across their lifecycles. It manages the whole range, from individual part through individual product to the entire portfolio of products in an integrated way. In the era of Industry 4.0, the effect of the combination of PLM and IIoT is becoming increasingly prominent. IIoT could address to the challenges of data information and knowledge during and within the PLM phases to enhancing the management of product lifecycle related information and knowledge. PLM can access data from different sensors, actuators, enterprise systems, and other novel data sources to better guide the production work of IIoT to achieve the high-level goals such as increasing product revenues, reduce product-related costs, and maximize the value of the product portfolio [18].

Regarding Smart Lifecycle, from the surveys conducted by Osservatorio IoT in the previous years (2020/2021), it emerges that the most frequent solutions are related to the optimization of new product development and to products' end-of-life management, as shown in Figure 5.

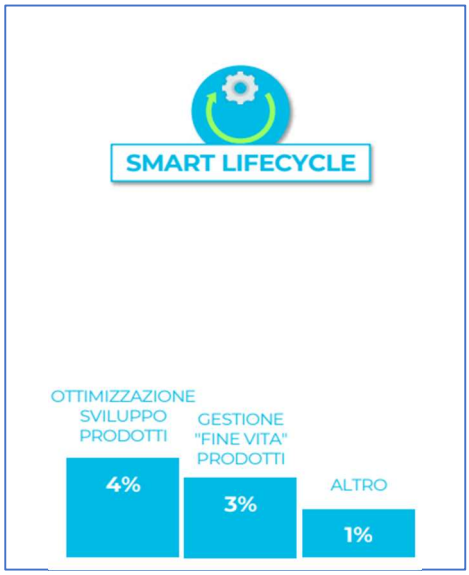

Figure 5 Osservatorio Internet of Things 2020-2021, «Industrial Internet of Things un confronto tra grandi imprese e PMI», Smart Lifecycle.

1.4.2. Weaknesses and Barriers

Industrial IoT (but also IoT in general) is a relatively new technology, developed in recent years thanks to the great technological improvement typical of the last decade. As a result, there are still several barriers and weaknesses that limit the implementation and use within today's factories. In the following section, I have tried to analyze the main barriers and possible points of improvement that

companies need to overcome in order to see a large-scale deployment of this innovative technology.

Cybersecurity

One of the things keeping industries away from IoT is their concern about privacy and security requirements. With the boom of IoT, industrialists face challenges of the protection and privacy of their data, as traditional security methods cannot be applied in IoT [3]. Cybersecurity is one of the main challenges faced by companies in the context of the Industrial Internet of Things (IIoT), in which a number of smart devices associated with machines, computers and people are networked and communicate with each other. In addition, the recent increase in smart working due to the COVID-19 pandemic means that the need for cybersecurity awareness is more relevant than ever, where cybersecurity awareness has been defined by Shaw et al. as: "The degree of understanding of users about the importance of information security and their responsibilities and acts to exercise sufficient levels of information security control to protect the organization's data and networks" [20]. Diverse types of attacks threaten the different parts of the IoT architecture, like unauthorized access to tags, denial of service attack and malicious code injection. IoT objects are more defenseless to these attacks since they are simple, and some security measures cannot be applied. Therefore, security and privacy issues need to be more considered in IoT environment, as the IoT security issues potentially cause severe disaster to us (Asghari, Rahmani, e Javadi, 2018). An industrial environment, that involve the intensive use of smart devices, wireless sensor networks, Internet protocols, the cloud, and data analytics technologies, contribute to make physical systems vulnerable to cyberattacks. Moreover, within IIoT-based scenarios, the increasing integration of operational technology (OT) with information technology (IT) has caused industrial systems to be exposed to a worrying number of new cyber threats [20]. As IoT is an interconnected platform all of the personal data is out there uploaded in the cloud which is highly vulnerable. If there is a glitch in security of IoT it will evidently compromise a person's privacy as well as security. This could be fixed by leveraging a safe gateway and developing protected algorithms and cryptographies for more secure environment [16]. This security barrier necessitates complete security solutions, which include efficient research in cryptographic solutions and security systems that help developers to develop secure systems. The integrity of messages sent and received, and the confidentiality and authenticity in a conversation between communicating parties should be considered [3].

Adaptation of infrastructure and integration

Infrastructure and education must be adapted. Producers as well as suppliers must work to adapt infrastructure and education as they embrace the technologies of Industry 4.0. This is best addressed through a combined effort involving government, industry associations, and businesses to achieve the following:

- Upgrade technological infrastructure, such as fixed- and mobile-broadband services. Infrastructure must be rendered fast, secure, and reliable enough for companies to depend on it for near real-time data.
- Adapt school curricula, training, and university programs and strengthen entrepreneurial approaches to increase the IT-related skills and innovation abilities of the workforce. [7].

Moreover, with the continuous advancement of IIoT, more and more workers are replaced by machines, and more and more manual operations are replaced by software automation. The continuous convergence of IT and OT can improve production operations and bring benefits such as increased productivity and security. However, the current integration of IT and OT cannot give full play to the advantages of IIoT. IT pays more attention to the upgrading of system architecture, trying to promote the efficiency of the whole system through the latest technology. OT focuses more on maintaining the stability of the system. Blind pursuit of new technology upgrading system will bring unstable factors to the system. Excessive emphasis on stability and not introducing new technology will affect productivity. Therefore, how to promote the deep integration of IT and OT is a major challenge for the development of all industries in IIoT [18].

Common standard

The common communication standard stills remain a question to its development. As the aim of IoT is to be more user-friendly and also communicate easily with other connected devices. Due to this, some common communication protocols which supports heterogeneity of networks and interoperability need to be established which are significantly easier for its user for its substantial development. Currently, several standards are used to support diverse industries' applications. As a result of the large amounts of data, different interconnected devices also have to adopt standards for collaboration, which is very difficult to perform, as well as within a variety of system restrictions. As a result, IoT systems are being developed to manage increasingly greater levels of interconnection. [3]. While different IoT devices and applications have been already developed, they commonly result in poorly interoperating of things. Interoperability as the

important challenge of IoT interactions between the smart objects and enterprise systems provides a framework for the IoT applications communications. The key challenges in this area include scalable architectures for interaction with sensors, actuators, and enterprise frameworks for self-adaptive IoT applications (Asghari, Rahmani, e Javadi, 2018). Furthermore, a major challenge for IoT is standardization. There are no specific guidelines for IoT solutions. It all depends on the individual vendor as to what they are providing and how they are developing their technology or service. This is mainly due to its rapid development, varying fields of implementation with different hardware and software as well as it being a relatively newer technology [3].

Energy consumption

One of the most important challenges in IoT is reducing the energy consumption. As a key concept, green IoT is a direction for developing various technologies and issues that try to achieve a sustainable smart world wherein the energy consumption of smart IoT objects should be reduced. Many issues such as green radio frequency identification, green wireless sensor network, green machine to machine, green cloud computing and green data centers enable green IoT (Asghari, Rahmani, e Javadi, 2018). Despite the significant advancements in monitoring and sensing technologies, sensors and actuators are typically required to continuously remain active to acquire instantaneous data. This aspect makes energy efficiency difficult, particularly in terms of lifespan extension; thus, organizations must employ energy optimization techniques [3]. Most of the devices employed over here uses battery and as once the sensor is in the field, it is almost impossible to replace its battery which will lead to heavy power consumption and ultimately global energy crisis. Therefore, another challenge is designing sensors that do not require any battery change over lifetime which can be achieved by producing more devices which run on renewable sources of energy. One of the most recent one is integration of IoT with solar energy [16].

Limited resources and data management

A large number of IIoT edge equipment have limited resources, network resources, storage resources, etc. Edge devices with limited resources can not undertake a large number of businesses that require computing power and cannot store a large amount of data. How to store a large amount of data collected by edge devices is an urgent problem faced by IIoT [18]. Moreover, a vast amount of data has been produced in the period of big data, but the management of data is very difficult.

Currently, centralized systems are used for computationally expensive tasks on platforms of the cloud. Nonetheless, there is a persistent concern that traditional cloud designs may fail to transfer the vast volumes of data produced, to be used by devices, and to load, which happens on computation. Other challenges also arise from the fact that, once the data are collected, they are then to be used intelligently to gain insights, but machine-learning models and algorithms that work on the neural network can perform automated decision making, which is not always accurate. Finally, one of the most important challenges is the skilled persons required, who know about implementing IoT with complex automation techniques and real-time data handling on a large industrial scale [3].

Internet connections

Internet is the soul of IoT and problems in internet connections would lead to poor service and inadequate performance of an IoT device. Almost all base station/gateways are designed with some limit of users that can access simultaneously when the count exceeds the limit, some user will not receive service. So, for IoT to be implemented successfully, fast, cheap and hassle-free internet should be established in a country [16].

1.4.3. Future developments

In this paragraph, I initially introduce the topic of blockchain, a technology that has gained a lot of popularity in recent years due to the large number of benefits it offers. In particular, I report the main benefits that the use of blockchain would bring in a company where the Industrial Internet of Things is used.

Blockchain

Industry 4.0 in general is a concept devised for improving the way modern factories operate through the use of some of the latest technologies, like the ones used for creating the Industrial Internet of Things (IIoT), robotics, or Big Data applications. One of such technologies is blockchain, which is able to add trust, security, and decentralization to different industrial fields [6].

Blockchain is a kind of distributed ledger technology and has features including decentralization, anti-tamper, transparency, anonymity, and contract-autonomy. These features are helpful to improve the services and promote the development of IIoT [18]. This is one of the most promising technologies to be applied in industrial environments, which originated from the cryptocurrency Bitcoin, and which allows

for creating decentralized applications (DApps) able to track and store transactions performed by a large number of simultaneous users and devices.
In general, two key costs may be reduced by blockchain: verification and networking costs. The former are related to the ability of verifying in an inexpensive manner the attributes of a transaction, while the latter are associated with the ability of operating without needing traditional middlemen [6].
Looking at what are the current challenges faced by the application of IoT in industrial scenario, it is possible to understand how blockchain could benefit this environment. IoT suffers from security issues. On the other hand, the innate security, the immutability of blockchains are the major reasons for its adoption in monetary and nonmonetary applications. Blockchain made this possible through its consensus approach and by using its ledger, which is distributed, i.e., not controlled, by only one node. As a result, the combination of these two technologies provides an additional layer of security. Furthermore, the security of devices will increase while also benefiting from one another [3].
In most industries trust in the authenticity of the collected data and in the transactions performed with certain partners, service providers, manufacturers, suppliers and even governments are necessary. Due to these reasons, a technology that provides mechanisms to enable transparency, verify accountability and to add trust is required. For the same reasons that data exchanged with third companies have to be protected and anonymized, all the data collected thanks to IoT devices should be kept private and secure to non-authorized parties. In that sense, blockchain allows IIoT systems to perform decentralized transactions and to exchange information during the different processing stages within a trust framework (e.g., a shared data ledger) where all the transactions are both signed and timestamped. Furthermore, it is really common to update Industry 4.0 systems (like IIoT devices) due to security issues or to upload new software/firmware. In certain scenarios the updating process requires to perform manual tasks in multiple devices spread throughout a large factory. Therefore, it is necessary to find a way to ease such tedious and inefficient tasks and distribute software updates simultaneously to as many smart devices as possible, while preserving the integrity and security to avoid malicious firmware updates [6].
Looking at the study conducted by Huo et al., it is possible to highlight the main benefits resulting from the application of Blockchain technology to IIoT. The report describes a lot of possible improvement coming from the use of blockchain in general, but I will show just the ones more related to the IIoT world.

- *Distributed Storage*: In traditional IIoT, the central server, as computing center, carries all computing tasks. The problem of central server will lead to the paralysis of whole system. By introducing blockchain, the edge server clusters can replace the substitute of central server. They will structure

blockchain with IoT devices collaboratively and complete the computing task, and then all nodes of blockchain will store the result. In this way, the computing task can be completed by other servers when a single server fails. In addition, distributed storage also reduces the possibility of maliciously attack and data loss. The existence of this feature strengthens the robustness of IIoT so it is possible to be applied in scenarios with high security requirement.

- *Decentralized Credit*: With the development of IIoT, cross-domain collaborative manufacturing between different enterprises is becoming an increasingly urgent need. However, current IIoT does not provide an environment in which cross-domain collaboration can be trusted. One of the most important features of blockchain in IIoT is to achieve true credibility when sharing data between different network domains. Blockchain technology can enhance the ability of regional cooperation and credible production

- *Unified Management Standards*: A unified standard is indispensable in the industrial production process. It can not only standardize the various operating steps of industrial production with unified standards, but also improve industrial production efficiency and ensure a safe production environment. IIoT equipment collects, shares, and processes a large amount of data and information. To protect the privacy and security of data, it is first necessary to protect the equipment from being controlled by malicious attackers. All parties involved in IIoT need to have uniform standards for testing whether new equipment is functioning properly. Blockchain has a great advantage in this regard. The equipment management-related standards can be stored in the blockchain, and subsequent standard revisions and related operations performed are recorded in the blockchain, which reduces the complexity of the procedure for unified revision of the standard and saves time and cost.

- *Privacy Issues*: The large amount of data collected from IIoT devices may contain personal privacy, such as personal health data, personal identification information, and personal behavior data, etc. Malicious attackers who obtain these private data will not only bring greater economic losses, but also bring greater threats to user privacy issues. The key

infrastructures of the blockchain can encrypt data so that only users with the corresponding credentials can obtain the data, thereby protecting the privacy and security of user data.

- *Storage Security*: The devices of IoT generate a lot of data and contain a large amount of data related to the privacy of users. In order to prevent data from being obtained by malicious nodes and infringe on the rights of data owners, how to store data safely has become an urgent problem to be solved. Data security storage is also a key issue in data collection and sharing. Traditional data storage methods have many drawbacks and cannot guarantee the safety of storage. Blockchain could solve these drawbacks with the distributed, tamper-proof, and traceable features.

- *Supply Chain Management*: All participants in the supply chain can automatically upload the necessary information to the blockchain-based data collection platform by IIoT devices. By using blockchain technology, each member does not have to manage its own supply chain itself. The members of supply chain can obtain verified information to make production, inventory, and transportation plan. Blockchain has improved the supply chain from multiple dimensions, such as environmental, economic, customer, and information

- *Production Traceability System*: In IIoT, there is an increasing need for traceability, transparency, and authenticity of products and their production processes. Due to the anti-counterfeiting of product, technologies such as IoT and RFID are gradually playing vital role in the production traceability system to digitize information so that the real-time production information can be collected. The production information, such as different level of production step detail, could be traced in production traceability system according to different requirements of traceability varied from industry to industry. The characteristics of blockchain make it highly applicable for traceability system. The blockchain based system provides many benefits such as improve quality, product fault traceability, and increase customer's reliability and trust-ability.

- *Product Lifecycle Management (PLM)*: IIoT could address to the challenges of data information and knowledge during and within the PLM phases to enhancing the management of product lifecycle related information and

knowledge. PLM can access data from different sensors, actuators, enterprise systems, and other novel data sources to better guide the production work of IIoT to achieve the high-level goals such as increasing product revenues, reduce product-related costs, and maximize the value of the product portfolio. However, with the increase of information exchange across enterprises, the traditional centralized PLM framework is hard to manage data of different enterprises securely and efficiently. Blockchain technology can continuously foster the development of PLM, and make PLM satisfy the demand of security, openness, and decentralization.

2 Research Objectives and Methodologies

After having introduced the themes around which the thesis work focuses, this chapter presents the main objectives that I aim to achieve through the research conducted. In particular, I will mention the research questions that will be answered in the following paragraphs, clarifying which aspect of the Industrial IoT is being addressed. Finally, I will explain what methodologies have been used to produce the thesis work, considering that each section presents specific ones.

2.1. Research Objectives

The primary objective of the research, which was carried out together with the Osservatorio Internet of Things of the Politecnico di Milano, is to deepen the state-of-the-art of Industrial IoT technology in Italy and in the world. The question I will answer with the thesis work is therefore:

Which is the state-of-the-art of Industrial Internet of Things technology?

At a time when the drive towards the digitalization of Italian companies is stronger than ever, spurred strongly by incentives related to PNRR, I want to analyze the current use of IoT, which is certainly one of the pillars of Industry 4.0. In addition, at a time as economically, socially and politically complex as the one we are going through, I want to understand how companies have been influenced in their adoption/development choices IoT projects, analyzing, in particular, whether the advent of the pandemic may have caused a slowdown in the development of IoT (and if so, to what extent). On the other hand, it will be deepened whether the large financial aid from the Italian government (through the PNRR) have instead contributed positively (and if so, to what extent) to the digitization of Italian factories. With the research work I will then try to understand what is the level of knowledge of IoT solutions within the company, investigating on the knowledge of what can be the benefits deriving from this technology (or the advantages of existing projects); it will be important to understand the factors that have driven companies to implement projects of this type and which are the most difficult barriers for any

company, understanding what are the causes that do not allow a rapid spread of the IoT. Moreover, it will be essential to understand which are the areas in which IoT is present to a greater extent, which are the most common application areas and their evolution over the years.

Finally, I will focus on the analysis of the future trends that will characterize the next years of IoT. Specifically, I want to understand which are the proposal of the most innovative start-up, in order to understand which are the aspect on which the market is focusing, defining the most recurrent innovations that will likely improve the spread of IoT among industrial companies. In addition, the objective will be to deepen the most spread and influential of the trends among the ones identified by proposing a framework that focus on the strategic choices made by the start-ups for their business. In particular, I want to understand how important is the theme of environmental sustainability for the start-up that are growing in the last years. Therefore, the questions I will answer are:

Which are the most influential trends that are changing the world of IIoT? How is the theme of environmental sustainability impacting on IIoT development? In what measure are companies focusing on it with their IoT solutions?

2.2. Methodologies

In this section I will clarify which methodologies were used to develop each section of the paper. In general, different types of sources have been used, listed below:

Literature review: to develop the first chapter, where the context in which the study is developed is discussed and the main features of the IoT are introduced, an analysis of the literature has been made that has allowed me to understand and report the fundamental concepts of this paradigm. To do this, the main articles on the subject were analyzed using the search engines of Google Scholar, Scopus and Science Direct. Being the IoT a technology that has witnessed (and is still witnessing) a great development, it has been chosen to select only the most recent sources, avoiding articles that discuss the topic in a context too different from the current one. In the first part of Chapter 1, the discussion carried out is general, with reference to the theme of Industry 4.0; for this reason, the keywords used are equally general, such as Industry 4.0, Internet of things, Fourth Industrial Revolution. But as we go along, I tackle more specific topics that have required more targeted research, using specific keywords for each small section such as Smart Supply Chain, Smart Factory, Smart Lifecycle, Blockchain and IoT, IoT Technology, IoT barriers.

Primary sources: the thesis revolves around the survey conducted in collaboration with the Osservatorio Internet of Things. Two separate surveys were conducted: one submitted by Large companies and the other submitted by SME. However, the thesis work focuses mostly on the results obtained from Large companies' survey. This was sent to Italian companies with the aim of obtaining fundamental information about their situation in IoT optics. Through the survey we investigated the current state of adoption of IoT solutions within the companies interviewed. The questionnaire consists of 25 questions and consists of parts dedicated only to those who have already started IoT projects and others dedicated to all the participants of the survey. The details of the questions that have been submitted to the companies can be consulted in the Appendix where the entire survey sent has been inserted. To define the recipients of the questionnaire, research has been carried out in order to obtain a good number of contacts of potentially interesting companies (inserting every contact found in a contact database). The analysis has been limited to companies belonging to the manufacturing/production sector and the logistics and transport sector, which represent the most significant sectors to study the use and diffusion of the IoT. In addition, it was decided to search (and eventually insert) only the contacts of business contacts closely related to IoT applications within the company and that can therefore provide accurate and up-to-date answers regarding the choices in this area. For this reason, the survey was limited to figures such as, for example, CIO, IT Manager, Production Manager, COO, Logistics and Supply Chain Manager, Automation and Innovation Manager.
After having received the answers of the surveys, an analysis of them has been proposed. All the information gathered from the question have been represented through chart.
For some questions a comparison between the results obtained by SME's surveys has been proposed. In this case, the results were directly delivered by Osservatorio Internet of Things, and the activities of definition of questionnaire's recipients were not conducted by me.

Secondary sources: in order to analyze the degree of diffusion of IoT in Italy and in the world, one of the objectives of the thesis is to map the projects that have been implemented in recent years. Since there is already a database in which all the projects related to previous years have been marked, I helped to expand this database by inserting the most recently implemented solutions. To find them the following sources were mainly used:

- IoT technology provider sites (which often report on their site case studies of projects implemented with key partners)
- specialized websites in the digitization world
- company sites.

Each project has been classified according to a number of parameters. First, general information such as the name of the company and the name of the partner involved (the person providing the technology solution to the company), the geographical location of the company (continent and geographical area) is indicated and the year the project was developed. Later, more specific information is included for each individual project: the progress of the project is reported (executive if the project is already operational, pilot if it is a project implemented but still in an experimental phase, feasibility analysis in the event that the feasibility of the solution is still being analyzed), the scope of the project is indicated (Smart Logistics, smart factory, smart lifecycle together with all the other possible applications of IoT) together with the detail, which defines in a very concise way the purpose of the project, and a brief description that summarizes in a few lines what the solution is. Finally, the latest items are: offer, to define if a company is buying hardware, software and/ or services, technology, where you indicate the specific technology needed for the IoT project and Service, used to describe the type of service offered by the partner company providing IoT solutions. The last column shows the sources from which the project information was derived, the types of which have been described above. Finally, to provide the analysis of the most innovative start-ups operating in the IoT sector a research on the website "Crunchbase" has been conducted. Here a total of 43 start-ups have been selected. The research was made by filtering as "Industry" all the possible industries related to the topic such as "Internet of Things", "Cyber-security", "Artificial Intelligence". Moreover, some filters on the field "Description Keyword" were inserted, trying to propose terms related to possible IoT innovation like "Metaverse", "Digital Twin", "Blockchain". The start-ups identified were grouped into innovation clusters and for each of them some examples were inserted. To conclude, a general analysis considering all the start-ups about the geographical distribution was done, together with the evaluation of the fundings raised by them. To do that I exploited the small database created with the 43 start-up, which is inserted in the Appendix. In addition, to develop the model regarding the start-up that focus their offer on the technology of AIoT, I select a total of 24 start-up: 16 of them were selected among the database that I created through my research (just the ones related to the theme of AIoT); the remaining were selected by a database of start-up active in the industry of IoT in general, that was previously created by the Osservatorio IoT. From the start-up present inside this database, I filtered just the ones that offer products/services for the Smart Factory and then I selected all those companies focused on AIoT.

3 Analysis of the current scenario of Industrial Internet of Things

3.1. Introduction

As anticipated in the previous section, one of the objectives of the thesis project is to map projects related to the Industrial IoT field that have been implemented in Italy and abroad. This process will then make it possible to visualize the current IIoT scenario, analyzing the state of deployment and the various trends of this technology.
To do this, I have leveraged the database of Industrial IoT projects previously developed by my colleagues and which I have helped to update by including cases of companies that have entered the IoT scenario more recently.
In searching for new projects to be included, I tried to analyze the international application scenario comprehensively. Nevertheless, it is evident that the database of projects focuses mainly in Italian companies, given the great dominance in percentage terms of Italian cases compared to those implemented in other countries of Europe and the world. In the analysis that I will present in the following section, I have chosen to first show some statistical analysis regarding the period of implementation of the projects, the geographic area in which they were developed, the status of the project intended as the state of execution (executive, pilot, feasibility study), the major partners contacted to support the development of these projects, and finally the application field of the case of interest. This last part will be given particular importance: for each macro application field (Smart Factory, Smart Logistics, Smart Lifecycle) the main applications (such as, for example, production optimization or predictive maintenance in the case of the Smart Factory) have been analyzed, proposing an in-depth analysis and including an example for each of them.

3.2. Analysis of Industrial Internet of Things Database

For the following analysis, just the IoT applications related to the industrial domain were considered, given that the thesis work is focused on the Industrial Internet of Things. As a result, a selection of the projects in the database was made, including only those related to Smart Factory, Smart Logistics and Smart Lifecycle, which represent the three main areas of IoT for industrial application.

As shown in Figure 6, Europe dominates over the other continents in terms of IIoT projects mapped, with more than 70% of business cases, followed by North America (15%) and Asia (11%) representing the two most significant alternatives.

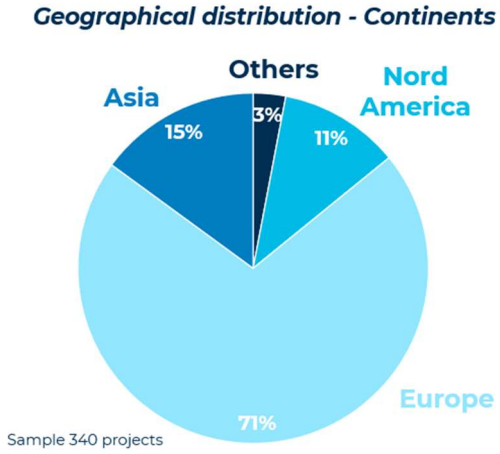

Figure 6 Geographical distribution of Industrial IoT projects (continent)

However, the great influence of projects developed in Italy should be kept in mind. As shown in Figure 7, it represents 44 % of the total sample. A percentage that undoubtedly does not reflect the current situation regarding the countries most advanced in the exploitation of this technology, but that is strongly affected by the way the projects included in the database were searched (often carried out on Italian websites that, despite dealing with the topic internationally, focus on initiatives carried out by Italian entities). The countries that follow Italy in the number of projects identified are the U.S. (13%), Germany (6%), UK (4%), China (4%), France (4%), Spain (3%), Japan (2%) and India (2%), which together with Italy, cover more than 80% of the sample.

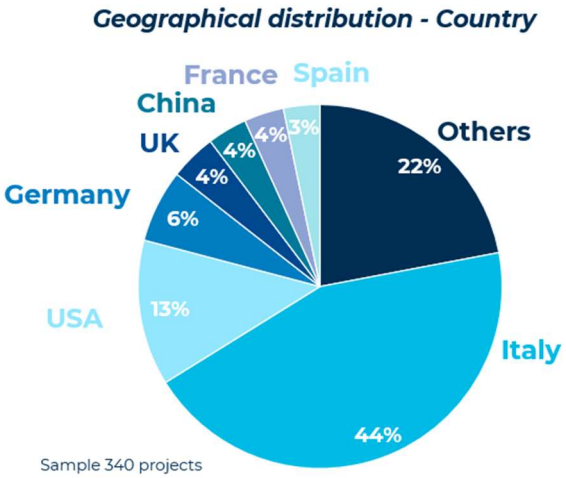

Figure 7 Geographical distribution of Industrial IoT projects (country)

On the other hand, to analyze the temporal distribution of Industrial IoT projects, we refer to Figure 8. It is evident a trend that, starting from the first years considered in the analysis (early 2000s), underscores an exponential development trend in the degree of diffusion of such projects. Focusing on the last years included, it is important to make two clarifications. In 2020, a decrease in mapped cases can be seen compared to the previous year. This is due to a (slight) stabilization/decrease in the investments that each company has dedicated to the development of this technology, mainly due to the outbreak of the Covid-19 pandemic, resulting in a crisis of international manufacturing companies. As pointed out by the report of Osservatorio IoT (Il mercato dell'Internet of Things in Italia tra Covid-19 e nuove opportunità) [13], 2020 showed a slight decrease in terms of the overall IoT market in Italy, which did not make it possible to confirm a strongly growing trend registered in previous years. And the same settling/decline has been noted by most analysts for other Western countries, which are therefore aligned with Italian trends. On the other hand, as far as the negative trend found in 2022 is concerned, this can be explained considering that the search for projects to be included in the database has not covered the entire calendar year and that the projects implemented (or under development) in the current year have not yet been shared and published by the companies that are carrying them out.

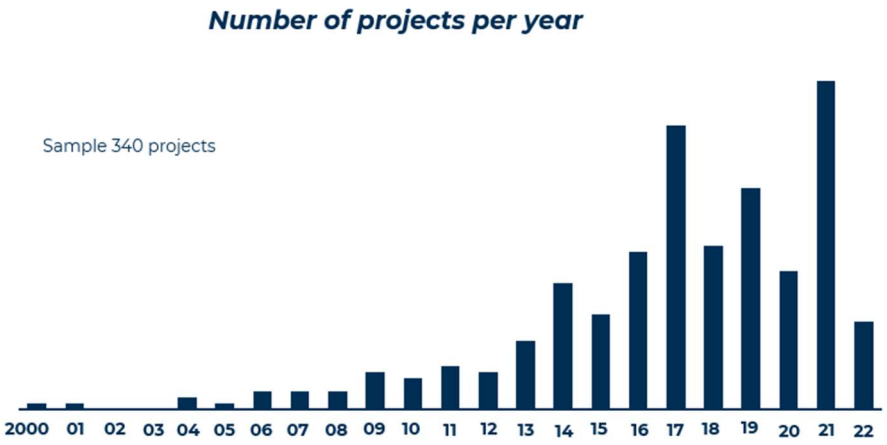

Figure 8 Distribution of Industrial IoT projects over the years

Figure 9 shows the distribution of industrial cases considering their state of progress. It is evident that the vast majority of projects considered for analysis are executive projects, and therefore already implemented by companies and functioning. The phenomenon can be explained if we think that companies are more likely to share their projects once they are operational and functioning, and that websites are more interested in publishing such types of cases, rather than pilot projects and those in the feasibility study phase.

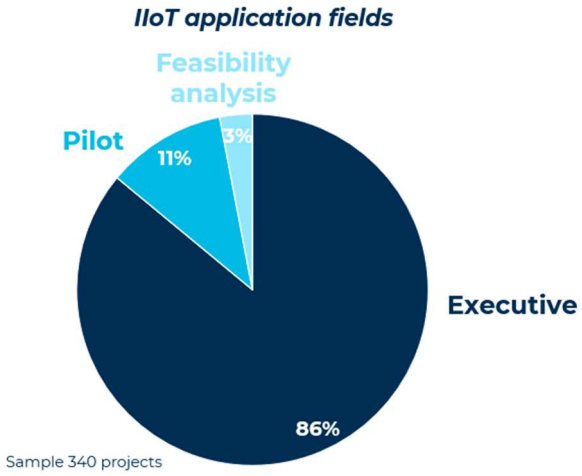

Figure 9 Status of Industrial IoT projects

It is also interesting to understand which companies are most often selected as partners, with whom to develop IoT projects in collaboration. Looking at all the cases in the database, it can be seen that the choice of IoT solution provider is not concentrated in a limited number of partners, but, on the contrary, space within a very large sample. It is 137 the total number of partners selected. It should also be

considered that each project can be followed by several partners at the same time. Among them, there are obviously some that stand out in terms of number of projects managed. In first place we find Cisco, which has been chosen as a partner 28 times, followed by PTC with 15 cases, Microsoft with 14, and Impinj with 9. Continuing, other companies to mention are Samsara (6), Schneider Electric (6), Stesi (6), Holonix (5), Libelium (5), IBM (5), Siemens (4), Kerridge (3), Tecnest (3), Zebra (3), and Zerynth (3).

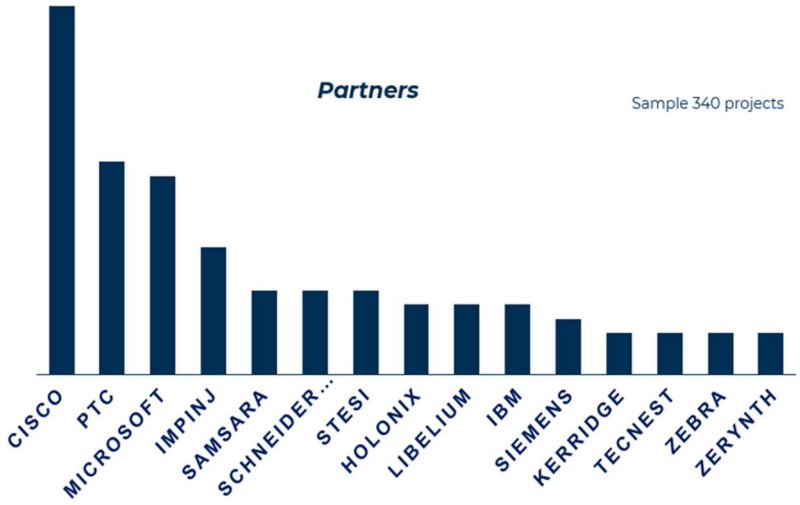

Figure 10 Major partners for Industrial IoT projects

In addition, it is possible to see from Figure 11, that the offer with which the partner companies contribute to the development of the project includes almost in all cases the sale of Software (85%) which turns out to be the backbone of the cases discussed. In addition, in the 68% of the cases mapped, the partner company is selling Hardware components. Finally, the offer is furtherly expanded with the selling of services in the 32% of the cases.

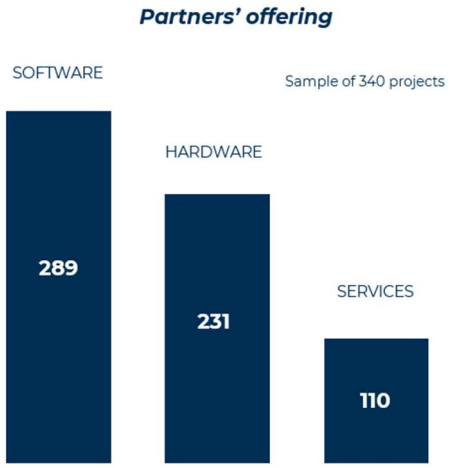

Figure 11 Partners' solution offer

As explained earlier, given that the focus is on the industrial applications of the Internet of Things, the field taken into consideration turn out to be 3: Smart Factory, Smart Logistics and Smart Lifecycle. Looking at Figure 12, which represents the percentage of projects surveyed for each application domain, it is possible to see a dominance by the Smart Factory, that represents the 70% of the cases. This is followed by Smart Logistics applications (27%) and finally Smart Lifecycle applications (3%). In the following paragraphs, all three are discussed by deeply analyzing, for each of them, how they are further subdivided, explaining some of the specific applications. For all the possible application, a case study is provided, taken from the sample of IIoT projects I was able to map.

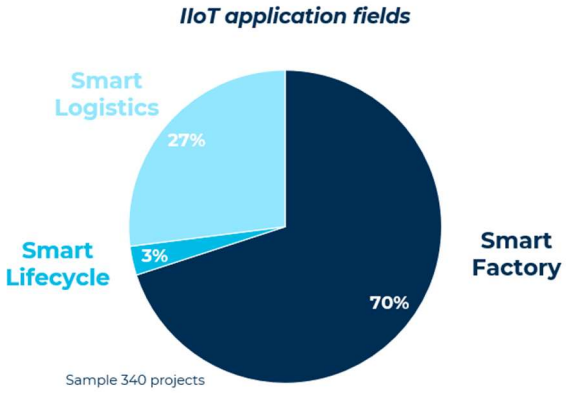

Figure 12 Industrial IoT application fields

3.2.1. Smart Factory

The term Smart Factory refers to the use of various digital technologies within the factory that, by combining with each other, make the operational processes within it more efficient and flexible, being able to dynamically coordinate processes, people and machinery. In particular, through IoT technology, a large amount of information related to the operation of the entire plant can be obtained, which, after being processed and analyzed, manage to generate a great value for the management of the factory. The innovative aspect consists in the centrality of information, given that the entire set of assets (a term that refers to both people and machinery) is in communication. This innovation has made possible the development of data-driven decision-making processes. This happens through the use of sensors (a hardware component) that are deployed, for example, where key parameters of the production process need to be monitored or where a specific piece of machinery needs to be connected to the Internet. Once the information is collected from these sensors in the field, it will then need to be processed through appropriate

software solutions. This occurs through the use of sensors (hardware component) that are deployed, for example, where it is necessary to monitor key parameters of the production process or where it is desired to connect a specific piece of machinery to the Internet. Once information is collected from these sensors in the field, it will then need to be processed through appropriate software solutions.

This gives rise to new ways of working, focused on cooperation and collaboration, thanks to information transparency to support operators. These, by leveraging shared data in the cloud, are able to work in a more aligned, efficient and timely manner. In addition, great relevance is being gained by As a Service and pay-per-use logics, which have developed with the spread of connected factories and are now a growing trend.

Analyzing in detail the projects mapped in Smart Factory, the following application areas emerged:

- Production optimization
- Predictive maintenance
- Preventive maintenance
- Energy management

Figure 13 shows the distribution of SMART Factory project considering their application area.

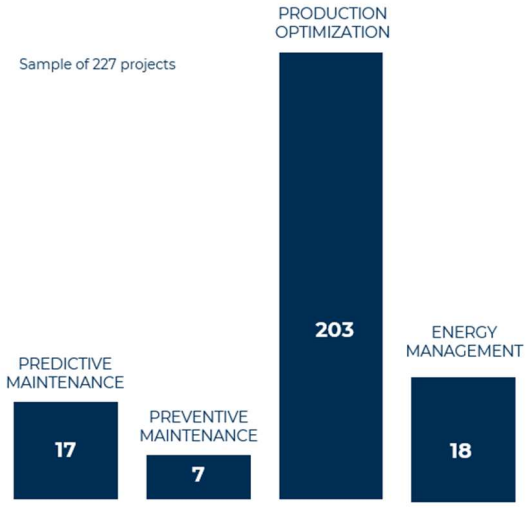

Figure 13 Smart Factory applications

Production Optimization

As highlighted in Figure 13, production optimization is a key piece considering that the 89% of the cases surveyed related to SMART Factory, were implemented for this purpose (considering that the same project can be implemented for more purpose). Production optimization is closely linked to monitoring the progress of production processes, with the goal of optimizing key parameters for each company such as time, cost, quality and safety. In fact, IoT inside the factory offers the possibility of inserting specialized sensors whose task is to control and optimize the quality of production, both in terms of process and product. Thus, it arises the possibility of monitoring compliance with production requirements, ensuring that the final product possesses all the characteristics necessary satisfy the customer. In order to do this, the ability to monitor product/process conditions in real time throughout the entire production process, is of enormous help, giving the possibility to take corrective action in real time (where necessary) or implement improvement actions following an analysis of historical data. There are various types of specialized sensors used for these purposes. The choice depends on the type of control to be implemented. Thermal imaging cameras are chosen when there is a need to monitor and measure product temperatures during processing (frequently used in process industries such as glass or rubber). Or stereoscopic cameras are able to reconstruct a 3D image and analyze it, making them essential for inspecting any non-conformities of a product, in checking the correct positioning of objects, counting the number of products processed, and verifying proper packaging and the integrity of the packaging used.

Following, a study case taken from the database of projects implemented has been proposed.

STUDY CASE – PRODUCTION OPTIMIZATION – ALFASIGMA SPA [31]

***Company*:** Alfasigma S.p.A.

Partner: Schneider Electric

Year: 2021

Application field: SMART Factory – production optimization

Company description:

Alfasigma is one of the top 5 players in the pharmaceutical industry in Italy, with revenues reaching nearly 1 billion euros in 2020. The company is more than 75 % owned by the Golinelli family.

Objective:

the main objective of the project was to be able to gather data coming from production to be inserted in the company information system. This would enable the monitoring of the performances of the production as well as the performances of the specific machineries and lines of production. Finally, the aim is to measure from those data, the efficiency of all the machineries used in the production to evaluate the state of each of them and take decision to optimize the production.

Solution description:

Thanks to the partnership with Schneider Electric, the company has implemented Data Wizard, which consists of a panel that is installed separately from the machine. In this way, the solution is able to pick up information from the machine without altering it. Specifically, through all the necessary components, electrical signals are converted into signals that can be transferred and read by other enterprise and factory systems. In addition, if needed, specific sensors can be associated with Data Wizard, again independently from the machine. This is extremely useful when the company needs to obtain different and specific types of information. Alfasigma has installed Data Wizar technology on 8 production lines in Pomezia. Thanks to them, it now has information that gives it a detailed understanding of machinery performance trends. This allows the company to optimize line performance. For instance, if a problem occurs in one of them, it is possible to understand and identify precisely what is the source of the problem (which would otherwise be complicated due to the large number of elements that make up each line) thanks to the possibility of monitoring. Alternatively, thanks to a sensor present at the end of the line, the company is able to count in real time the number of pieces actually produced for each batch and, thus, calculate in real time the Overall Equipment Efficiency (a significant indicator of the efficiency of a production line). In general, the implemented technology allows the operator to obtain more detailed information automatically and immediately. This represents a significant step forward, considering that previously information was collected manually and analyzed through paper records. Alfasigma has implemented the most advanced model of Data Wizard technology (Ultra model), so that additional features can be inserted, such as monitoring energy consumption for related cost reductions and inserting sensors for thermographic monitoring of machines (which will be then transmitted to operators through dashboards).

Preventive Maintenance

Preventive maintenance consists of a precise maintenance policy that is based on performing maintenance intervention before failure occurs. To do so, the intervention is scheduled according to predetermined intervals of time or units of

use, or prescribed criteria, to reduce the Probability of Failure. All of this is made possible through the exploitation of IoT and data analytics, which make obsolete an asset management approach based on the "run to failure", which is an approach based on the principle of scheduling intervention only when failure occurs (corrective maintenance). Currently, two types of preventive maintenance are mainly utilized, which differ in the criteria by which preventive maintenance interventions are organized. We speak of Time-based maintenance (or cyclic maintenance), in the case where the intervention is done after predetermined time intervals (leading to a cyclic recurrence of them). Conversely, we speak of Condition based maintenance, when the interventions are based on the condition of the component being maintained; this involves monitoring / inspection / testing to measure one or more parameters characterizing the degradation process. These parameters are then compared with set thresholds, and, in case of excessive deviations, an alert signal is sent that calls maintenance technicians for intervention. The use of preventive maintenance can generate great benefits to companies. First, there will be obvious benefits in terms of reducing unwanted downtime, of spare parts management, and of operational efficiency of individual machines and the entire plant. In addition, anticipating failure before it occurs would ensure a significant increase in the useful life of machinery, which would generate a significant economic benefit for the company.
Finally, preventive maintenance (particularly condition-based maintenance) could be extremely useful thinking of a possible future shift to predictive maintenance logic (this type will be explored in more detail in the next section). Indeed, the large amount of data collected during machine condition monitoring (necessary to understand when to do the intervention), could be used to feed machine learning models to generate predictive algorithms.

The study case proposed is the following:

STUDY CASE – PREVENTIVE MAINTENANCE – CERTARUS [32]

Company**:** Certarus

Partner: Samsara

Year: 2021

Application field: SMART Factory – preventive maintenance

Company description:

Certarus provides compressed natural gas delivery and mobile CNG distribution from sourcing and compression to on-site delivery and decompression. Certarus' business is built around their mission to displace more emission intensive fuels—such as diesel and propane—with low-carbon compressed natural gas (CNG) and

renewable natural gas (RNG). To do this, the company maintains a 24/7 energy-as-a-service platform which involves compression, transportation, and integration of natural gas for more than 500 customers. Certarus' CNG platform is also capable of serving the emerging hydrogen market to help more customers make the low carbon energy transition. In order to help their customers to minimize their carbon footprint, Certarus exploit sensor to gather data to monitor the safety and the efficiency of their operations.

Objective:

With more than 250 vehicles and 1,200 assets across 16 hubs, the objective of Certarus was to develop a platform that could scale with them as they grew. After trialing Samsara's connected operations platform, Certarus found unique value in having all their operations in one single system. The objective of the project was to minimize the downtime and provide top-tier customer service across the United States and Canada. In particular, Certarus' number one goal is zero downtime. Since their customers depend on CNG to maintain their operations, it's critical that every aspect of their operations is functioning 24/7. In some cases, a service interruption can mean running houses out of gas or bringing critical infrastructure to a halt, costing some of their customers hundreds of thousands of dollars.

Solution description:

Using the Samsara dashboard, Certarus operator are able to monitor from remote and in real-time the health metrics, to turn equipment on or off, and to see if pressure levels rise or fuel levels drop. Thanks to real-time alerts, they can promptly react to changes, solving problems immediately and avoiding interruption of their customers' operations. Thanks to the platform implemented, Certarus has adopted a preventive approach of maintenance, managing to increase the efficiency of work orders execution, reducing costs and increasing the uptime of equipment and vehicles.

By exploiting Samsara open API, Certarus manages to integrate their maintenance management system, UpKeep. In this way, it can generate in an automatic way work orders and improving the efficiency. This helps maintenance teams get critical equipment up and running faster—even when the equipment is scattered across remote locations. Having real-time data allows the operators to be more reliable for work orders to be completed on-time. Now that the operations of Certarus are completely connected in Samsara, the company can understand when the accidents are going to take place and prevent it, using the resources in a more efficient way and, therefore, reduce costs and environmental impact.

Predictive Maintenance

Predictive maintenance is perhaps the IoT application in the Smart Factory environment that is experiencing the greatest increase in implementations among the 4 that have been described. Predictive maintenance can be seen as an evolution of preventive maintenance, discussed in the previous section. The key feature of predictive maintenance is that the interventions scheduling is based on the forecast of trend of one or more parameters linked to the degradation process. It can be considered as a condition-based maintenance (CBM), advanced thanks to the prognostics capability. As anticipated in the previous paragraph, predictive maintenance uses machine learning algorithms, that allow to predict what will happen to the plant or a specific piece of machinery, in a specific time frame. Through AI, it is possible to prevent failures and malfunctions by recognizing signals from the machinery that may indicate anomalies in a timely manner. As is the case with condition-based maintenance, the company must select one or more parameters which will be used to estimate machine condition and monitor its progress. After that, through the aforementioned models, the time remaining before the failure occurs (also called Remaining Useful Life) can be calculated. This prognostic capability is a kind of logical extension of the condition monitoring. This highly innovative approach has in forecast accuracy one of its main strengths. By adopting a predictive rather than a preventive or corrective maintenance policy, a great reduction in the time and cost associated with machinery downtime is made possible. As a result, a reduction in labor costs associated with emergency maintenance interventions, an increase in revenues due to greater continuity of production, and a lengthening of the useful life of machinery with a consequent reduction in costs would be achieved. Currently, however, the adoption of this maintenance model is limited by the substantial economic resources required to implement this solution effectively. In fact, the data, in order to be interpreted and implemented in the correct way, required highly qualified personnel, which is also essential during all the phases of algorithm training (a particularly time-consuming activity) and the definition of machinery operation thresholds.
The study case proposed is the following:

STUDY CASE – PREDICTIVE MAINTENANCE – NESCAFE' [33]

***Company*:** Nescafé

Partner: Schneider Electric

Year: 2021

Application field: SMART Factory – predictive maintenance

Company description:

Nescafé is a brand of coffee made by Nestlé. In Toluca, near Mexico City, the Nescafé Nestlé plant produces about 1 million cans of soluble coffee a day. In 2013, the company expanded the plant's production capacity by 40%, investing about $125 million to make it the largest soluble coffee factory in the world. At these levels of production, preventing operational disruptions and ensuring continuity of service is critical to Nestlé's business both to increase the safety of people and the availability of production lines and to extend the life of equipment. The reactive approach to asset performance management exposed the company and employees to critical risks and daily uncertainties.

Objective:

The main objective consists of being able to predict equipment outages in a way that identifies critical points in advance and that allows to address them before they become problems. This has saved the company costly outages and increased its ability to respond to changes in demand, being able to offer customers better service and also reduce the environmental impact of operations.

Solution description:

Nestle has adopted Schneider electric's EcoStruxure Asset Advisor technology to move to predictive maintenance strategies for the management of critical assets enabling staff to proactively address any problems and thus, avoid costly unplanned outages that can cost up to $52,000 per hour. By relying on data analytics to establish service intervals, Nestlé's dedicated electrical systems staff can now spend less time on reactive actions. The result is that systems run optimally for longer time. Indeed, Schneider Electric's software enables real-time visibility and 24-hour remote monitoring of electrical systems, allowing operators to prevent problems and managed them before they turn into critical incidents. This result is achieved thanks to advanced analytics tools that reduce safety risks and avoid unplanned outages, loss of uptime, and costly maintenance interventions. With data coming from critical connected assets, Asset Advisor enables Nestlé's dedicated operators to take informed critical decisions, in order to intervene themselves or rely on Schneider Electric's Digital Service Hub while systems run in an optimize way for longer.

Energy management

Consumption efficiency is undoubtedly one of the goals set by every type of company. This factor is particularly relevant in the manufacturing industry, notoriously the most "energy-intensive" one. There is, therefore, the need to adopt strategies to monitor actual energy efficiency levels. This would make it possible to

develop solutions to reduce the various energy wastes present in plants. In addition, energy efficiency is crucial in the context of moving more and more toward sustainable production, a factor that is gaining considerable importance as a result of increasingly stringent regulations in this area. Indeed, by leveraging the IoT, it is possible to pay more attention to energy consumption, enabling the company to reduce its environmental impact (along with a significant reduction in energy costs). Through the massive use of sensors applied at various points in the plant, it is possible to create detailed reports regarding actual consumption and exploit them in order to reduce as much as possible energy consumption and bill costs, and to gain operational efficiency. In summary, monitoring energy consumption can benefit the company in several ways:

- Increasing plant efficiency by understanding the consumption of various resources and finding a more effective way to deploy them.

- Use of automatic actuators, in order to reduce or shut down through dashboards, timers or sensors according to energy needs.

- Verification of actual consumption, compared with bill values.

- Use of energy optimization devices.

- Verification of rates charged according to contract conditions.

The study case proposed is the following:

STUDY CASE – ENERGY MANAGEMENT – BOSCH BUILDING TECHNOLOGIES [34]

***Company*:** Bosch Building Technologies

Partner: Microsoft

Year: 2020

Application field: SMART Factory – energy management

Company description:

Bosch Building Technologies is a division of Bosch Group, that offers solutions and services to monitor and analyze energy consumption in real time to actively manage the business processes and to provide useful insights for operators.

Objective:

The objective of the project was to develop an in-house energy platform to analyze energy consumption and pursue ongoing energy efficiency.

Solution description:

The solution developed is built on Microsoft Azure and it exploit many Azure services such as Azure Functions, Azure Data Lake, Azure Data Factory, and Azure Cosmos DB.
Customers use the Energy Platform to connect IoT devices to what they want to track and then link existing meters, sensors, and machines. It reads, transmits, and analyzes the data allowing the customers from all over the world to make informed decisions improving energy and resource efficiency. Bosch both offers the solution to customers and uses it internally at more than 100 manufacturing plants and other locations worldwide. In addition to the Energy Platform on Azure, Bosch Building Technologies adopted Azure Digital Twins to create a contextually aware solution and digital models that come to life for Connected Building Services. By incorporating Azure Digital Twins, the company is able to gather data from whole rooms and spaces, rather than disparate sensors, to build digital models of the physical building environment. With this solution, Bosch is able to virtually replicate the physical world thanks to the digital twin, which helps Bosch perform data modeling that supports graph relationships to model interconnected assets, business systems, and the physical environment, providing rich context for data processing and business logic.

Thanks to Azure Digital Twins, Bosch clients receive a deep analysis of how they are consuming energy, that allows them to make smart changes and reduction of energy consumptions.

3.2.2. Smart Logistics

With the pandemic we are currently experiencing, there appears to be an increasing need to use cutting-edge technologies that enable to obtain more information about logistics flows (generating a better and more responsive decision-making process). Smart logistics solutions are generally based on optimizing all organizational and strategic operations related to the management, storage and destination of goods. To achieve these goals, it is necessary to make logistics processes (internal or external to the company) as transparent as possible, including analyzing the operations of collaborators, partners and suppliers. All parties must then be able to communicate the operations they have performed (or are performing) quickly and securely. After integrating all the data, it will be possible to get a real-time snapshot of all logistics processes, enabling in-depth analysis (where a particular product is, what the values of various business KPIs are, what performance the company is achieving compared to the past). IoT enables precise and timely monitoring of all objects connected to the system, enabling companies to organize logistics processes

in an optimized way. As explained in more detail later, the logistics processes impacted by IoT are both those inside the company, particularly in the warehouse, and those outside the physical company, that is, along the entire supply chain. The increasing deployment of IoT sensors allows companies to collect data continuously in many different situations such as the loading and unloading phases of products, the picking phases and the packaging, shipping, and handling phases inside the warehouse.
In summary, these types of solutions enable companies to improve logistics processes, reducing errors and costs, increasing operational flexibility, automating operations, and improving forecasting by supporting staff decisions. All of this is made possible if there is an architecture at the foundation of the company that ensures the speed, security, and integrity of information flows.
Analyzing in detail the projects mapped in Smart Logistics, the following application areas emerged:

- Traceability of internal warehouse
- Traceability along the Supply Chain
- Logistical assets management
- Cold Chain monitoring

Figure 14 shows the distribution of SMART Logistics project considering their application area.

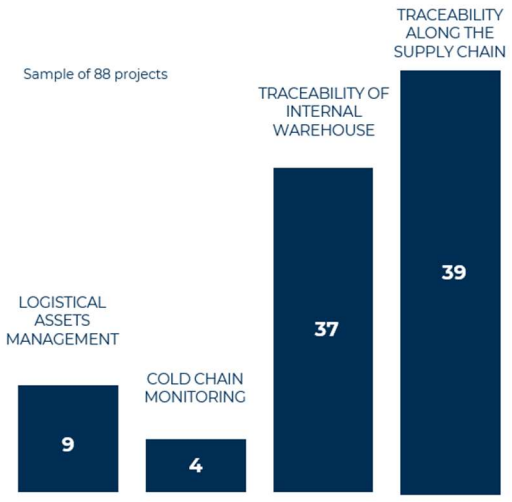

Figure 14 Smart Logistics applications

Traceability along the Supply Chain

This application field is the most present within the database of IoT projects (considering SMART Logistics application). It is related to the 43% of the SMART Logistics projects. The ever-increasing complexity and variability of supply and supply chains, stimulates companies to invest more and more in asset tracking solutions along the supply chain. The Covid-19 pandemic and geopolitical conflicts have devastated the functioning of entire supply chains. This scenario meant that only the most resilient chains could survive. This has given rise to the big push for technology investments to modernize supply chains, to make them more transparent resulting in monitored and mitigated risks. These solutions include both supply chain and distribution chain management. Companies are able, for example, to monitor the progress of deliveries in real time, being able to plan and manage them optimally. In general, they have the ability to make faster and smarter decisions throughout the entire lifecycle of supply chains.
Through track and trace solutions, companies are able to significantly reduce inventories through real-time visibility of inventory and shipment levels. As a result, there are significant savings in inventory management costs.
Also of great importance is the security aspect. Tracking of goods becomes essential when they are moved on a global scale, in order to minimize the risks of product loss or theft, thereby avoiding possible disputes with customers.
From the database the following study case has been selected:

STUDY CASE – TRACEABILITY ALONG THE SUPPLY CHAIN – FIDA S.P.A. [35] [36]

Company: Fida S.p.A.

Partner: Qualitas Informatica

Year: 2021

Application field: SMART Logistics – Traceability along the supply chain

Company description:

Fida S.p.A. is a food company founded in the early 1970s in Castagnole delle Lanze, in the province of Asti. From its first artisanal activity in the production of fruit jellies, over time it has expanded its portfolio in the field of candies, eventually acquiring the well-known Rossana brand from Nestlé in 2016, joining other well-known brands such as Bonelle, Sanagola, Gocce, Linea 1926 and Gnammy. With a turnover of about 20 million euros, Fida today has a 3.5% market share of the total family candy business.

Objective:

For a food company such as Fida, being able of tracking and tracing a lot is a major issue. For this reason, the company's main goals were to overcome manual management of these activities. Production operators, before the implementation of the solution, marked the various batches used on sheets of paper that were then collected and delivered to a person in charge of entering all the data into the company's management system. This procedure involved some problems, including:

- physiological percentage of human error due to manual transcription.
- difficulty in tracing any error to be found along the document chain.
- delays in uploading data that occurred the next day or days later.
- almost exclusive engagement of one person in data-entry functions.

Solution description:

Today, with the help of Qualitas Informatica, it has been implemented a MES based on NET@PRO. Thanks to it, the company has developed real-time tracking and tracing. While previously there was manual uploading of all data into the company's management system, now the activity is carried out directly in NET@PRO and this allows to know the status of batches in real time. In addition, the implemented solution ensures regulatory compliance, speeding up operations and reducing human error, and avoids wastage of raw materials and semi-finished products

Traceability of internal warehouse

This is the second most spread application regarding the SMART Logistics field. It is related to the 40% of SMART Logistics projects mapped.
Also for this specific application, the principles of visibility are taken up as the basic point of any project. Companies are able to achieve great results in terms of work safety, efficiency and a relative reduction in costs, all thanks to the tracking of operators, vehicles and assets within the warehouse.
In this area, some of the solutions most widely used by industries are:

- RFID (radio frequency identification) tags, which, thanks to a chip (unique code), automatically send recognition data to the optical reader. This makes it possible to update the warehouse database in real time.

- Wearable technologies, such as smart rings used for code reading, helmets equipped with sensors that allow the operator to work hands-free while consulting documentation on a visor goggle, wristbands equipped with code readers or portable systems for printing labels or codes.

- Pallet stacker cranes, machines that enable automatic storage, controlled by management software, greatly improving handling in the warehouse.

- Digital twin of the warehouse, i.e., virtual reproductions of the warehouse environment that allow detailed analysis of all the operations that are carried out within it, offering the possibility of simulating different scenarios without having to test them in reality (resulting in higher costs and time).

The study case proposed is the following:

STUDY CASE – TRACEABILITY INSIDE THE WAREHOUSE – ITALDADI SRL [37] [38]

Company: Italdadi Srl

Partner: CD soluzioni, Global Tag Srl

Year: 2019

Application field: SMART Logistics – Traceability inside the warehouses

Company description:

Italdadi produces nuts for fittings, as well as caps and ferrules machined with a wide range of surface finishes. With a production capacity of more than ten million pieces per month, Italdadi has succeeded in transforming its product into more than just a commodity: state-of-the-art machinery and an advanced information system ensure that the production process can be monitored in real time, guaranteeing flexibility and efficiency, while the warehouse handles more than 1,000 containers including metal boxes and pallets.

Objective:

Italdadi's need is to know in real time the location of the caissons within the warehouse of about 1,000 square meters and within the production area, spread over 1,000 square meters: through a fast and reliable information system, the company would be able to optimize the search and reduce the time of caisson movements, without having to rely on the operators' memory anymore. In the past, searching for caissons was in fact too time-consuming, aggravated by the risk of human error: these inefficiencies on logistical timing inevitably affected production as well.

Solution description:

To meet these requirements, the company, through collaboration with CD Soluzioni (specializing in IoT-focused management software), Global Tag, which provided the Beacons, and BluEpyc, with its contribution of EchoBeacons and BLE Gateways, has developed an innovative, cost-effective and practical indoor location system

(IPS) based on Bluetooth Low Energy wireless connectivity technology. Backbone of the Bluetooth Low Energy hardware infrastructure are Gateways, stationary devices that are powered and connected to the corporate network via Ethernet, and EchoBeacons, devices with a repeater function (they receive data from the Beacons and transmit it to the Gateway, thus providing more granular monitoring of the area presided over by the EchoBeacon) that only need to be powered, which can reduce installation costs and improve the location of the caissons.
Beacons, that can be attached to the caissons with ease, send the radio signal to the EchoBeacons and are the beating heart of the system, while the software has become the operational brain. Going into more detail about the individual components, the Beacons are affixed to about 400/500 metal caissons stored in Italdadi's warehouse and about 100 caissons in the warehouse adjacent to production, ready to be shipped to material suppliers. The solution, implemented and operational since October 2019, is based on 4 Gateways, 24 EchoBeacons and more than 500 Beacons installed on caissons and cases. The main strengths of the system are:

- very low cost of Beacons applied to the caissons, without reducing their performance, and ease of installation,
- being wireless, EchoBeacons do not require connection to the company network, so they facilitate and reduce installation costs while improving detection accuracy,
- the software optimizes the radio signals received from the Bluetooth LE system and returns the desired information, i.e., the storage location of the bin.

All this results in rapid traceability of material for production and the ability to share information, which, made available to all, no longer depends on the presence and on the memory of operators in the warehouse.

Management of logistical assets

In this case just the 10% of SMART Logistics projects has as one of its purpose this application.
One of the most common applications of logistics asset management is in enterprise fleet management. Companies, in fact, by connecting their fleet via IoT sensors, are able to optimize its performance (in terms of safety, energy consumption, productivity), thanks to continuous real-time monitoring. This possibility is particularly interesting for cold chain management. Some companies, in fact, need to ensure a precise degree of humidity and temperature during the transportation

of goods. The ability to continuously monitor these parameters would make management much smoother, optimized and safer.

IoT sensors can also be used internally in the warehouse for the purpose of managing assets within it more effectively. Trolleys and racks can be equipped with mutual sensing sensors in order to transmit data regarding the operation of the trolley within the warehouse. These solutions would allow to optimize the allocation and movement processes of internal logistics assets.
The study case proposed is the following:

STUDY CASE – MANAGEMENT OF LOGISTICAL ASSETS – ALLAN REDER [39]

Company: Allan Reder

Partner: Samsara

Year: 2019

Application field: SMART Logistics – Management of logistical assets

Company description:

Allan Reder is a family business that started its business in 1971 by distributing cream in London. Today it delivers more than 500 dairy products to many of London's best-known restaurants, catering companies and bakers.
Its success is strongly related to the great commitment to customer service, to its staff and to its high-quality products.

Objective:

Given the great importance that the company gives to the quality of the products and of the services offered, the management decided to evaluate innovative technologies with the aim of optimizing the deliveries of their products and further improve the service offered to its customers.
The company has to manage a fleet of more than 50 lorries, vans and other road vehicles and it was looking for some sophisticated technologies that could allow to overcome their current GPS tracker. Moreover, the solution had to be responsive, efficient and effective given that Allan Reeder is operating almost 24/7.

Solution description:

The final solution combines tracking device with dual-facing dash cameras and environmental monitors for temperature monitoring. It is surprisingly easy to use, and it allows, by looking rapidly at the dashboard provided, to get a precise snapshot of the fleet, determining if there is any problem and, eventually, addressing them immediately when they show up.
With the real-time view of company's fleet, the management is able to see where each of the vehicles are in that precise moment. This is crucial for a company that

has the objective to guarantee the highest service level to its customers. Indeed, knowing exactly in real-time where all the vehicles are, allows the company to communicate to the customers the precise delivery time or to promptly communicate to them possible changes in the schedule. In addition, the real-time tracking ability, results in being crucial also for the improvement of the efficiency, by allowing to analyze which are the vehicles closer to the customers and, therefore, decide how to organize the dispatches saving a great amount of time.
As anticipated before, another important feature of the solution developed with Samsara is the temperature monitoring. Indeed, for a company like Allan Reeder whose activities are based on the shipping of dairy products, the ability to maintain them at specific temperature throughout the entire shipment is essential. To do that, Samsara's environmental monitors were used, which guarantee that the products remain within an approved temperature range at every stage of the journey.

Finally, the dash cams were inserted. Thanks to them, the management of the company is able to review incidents. With this solution, it is particularly easy for them to see harsh events or distracted driving. As a result, the drivers involved in the issue, are provided with feedback, and, in case of repeated dangerous driving incidents, the driver has also been dismissed. However, the management intend to use the cameras with the aim of supporting their drivers.
After the installation of the cameras, the company has noticed a significant reduction in terms of number of incidents per year, leading to a relevant reduction of costs.

3.2.3. Smart Lifecycle

In general, the management of the lifecycle of a product (or of an asset), encompasses all those activities of a strategic and operational nature that characterize its production process, which characterize the stages of design, use, market launch, maintenance and finally disposal.
The main phases of a product's life cycle are 4:

- creation/design, during which the product is first defined according to business strategies. Taking into consideration the target customer base, product characteristics are defined. Next comes the actual design of the product.
- Production, preceded by a ramp-up period before the actual launch in the market, aimed at solving possible problems in production processes.

- Operation, when the product is on the market and being used by customers.
- Disposal, where the possibility of reusing the product is evaluated or appropriate areas are identified for its disposal.

IoT would allow companies to develop a holistic view of all phases of the product life cycle. In fact, a connected product would be able to collect data from creation to final disposal, which, once analyzed by the company, would be of critical importance in optimizing each of the product's life stages. However, currently Smart Lifecycle applications are not widespread in every phase of a product's life but are mainly concentrated in two specific areas: optimization of new product development (which will be explored in more detail in the next section since it is the most common one in the Smart Lifecycle field) and "end-of-life" management of products. All the projects present in the database refer to the application field of Optimization of the development of products. The following figure show the distribution over time of SMART Lifecycle projects. From this, it is possible to understand that this field of the Industrial IoT is the one that has developed later and the one with the greatest margin of improvement.

Optimization of the development of products

Smart Lifecycle applications are those that enable companies to make new product development processes more effective. This requires continuous collection of data generated by products (already in the market) connected and equipped with IoT sensors.

Some of the main benefits that companies find by using solutions of this type are the reduction of time between product conception and sale (time to market) and the reduction of product development costs.

In fact, the goal of companies is to optimize and make more effective the design and development phase of their products by leveraging information from related products already used by customers (such as, for example, how a product is used by the customer, what are the most required features). Knowing precisely how the product is being used, ensures that companies have insight into customer needs, making it significantly easier to design new and increasingly competitive products.

The study case proposed is the following:

STUDY CASE – OPTIMIZATION OF PRODUCT DEVELOPMENT – VAILLANT GROUP [40]

***Company*:** VAILLANT GROUP

Partner: PTC

Year: 2021

Application field: SMART Lifecycle – Optimization of product development

Company description:

The Vaillant Group is a global market leader in heating, ventilation, air conditioning technologies and energy-saving eco-friendly solutions, all focused on the use of renewable energy.

Objective:

Vaillant's goal was to promote digital transformation for product lifecycle management (PLM) by taking a long-term approach. Specifically, one of the company's desired outcomes was to decrease project lead time, which is the latency time between the start and the end of a project. This would also lead to a decrease in time-to-market (a fundamental KPI for measuring a company's operational performance at the product development and management level), generating a competitive advantage for the company.

Solution description:

through a collaboration with the partner PTC, the company implemented Windchill software, connected to SAP with a multilevel interface.
In the first phase, which lasted until 2017, the company focused on the main elements of PLM such as the creation with controlled workflow of parts and BOMs, the concept and pilot project for design change management and release as well as the process of releasing the first physical sample, the management of product documents, the concept of product maturity status "from cradle to grave," the automatic transfer of product data from Windchill to SAP, the enrichment with controlled workflow of SAP views, and other activities related to the product creation following the "Design Freeze" phase. The second phase (2018-2021) involves the addition of advanced PLM capabilities mainly for the purpose of managing the entire process of collecting, consolidating, approving and testing product requirements, managing and monitoring product compliance/sustainability, managing costs during the development phase and also the phase-out phase. Also included in this phase is the productive use of engineering design change management and global release, as well as the process of releasing the first physical sample.
In the final phase, which is expected to take place in the years 2022-2024, the company plans to close the information loop between the stages of the product life cycle through the application of digital transformation technologies. For example, the company plans to use connected product information, acquired from IoT

(Internet of Things) sensors, to predict failures and optimize new and existing products through the use of implemented product data as design inputs.

3.3. Survey Analysis

In the following chapter, I would propose the results of the survey that has been conducted together with the Osservatorio Internet of Things. The survey is composed of 25 questions, and it is inserted in the Annex. The total number of companies that answer to it is 153. An important issue to remark, is the choice of the professional figure inside the companies, to which send the survey. Indeed, in order to gather information as accurate as possible, it was very important to select those people that are most probably in the front line of each IoT project implemented in their company. As a result, we limit our selection to figure like COO, CIO, logistics manager, production manager Its main objective is to investigate more in depth what is the level of adoption of the technology of Industrial Internet of Things among Italian companies. As a result, the question proposed, cover a wide range of topic that better explain the relationship of each company with the technologies analyzed. In particular, the aspect on which the questions focus on are:

- The effect of the current economic and political instability over the performances of the company

- How the companies are trying to obtain the funding of the PNRR, and how it has impacted on the investments budgeted by the company

- The relationship of the company with the IoT technology (if there is a strong awareness inside the company, if the theme is relevant for it and if it has already implemented IoT projects in the past)

- If the company is investing in services as well, together with the IoT solutions. The survey further deepens on who is the provider of this services and on what are the point of weaknesses on outsourcing those services.

- The main driver for the implementation of IoT project

- The most influential professional figure inside the company for the implementation of IoT projects

- If and how the company has exploited the data generated by IoT projects (and, eventually, why they have not been exploited)
- The feedback about the project already implemented
- The main barriers (if any) that prevent from the launch of IoT projects
- The most crucial phase of an IoT project
- Future plan regarding the implementation of IoT projects and, eventually, which kind of application of Industrial IoT the company would like to exploit
- The objectives that the company would like to achieve with new IoT projects
- The development of the company in terms of cybersecurity in IT systems
- The willingness of the company to collaborate with third parties for integrated IoT projects (and, eventually, with which actors)
- The impact that IoT projects implemented had on some specific performances

As mentioned in Chapter 2, the survey on which the thesis work focus has been delivered to Large companies. However, another questionnaire was submitted to SME by Osservatorio IoT, which delivered to me just the final results of the analysis. This allowed me to propose (just for the questions that are present in both the surveys) a comparison between the results obtained for Large companies and for SME.

Following, the results obtained from each question are shown.

The first question is intended to collect general information about the company in which the respondent is currently working.
In particular, in addition to the name of the company and the name of the respondent, the survey investigates the professional role of the employee that is filling the survey (as said before, the selection of the respondents was conducted considering this field, giving the priority to the employees that are more likely to

have experience with Industrial IoT).
Afterthat, the survey asks questions about the size of the company and its turnover (to understand whether the company is a Large company or a SME).
Finally, the respondent has to insert some contact information.

Following, the questions inserted aims at understanding what was the impact of the current political and social factors on the companies.

Question3:
Quali conseguenze ha generato l'attuale instabilità economico-politica all'interno della sua azienda? What consequences has the actual economic and political instability generated within its company?

The question wants to investigate the main effects of the current economic and political situation over the management of the companies. Some of the most expected answers were given as alternative to select. In particular, it is expected that the economic and political issues of nowadays have affected mostly availability and price of raw materials, semiconductors, energy and may have created difficulties in the relationships with suppliers/clients.
As can be seen in Figure 15, the current situation of political and economic instability has brought inside the companies interviewed two main consequences. Indeed, the 86% of the respondents stated that their company experienced a lack of raw materials together with their increase in prices, while the 79% experienced and increase in energy prices.
Afterthat, it is important to highlight that the 40% of the companies face issues related to the lack of semiconductor (with the relative increase in prices).
Less spread but still significant is the effect of interruption of relationship with companies' clients and/or suppliers.
Finally, it is important to focus on the fact that just the 4% of the companies stated that no consequences were generated by this difficult economic and political situation, a data that explain the great impact that this had on the businesses.
The results highlighted for Large companies are in line with the ones of SME. The only relevant variance is the percentage of the companies that are experiencing a lack and increase in price of semiconductors, which is significantly lower for SME (12%)

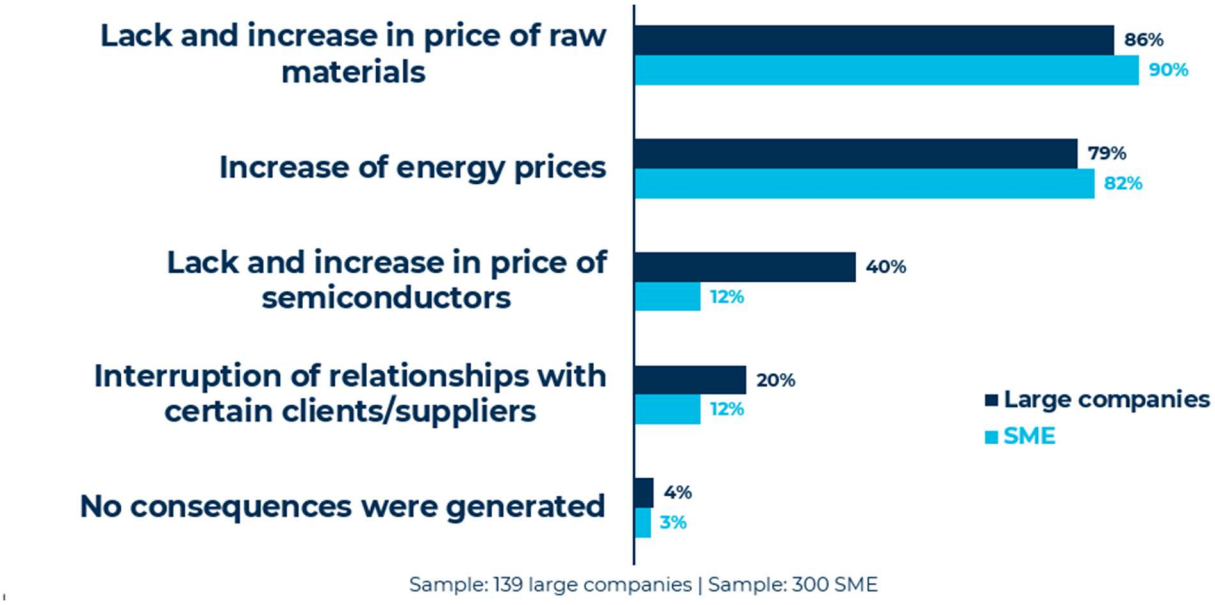

Figure 15 Consequences of economic and political instability

Question4:
Quali conseguenze ha generato la carenza di semiconduttori nella sua azienda? What consequences has the lack of semiconductors generated within your company?

This question was asked just to the respondents that selected the option "lack and inflation of semiconductor" in the previous question.
Now, the focus moves to a more specific economic and political issue, which is the lack of semiconductors registered in the last years and that has disrupted several global supply chains. However, despite the lack of semiconductor is being certainly a major threat for today's companies, worsening their performances, it may also be seen as an opportunity by them, forcing them to develop countermeasures for risk mitigation (i.e., for a more resilient company). As a result, among the suggested answers, both negative consequences (such as increase of purchasing cost, late production, late development of new products) and opportunities (such as development of new resilience model or review of purchasing logic) were inserted.
The lack of semiconductor generated as a consequence an increase in purchase costs for almost all the companies interviewed (91%).
Going ahead, a great portion of them declared to face issue regarding the delay in production (71%). In the same way, also the review of purchasing logics, the delays in the development of certain products, the increase of stock required to face the emergency were detected by the majority of the companies, as can be seen in Figure 16.
Finally, some of the respondents, stated that the situation has caused the necessity

to review business strategies of the companies (31% of the respondents) and the development of new resilience model (29%).
As a result, it emerges that a great portion of the companies was forced by the lack of semiconductor to make strategical change in their business in order to both overcome this issue and be ready in the future to face situation like this one.
The results follow the same trend for SME, with the only exception being the delay of development of products, which has been selected by the 38% of the respondents (compared to the 60% for Large companies).

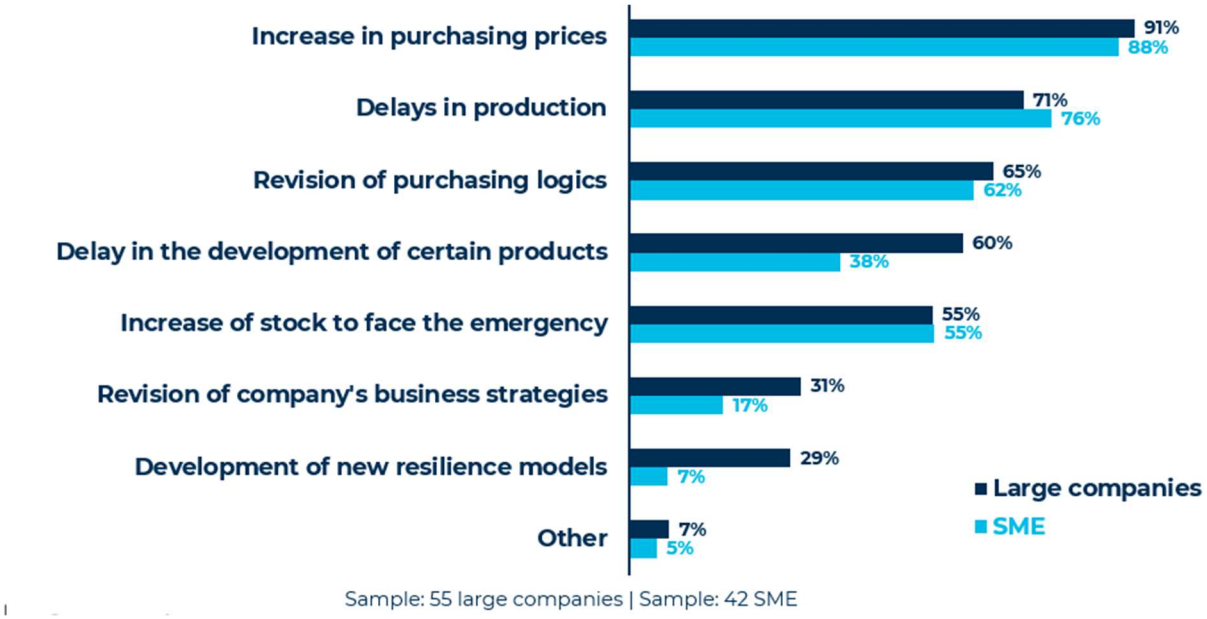

Figure 16 Consequences of semiconductors lack

Question5:
Alla luce degli interventi previsti dal Piano Nazionale di Ripresa e Resilienza (PNRR), a quale/i delle seguenti Missioni punterà la sua azienda per accedere ai finanziamenti?
In light of the interventions planned by Piano Nazionale di Ripresa e Resilienza (PNRR), which of the following Mission your company will target to grant the access to the financing?

The answers show, for those that are willing to earn the access to PNRR financing, how the companies will try to achieve it. They have 6 different ways to achieve those financing, which consists of the 6 missions of the PNRR. Each of them focuses on a specific objective, that the company will have to pursue.
First of all, it is important to notice that the 90% of the respondents stated that its company will aim to access to the funds related to the PNRR.
The most spread mission, on which the company will focus to achieve the finance

is the Mission 1, which is related to the Digitization, Innovation, Competitiveness and Tourism. It is followed by the one related to Green Revolution and Ecological Transition (Mission 2).
A significant portion of the respondents, equal to the 29%, uncertain on which Mission the company will focus on.
Another big percentage (21%) will try to reach the financing with Mission 4, linked to Instruction and Research.
Finally, the ones on which companies will focus on the least are Mission 3, related to Infrastructure for a Sustainable Mobility (5% of the respondents), Mission 6, related to Health (4% of the respondents) and Mission 5, related to Inclusion and Cohesiveness, among which urban regeneration (2% of the respondents).

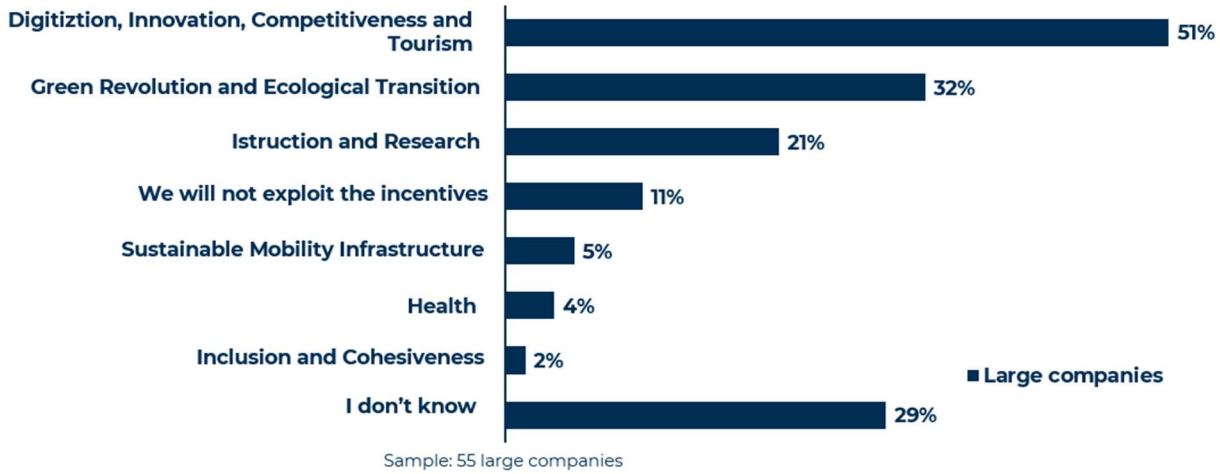

Figure 17 Targeted PNRR missions

Question 10:
In valore assoluto, come sono variati gli investimenti in progetti IoT per l'Industria 4.0 in seguito all'attuazione del Piano Transizione 4.0/PNRR?
In absolute terms, how did the investments in IoT for Industry 4.0 change, consequently to the implementation of Piano Transizione 4.0/PNRR?

The result of this question allows to understand the impact that PNRR had on the strategic choice taken by the companies regarding the investment choice for IoT projects. Obviously, a great increase of the investments budgeted consequently to the implementation of PNRR, would signal the major significance that this had on the digitalization of the factory.
From Figure 20, it is possible to understand that 45% of the companies surveyed has experienced an increase, in absolute terms, of the investments related to Industrial IoT projects after the implementation of the PNRR.
On the other hand, 51% of the faced no variations in terms on investments despite

the great financing achievable thanks to the PNRR.
It is interesting to go more in depth with the portion of companies that raised their investments, to understand how much their investments varied compared to the levels prior to the PNRR. The 50% of them experienced an increase between the 5 and the 10 per cent. The 30% has a significant growth from 10 to 30 per cent of their investments. The 20% had a very strong boost of more than the 30% of increase.
Finally a small portion of companies had a variation outside the ones proposed.
Looking at the answers given by SME it is possible to highlight an important difference of the number of companies that increase their investments. SME registered a +13% considering the number of companies that stated to have increased IoT related investments.

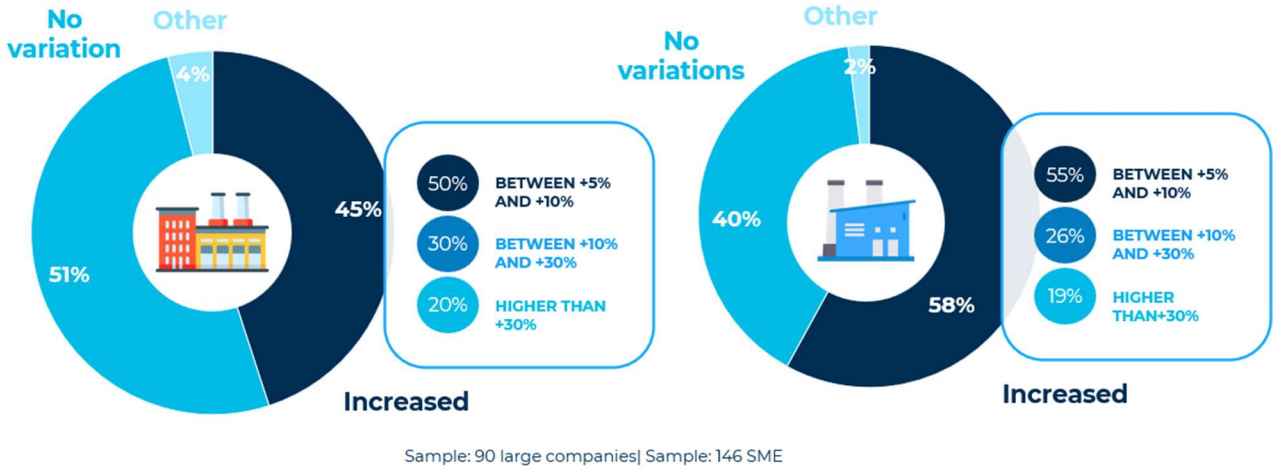

Figure 18 IIoT investments after PNRR

The following questions are intended to deepen what is the relationship with IoT technology of each company in the recent years. As a result, the objective is to better understand is the company has implemented in the past IoT projects and, in case of positive answer, analyze more in depth various aspect related to those projects.

Question6:
Ha sentito già parlare di soluzioni Internet of Things (IoT) per l'Industria 4.0? Have you already heard about Internet of Things (IoT) for Industry 4.0?

To help the respondent, a set of possible IoT solutions have been suggested (e.g., utilization of machineries connected through cabled or wireless technology, able to detect and alert when a breakdown is going to take place, being able to minimize idle time). Based on the knowledge of the level of familiarity that the respondents

have with these solutions proposed, they choose among the 4 different level of expertise proposed. First of all, it is important to highlight that almost all the companies' representative surveyed (98%) already heard about the theme of Industrial IoT. This underline the significant spread that this technology has gained during the last years. Moreover, the survey goes more in depth in analyzing what is the level of knowledge of each respondent about the IoT solutions applied to the industrial scenario. The results show that there is an in-dept level of knowledge. Indeed, 29% of the ones that has already heard about Industrial IoT stated to have a great level of knowledge of these solutions; the 55% stated to have a good level of knowledge; just the 16% stated to have a superficial level of knowledge. For SME the levels of knowledge is still fairly high (87%) even though still much lower than the one of Large companies, especially if we consider that almost half of the companies that already knew Industrial Internet of Things have only superficial knowledge of it.

Question7:
Quanto è rilevante il tema Industria 4.0 per la sua azienda?
How much is the theme of Industry 4.0 relevant for your company?

The results shown in Figure 19, highlight that, nowadays, companies are giving great importance to the technology of IoT. The majority of the respondents consider the theme of Industry 4.0 fairly important, while the 39% of the companies see it as extremely important. Finally, just the 9% of the interviewed consider it irrelevant. For SME there is a decrease of companies that consider the theme very important (21%) and there is a not null percentage of them which considers it not relevant at all.

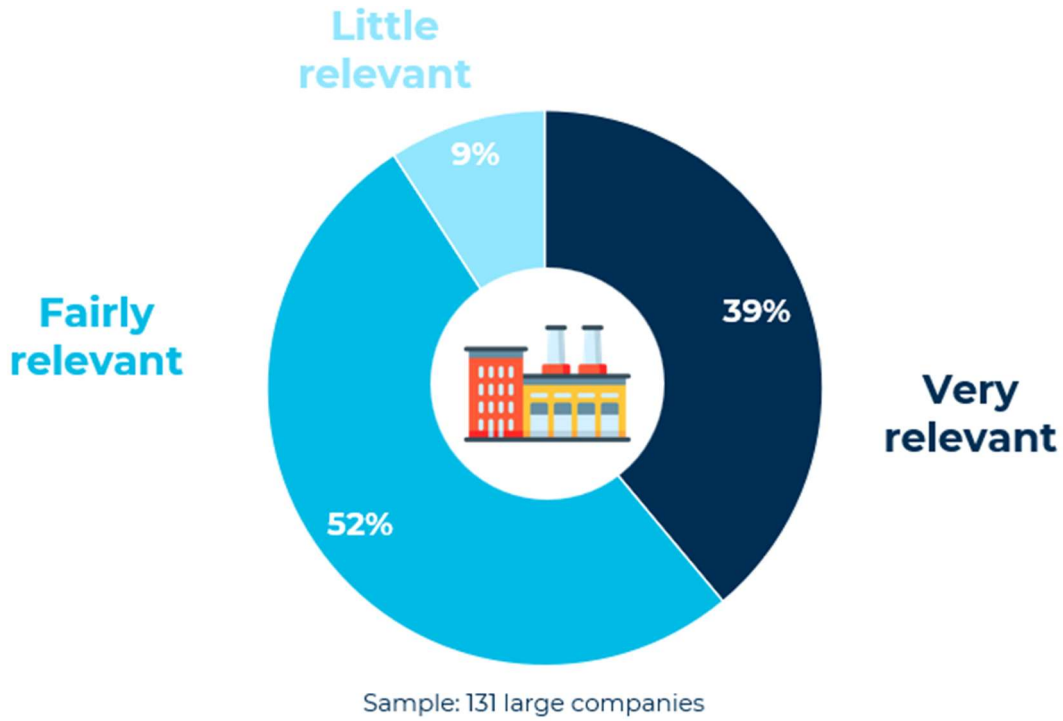

Figure 19 Relevance of Industry 4.0 theme

Question 8:

La sua azienda ha avviato progetti IoT per l'Industria 4.0 in passato, a supporto delle attività logistiche o di fabbrica?
Has your company launched IoT projects for Industry 4.0 in the past, in support of logistical activities or of the factory?

The question allows to define the evolvement over the years of the number of Industrial IoT projects implemented. The first thing to notice is that 77% of the companies surveyed has implemented at least one IIoT projects. In addition, it is possible to deepen the time distribution of projects implementation. Among the ones that has already developed this kind of solution 56% of the companies had already implemented IoT projects before 2020. In 2020 the 34% of the interviewed stated that the company they are working in has launch an IoT solution. The percentage increase for 2021, for which it become the 46%. This shows the positive trend of growth that the technology of IoT applied to the industrial scenario is facing in these years. Finally, in the graph, it is possible to notice that in 2022 the percentage of companies that has implemented these kinds of solutions decrease with respect to the previous year (39%). However, it is important to notice that the survey has been answered by the representatives of the companies in August. As a result, the analysis does not take into consideration the entire year

and, therefore, the percentage shown in the graph is expected to grow by the end of the year. As expected, the number for SME are lower compared to the Large companies' ones. In 2022 the 21% of the companies implemented a project; the biggest difference lies in the data of projects implemented before 2020 (56% versus 20%), which is given by the fact that IIoT is still a fairly recent technology for SME among which is spreading just over the last years.

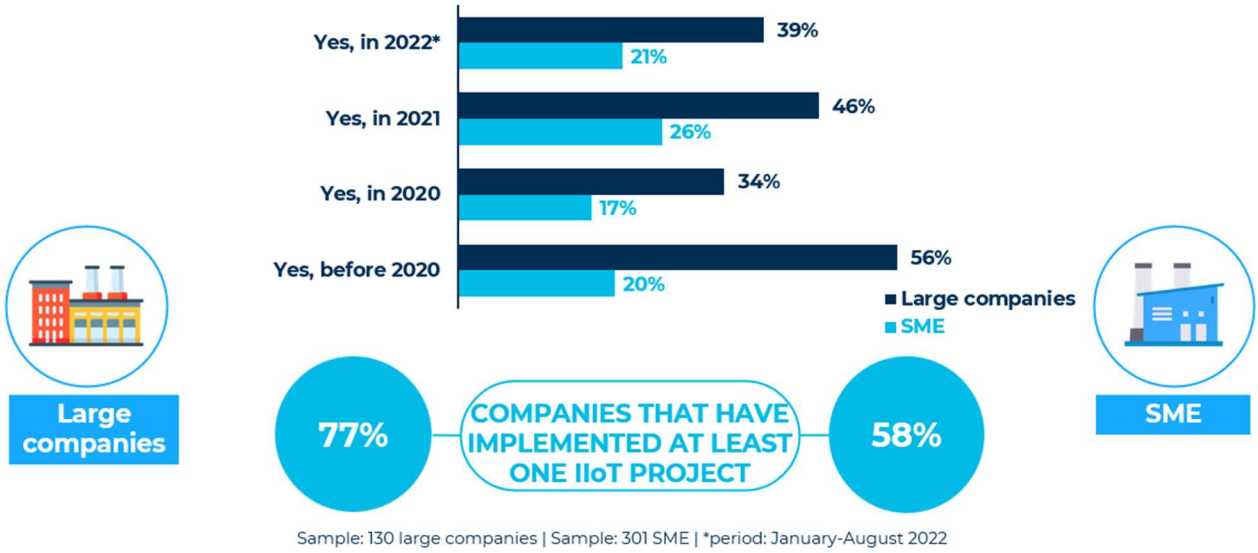

Figure 20 IIoT projects implemented in the past

Question 9:

La preghiamo di indicare, per ciascun progetto IoT per l'Industria 4.0 avviato dalla sua azienda, lo stato di avanzamento (analisi preliminare, progetto pilota, progetto esecutivo). Se possibile, le chiediamo di indicare nel campo Note la tipologia di device utilizzati per la realizzazione dei progetti Industria 4.0 che avete avviato (es. telecamere video, sensori audio, tag RFId, ...) Please indicate, for each IoT project for the Industry 4.0 launched by its company, the state of development (preliminary analysis, pilot projects, executive project). If it is possible, please indicate under the field "Note" the typologies of devices used for the realization of Industry 4.0 projects that you have launched (for instance, video cameras, audio sensors, RFID tags…)

This is the question with which it is possible to understand all the past experience that the company had in terms of IoT projects implemented. The objective is to understand in which field of application the company exploit the technology of IoT. The projects considered are the ones in the field of Smart Factory, Smart Logistics and Smart Lifecylce. For each of them, other precise application has been proposed.

In addition, for each project, the respondent has to indicate its state of development. For each project implemented the respondents have to select its state of development. The alternatives proposed are preliminary analysis (first step for all the projects, where its feasibility and its potential value is evaluated), pilot project (first step of implementation of a projects, once the company has decided to launch it) and executive project (which consists of an IoT project already completely implemented and functioning). First of all, from the analysis of the answer to the question, it is interesting to understand the distribution of the projects based on the field of application. As expected, the field with the greatest number of projects (considering all the three possible phase of implementation) is Smart Factory, with the 48% of the projects. It is followed by Smart Logistics and Supply Chain, which has the 36% of the projects inserted in the survey. Finally, the field with the least projects is the Smart Lifecycle, with the 16% of the projects.
The ranking of the different fields, in terms of number of projects implemented, was expected. Indeed, over the years, we have seen how Smart Factory was the field most spread and mature, and with the greatest number of application, while Smart Lifecycle is a field of application that is still developing year after year and, therefore, still not mature and spread as the others.
Going more in depth with the analysis, it is possible to focus on the distribution of the specific applications for the macro field of Smart Factory.
Looking at Figure 21, it is possible to notice that the most spread one is the Optimization of Production with the 9% of the overall number of projects (considering also Smart Logistics and Smart Lifecycle projects). It is followed by Energy Management, with the 8% and by Preventive Maintenance, which has registered the 7% of the overall projects.

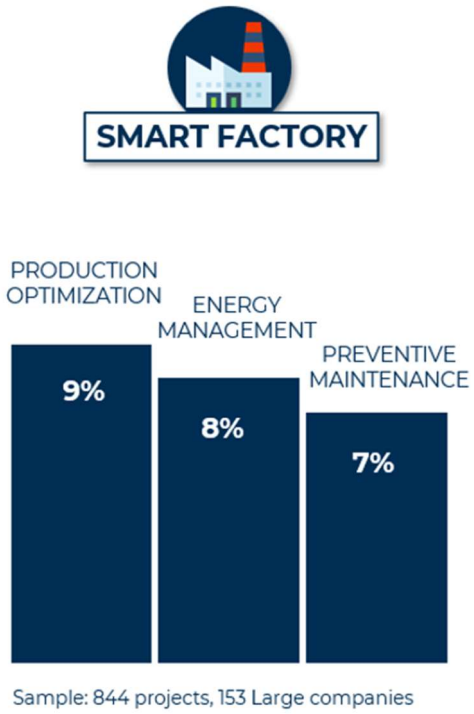

Figure 21 Smart Factory application

Question 14:

Quali sono stati i principali obiettivi che hanno portato l'azienda ad avviare progetti IoT per l'Industria 4.0?
What are the main objectives that have brought the company to launch IoT projects for Industry 4.0?

A large set of possibilities can be chosen by the respondents. This because Industrial IoT technologies can be used by the company for a very wide range of objectives, thanks to its flexibility. The alternatives include both opportunities of performance improvement that can be reached through the implementation of such technology, strategical factors (such as the improvement of company's brand or need of alignment with the competitors) and need of alignment to specific constraints (such as regulatory obligations or Covid-19-related restrictions).
As can be seen in Figure 22, the objective on which companies focus the most is the achievement of efficiency benefits (such as reduction of costs and time). Indeed, almost the 70% of the companies stated to have efficiency as an objective to reach with the implementation of IoT projects.
After that, a set of 4 possible objectives has registered significant results. These are: the achievements of effectiveness benefits such as improvement of production process quality (41% of the companies is focusing on it); the possibility to exploit

data available thanks to connected assets (35%), which will bring for instance to the awareness of which are the area with more inefficiencies or which is the real utilization of machineries; access to national incentives, like PNRR (34%); possibility to gain or maintain a competitive advantage with an innovative offer compared to the rest of the market (31%). Going ahead, other possible objectives that many companies are pursuing with their IoT applications are the possibility to activate valuable services (17%), the willingness to experiment innovative solution (12%), the improvement of environmental sustainability with a possible reduction of CO2 emission or an increase in energy efficiency (14%) and the improvement of company's image (14%). Finally, some of the respondents selected the objective of necessity of alignment toward competitors' offers (6%), adaptation toward legal constraints and regulatory requirements (2%) and the adaptation towards Covid-19 emergency (1%). Comparing the results with the ones of SME, some differences emerges: the possibility to exploit data has been an objective for just the 17% of the companies (compared to the 35% of the Large companies); on the contrary more SME has selected as an important objective the possibility to access to national incentives.

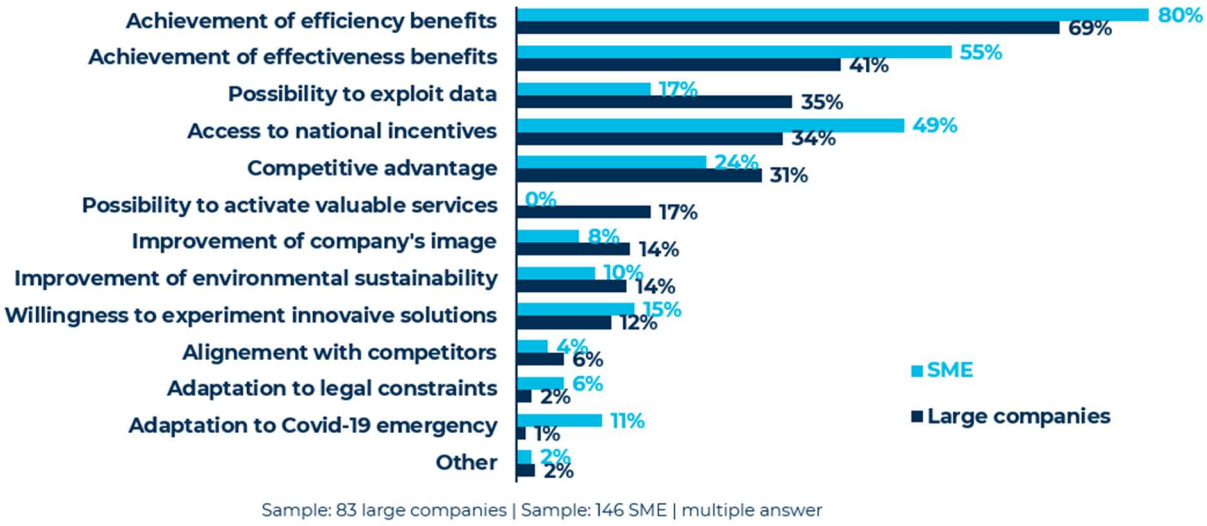

Figure 22 Objectives behind IIoT projects

Question 15:

Quale figura aziendale è stata determinante fin dall'inizio per l'avvio dei progetti indicati?
What company figure has been decisive from the very beginning for the launch of the indicated projects?

Looking at Figure 23 it is possible to have a complete idea about which figure of a company are considered the most influential and important for the correct launch

and management of Industrial IoT projects.
For the 61% of the respondents, the CEO is one of the most significant figures to deal with those kinds of solutions. it is followed by the COO which has been selected by the 48% of the companies and by the CIO, selected by the 46%. Moving on, we find the Factory Responsible (23%), the Innovation Manager (14%) and the R&D Responsible (13%). In some cases also a figure external to the company, like an external consultant, is considered as a crucial figure for the implementation of these projects. Finally, the company figures less selected are the Finance Responsible (8%), the Supply Chain Responsible (7%), the Marketing Responsible (5%), the HR Responsible (1%) and the Sales Responsible which has not been selected by any respondents.
Looking at the results obtained for SME, it is possible to highlight the less significance (compared to Large companies results) of Operations Responsible (17%), of the CIO (26%) and of the Innovation Manager (4%). On the other hand, it results to be more impactful Finance Responsible (24%), the Supplier/external consultant (20%) and the Factory Responsible (34%).

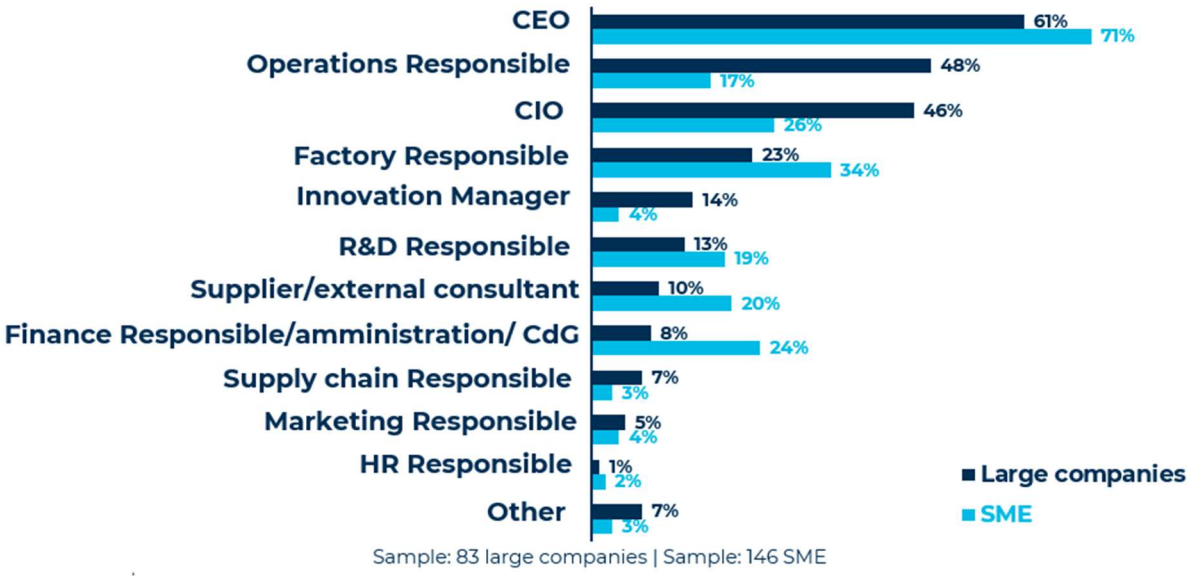

Figure 23 Relevant fiures within company for project implementation

Question 16:

Avete utilizzato (ed eventualmente rielaborato) i dati che avete raccolto tramite i progetti IoT per l'Industria 4.0?
Have you used (and eventually reprocessed) the data that you gather thanks to IoT projects for Industry 4.0?

As explained during the thesis, the great potential of IoT technology lies on its ability to generate huge amounts of data. However, one of the main limitations of the adoption of this technology is precisely the ability to exploit all this data. Looking at Figure 24, it is possible to analyze if and eventually how companies are currently exploiting those data collected thanks to the IoT projects implemented in their factories.
The results show that there is still a big room for improvement in the field of exploitation of data.
Indeed, the 46% of the companies is not exploiting the potential value coming from the analysis of data. In particular, 27% of the respondents have stated that their companies are currently not exploiting data, but their usage is planned for the future while 2% of them stated that they are not currently exploiting the value coming from the data and this exploitation is likely not going to take place in the next future. Finally, 17% of the companies is currently using in weak way the data collected.
On the other hand, 51% of companies' representatives declared that their companies is already using the data generated in the proper way: 20% stated that the company is widely using them in an unprocessed form and the 31% stated that is widely using them both in unprocessed and processed form.
Analyzing the results of SME, the evident and expected difference lies in the number of companies that has widely used data collected both in raw form and in processed form (just the 12% of SME selected this option).

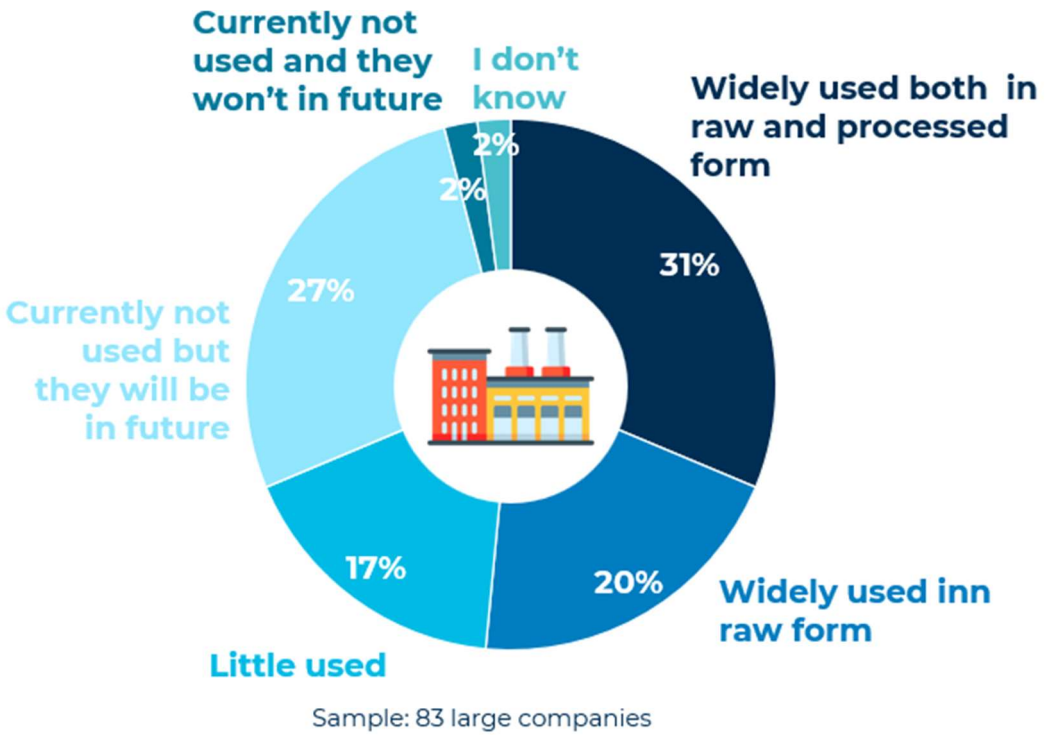

Figure 24 Usage of data for Large companies

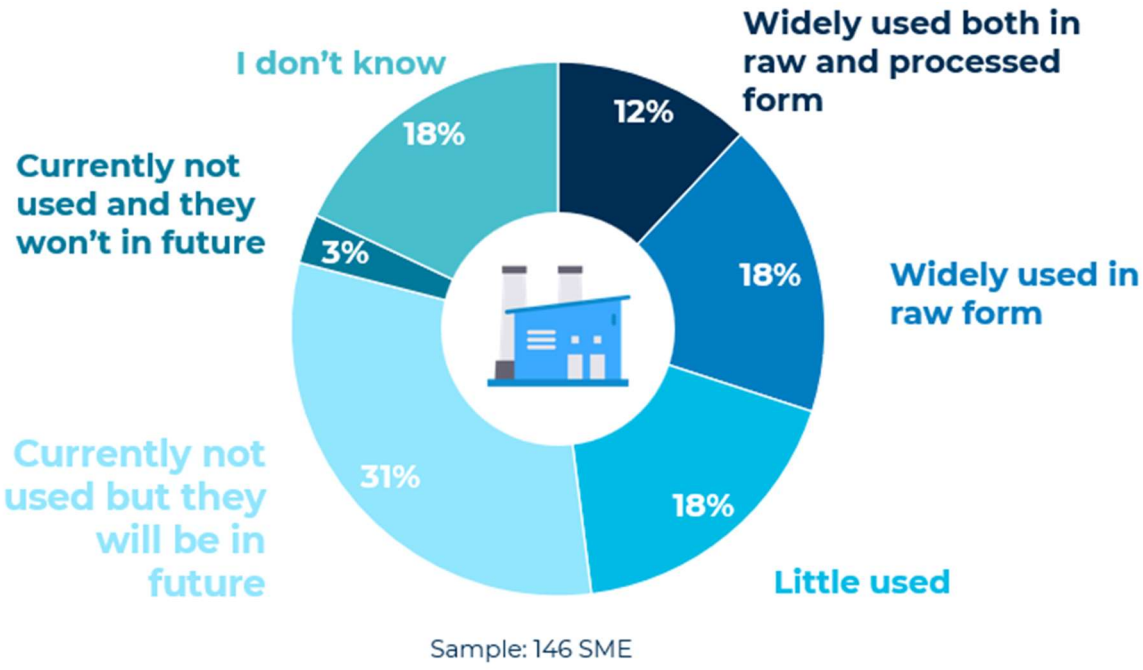

Figure 25 Usage of data for SME

Question 17:

Quali sono i motivi per cui i dati raccolti tramite i progetti IoT non vengono valorizzati?
What are the main motivations behind the non-valorization of the data gathered?

This question has been proposed just to the respondents that has selected, in the previous question, one of the following alternatives: weakly utilized, not currently utilized and will hardly be utilized in the future, not currently utilized but their usage is planned for the future. This because, it is significant to deepen the companies' inability to use all the potential value coming from the implementation of Industrial IoT projects.
It is of paramount importance to understand why companies are struggling so much to exploit the data generated by IoT solutions. This would allow to address the points that prevent from exploiting IoT at its full potential.
Looking at Figure 26, which shows the results of the survey, the most significant issue the companies are facing, for which the data collected through IoT projects are not exploited, is the lack of competences and the lack of specific figures inside the companies responsible for data enhancement. Fifty per cent of the respondent select this option. After that, the 28% of the companies find difficult to understand the real value that could be generated by the data collected, experiencing a lack of motivation of invest time and resources for this activity.
The 23% of the respondents stated that the lack of appropriate IT resources for the management of the data is a reason for the low data valorization.
In addition, other alternatives that were selected by a significant sample of the companies were lack of application on which they could test data utilization (10% of the companies selected this option) and the one related to the difficulties in sharing the data gathered within the company, despite they had been collected in a proper way (15%). Finally, just a small portion of the respondents detect problem in the field of data collection. Indeed, just the 5% consider the improper data collection process (low precision and/or reliability of the data) as a possible reason for the low utilization of data inside their companies.
In the case of SME, less respondents selected as main motivation the lack of competences and specific figures able to valorize them (30%), even though it remains the most selected answer. Looking at the other options, for SME it is more frequent the selection of lack of application and use cases and the adequacy of data collection process as motivation behind low data utilization.

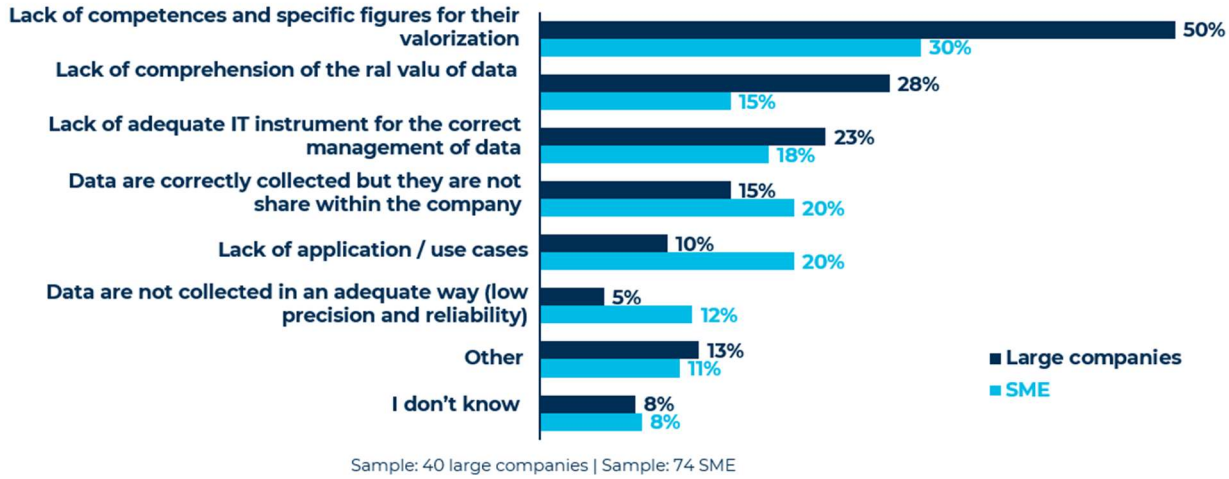

Figure 26 Motivations behind low utilization of data

Question 18:

Per la gestione dei dati raccolti tramite progetti IoT, la sua azienda utilizza una piattaforma IoT?
Does your company use an IoT platform for the management of the data gathered?

This question is proposed just to the respondents that has selected, in the question regarding the data usage of their companies, one of the following alternatives: "the data collected have been widely used in raw form (without reprocessing)", "the data collected have been widely used and reprocesses", "I don't know".
For the management of the data collected, companies have generally two main alternatives: use a platform that has been developed internally to the company or use a platform that has been developed by an external provider. As expected, these two alternatives are the most frequently selected by the respondents. In some cases, it can happen that no platform is exploited for the management of the data.
From Figure 27 it is possible to see the result of the analysis conducted: 70% of the companies stated that they are currently exploiting an IoT platform for the management of the great amount of data collected. In particular, the 37% is exploiting a platform that has been developed internally to the company and 33% of them is on the contrary exploiting an IoT platform that has not been developed by the company but by third parties.
There is still a small percentage of companies (equal to the 14% of the respondents) that is not using a platform for the management of data.
SME registered similar results, with a decrease of number of companies that use a platform developed internally (28% compared to 37% registered by Large companies)

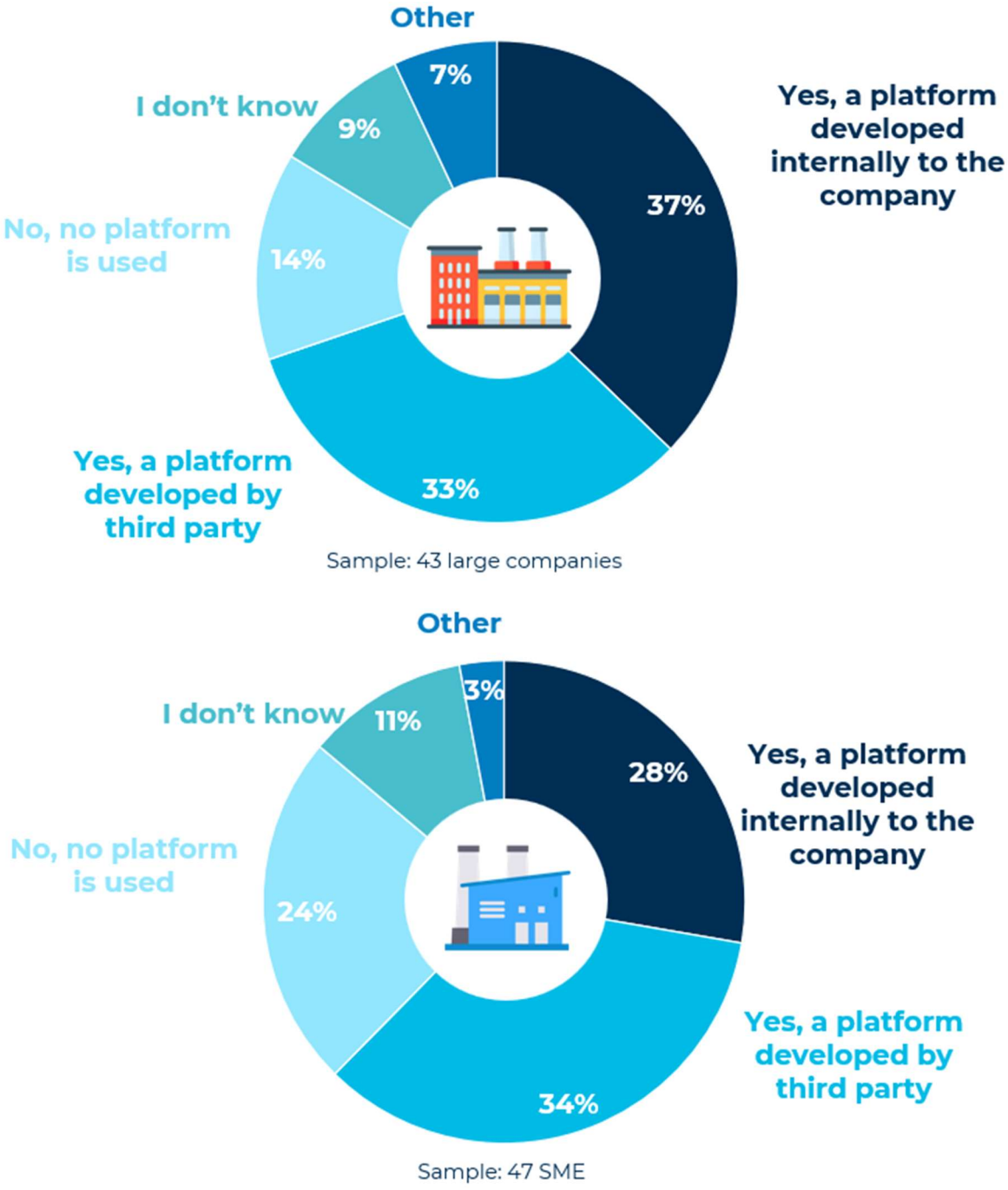

Figure 27 Platform usage for data management

Question 19:

Come valuta complessivamente i progetti IoT per l'Industria 4.0 realizzati dalla sua azienda?
How do you evaluate, overall, IoT projects for Industry 4.0 implemented by your company?

From the analysis conducted with the survey it is interesting to highlight that no respondents has selected those alternatives that imply a negative evaluation of the Industrial IoT projects implemented in their companies.
As a result, as shown in Figure 28 the results show that those that has already implemented these kind of solutions have developed a positive evaluation of them. In particular, 57% of the respondents stated that has a positive overall evaluation of the projects, while the for the 39% the evaluation is very positive. Just a small percentage of the companies declares that the solutions implemented did not have an impact for company's business.

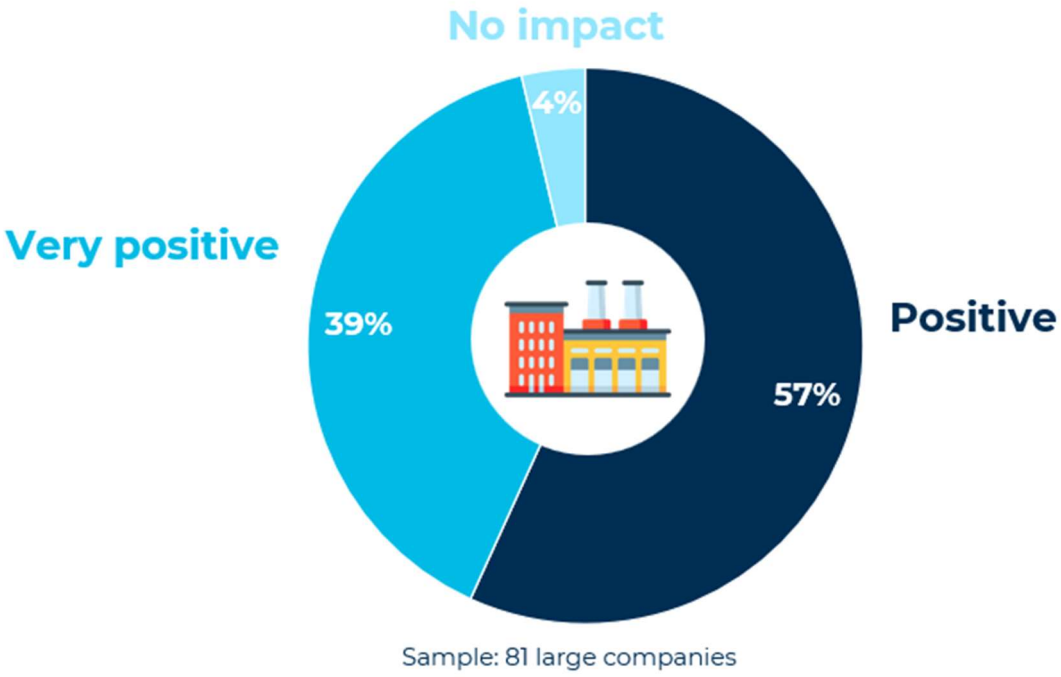

Figure 28 Evaluation of IIoT projects implemented

Question 20:

Quali sono le barriere (interne ed esterne) che secondo lei rallentano o impediscono l'avvio di progetti IoT per l'Industria 4.0 nella sua azienda?
Which are the main barriers (both internal and external) that, according to you,

slow down or prevent from the launch of IoT projects for Industry 4.0 in your company?

There can be many possible barriers that prevent from the optimal implementation of IoT projects. As a result, many alternatives were presented to the respondents, even though many others may exist. Among them, there some motivations linked to different kind of issue. There are both limitations linked to the internal capabilities of the companies and others linked to the external environment and the current economic and social situation.
Among the respondents, only the 13% stated that its company have not faced any barriers for the implementation of IoT projects.
It is evident from Figure 29 that the lack of knowledge regarding the theme of Industrial IoT and the lack of internal competences able to manage those projects is the most problematic factor. Indeed, 44% of the companies consider it as a barrier for the adoption of IoT solutions.
It is followed by the difficulties in terms of integration of old hardware and software (25%) and the lack of comprehension of the real value that this kind of solutions con bring to the business (25%). Moving on, other problematic factors that many companies have to face are the issues related to the actual economic instability, which generate for example the lack of raw materials and the increase of energy prices (21%), the low availability of economic resources (16%), the lack of coordination between the different department of the companies (14%) and possible internal resistance (13%).
Still significant are the difficulties encounter by the companies to access to national incentives, like PNRR (11% of the cases) and issues related to privacy and cybersecurity (like employee which are not willing to monitoring their own activities or extreme vulnerability of the exchanged data), which happens in the 10% of the cases.
Finally, there are other possible reason, which have been selected by a reduced percentage of the respondents: lack of proper products and technologies, lack of appropriate suppliers, low availability of semiconductor on the market, the persistent uncertainty linked to the health and economic emergency and unavailability of services.
For SME it has been more impactful the instability of economic context, which is the second most selected options. In the same way, the lack of economic resources impacted more for SME than for Large companies.
On the other hand, less respondents, compared to the ones of Large companies, see internal resistance and lack of coordination as a barrier for their companies.

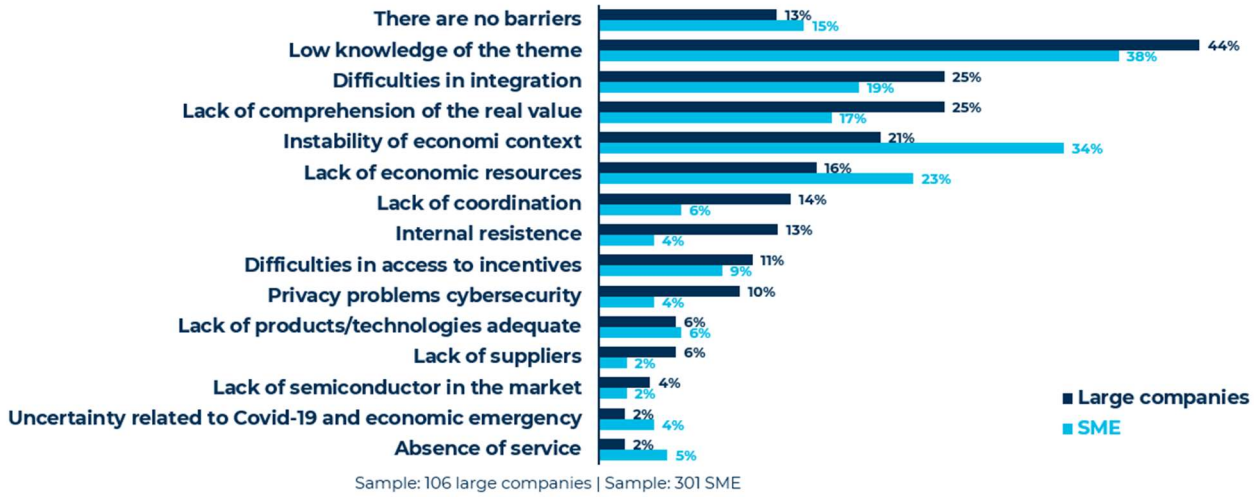

Figure 29 Main barriers for IIoT projects implementation

Question 21:

Quali fasi di un progetto Industrial IoT risultano più critiche o ne impediscono la realizzazione?
Which are those phases of an Industrial IoT projects that are the most critical or the ones that prevent from its realization?

The question is interesting because it allows to understand what are the most critical phases of the implementation of an IoT projects.
The results highlight that the main difficulties are faced in the very first phases, when the company has to understand which are the potential benefits of the IoT solution proposed. This is in line with the results seen until now. Indeed, being the lack of capabilities and expertise related to the world of Industrial IoT a major obstacle of today's companies, it is difficult for them to comprehend deeply the importance of these kind of solutions and the benefits that they could achieve in terms of performances.
The implementation step that has generated the greatest difficulties is the identification of potentialities, with the 37% of the respondents that select this option. The following most current criticalities are still faced before the implementation of the projects. Indeed, 31% of the companies selected as a problematic phase the analytical activity for the collection of the prerequisites, the identification of specifics, the processes' mapping and the collection of technical prerequisites. Moreover, almost the same percentage of respondents (30%) select the definition of a project plan, of the activities to execute and of the organization of the resources involved.
Moving ahead, it is common for the companies to face issues with the redesign of the roles and of the tasks in the productive organization (23%) and with the development and experimentation of pilot solutions, prototypes/proof of concept

(19%).
Finally, just a limited number of companies has met obstacles in the supporting of implementation activities and the activity of Project management (8%) and in the maintenance of the solution implemented (5%).
The trend is fairly similar also for SME with the only exception of the number of companies that has never considered the implementation of an Industrial IoT project. The percentage is indeed equal to 29%, which is extremely high compared to the results seen for the Large companies.

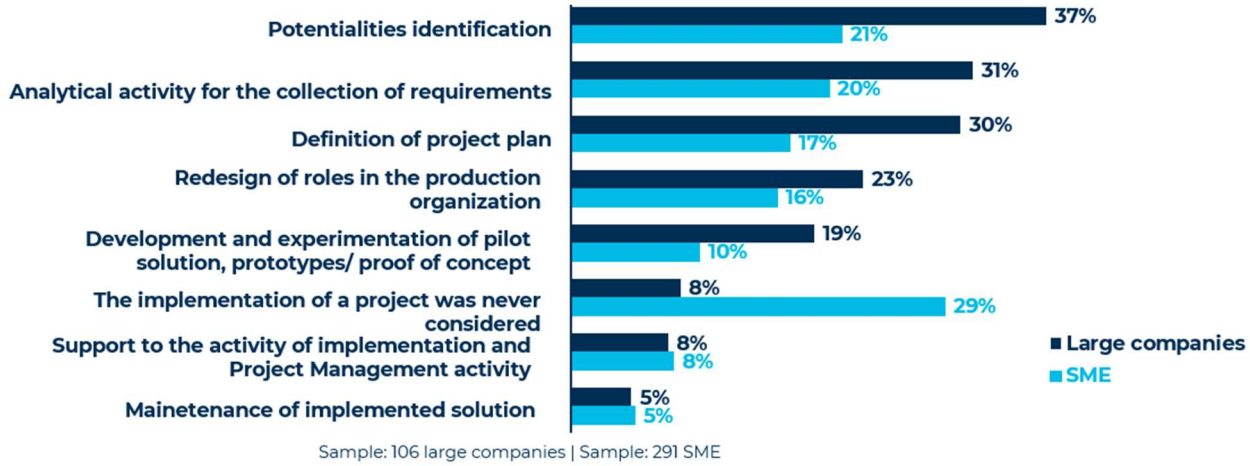

Figure 30 Most critical phases of IIoT project implementation

Question 25:

Crede che la sua azienda abbia valutato le giuste misure da implementare in tema di cybersecurity nei propri sistemi IT?
Do you believe that your company has evaluated the right measures to implement in terms of cybersecurity in its own system?

On Figure 31 it is possible to see the results of the analysis. It is evident how the theme of cybersecurity has gained great attention by the companies. Indeed, the 96% of the respondents stated that its company consider the implementation of cybersecurity in its own IT system as a relevant theme. In particular, 54% of the companies has already made the required evaluation, while 36% of the company has still to make evaluation or they are doing that in this period. Moreover, a small percentage (6%) did not complete any necessary evaluation, even though it considers cybersecurity an important issue.
It is important to remark that no one among the respondents does not considers cybersecurity as a significant theme for their companies.
In general, from the results obtained for SME, it is evident that the theme of Cybersecurity is considered with more priority by Large companies. Indeed, SME that has already made evaluation are 19% less than Large companies.

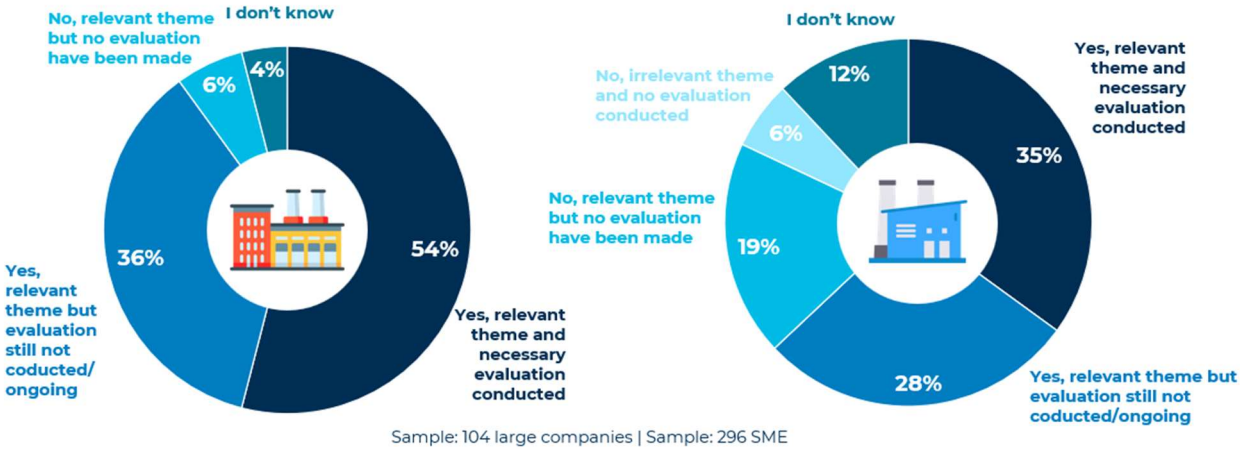

Figure 31 Cybersecurity relevance

Question 11:

Le applicazioni IoT per l'Industria 4.0 che avete avviato, indicate nella domanda precedente, hanno previsto l'acquisto di servizi aggiuntivi da parte della sua azienda?
Have IoT applications for Industry 4.0 that you have launched, indicated on the previous question, planned the purchasing of additional services by your company?

The purchase of additional services together with the solutions IoT is trend that is experiencing a considerable growth, which has brought to an increase of the possible services offered, as well. The question has the objective to monitor the path followed by this trend. The ones mentioned as alternatives are just some of the possibilities among a wide range of services that providers are now able to offer to their clients. As can be seen on Figure 32, the majority of the company that answer to the question has already activated additional services to their Industrial IoT projects. In particular, the 64% of the respondents belong to this category. On the other hand, it is still significant the percentage that has not activated those kind of solutions (30%). Analyzing more in depth which kind of services have been activated, the results are that for the 77% of the companies that have already implemented an additional service, it consists of an information service. Particularly spread are energy management services (activated by the 45% of the companies), that include the reception of report with the analysis of energy consumption trends and with personalized suggestion on how to decrease them. After that, we find the maintenance services, split into preventive maintenance services (32%) and predictive maintenance services (23%). As explained in the previous chapters, the first one consists of define in advance of the moments in which the maintenance of the assets is performed, while the latter one consists of optimizing the choice of when performing the maintenance intervention based on

the real utilization of the machinery/asset. Going on, we find pay-per-use services (16%), which include the payment of connected objects (like machineries or assets) not in the purchasing moment, but throughout their lifecycle based on their real utilization. Finally, the least spread service are the insurance coverage (2%) on the connected objects based on their real utilization. The distribution registered for SME is similar to the one of Large companies even though the number of companies that activated additional services is lower: information services are still the most widespread, while insurance are still the least selected option. Moreover, there is a great difference regarding energy management services, with just 14% of SME that activated this kind of services.

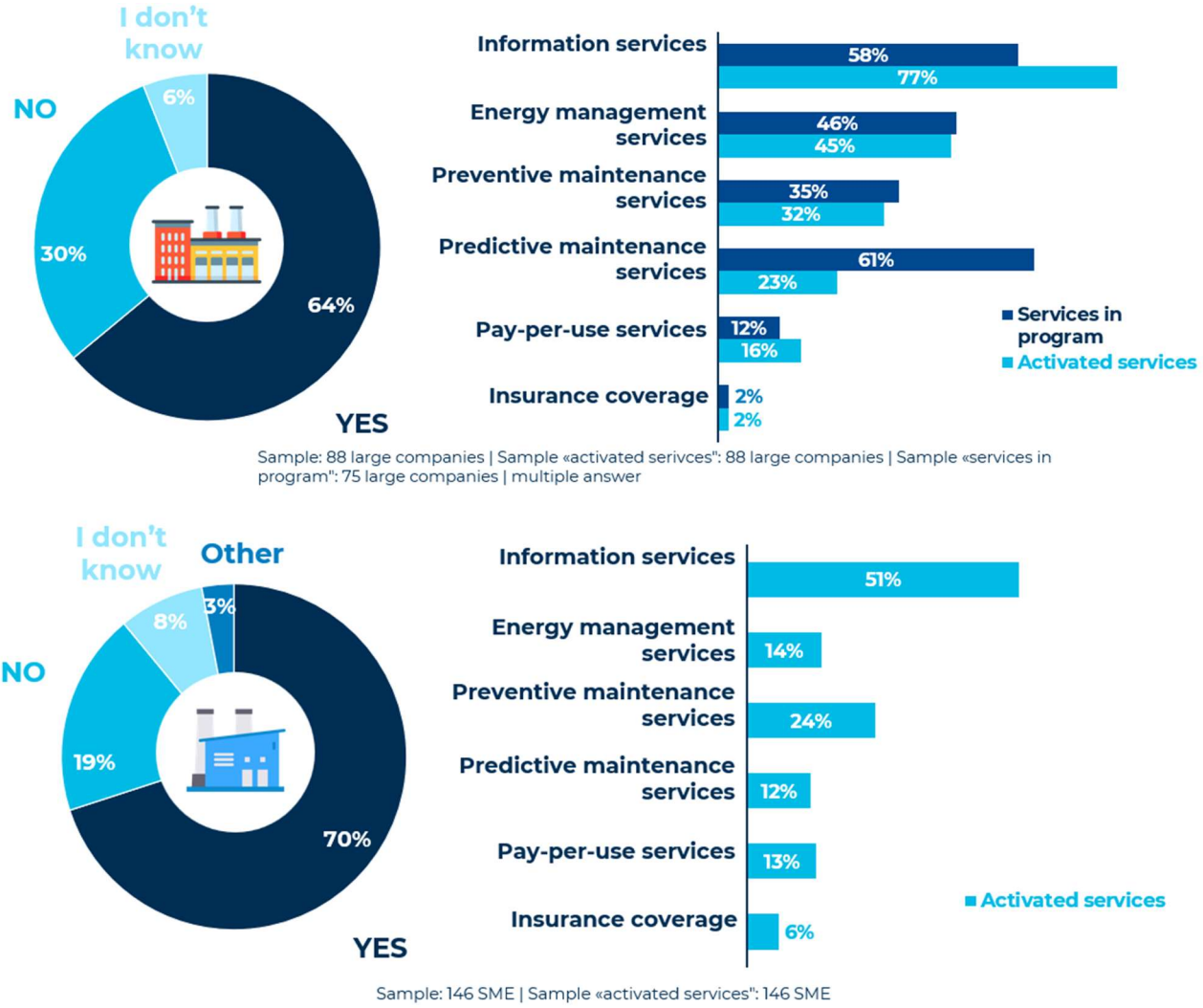

Figure 32 Additional services to IIoT projects

Question 12:

Da chi comprate questo tipo di servizi?
From whom do you buy those kinds of services?

This question is proposed just the respondents that has stated in the previous question, that their company has already activated additional services to their IoT environment.
Given the great potentialities of these kind of services, manage to find an optimal provider is an issue of paramount importance for companies active in the IoT field. The majority of the companies (56%) stated that they are buying those services by the manufacturer of the machinery/system. It is followed by the category big consulting companies operating in the field of system integration, which has been selected by the 38%. Also small consulting companies operating in the world of Industrial IoT are frequently considered by the companies for the activation of services (28% of the cases). Going on, we find the manufacturer of complex productive systems that integrate different plant (25%) and the manufacturers of plant's parts (21%).

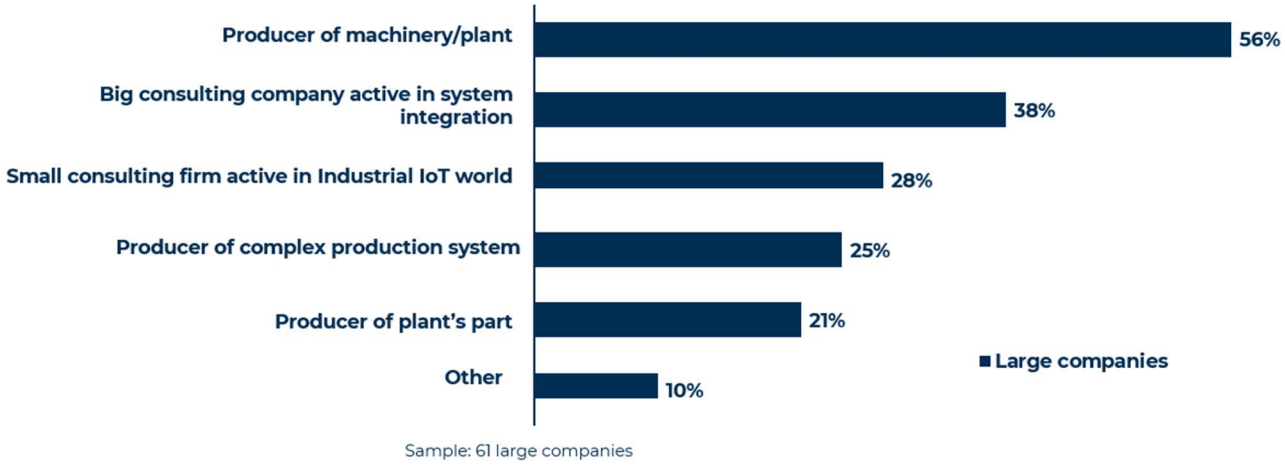

Figure 33 Supplier of additional services

Question 13:

Quali sono i fattori che vi scoraggiano maggiormente ad adottare questo tipo di servizi?
Which are the factors that are discouraging you the most from adopting those kinds of services?

The adoption of solutions with services integrated with products it's a relatively new trend. As a result, there are still some barriers that do not allow for their widespread adoption, discouraging companies. However, it is worth to notice that more than the 70% of the companies that have activated an additional service has

stated to have not faced any possible factor that discouraged them from the adoption of these solutions. Among the barriers found by the companies, in 18% of the cases they are related to a financial issue: for some companies it is more difficult to justify an "investment on a service" rather than an "investment on a machinery on which the company will have full ownership". Another frequent factor is that some companies want to have the full control of the machinery and, therefore, they are not interested on related services (14%). In the 12% of the cases, it is linked to an accounting reason: for this category of companies is currently better to sustain investments (CAPEX) rather than recurring operative costs (OPEX). Going on, there are companies that are not willing to provide the data coming from their machineries/assets to the manufacturers or to third parties in general. This happens for the 11% of the respondents. Finally, the least selected option is related to the fact that certain purchasing function prefer the purchase of an asset through investment (6%).

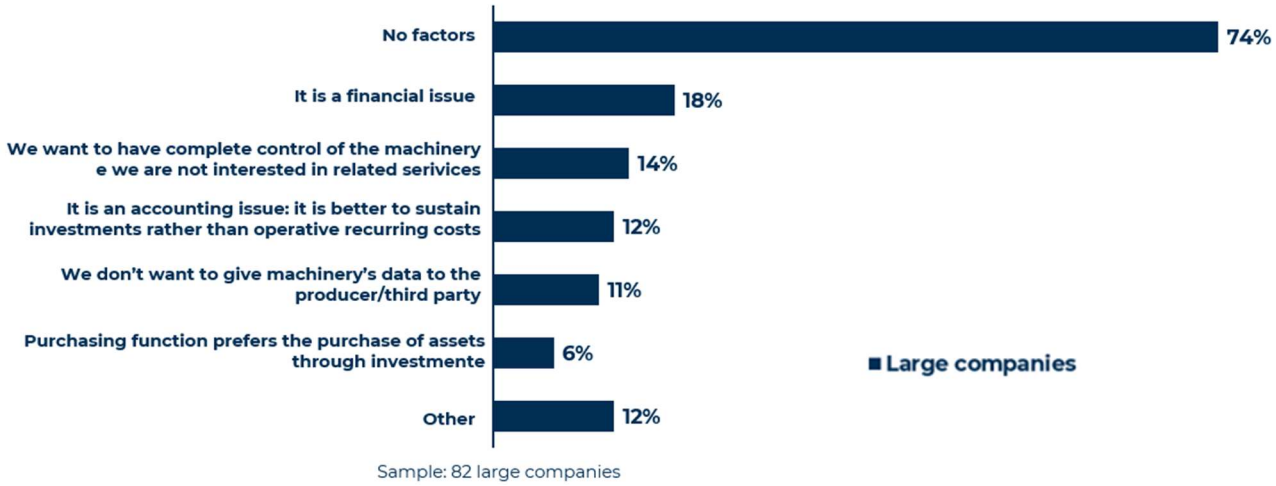

Figure 34 Motivation that avoid the adoption of additional services

Finally, the last set of questions is meant for having an idea of what the companies are planning for the future, in terms of investment for IoT projects. In particular, the objective is to understand if the companies are willing to launch new IoT projects in the next future, and, in case of positive answer, what are the motivations behind this choice.

Question 23:

L'azienda di cui fa parte è interessata ad acquistare servizi aggiuntivi abilitati dalle tecnologie Internet of Things? Se sì, quali?

Is your company interested in purchasing additional services enabled from Internet of Things technologies? If yes, which ones?

As can be seen on Figure 35, the majority of the company that answer to the question is willing to activate additional services to their Industrial IoT projects. In particular, the 55% of the respondents belong to this category. On the other hand, it is still significant the percentage that is not interested in this kind of solutions (31%). Analyzing more in depth on which kind of services the companies are more interested, the results are that for the 58% of the companies that is willing to invest in additional services in the future, it consists of an information service, based on the delivery of real-time notification in case of predetermined event (like the stop of a machinery or a lack of gas). The result of energy management services is in line with the percentage of companies that has already activated this kind of services (46% of the companies). After that, we find the maintenance services, split into preventive maintenance services (35%) and predictive maintenance services (61%). The latter one is the field that has registered the greatest percentage increase compared to the number of respondents that stated to have already implemented these kind of services. Going on, we find pay-per-use services (12%), which include the payment of connected objects (like machineries or assets) not in the purchasing moment, but throughout their lifecycle based on their real utilization. Finally, the least spread service are the insurance coverage (2%) on the connected objects based on their real utilization, whose result is completely equal to the one registered in question 11.

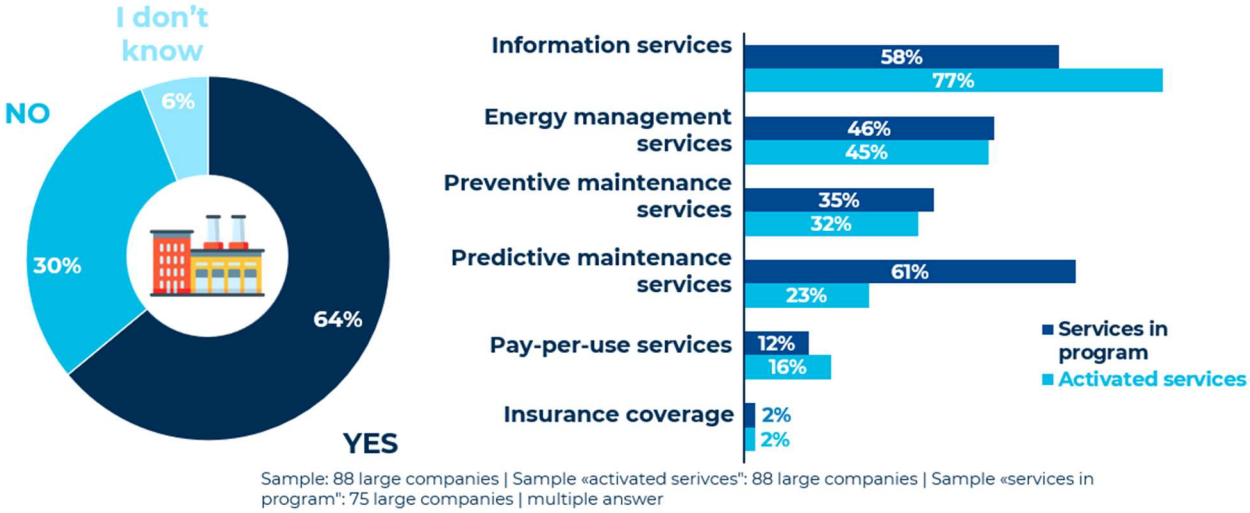

Figure 35 Interest in purchasing additional services

Question 22:

L'azienda di cui fa parte ha in programma di avviare progetti IoT per l'Industria 4.0 in futuro? Nel caso si intendano avviare progetti, specificare gli ambiti applicativi di interesse.
Has the company you work with planned to launch IoT projects for Industry 4.0 in the future? In case the company is willing to launch new projects, please specify the application fields of interest.

The analysis of the result of this question, allow to take an overview about the trend of each main Industrial IoT field. By analyzing company's future plans in terms of launched projects, it is possible to evaluate which are the fields that are going to evolve the most during the next years.
To do that, it is interesting to compare the current distribution of Industrial IoT projects with the expected distribution of launched projects in the future. In this way, the analysis highlights the fields on which companies will concentrate their investments in the future. Among the respondents, the 19% stated that its company is not going to activate an Industrial IoT projects. As a result, in the next years, the great majority of the companies will invest in this type of solutions. In particular, looking at Figure 38 and Figure 36 it is possible to understand on which application field they will focus for the next projects. As expected, the majority of the projects that will be launched will focus on Smart Factory field (54%). It is followed by applications in the field of Smart Logistics and Supply Chain with the 32% of the companies that will concentrate on it.
Finally, the 12% of the companies will start projects for Smart Lifecycle, which is, as seen before, the field of application less mature among the three.
Looking at the results of SME, it is possible to highlight a significant difference: the percentage of companies that will implement IIoT projects in the field of Smart Logistics and Supply Chain is very low compared to the same values for Large companies (12% versus 32%). On the other hand, the results are the opposite if we consider the projects implemented in Smart Lifecycle field.

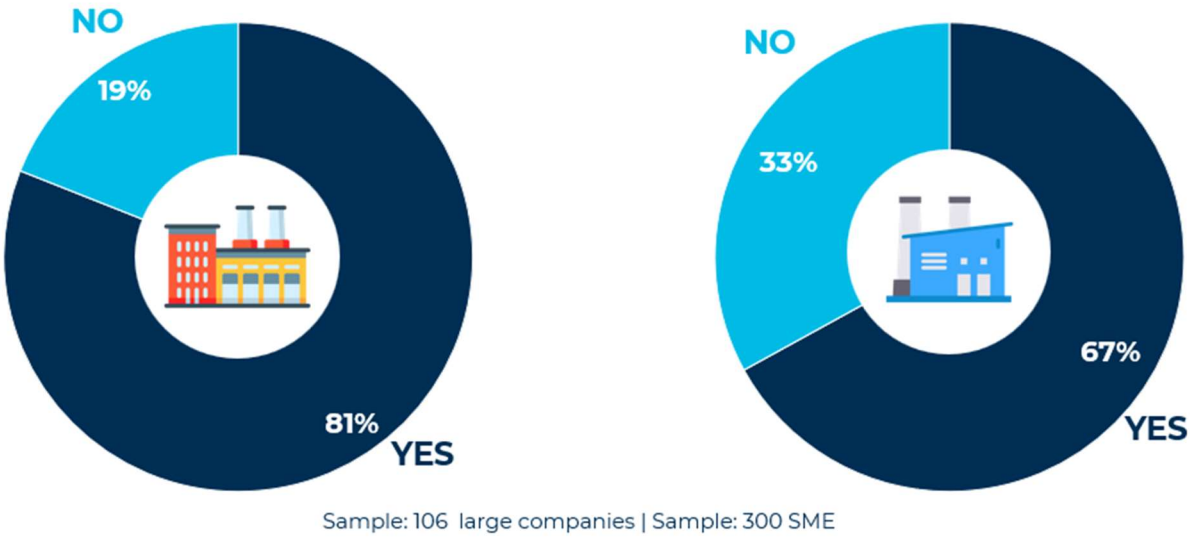

Figure 36 Willingness to implement IIoT projects in the future

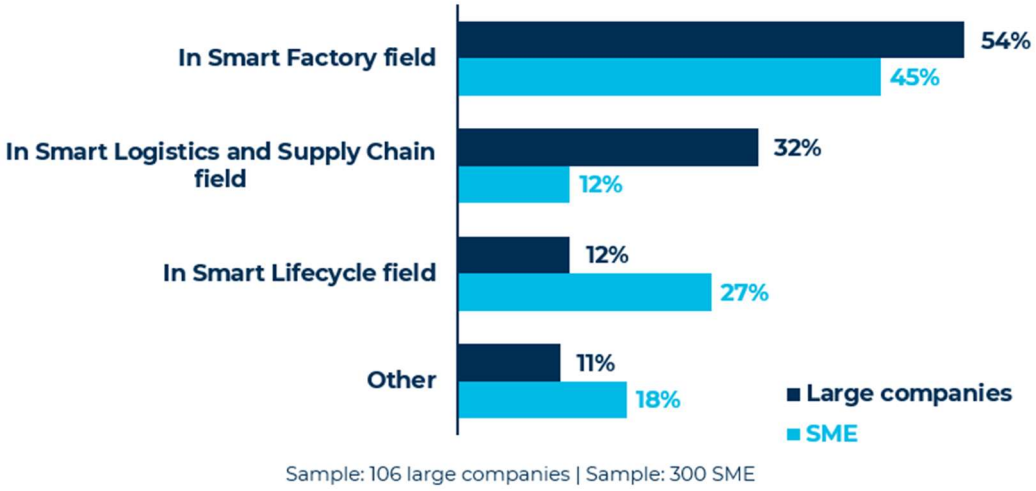

Figure 37 Field of application for future IIoT projetcs

Question 24:

Nella sua azienda quali potrebbero essere in futuro i principali obiettivi alla base dell'avvio di eventuali progetti IoT per l'Industria 4.0?
In your company, which could be the main objectives for the launch of eventual IoT projects for Industry 4.0?

As remarked before, the possible drivers that push companies to invest in Industrial IoT solutions are several and can belong to different areas: performances improvement (efficiency and effectiveness benefits, exploitation of data collected), strategic choice of the companies (brand image, alignment with competitors, access to national incentives) and regulatory constraints (regulatory obligations).

As can be seen in Figure 38 the results are in line with the ones of question about the objectives that bring the companies to invest in IoT projects: the objective on which companies focus the most is the achievement of efficiency benefits (such as reduction of costs and time). Indeed, more than the 60% of the companies stated to have efficiency as an objective to reach with the implementation of IoT projects. After that, a set of 4 possible objectives has registered significant results. These are: the achievements of effectiveness benefits such as improvement of production process quality (40% of the companies is focusing on it); the possibility to exploit data available thanks to connected assets (38%), which will bring for instance to the awareness of which are the area with more inefficiencies or which is the real utilization of machineries; the improvement of environmental sustainability with a possible reduction of CO2 emission or an increase in energy efficiency (27%); possibility to gain or maintain a competitive advantage with an innovative offer compared to the rest of the market (30%). Going ahead, other possible objectives that many companies are pursuing with their IoT applications are the access to national incentives, like PNRR (34%), the possibility to activate valuable services (20%), the willingness to experiment innovative solution (14%) and the improvement of company's image (14%). Finally, some of the respondents selected the objective of necessity of alignment toward competitors' offers (6%), adaptation toward legal constraints and regulatory requirements (3%) and the adaptation towards Covid-19 emergency (1%).

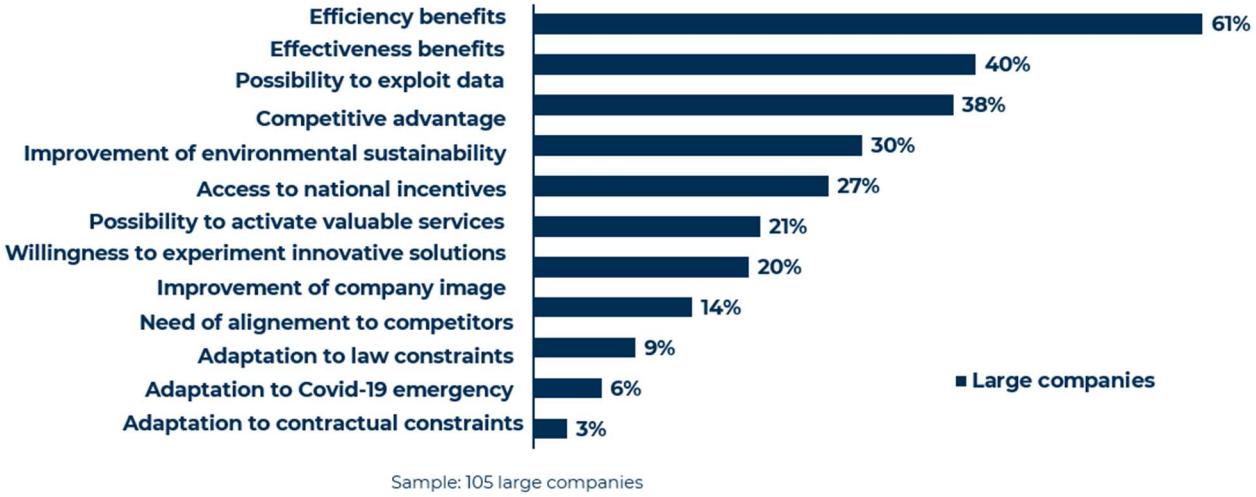

Figure 38 Objectives behind IIoT project implementation

Question 26:

La sua azienda sarebbe propensa a collaborare con altri attori con il fine di creare un ecosistema di partner per realizzare progetti IoT integrati?
Is your company willing to cooperate with other actors aiming at creating a partners' ecosystem for the realization of IoT integrated projects?

Looking at Figure 39, it is possible to get the results of the analysis. Just the 13% of the respondents stated that its company will not be willing to cooperate with other companies with the aim of creating a partner's ecosystem for the realization of integrated Industrial IoT projects.
By looking at the other ones, the 46% stated to be in favor of this kind of collaboration, while the 44% has still not taken a precise position for this theme. The comparison of the results of SME and Large companies highlight a significant difference in this theme. Just a small portion of SME stated to be willing to collaborate with other actors (17%). More than half of the respondents clearly stated their opposition to this kind of solutions.

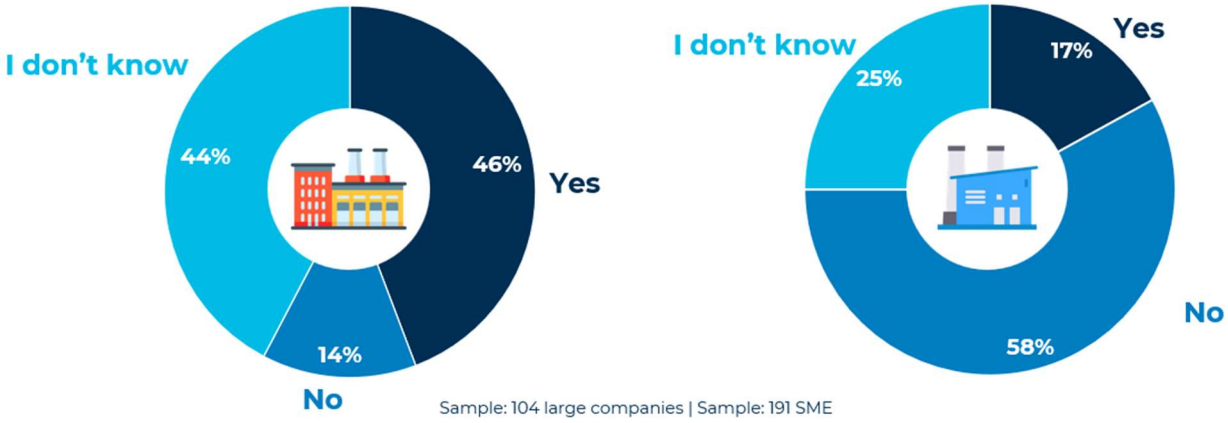

Figure 39 Collaboration for IIoT integrated projects

Question 27:

Con quali attori vorrebbe collaborare?
With which actors would your company like to cooperate?

This question was proposed just to the respondents that has stated, with the previous question, that their companies would be willing to collaborate with other actors for the realization of IoT Industrial integrated projects.
From Figure 40 it is possible to see which are the entities with which companies are more willing to cooperate are Universities and research centers (78%), followed by the System Integrators (70%). Half of the respondents would like to work with Innovative Start-ups and the 41% with manufacturer and developer of hardware/software.
Moving on, a significant percentage stated to be willing to cooperate with Utility (26%), with Services Providers (20%) and with Telco Operators (20%). For the rest of the option, the respondents that make the selection were less than 10%. In particular, 9% selected Private Companies that offer security services, 9% Tower Company/Network Operator, 4% Public Entities/ Public Administration and, finally, just the 2% selected as a possible partner Bank and Insurances.

The preferences highlighted by SME are similar to the ones of Large companies. The main variances are registered for Utility actors which have been selected by just the 10% of SME and for private security services' companies, public administration and bank and insurances which have been selected by a higher percentage of SME (compared to Large companies) as the actor with which collaborate.

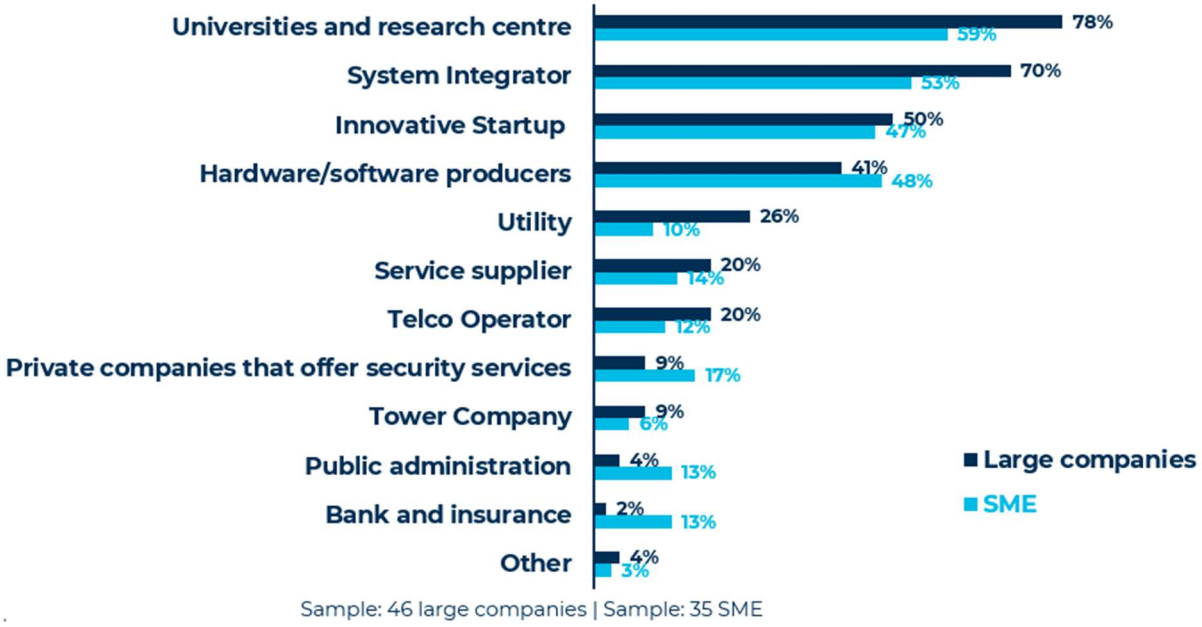

Figure 40 Actors desired for a collaboration

4 Directions of future development

After having understood what the current state of adoption of Industrial Internet of Things is, firstly by proposing an analysis of all the IIoT projects implemented worldwide that have been identified by me and by my colleagues in the last years and recorded in the database introduced in chapter 3, and secondly by focusing on the Italian scenario with the issuing of the survey (and the relative analysis), I decided to propose a deepening about the future trends of this technology.
In fact, if on the one hand this technology, as we have seen with the results of the survey, turns out to be more and more known and used inside the companies, it is evident that there are still enormous potential for growth. These are primarily dictated by the technological developments that we are witnessing in recent years. Companies, in fact, having understood the great advantages that IoT projects can bring within their plants, their supply chain and their business processes, are choosing to implement projects of this type in an increasingly massive way, also encouraged by the national incentives currently in place. However, in parallel with the growth in terms of adoption, there are also numerous trends in the development of innovative technologies, which, integrated with IoT technology, make projects of this type even more impactful on business performance, being able to guarantee quality levels, productivity, flexibility, efficiency (and many other features) always higher. It is therefore essential to understand which technologies, more than others, will have an impact on the Internet of Things applied at the industrial level. To do this, in the following chapter I decided to develop an analysis of the innovative Start-ups active on the Internet of Things industry that have developed in recent years. The analysis was carried out at a global level, including realities developed in all continents.
The aim of this research is to be able to understand the main trends that are developing in the Internet of Things, focusing on its applications for the Smart Factory.
This will allow to understand which innovative technologies and trends are currently focusing more on, developing a clear idea of what changes and improvements will be recorded in the coming years in Industry 4.0 and IoT.
Different start-up clusters will be proposed, each one focused on a common offer in terms of technology and application. For each cluster, some examples will be

provided, taken from the 43 start-ups identified in the research. The entire list of start-ups can be found in the appendix.

4.1. Start-up research and Cluster Analysis

4.1.1. AIoT

One of the main trends that has been identified by analyzing the offers of new start-ups, is the joint use of Artificial Intelligence and IoT, with the aim of creating synergies between IoT tools and AI algorithms, allowing companies even greater performance improvements. Experts often refer to this type of integrated solutions as AIoT. The results deriving from the use of Artificial Intelligence are in fact proportional to the goodness of the data with which the algorithms are trained. The greater the reliability of the sources, the better the training of AI algorithms will be. Hence the joint use of AI and IoT. The IoT, in fact, ensures a continuous flow of reliable data from sensors installed in the factory that can be exploited by algorithms. Through a large number of connected devices, companies can collect and transfer data effectively. Likewise, AI and Machine Learning enhance investments in Industrial IoT solutions, generating essential information for performance improvement, starting from the data collected.
The great advantage of using artificial intelligence in data analysis is the ability to generate predictive analytics, which would allow to anticipate problems or possible opportunities for improvement within the factory processes. The AI in fact allows you to make decisions taking into account those taken in the past, predicting what will happen in a given scenario and thus making possible the continuous optimization of the performance of the factory. Machines become fully "thinking".
There are many possible advantages that can be obtained from this combination of technologies: the possibility of enabling new and improved services, through better data processing; increased effectiveness of the implemented solutions, by the possibility with the AI to process large quantities of data and to predict the operating conditions of the machine suggesting the necessary changes to achieve better performance; increased efficiency of the production plant; improved risk management (particularly useful in today's changing market world). The data can be analyzed to predict possible risks and to prioritize the possible responses to mitigate them. Such solutions, in fact, foresee the problems even before they occur succeeding in preventing them completely or mitigating them as quickly as possible.

AIoT - Performance Improvement

In the start-up classification I decided to divide the AIoT solutions into two subgroups depending on the purpose for which these technologies are inserted within the companies. The first one is characterized by the use of the above technologies based on the improvement of the performance of the production process (such as quality, speed, productivity, efficiency). The second, focuses on improving the environmental sustainability of companies that adopt such solutions (through, for example, the monitoring of energy consumption), which is a theme more than ever current. There are many start-ups that aim to offer an integrated system of AI and IoT with the aim of increasing the performance of their customers. Firstly, the integrated use of these technologies enables the development of predictive analytics. All the data that are collected by the various devices installed in the factory are stored in databases and analyzed through machine learning algorithms. The result is the optimization of the production, made possible by the forecasts of the AI regarding the various scenarios of use of the machinery.
A typical example is predictive maintenance, which has already been discussed in the previous paragraphs. The algorithms are able to predict the best time to perform maintenance, preventing possible machine failures and optimizing the process.
To summarize, using AIoT helps companies be more effective in manufacturing. In fact, by being able to analyze the collected data in a correct and in-depth way, you can make better strategic decisions and, consequently, reduce costs and increase earnings.
Following, two examples of Start-ups active in the field of AIoT.

PROAXION [41]

ProAxion is a start-up, founded in 2015 whose headquarter is located in US. In 2022 he granted its last funding reaching an overall value of $2.8 million. The company offers a suite of innovative and performant products which allow the clients to prevent the unexpected failures of critical assets:

- The TACTIX sensor is used to collect data from the most critical assets of industrial companies. They are easy to install and are able to provide a complete monitoring and diagnosis insight. Thanks to its ability to alert in case of changing in machine operations and to understand the reason behind this change, companies are able to define the best strategy to adopt

- The ProAxion Gateway grant the integration between the plant floor and all the personal devices (such as pc, tablet, phone). It is capable of deliver the information in real time, with maximum accuracy and it uses the latest security protocols. With this solution it is possible to guarantee the information flow from one to fifty machineries.
- The ProAxion Cloud Software is the "brain" of the solution. The software receives the great amount of data regularly, organize them into dashboard (with key insight report). The solution is able to generate outcomes thanks to predictive maintenance solutions and it is integrated with information services, such as alerts that distribute warnings and alarm threshold. The analytics program is different for all the customers depending on their need and their machineries.

The company is therefore exploiting AI and IoT to enable predictive maintenance. The products allow to capture insight on machine health well before the failure occurs, avoiding it to affect the production. As a result, companies that adopt this solution will reach less downtime, lower maintenance costs, reduced repair complexity, fewer fire drills and longer assets-life

"ProAxion will transform the way you think about machine health, leverage predictive technologies, and optimize the performance of your industrial assets. Our mission is singularly focused on driving business outcomes. That's why we've created an integrated solution that combines best-in-class products with workflow and analytics software that enables your associates to better manage machine health"

IOTFLOWS [42]

"Our mission is to connect the unconnected to the internet
IoTFlows is a technology company that builds IoT infrastructure for the internet. Companies use our software to communicate data from their sensors, machines, and processes to the cloud"

IoTFlows is a start-up whose aim is to deliver to companies the technology necessary to create better and more performant IoT infrastructure. To do that, it helps different kind of industries in integrating their data coming from machineries, sensors, enterprise system and operational sources to the cloud. After that, the information is analyzed thanks to real-time analytics engines and the results are accessible with remote monitoring and control.
The solution developed by the company can help businesses with different functionalities:

- Stream Analytics Health Monitoring: it allows to get alerts and notification depending on the state of the critical assets. The solution (IoTFlows Stream Analytics Engines) is able to identify in real time critical health situation, enabling the users to know every moment the precise condition of the equipment.
- Encrypted Device Management: IoTFlows Encrypted Device Management, thanks to its encrypted remote access, make possible for users to access safely to all the devices from remote.
- Predictive Maintenance: thanks to the aggregation of all the data collected through sensors, devices, operational systems, and enterprise systems, users can have information about possible failures and their related impact on company's operations. The result is the possibility to develop predictions on the failure of the assets that enables the reduction of maintenance costs and the optimization of assets' usage
- AI Machine Optimization: IoTFlows AI Machine Optimization allows companies to maximize their production (and therefore their revenues), thanks to an increased productivity. Thanks to AI algorithms and the learning engines the solution delivers insight used to optimize the utilization of the machineries and the quality of production.

The typical use case of the solution developed are the following. First of all, it grants machine-to-machine connectivity by aggregating all the data coming from sensors and analyzing in an extremely accurate way the working condition of the assets, monitoring and reacting to possible change in condition; moving on, Digital twin (replicates of the physical systems) can be created, in order to have a clearer understanding of the conditions of the real system being able to make change and adjustment; moreover, it is possible to exploit the system for Remote Production Control, by monitoring various field device around the world; finally, the solution can result extremely useful for supply chain management thanks to its ability to track assets along the whole supply chain together with the possibility to control in real time different product quality (vibration, temperature…).

AIoT – Environmental Sustainability

Analyzing the offerings of AIoT start-ups, it emerges that many of them focus on selling solutions that help companies be more sustainable. Nowadays, for companies, increasing their sustainability has become necessary. In recent years, in fact, there has been a marked increase of the pressure in this regard, primarily through the UN Sustainable Development Goals (SDGs) and the ESG

(Environmental, Social, Governance) themes. These, together with the increasingly stringent demands from shareholders and consumers in a "green" vision, have made environmental sustainability issues an integral part of business strategies. Their lack could lead both to a serious damage of image for the company and to a lack of compliance with a consequent impact in the accounts. In this sense, AIoT can represent an extremely useful technology, able to help companies to ride the trend towards a more "environmentally friendly" production. Indeed, one of the points most debated by environmental sustainability-focused policies is the consumption of the industrial sector. There are now many regulations aimed at reducing greenhouse gas emissions and CO2 generated by industrial production processes. This issue is particularly relevant for those cases where large companies are involved in sectors particularly characterized by massive energy consumption. Monitoring and reducing energy consumption are therefore fundamental issues if we want to achieve more a sustainable growth. The result is that for companies a better management of their consumption is one of the possible weapons (perhaps the most impacting) to make the company more respectful of environmental issues. In addition, energy efficiency is also one of the main levers that companies have to maintain their competitiveness on the market, especially in historical moments such as the one we are going through, where many companies risk to stop production, or even fail, because of stellar and extremely volatile energy prices.

ECOPLANT [43]

"Bring machine intelligence to compressed air for a greener world"

Ecoplant offers an integrated solution, based on a cloud-based platform, whose objective is the control and monitoring of air compressor exploiting Artificial Intelligence. Indeed, the platform, thanks to IoT technology and predictive analytics, is able to control in an automatic way the air compressor system, guaranteeing the maximum energy efficiency, system reliability and off-site productivity.
The products/service offered by the company are the following:

- SaaS proactive analytics and control: the system performs an assessment of the energy usage of the plant (either on a daily, weekly, and seasonal bases), monitoring dynamically the systems via production profiles. The objective is to reduce the energy waste (up to 50% according to the company), redundancy, and excess utility costs. Indeed, the algorithms helps the users to detect and isolate possible leaks, reduce the runtime of back up and rental air compressors and optimize the efficiency of the air compressor.

Figure 41 Ecoplant offer

- Predictive maintenance platforms: thanks to the intelligent algorithms the system can identify potential breakages, respond to maintenance failures, and send the alert signal. This help company in minimizing the production outages, stabilize the pressure levels of the air compressor, meet air ISO quality standards and optimize the system exploiting the power of dynamic AI.
- Cloud-based remote platform: it granted to the users of Ecoplant solutions to develop an off-site visibility. The platform allows to respond in real time and with the maximum flexibility, thanks to immediate maintenance alerts, personalized thresholds and a simple data and analytics dashboard.
- Customized dashboard and reporting: it helps companies to track the energy consumption, system operation and analytics of machineries. Thanks to this dashboard company con develop a clear understanding of their inefficiencies and the usage of their machineries. Real-time analytics helps them to keep under control the costs and obtain energy consumption insight to finally take proactive decision aiming at long-term efficiency.

The onboarding process consists of 4 main steps. First a data collection phase is performed by locating all the necessary sensors in the real systems; then, the installation and training of the intelligent system is carried out, without causing any downtime; after that, the learning phase take place, during which the algorithm

monitor and analyze all the data collected; finally, the AI system can show its value with an AI-dynamic automation, active 24/7/365.

The results coming from the utilization of the platform are multiple:

- Zero-downtime implementation: the solution is characterized by a no-fee turnkey setup, together with a simple and fast installation and a high compatibility with most brands and technologies.
- Dynamic controls and adjustments: thanks to AI algorithms, the platform learns the system behavior and is able to adjust in real-time the use of energy with the aim to reduce wastages and therefore energy annual consumption.
- Immediate monitoring and reports: the platform give the possibility to access instantly to systems real data, analytics and maintenance alerts obtaining a higher reliability.

QUBE TECHNOLOGIES [44]

Qube Technologies is a start-up that is focusing on providing the energy sector (and in particular oil and gas facilities) with a solution for continuous monitoring, to enable them to understand their situation and start their path towards emission abatement. In fact, over the last years the theme has gained more and more importance thanks to the numerous regulations and ESG standards. To do that, the company is developing an IoT device, integrated with artificial intelligence that allows to detect and reduce greenhouse gas emissions.

"Qube combines the best of hardware and physics-guided machine learning to provide an affordable, reliable alternative for emissions monitoring".

The solution of Qube is articulated in three steps:

- Detect: the device used in this step is the Qube's Axon. It is used to monitor greenhouse gas emission and it does not require an external power source. It is constituted by environmental sensors, communication modules, gas sensors and an edge computing.
- Measure: during this phase, all the data collected by the sensors are analyzed, delivering insight such as leak location, quantity involved and classification of the type of leak. This is done thanks to the physics-guided algorithms, and it allows to understand which leak prioritize. The solution is able to monitor constantly without the request of human intervention and it send alerts once the certain conditions are detected.

- Reduce: thanks to the solution proposed it is possible to monitor in real-time emissions performances and the health level of the device from remote. There is the possibility to set personalized threshold that, once they are overcome, will trigger the alerts. Moreover, to reduce the emission, companies can link certain level of them to precise operational events, in order to be faster in the emissions reduction. The emission can be managed from a company-wide perspective thanks to the continuous flow of data coming from all the sites. This allows also to identify trend over time. The reporting system is automated, exporting all the data needed for analysis and certification in a simple and automatic way.

The solution proposed has several advantages. It works continuously, being able to detect emissions in the exact moment when they happen. It has low cost, enabling companies to up to 80% with respect to the traditional solution used. It is robust, allowing users to use it in remote locations also in extreme weather conditions. Finally, it is approved by regulators, that make Qube the first continuous monitoring technology to be approved for regulatory use.

4.1.2. Cybersecurity

Industry 4.0, with all its technologies, represents a real revolution in the manufacturing world. However, the numerous advantages in terms of automation and production synergy between stocks, supply chains and customer demands, are accompanied with an increase in the risks of computer science [27]. And despite the literature is now full of studies related to the world of cybersecurity, companies do not always focus enough on solutions of this type [27], as can be seen from the results obtained in the survey. As reported in the first chapter, the theme of cybersecurity is one of the barriers that hinder companies in the development of industrial IoT projects. In fact, there are many possible issues that companies face in terms of privacy and security. In general, within the theme of Industry 4.0, cybersecurity has a fundamental role in maintaining the competitiveness of companies. It is part of the enabling technologies (Key Enabling Technologies) of Industry 4.0 defined by MISE (as mentioned above). Being subject to cyber-attacks would make companies extremely vulnerable. Many companies have developed interconnected production and management systems, which, as a result, increasingly use connectivity between various devices and standard communication protocols. This has made the protection of critical industrial systems and production lines from cyber-attacks of paramount importance. As a result, the development of safe and reliable communication systems and advanced systems for managing identity and machine access is becoming increasingly important for companies [7]. Moreover, the use of IoT devices adds a great level of

complexity in terms of cybersecurity, due to the integration of the physical world with the computer one. In fact, the countless devices that are used to exploit the power of IoT (creating a connected and intelligent factory) make companies even more vulnerable to possible threats and violations. With the development of IoT, indeed, the concept of Cyber-Physical Systems (CPS) was born. Through it, companies can collect data via sensors and, after being processed, can be used in the cyber world. It remains however to resolve the weakness in terms of cybersecurity that could cause serious consequences for those who use IoT systems and that therefore limits the adoption of this technology.

XAGE [45]

Xage is a start-up active in the field of Cybersecurity. It offers a zero-trust real-world security solution. Their objective is to fasten how companies secure and manage digital operations across OT, IT, and the cloud, making the process simpler. The solution proposed by the company is the so called Xage Fabric.

"The Xage Fabric delivers comprehensive security for industrial and real-world operations. It protects every element, new or legacy, secures every interaction, local or remote, and enables dynamic data security for OT, IT and cloud".

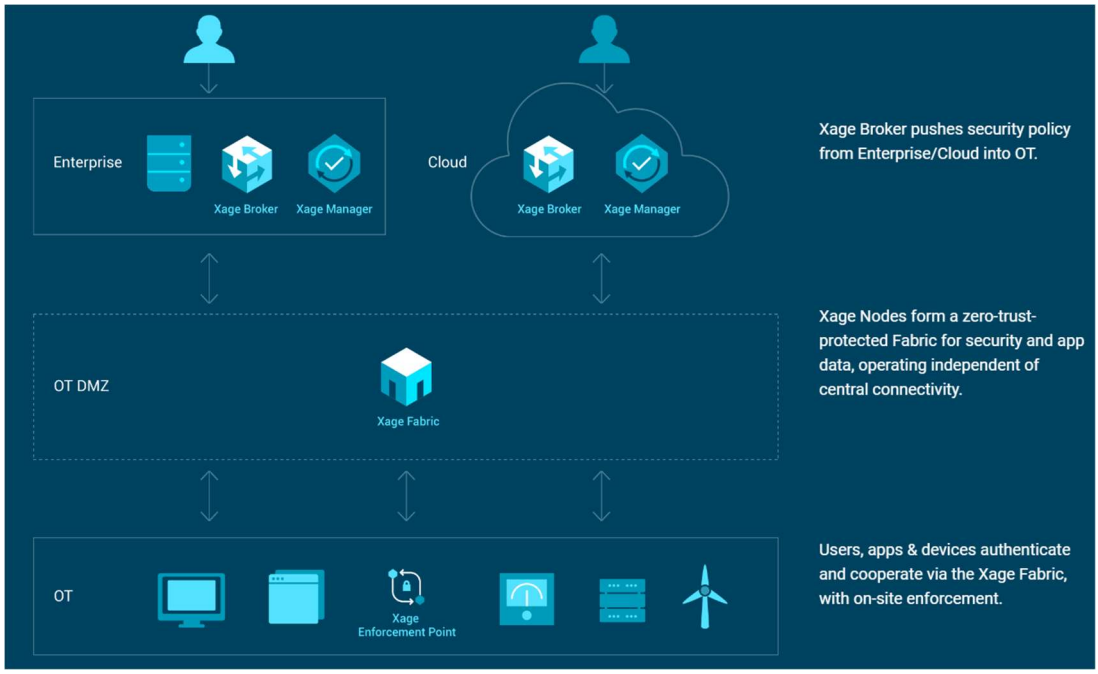

Figure 42 Xage Fabric offer

The solution proposed by the company are all based on Xage Fabric and they are:

- Identity & Access Management (IAM): it can be delivered both on the cloud or on the site. It "deliver granular application-level security and control. Operators are able to instantly create or revoke groups and policies for devices, applications, and people, enabling secure access and secure cooperation. All access attempts are tracked with a tamperproof audit-log". The policies are defined centrally and delivered on the field thanks to Fabric solution. The final result is the maximization of uptime and the avoidance of inline dependencies on remote access.
- Zero Trust Remote access: "Xage's Remote Access solution enables secure access to modern and legacy assets spanning OT, IT, data center and cloud". it consists of a "zero-trust" solution, which means that access is control in the most accurate way. The system uses identities in order to grant the authorization just to specific and limited interactions. This solution was designed specifically for OT/IoT environments.
- Dynamic Data Security: it allows clients to develop an end-to-end security across the whole data platform, "from physical machines through edge analytics to shared cloud-based data lakes". In this way, many participants (together with their applications) are able to access to the data platform and publish data safely. As a result, they can collaborate avoiding losing control or exposing themselves to potential cyber-attack.

SHIELDIOT [46]

Shield-IoT is a start-up that offer an innovative solution for cybersecurity. Their solutions allow clients to secure both the existing and the new sensors installed within the company, protecting from security threats and operational risks. The company delivers a solution to automatically detect the first possible signs of cyber-attacks, thanks to their *"coreset-AI agent-less anomaly detection Saas solution, analyzing device-to-cloud communication"*. As a result, they are able to prevent any kind of impact on IoT networks implemented by their customers.

"Shield-IoT analyzes device-to-cloud traffic statistics, mirrored from the network via the Telco/MVNO connectivity provider. Detected security events and operational anomalies are displayed on a multi-tenant dashboard and/or accessible to third party systems via API".

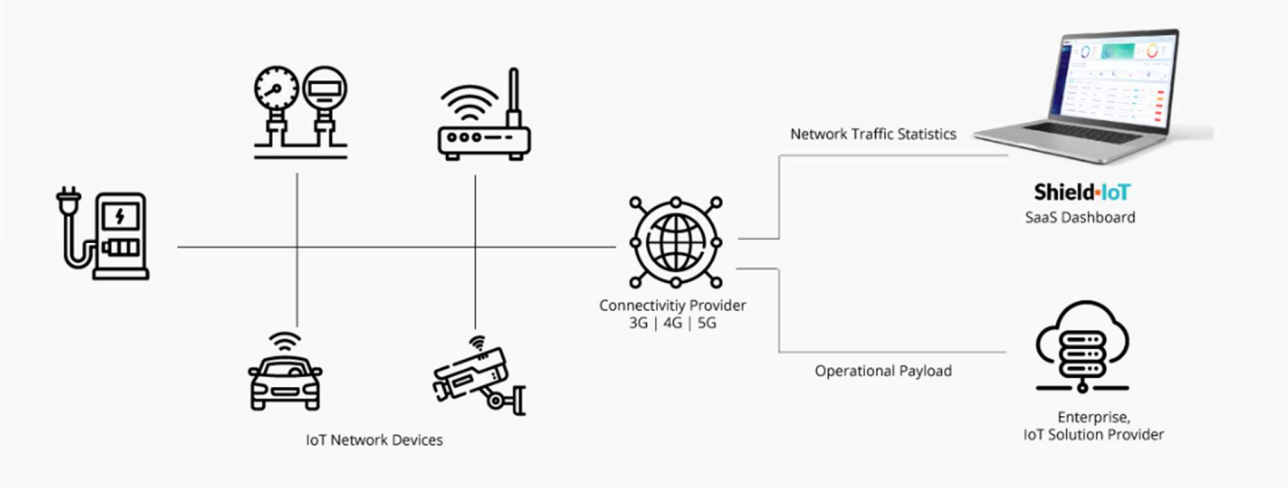

Figure 43 Shield IoT offer

The solution of Shield IoT is able to protect any IoT device, application or network, using an anomaly detection solution that is agent-less, context-free and centralized. Moreover, it is capable of mitigate the possible threat exploting its ability of event detection in real time and the possibility to send actionable alerts. Moreover, it guarantees the possibility of scaling up, being able to secure millions of connected devices. Indeed, the technology can guarantee precise analytics at a mass scale.

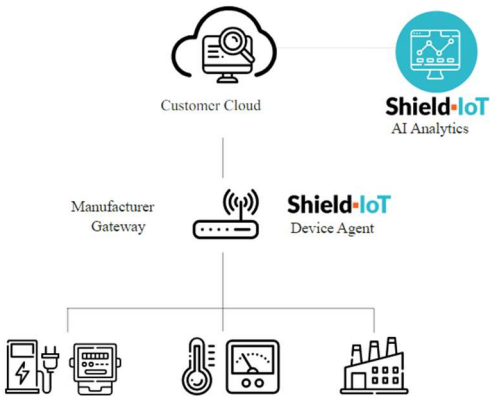

Figure 44 Shield IoT offer

In addition, the start-up proposes a solution for IoT device manufacturers, offering them the possibility to amplify their actual selling proposition, shifting from the sale of hardware and devices to the sales of solutions and software services.

The solution uses cloud-level AI to secure any mass scale industrial IoT devices from any possible cyber-attack. Thanks to AI analytics, the technology can prevent cyber threats by detecting the first signs of attacks. The functioning is articulated as follows: Shield-IoT device software agent collect data from sensors and send them to the customer cloud; from there, data are sent to Shield-IoT AI Analytics which perform the analysis (this step can be performed both in customer cloud or thanks to a SaaS service); operational and security alert are generated in real-time and they are finally shown through the dashboard and sent to the cloud of the customer.

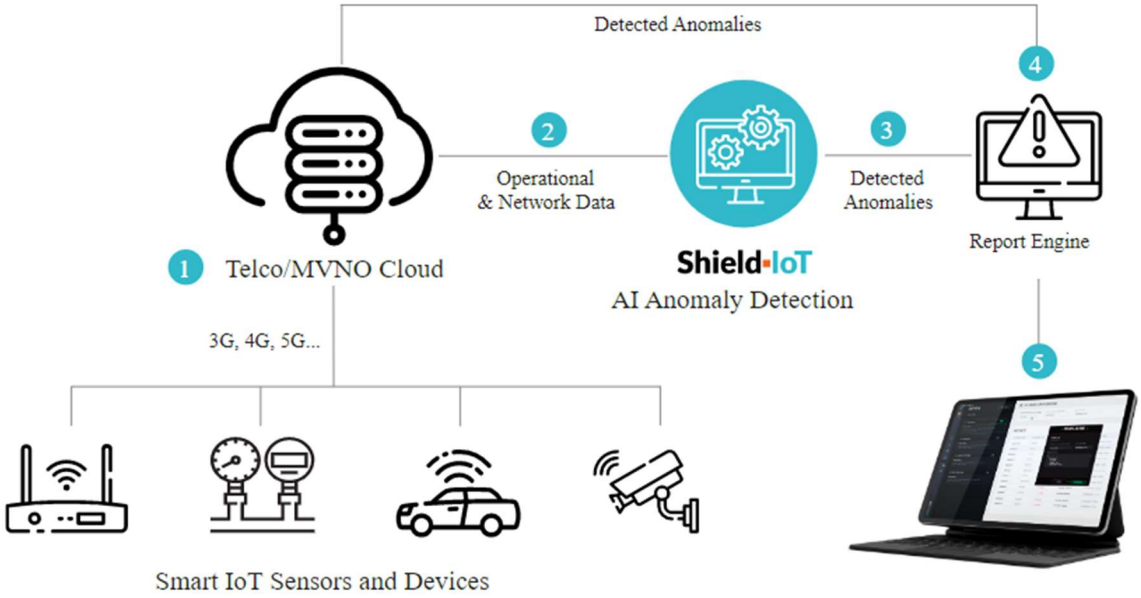

Figure 45 Shield IoT offer

Blockchain

After showing several proposals of start-ups active in the field of cybersecurity at the industrial level, I will focus on a specific technology in the field of cybersecurity, namely the Blockchain. Already in the first chapter I introduced this theme as a possible solution to the security problem related to IoT devices used, describing the intrinsic characteristics of Blockchain technology and what advantages they could bring within a Smart Factory. In fact, Blockchain is based on the concept of decentralization thanks to the presence of a distributed Ledger. In traditional centralized databases, where a central server is used to store, delete or update data from a centralized authority (which, with this approach, must have maximum trust). In addition, this would create the so-called single-point-of-failure problem, which could compromise the functionality of the entire system. In the blockchain, data is shared across multiple "nodes" that use precise software to ensure that data remains unchanged. As a result, since all information is decentralized, it is more difficult for an attack to be able to tamper with the information. In addition, a greater security of sensitive and stored data is guaranteed thanks to the use of distributed Ledgers.

STAEX [47]

Staex is a start-up that developed a software platform that *"redefines how IoT software applications are built, distributed, installed, and managed"*. Its aim is to guarantee a reliable communication for IoT infrastructure. To do that, it provides a secure peer-to-peer networking from the cloud to the edge and a secure blockchain backbone. Moreover, it grants encryption (necessary to make insecure connection safe) and it provides service discovery.
The solution can both run on the edge (being fully distributed and lightweight enough) or manage cloud and on premise servers. As a result, it has no single-point-of-failure.
The solution proposed by Staex is composed by two main components, both designed to be completely peer-to-peer. They are:

- Staex MCC (Mesh Companion Container): its function is to provide a virtual network able to connect all the different computers present in the whole system (like office desktops, field's devices, servers in the cloud). It guarantees a transparent tunneling, a secure certificate-based encryption, a reliable connectivity and a distributed service discovery.
- StaexD (Staex Daemon): its aim is to managing applications by making them run on top of the virtual network of MCC. It "selects devices to run applications on (based on the resources specification), connects applications to each other over MCC's virtual network and monitors their state". It is fully distributed and decentralized.

The results obtained with Staex solution are:

- Resilience and security: the solutions can guarantee 0% outages of IoT systems thanks to a blockchain-inspired technology and a fully distributed and fully decentralized stack.
- One day integration: it generates a 70% cost savings thanks to the simple integration between cloud, legacy systems, and IoT devices whatever the size of the vendor is
- Faster response: Staex network reduces overhead for device communication. Therefore, the level of throughput that can be reach are much higher.

BLOCK ARMOUR [48]

Block Armour is a start-up active in the world of cybersecurity. Its main objective is to exploit innovative technologies such as Blockchain to propose solutions to the cybersecurity challenges of today's world.
The company has developed the so called next-gen Zero Trust security platform and its offer is characterized by integrated cybersecurity solutions for critical enterprise system, Cloud and Integrated IoT networks.
The company develops the platform IOT Armour, with the specific aim to protect the infrastructure and the devices in the Internet of Things. The architecture of the solution is based on a Blockchain. Moreover, the platform can be delivered either on-premises, in country and in the Cloud, allowing customers to secure their IT systems while, at the same time, complying with local and industry regulations.

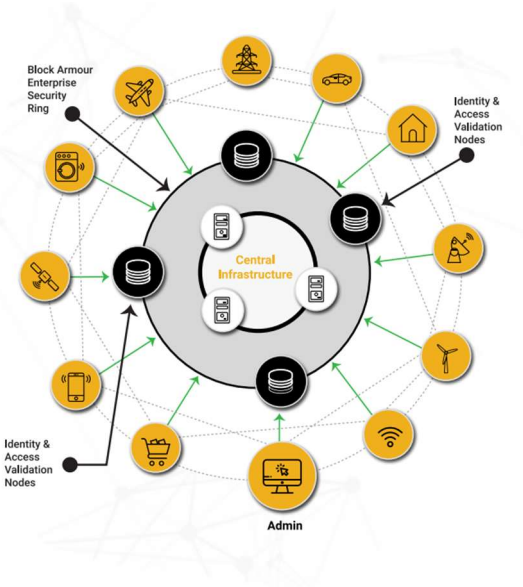

Figure 46 Block Armour offer

"The platform leverages digital signature-based identity and authentication for humans, machines and data; tightly ring-fencing critical infrastructure and securing connected devices in the Internet of Things. IOT Armour delivers an enhanced Software-Defined Perimeter using private permissioned Blockchain and TLS technology. It harnesses digital signatures to identify, authenticate and authorize devices thereby also securing IoT Communication".

The solution can guarantee:

- cryptographically secure digital identity, for users, devices and servers
- Invisible and locked down critical systems
- Best-in-class military-grade encryption, for a secure IoT communications and device access
- Immutable and tamper-proof logs, safely stored on the Blockchain

4.1.3. Metaverse & Digital Twin

To conclude the analysis of the main technological trends that are likely to characterize the innovations of the next few years, I will focus on the applications of Metaverse technology in the industrial field.

Among those mentioned, this is undoubtedly the most innovative technology but also the least mature. This is evident from the number of solutions available on the market. There are few start-ups that offer such services if compared to the number of active realities in the aforementioned trends.
The term Metaverse refers to a digital universe that users can access, through the technologies of Augmented Reality (AR) and Virtual Reality (VR) and live virtual experiences. In a recent McKinsey study, it was estimated that in 2021, venture capital and private-equity funding into the metaverse reached $13 billion and that by 2030 the Metaverse market will reach about $5 trillion. The most spread application of Metaverse nowadays were found to be the following: marketing campaign or initiatives, learning and development for employees, meetings in the metaverse, events or conferences and product design or digital Twinning. This highly innovative technology can also be used on an industrial level, even if the applications in this field, as mentioned before, are still very limited. In this case we talk about Industrial Metaverse, a particular Metaverse (applied to the world of factory and logistics) that uses the technologies of AR, VR and Internet of Things to improve the efficiency and productivity of industrial companies. The IoT has the task of collecting the large data moles needed to recreate a virtual environment that is as faithful as possible to the real, while the AR and VR allow the user to access this digital reality. If we consider the application at the industrial level, one of the key technologies on which the Metaverse is based is that of the Digital Twin, already developed in some companies. Thanks to digital twins, in fact, it is possible to duplicate any environment and process: from the simulation of complex industrial plant processes to the dynamics of warehouse goods handling. The possibility of representing any aspect of the physical object at a mechanical, geometric and electronic level, according to an approach that allows to develop experimental and predictive activities, it allows both to save on the costs of very expensive physical prototypes and to predict in advance any malfunctions and anomalies, reducing the risks and errors that could negatively affect all industrial processes.

LIVNSENSE [49]

LivNSense Technologies is an innovative start-up which has developed over the year products and services that differentiate the company from the competition for their ability to solve complex business problems and offer cost and revenues maximization drivers. Their mission is to *"enable Deep Learning and Artificial Intelligence for Industries with "Predictive Analytics and Safety 4.0"*. the objective is to give to manufacturing companies the possibility to manage their assets in the most efficient and productive way. Their offer is centered on an Industrial IoT platform with Digital Twins. The name of this specific solutions is GreenOps.

"Our state-of-the-art platform GreenOps converts continuous and discrete process industries with standard OT/Electronic systems, into a Cognitive Living Equipment, thereby significantly lowering the Cost of operations, Improving Safety and Reducing the energy consumption & carbon footprint. The platform is enabler for the "Factory of Future" by optimizing the production processes, improving quality and asset uptime with "Safety First" approach".

As a result, through the platform, companies can obtained cross-functional insight and predictive foresight by creating "live Digital Twin" and, in addition, an assessment of the economic impact of all the potential (or real) anomalies of systems. The solution offered by LivNSense is intelligent, with a combination of sensors and AI vision based technologies, intuitive, fostering collaborative ecosystem to have an impact on the value chain of manufacturing world, interactive thanks to AI based predictive insight and decision tools and immersive, thanks to the Digital twin used to have an impact on assets, process and value chain.

CEREBRUM TECHNOLOGIE [50]

Cerebrum Tech is an innovative technology start-up born in 2020, whose objective is establishing a strong ecosystem with their technological solutions, in order to become the leader of digital transformation. Indeed, the company offers an extremely wide range of solutions. Specifically, its services focus on data analytics, blockchain, AI, AR-VR, Cybersecurity, Mobile Apps, Robotics and Metaverse. Focusing on the solutions developed in the field of Metaverse (which is the most innovative one and the aspect that I am inspecting in this paragraph), the company has developed the so-called Cereverse. It consists of a Metaverse ecosystem, where different users can be in contact interacting with each other.

"Cerebrum Tech have the full capacity to construct an AR/VR metaverse from its software architecture to design elements and animations. Our unique patents allow building 3D designs by enabling the collaboration of physically distant designers in a virtual AR/VR environment."

Moreover, Cerebrum developed a solution for innovative training system for the business world called Workplace Safety Training Platform, whose aim is to deliver training inside the digital environment through realistic visuals of the highest quality. Regarding the content of the training delivered, they are created by experts being comply with alle the regulations.
Finally, the company developed CareMeet. It consists of a platform developed in the Metaverse for productivity and communication. It is constituted by an extremely realistic 3D environment, characterized by all the capabilities of

traditional communication platforms, where users can interact through avatars. They can access to different event rooms and meeting using both presentation and video screens.

4.2. Comprehensive analysis

In total, 43 start-ups were analyzed, taking into account all the clusters mentioned above.
Analyzing where the respective headquarters are located it is possible to see a predominance of USA with 15 start-ups located in that area. There is a strong presence in Israel as well, with 6 start-ups. After that, we find 11 start-ups in the APAC zone (divided between India, Taiwan and Singapore and Korea) and 10 in Europe (divided between Italy, Germany, Poland, Portugal, Switzerland, UK and France).
Analyzing instead the values of the financings and the typologies of the last rounds of investment, it can be noticed as the cluster of the cybersecurity is the most mature between those mentioned. In fact, for this category, the average of the investments obtained is $30 mln and the types of financing are series A or series B. This shows that investors have already focused on companies that offer services and products of this kind, having understood the importance that this trend will cover in the future.
Taking the Blockchain cluster into account, the average investment drops to $2.7 million with funding mostly in the seed and pre-seed stages. The same can be said for start-ups whose offer is based on AIoT, for which the average of the investments collected is $5.8 mln and, again, the most present financing phases are the seed and pre-seed.

4.3. AIoT Model

After having proposed an analysis aimed at understanding the main trends that characterize IoT technology, I decided to focus on one of them, developing a model that provides a more detailed view of its evolution: the AIoT.
From the research conducted, it emerges that this, along with cybersecurity, is the topic that is attracting the most attention in the IoT sphere, due to its great potential that has been discussed in the previous paragraphs.
Having already anticipated which are the two main macro-areas of application that have been identified, I will try to show in detail the distribution of the various

companies according to the objective they aim to achieve with their proposals. In particular, I have previously shown how AI can be exploited both to optimize company production performance and to improve the environmental sustainability of their businesses. Furthermore, start-ups will be evaluated for another strategic aspect. In fact, through the model, I intend to show which, among the selected cases, has decided to adopt the strategy of focusing on a specific industry sector, proposing solutions suitable only for environments with very specific characteristics, or the strategy of proposing a solution that guarantees the possibility of being used in very different environments and structures, ensuring an extremely varied clientele. In total, 24 start-ups were considered in the model. Part of these (16) came from the IoT trend analysis research conducted by me. Out of a total of 43 selected start-ups, 16 are those that propose AIoT solutions for Industry.
Then, to make a more truthful analysis of the situation, the IoT Start-up Database updated by the IoT Observatory was also taken into consideration. This contains start-ups that offer solutions in the world of IoT, considering all possible fields of application (Smart Factory, Smart Logistics, Smart City, Smart Agriculture, Smart Car and many others). From these, only companies operating in the Smart Factory world were selected, and after checking what their offerings were, all those proposing products/services that exploit AIoT technology were considered. A total of 8 start-ups were then selected from this database.

As mentioned, the objective of the model that will be shown in this section is to classify the start-ups considered, according to two different characteristics, which will be represented through the two Cartesian axes.
The x-axis will take into consideration the scope of the solutions proposed by the various start-ups. As previously mentioned, in fact, the integration between Internet of Things and Artificial Intelligence can lead to many benefits within the factory. In particular, two main macro-areas of application for these solutions emerged from the previous analysis: the improvement of the factory's production performance and an increase in the company's environmental sustainability. In the first case, the combination of IoT and AI is exploited to optimize the production process. The analyses enabled by AI make it possible to apply predictive logics by enabling services such as predictive maintenance and an improvement in various performances such as quality control, optimization of production scheduling, maximization of machinery utilization, increase in productivity, and increase in occupational safety. A typical example of a start-up whose offer is focused on improving customers' production performance is IoTFlows. Its offer is clearly focused on the optimization of the production of its clients. Indeed, thanks to the usage of AI algorithm and the aggregate data coming from sensors, devices, operational system and enterprise system, IoTFlows Predictive Maintenance enable

the predictions on assets failures (bringing to assets usage optimization and reduction of maintenance costs). With IoTFlows AI Machine Optimization the solution can deliver insights that will be used for the optimization of the usage of the machineries considering the scheduling, quality issues and machine utilization. Moreover, thanks to IoTFlows Stream Analytics Engines, the clients will receive alerts regarding their critical operations in real-time, allowing them to remain up-to-date with their equipment and process status.
In the second case, when the primary purpose is to increase the environmental sustainability of the various businesses, the combination of the two technologies is exploited, for example, to achieve a decrease in the carbon footprint of each company, to monitor and reduce greenhouse gases generated by production, to reduce energy consumption or to enable circular economies.
For instance, one of the companies that is placed on the left side of the x-axis is definitely Qube Technologies. Indeed, the start-up develop an Industrial IoT device integrated with Artificial Intelligence capabilities. Thanks to AI algorithms, the proposed solution is able to detect, measure and reduce greenhouse gas emissions at oil and gas facilities. The solution is characterized by physics-guided AI that infers leak quantity, location and classification.
However, there are several cases of start-ups offering solutions that pursue both objectives. In particular, the reduction of energy consumption is the link between improving production performance and increasing the environmental sustainability of production. Constant control and optimized management of the energy used can, on the one hand, guarantee an increase in production efficiency by considerably reducing production costs (especially in a historical period such as the current one where energy has become an extremely precious commodity) and, on the other hand, ensure that activities (especially those in the most energy-intensive sectors) comply with the principles of sustainable growth, characterized by a decrease in energy consumption. Consequently, we will find in the central part of the x-axis, all those companies that, among the various services they promise to fulfil, there are also those of monitoring and management of energy consumption, always exploiting the potential of IoT and AI algorithms combined. Obviously, even within this cluster of companies, there are different degrees of interest in one or the other objective: companies whose proposed services/products aim to ensure improvements both in terms of decreases in emissions and energy efficiency and improvements on production KPIs, but are focused more on one of the two aspects. A typical example of a start-up that is part of this set is EcoPlant which, thanks to the cloud-based platform developed, guarantees both an assessment of the energy usage of the plant, enabling a reduction of energy usage and energy wastes, and predictive maintenance services, able to identify potential breakages and send

alerts, allowing the company to minimize production outages and optimize the system with AI algorithm.

Below is the table where the objective of each start-up considered is listed alongside the name of each proposal.

ECOPLANT	EcoPlant	Management of energy consumption, Predictive maintenance
ulalaLAB	ulalaLAB	Quality management, Environmental management, Energy management, Facility management
QUBE	Qube Technologies	Monitoring and Management of greenhouse gas emission
Oxys	Oxys	Energy monitoring, Predictive maintenance
Acoustic Wells	Acoustic Wells	Smart and clean management of Assets, maximize oil field efficiency, reduce environmental impact.
LivNSense	LivNSense	Asset health monitoring, Predictive maintenance, Digital twin, Performances optimization
seebo Now part of AUGURY	Seebo	Prevention of production losses
Alleantia	Alleantia	Optimization of production process, Predictive maintenance
Petasense	Petasense	Process monitoring, Management of energy consumption, asset health monitoring
IoTFlows	IoTFlows	Predictive maintenance, Machine optimization (quality, scheduling, utilization)
switchon	SwitchOn	Quality of production management (zero waste)
PROAXION	ProAxion	Optimization of the performance, predictive maintenance, machine health analysis
cpnet.io smarter manufacturing	CPNet	Optimization of production line, management of quality and yelds, management of productivity rate, management of energy consumption, maintenance
Toumetis	Toumetis	Predictive maintenance, Data-driven planning, Process optimization
IRS ISHITVA ROBOTICS SYSTEMS	Ishitva Robotics Systems	Management of wastes (automatic picking, sorting and segregation of dry waste materials)
QuantWave	QuantWave	Quality management
mCloud	mCloud	Management of energy production, management of wastes
SENSORO	Sensoro	Management of energy consumption, Environmental management
ALTERIA AUTOMATION	Alteria Automation	Predictive maintenance
ALTIZON	Altizon Systems	Productivity management, Quality management, Maintenance, Management of energy consumption, Traceability, Real-time planning
KONUX	Konux	Predictive maintenance, Asset utilization optimization
SHEPHERD	Shepherd Network	Management of energy consumption management, Management of carbon emission footprint, Optimization of performances, Predictive maintenance
SIGHT MACHINE	Sight Machine	Quality management, Productivity management
VOXEL	Voxel	Workplace safety

Figure 47 AIoT start-up and main objective of their offer

In the y-axis, the characteristic that is analyzed is the specificity of the proposed solution. In fact, the objective is to understand whether start-ups are proposing solutions that are extremely focused or, on the contrary, can be applied to a broad spectrum of cases. In order to define how specific/focused a solution is, I took into consideration two factors

- the number and variety of sectors in which the solution can be used. In fact, among the start-ups included in the database, we find both cases in which the proposed solution was conceived only for a specific application and therefore applicable to a single sector, and companies that, on the contrary, have developed products/services that can be perfectly adapted to even very different contexts thanks to their great flexibility.
- the number and variety of applications included in each start-up's proposal. Once again, among the various start-ups analyzed, it is possible to find both proposals characterized by a single product/service and others that comprehend a great variety of products/services offered.

These two characteristics are almost always interconnected: start-ups that offer several different services and various products with different possible uses are often able to address a broader spectrum of business sectors. Conversely, start-ups offering only a specific product/service are likely to address a specific type of companies with certain needs and characteristics.

In the lower part of the graph, all companies offering a single solution applicable to only one specific business sector or even to only one specific type of machinery will therefore be placed. It is possible to take as an example the same company mentioned previously, which is Ecoplant. Indeed, the company offering consist of a smart air compressor control & monitoring platform. As a result, the products and services of the company just referred to air compressor system, resulting in being very focus in one specific application. As can be seen, the company's strategic choice was to focus on a very specific market. In fact, the proposed solutions were designed and developed specifically for this system. While using a strategy of this kind generates an obvious disadvantage in terms of flexibility compared to those solutions that can be applied in different sectors/systems/machineries, it also guarantees that the company has developed a solution specifically with the needs of a precise type of company in mind, a factor that may be fundamental in being able to meet the customer's requirements more accurately. On the contrary, in the upper part of the graph will be placed all those companies that can potentially attract customers belonging to very different sectors. These realities have bet both on the flexibility of their solution as a feature capable of generating a competitive advantage over other start-ups active in the field of IoT, and on the proposal of a

good variety of products/services that allow them to adapt, depending on the context, to very different types of production and types of machinery. On the other hand, as regards companies that propose a solution that is extremely adaptable to various business contexts (top of the graph), one can mention Alleantia. It offers a solution based on a platform that allows to monitor in real time all the operations of the entire production system of its clients, enabling them to reduce machine downtimes, reduce errors and quality problems and speed up the processes. maximize the efficiency and the uptime of their assets. It is applicable to a huge variety of environments.

"*Alleantia is the best plug&play solution on the market to feed applications for monitor production progresses in real time in any type of manufacturing context, from the smallest and most traditional to the largest and most innovative".*

The flexibility of the solutions proposed granted to the start-up the possibility to deliver it to an extremely variegate client base belonging to food, textile, cement, chemical, pharma, glass, steel & metal, oil & gas, plastic and metal forming, paper, bricks & ceramics, transportation and energy & utilities sector.

Focusing instead on start-ups that are somewhere between high and low specificity, it is possible to find those companies that propose solutions that require specific characteristics of the type of production of the customer that is adopting them. Consequently, this type of proposal can only address a limited number of sectors. A typical example of such a start-up is QuantWave. It created a novel sensing system that *"integrates microfluidics, high-frequency microwave and machine learning technologies to provide online monitoring and predictive data analysis".* The objective of the solution is to increase the quality of industrial manufacturing processes. However, the solution proposed, can be used only for the manufacturing processes of liquid products, by capturing a unique liquid fingerprint. As a result, the industries to which QuantWave sells its solutions belong mainly to water/wastewater, food & beverage, cosmetics and pharmaceuticals sector. *"Our product has been demonstrated to be capable of fingerprinting complex water/wastewater matrix and predict commonly used water quality parameters. It has also been verified in dairy and brewery market providing producers and processors with real-time early warnings of manufacturing abnormalities".*

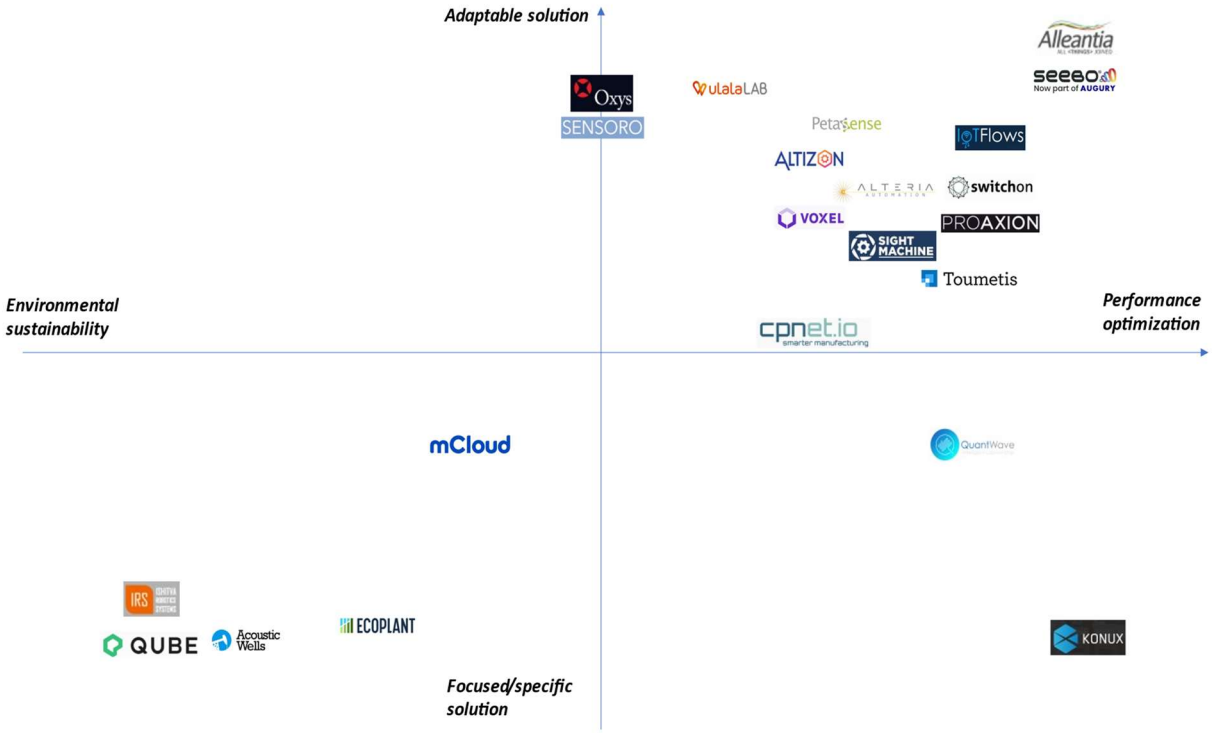

Figure 48 AIoT model, objective of the offer – specificity of solution

In spite of the fact that the environmental and energy issue, as explained above, represents a topic of extreme importance for companies, having a significant impact on their business, from the analysis conducted it emerges the predominance of the tendency of start-ups to propose solutions that focus on improving production performance, or in any case, propose solutions that have a positive impact on the environment, but in an indirect manner. The companies that propose energy monitoring solutions as part of a broader range of services/products offered, do so with the aim of impacting on the performance of the factory (increasing energy efficiency and consequently reducing related costs). Even fewer start-ups focus on proposing solutions that have a direct impact on environmental sustainability, thus having the main purpose behind their business to reduce carbon emissions, reduce greenhouse gas emissions in general, decrease energy consumption, reduce waste and enable circular economies. Shifting the focus to the specificity of the various offerings, it emerges that all the start-ups belonging to this set propose highly specific solutions, thus applicable in very specific contexts and sectors. On the contrary, the start-ups that focus on using AI in combination with IIoT to generate predictive analyses with the aim of optimizing the production performance of companies, almost always manage to create products that are extremely well suited to the most diverse sectors, such as pharmaceutical, food and beverages, automotive, oil and gas, aerospace, electronics and many others. The algorithms

used to analyze data from IoT structures are flexible with respect to so many types of machinery and assets. This undoubtedly generates an extremely important competitive advantage, being able to develop a much broader customer base in terms of variety.

To conclude the analysis of the AIoT trend, I would also propose three examples of companies that, in recent years, have exploited IoT technology combined with AI technology to enhance their businesses. I therefore propose a change of perspective, moving from analyzing the supply side, through the proposed model, to the demand side. In this case, since we are dealing with companies belonging to the demand side, rather than the supply one, they will be categorized only according to the objective they aim to achieve through the project they implemented, leaving aside the analysis of the specificity of the product used.
As mentioned, I wanted to give three examples: one concerning a project implemented with the objective of improving production performance, another dealing with a company that wanted to focus on improving the sustainability of its business, and finally a project that aims to achieve both objectives.
A perfect example of company that is pursuing the operational excellence thanks to the AI and the IoT technology is the the Siemens Electronics Works Amberg (EWA) [51]. Indeed, Siemens is promoting the digital transformation of industry, both at customer's plants and inside its own plants. The aim of the company is to exploit the latest technology in order to achieve an optimized throughput, ambitious cycle times, reliable security measures and other possible performances improvement. AI and IoT are used in many part of this plant. For instance, they were extremely important for the optimization of the production of PCBs. *"The model predicts whether or not the soldered joints on the PCB are free of faults: in other words, whether or not an end-of-line test is necessary"*. As a result, in this case, it was possible to increase the throughput of the production by eliminating the bottleneck phase.
Moreover, another important application enabled by these technologies is the predictive maintenance. The dedicated team collect data about two parameter that impact on the unscheduled downtime of the machinery considered (milling). This data were then fed into AI algorithm that enabling the operators to be informed about possible system failures from 12 to 36 hours before the potential occurrence.
On the other hand, focusing on those companies that use AI and IoT to increase the environmental sustainability of their production, it is possible to highlight Schneider Electric's [52], in particular its facility in Le Vaudreuil, France. In this plant, the company manage to use IIoT sensors and platforms in order to "optimize energy management by 25%, reduce material waste by 17% and minimize CO2 emissions by 25%, with an objective to be net-zero carbon by 2025. […] It is also equipped with a zero-reject water recycling station connected to cloud analytics and monitored by an artificial intelligence (AI) model to predict process drifts, leading

globally to 64% in water reduction". The technology exploited was Schneider Electric's EcoStruxure Building Operation. Thanks to that the company was able to consolidate data coming from all the sensors installed in the factory, analyze them in order to understand the energy consumption at a granular level, and finally propose an action plan. Moreover, the company exploited Industrial IoT sensors and AI to track the chemical composition of a products that showed some problems in the past, being able to adjust it on the fly. This allows for a significant reduction of company's environmental footprint given that the chemical processes used to produce this material, generated dangerous wastes. And thanks to this solution the company was able to both reduce the wastes generated and the energy consumption in the recycling of the water used in the process. To conclude, moving to the company that implemented an AI and IoT integrated project pursuing both the optimization of the production and the increase of environmental sustainability of its business, a possible example is HIL Limited. HIL Limited [53] is a leader company in the manufacturing of building materials and it offers also comprehensive building solutions. The company implemented a solution of Altizon, with the aim of optimize productivity and evaluate possible opportunities for cost and energy saving. One of the main issues to overcome was the lack of visibility into process data, that generate quality issues. In addition, the company was not able to understand their current level of energy consumption (and so energy costs) generated by its processes. As a result, HIL exploit the solution proposed by Altizon to reach productivity optimization, energy expenditure monitoring and quality improvement. In particular, the solution used is an IoT platform that is able to connect devices, making them exchange information in real time. Thanks to the power of AI, it is also capable of analyze the data in real time and deliver alert for the occurrence of failures. In addition, machine learning algorithm allow to generate models from the data collected and make predictive analysis. Indeed, thanks to the IIoT platform, it was possible to have real-time and accurate data coming from the connected shopfloor, that enable to the operators to take corrective actions in real time. They will also receive alerts thanks to the continuous monitoring of the most important parameters for the processes. Moreover, thanks to the platform, operator can analyze and monitor energy consumption linked to all the machineries and all the processes.

5 Conclusions

In the following chapter I will summarize all the major points that has emerged throughout the entire work of thesis. Specifically, I will answer to the questions proposed in the Research Objectives Chapter. The final results that are presented in the following paragraph focus on the understanding of the current scenario in terms of Industrial IoT development, and they come both from the deep analysis conducted with the survey submission and from the research of real cases of Industrial IoT implemented worldwide.

Thanks to the latter, it was possible to identify, firstly, a trend of considerable growth in terms of the number of projects surveyed year after year. With regard to the geographical distribution of the various projects, there is a clear predominance of Europe over the other continents in terms of projects developed. However, this figure is strongly influenced by the very large percentage of projects developed in Italy with respect to the total number of projects (around 44%). This, as explained, is due to the manner in which the search for cases to be included in the database was conducted, which often started from specialized Italian sites, that, despite dealing with the topic internationally, they focus on initiatives carried out by Italian entities.
The research also made it possible to identify the partners most often chosen by companies to implement Industrial IoT projects. The results show that Cisco, PTC and Microsoft are at the top of the list. Furthermore, analyzing the distribution of the various projects according to application field, Smart Factory is clearly the most popular option among companies, followed by Smart Logistics and finally, with a few percentage points, Smart Lifecycle.

On the other hand, focusing on the survey conducted, it was possible to collect the following results. The Industrial Internet of Things is facing a continuous development and growth over the years. Nowadays, the technology has evolved heavily and, at the same time, the solutions available in the field of Industrial IoT have grown exponentially. As a result, an increasing number of companies is finding value in making investments in this field. The spread is confirmed by the results obtained from the analysis in terms of awareness. Almost every company already knows the technology of IoT and many of them have stated to have an in-depth knowledge. Moreover, the 77% of the companies that answered to the survey has already implemented an IoT project in the past, signaling that theme of IoT and Industry 4.0 is now widespread among the Industrial sectors.

A significant role for this evolution in terms of diffusion was played by the national incentives, in particular by Piano Nazionale Transizione 4.0 and the PNRR. Italian government brought forward large amounts of investments for the digitization of the Italian Industrial scenario. From the survey analysis it was possible have an overview about the increase in investments of the companies, following the implementation of the PNRR. It emerged that the 45% of the respondents has seen their investments, in absolute terms, grow. This can be considered as a good result in terms of impact of the PNRR, if we consider also that the last years have been characterized by a strong economic and political instability, during which many companies struggle to continue their business.

There are many possible advantages resulting in exploiting IoT for the Industrial scenario. This because Industrial IoT technologies can be used by the company for a very wide range of objectives, thanks to its flexibility. It emerges that most of the time, the reason behind the adoption of IoT is the possibility to achieve benefits in terms of efficiency (such as reduction of costs and time). Moreover, this technology can bring benefits of effectiveness such as improvement of production process quality, increase in the awareness about the real performances of assets and machineries, higher environmental sustainability of the company thanks to reduction of energy consumption, or development of competitive advantage of the company with an innovative offer that differentiates itself from the market.

However, IoT is far from reaching its full potential: there are still many possible barriers that prevent from the optimal implementation of IoT projects. There are both limitations linked to the internal capabilities of the companies (first of all, the lack of knowledge regarding the theme of Industrial IoT and the lack of internal competences able to manage those projects) and others linked to the external environment and the current economic and social situation (like the current economic instability, the lack of raw materials and the increase in energy prices). In terms of implementation steps, the main difficulties are faced in the very first phases, when the company has to understand which are the potential benefits of the IoT solution proposed. Indeed, being the lack of capabilities and expertise related to the world of Industrial IoT a major obstacle of today's companies, it is difficult for them to comprehend deeply the importance of these kind of solutions and the benefits that they could achieve in terms of performances.

The evolution of IoT, applied to Industrial scenario, can be seen from the development and spread of additional services linked to IoT projects. The purchase of additional services together with the solutions IoT is a trend that is experiencing a considerable growth, which has brought to an increase of the possible services offered, as well. The majority of the respondents (64%) stated that their companies has activated an additional service. Looking at the type of services implemented, it

is possible to say that the information services, based on the delivery of real-time notification in case of predetermined event (like the stop of a machinery or a lack of gas) are the most mature ones. To monitor in the future are the maintenance services, in particular predictive maintenance services, a trend which is experiencing a strong growth over the last years and it is the one that is expected to grow the most in the following year (given that 61% of the respondents declared to be interested in the activation of this kind of service soon). Still not widespread are the pay-per-use services, which have been activated just by the 16% of the respondents.

Moreover, another significant field that research need to keep under control in order to monitor how IoT is evolving over the years is the usage of data (i.e. how companies are able to exploit the great amount of data coming from all the sensors installed in their IoT project). As explained during the thesis, the great potential of IoT technology lies on its ability to generate huge amounts of data. However, one of the main limitations of the adoption of this technology is precisely the ability to exploit all this data. Indeed, the 46% of the companies is not exploiting the potential value coming from the analysis of data and many of them has not even planned to do that in the near future. Just the 31% of the companies surveyed, is currently processing the data gathered, being able to exploit them at best. In addition, going more in depth to analyze why the companies are struggling in this way to extract value from data, it emerges that the most spread problem is the lack of competences and the lack of specific figures inside the companies responsible for data enhancement, followed by the inability of the companies to understand the real value that they could extract from the data.

Finally, analyzing the trends related to IoT technology, which are developing during the last years and which will characterize the near future, it was possible to highlight several technology clusters, identified following the search for innovative start-up active in the world of IoT. One of the strongest trends is surely the one of AIoT, that consists of the integration of artificial intelligence with IoT technology. Leveraging the power of machine learning algorithms enables companies to extract maximum value from their IoT projects. In fact, through AI significantly increases the quality of analysis available to decision makers, who are therefore able to make better and better decisions, optimizing different business performance. From the analysis it is also possible to identify a strong push, by the new emerging businesses in the IoT world, towards the issue of cybersecurity. Having pointed out at the beginning of the work, how this represent one of the main weaknesses of IoT technology applied in the industrial field, this trend is particularly important in order to allow this technology to reach ever greater levels of diffusion. Finally, it has been taken into account a technology still very little present in

manufacturing companies, namely the Metaverse, a digital universe to which users can access, through the technologies of Augmented Reality (AR) and Virtual Reality (VR) and live virtual experiences. At the industrial level it is still very premature to think about a massive diffusion of this technology, both for the need to create standards for this extremely innovative technology and for the need to adopt VR devices within the factory, that will require time to reach high levels of diffusion. However, the technology of Metaverse lays the foundation on another technology that is developing very quickly and that is already present in some of the most technologically advanced companies: the Digital Twin, a virtual copy of a real system (from the single machinery up to the entire business production process), which uses artificial intelligence algorithms to determine the optimal management of the system considered and then apply it to the real one. Moreover, thanks to the model developed in order to deepen the trend of AIoT, it was possible to highlight some points. Although the topic of environmental sustainability is gaining increasing attention, it is still less present among the offerings of the various IoT start-ups than the topic of improving production performance (such as, for example, productivity and production quality). The two objectives, however, are often united by the presence of energy monitoring and energy management solutions within companies' offerings. These, by enabling the increase in efficiency of company's energy consumption, make it possible both to improve the environmental sustainability of production (by reducing emissions and energy consumption) and to drastically reduce production costs, making it more efficient.
In addition, the model showed that those solutions whose business model is based on improving the sustainability of their customers' business tend to be highly specific. In fact, these types of solutions are generally applicable in specific contexts (to a specific sector or even to a specific machine). This is not the case for solutions that focus on production performance, which are almost always applicable to very different manufacturing contexts.

To conclude, analyzing the application scenario of IoT technology, if, on the one hand, the technological trends allow a continuous development of the IoT (in terms of performance, safety, efficiency, costs), the main barriers encountered by companies with the implementation of this kind of projects are not due to technological or performance problems (companies that implements IoT projects remains satisfied, as can be seen from the results of the survey). On the contrary, they are mainly recorded in the implementation phase of the project as well as in the pre-implementation phase when the possible benefits are assessed. Consequently, the problems to be solved to guarantee a massive spread of the technology (both among large enterprises and SMEs) are mainly within the company (for example, due to lack of experts, lack of knowledge of potential

benefits) and not in the technology itself. In this sense, the PNRR can be a very important ally to broaden the knowledge of the power of IoT, spreading it massively not only in large multinational companies, which are already focusing on the digitization of processes since many years being well aware of the potential results obtainable and inserting IoT experts in their organic, but also in the smaller and local realities that were not yet aware of the topic or that had not yet developed a thorough knowledge of how to successfully implement IIoT projects in their company. In fact, with the possibility of securing important funding, many companies are encouraged to open up to the digitalization of their companies.

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A Appendix

A.1. IoT Survey

"OSSERVATORIO INTERNET OFTHINGS" INDUSTRIA 4.0

SCHOOL OF MANAGEMENT DEL POLITECNICO DI MILANO

INDAGINE SUI PROGETTI INTERNET OF THINGS PER L'INDUSTRIA 4.0

Obiettivo dell'indagine: **approfondire lo stato di diffusione in Italia dei progetti Internet of Things (IoT) per l'Industria 4.0**.

L'espressione *Industria 4.0* esprime una visione secondo cui, grazie alle tecnologie digitali, le imprese industriali e manifatturiere aumentano la propria competitività ed efficienza tramite l'interconnessione e la cooperazione delle proprie risorse (impianti, persone, informazioni), sia interne alla fabbrica sia distribuite lungo la supply chain.

Il paradigma IoT sta acquisendo sempre più chiaramente il ruolo di tecnologia abilitante dell'Industria 4.0, grazie ai suoi numerosi impieghi per ottimizzare l'uso delle risorse e potenziare i servizi offerti.

Guida alla compilazione del questionario: **La compilazione la impegnerà non più di 10 minuti. Non sono necessarie competenze tecnologiche specifiche.**

Se desidera interrompere momentaneamente la compilazione, al termine di ogni pagina potrà salvare le sue risposte cliccando su "Salva". Le sue risposte saranno conservate e le verrà inviata un'email con il link per ritornare al questionario e terminarlo.

Eventuali chiarimenti in merito alla compilazione del questionario possono essere richiesti a Roberta Vadruccio (roberta.vadruccio@polimi.it – 3339020813). Qualora preferisse è possibile rispondere alle domande del questionario tramite intervista telefonica.

Per visualizzare l'informativa privacy è possibile cliccare qui.

Questionario

1) La preghiamo di inserire i suoi dati anagrafici:

Nome azienda	
Nome e Cognome	
Ruolo professionale	
Dimensione azienda	☐ <250 dipendenti ☐ ≥250 dipendenti
Fatturato	☐ Fatturato <50 mln € ☐ Fatturato ≥50 mln €
e-mail	
Contatto telefonico	

1) L'Osservatorio Internet of Things si pone come obiettivo, tra gli altri, quello di facilitare l'adozione di soluzioni per l'Industria 4.0, mettendo in contatto le aziende e organizzando incontri one-to-one tra aziende che lo richiedono e che manifestano specifiche esigenze. Sarebbe interessato a partecipare a questi incontri e ai momenti di networking sul tema Industrial IoT che l'Osservatorio organizzerà nei prossimi mesi?

☐ Si

☐ No

☐ Altro (specificare nelle note)

Note:

2) Quali conseguenze ha generato l'attuale instabilità economico-politica all'interno della sua azienda?

Selezionare una o più alternative

- ☐ Non ha generato alcuna conseguenza
- ☐ Carenza e rincaro materie prime
- ☐ Carenza e rincaro semiconduttori
- ☐ Rincaro energia
- ☐ Interruzione del rapporto con alcuni fornitori/clienti
- ☐ Altro (specificare nelle note)

Note:

Chi ha selezionato l'opzione "Carenza e rincaro semiconduttori"

2.a) Quali conseguenze ha generato la carenza di semiconduttori nella sua azienda?

Selezionare una o più alternative

- ☐ Ritardo nella produzione
- ☐ Revisione delle logiche di acquisto
- ☐ Aumento dei costi di acquisto
- ☐ Accumulo di scorte per fronteggiare l'emergenza
- ☐ Revisione delle strategie di business dell'azienda
- ☐ Ritardo nello sviluppo di alcuni prodotti
- ☐ Sviluppo di nuovi modelli di resilienza
- ☐ Altro (specificare nelle note)

Note:

3) Alla luce degli interventi previsti dal Piano Nazionale di Ripresa e Resilienza (PNRR), a quale/i delle seguenti Missioni punterà la sua azienda per accedere ai finanziamenti?

Selezionare una o più alternative

☐ Digitalizzazione, Innovazione, Competitività e Turismo (Missione 1 PNRR)
☐ Rivoluzione Verde e Transizione Ecologica (Missione 2 PNRR)
☐ Infrastrutture per una Mobilità Sostenibile (Missione 3 PNRR)
☐ Istruzione e Ricerca (Missione 4 PNRR)
☐ Inclusione e Coesione, tra cui rigenerazione urbana (Missione 5 PNRR)
☐ Salute (Missione 6 PNRR)
☐ Nessuna delle precedenti, non abbiamo intenzione di sfruttare gli incentivi del Piano
☐ Non lo so

Note:

4) Ha sentito già parlare di soluzioni Internet of Things (IoT) per l'Industria 4.0?

Esempio: utilizzo di tecnologie (es. RFId) in grado di tracciare i prodotti o i semi-lavorati presenti in fabbrica per ottimizzare la gestione della produzione, fornire un maggior supporto agli operatori di linea e ridurre gli errori.

Esempio: utilizzo di macchinari connessi tramite tecnologia cablata o wireless, in grado di segnalare quando sta per verificarsi un guasto e minimizzare i fermi-macchina.

Esempio: utilizzo di sensoristica e tecnologia RFId per monitorare posizione e temperatura dei prodotti (catena del freddo) lungo la supply chain.

Esempio: presenza nella fabbrica di dispositivi connessi per la gestione dei sistemi di riscaldamento, climatizzazione e illuminazione (es. sensori che attivano lo spegnimento/accensione di luci nelle stanze a seconda dell'occupazione).

Selezionare una sola risposta

☐ Sì, ho un elevato livello di conoscenza

☐ Sì, ho un discreto livello di conoscenza

☐ Sì, ma ho un livello di conoscenza superficiale

☐ No, non conosco il tema

Note:

5) Quanto è rilevante il tema l'Industria 4.0 per la sua azienda?

Selezionare una sola risposta

☐ Molto rilevante

☐ Abbastanza rilevante

☐ Poco rilevante

☐ Per nulla rilevante

Note:

6) La sua azienda ha avviato progetti IoT per l'Industria 4.0 in passato, a supporto delle attività logistiche o di fabbrica?

Selezionare una o più alternative

☐ SI, nel 2022

☐ SI, nel 2021

☐ SI, nel 2020

☐ SI, prima del 2020

☐ NO, non abbiamo mai avviato progetti di questo tipo

Note:

SEZIONE DEDICATA A CHI HA AVVIATO PROGETTI IoT PER L'INDUSTRIA 4.0

A CHI HA DICHIARATO DI AVER AVVIATO ALMENO UN PROGETTO NELLA DOMANDA 6)

7) La preghiamo di indicare, per ciascun progetto IoT per l'Industria 4.0 avviato dalla sua azienda, lo stato di avanzamento (analisi preliminare, progetto pilota, progetto esecutivo).

Se possibile, le chiediamo di indicare nel campo Note la tipologia di device utilizzati per la realizzazione dei progetti Industria 4.0 che avete avviato (es. telecamere video con componente edge, sensori audio, tag RFId, …)

Selezionare una o più alternative

SMART FACTORY	STATO DI AVANZAMENTO			
	Nessuna iniziativa	Analisi preliminare	Progetto pilota	Progetto esecutivo
Manutenzione preventiva (monitoraggio di uno o più parametri – es. il numero di pezzi realizzati, le ore di funzionamento della macchina - per programmare quando effettuare gli interventi di manutenzione)	☐	☐	☐	☐
Manutenzione predittiva (monitoraggio di uno o più parametri – es. la rumorosità della macchina - per stimare il tempo residuo prima che si verifichi un guasto)	☐	☐	☐	☐
Controllo qualità (monitoraggio della qualità della lavorazione effettuata, supporto agli operatori per ridurre gli errori, etc.)	☐	☐	☐	☐

Material handling (monitoraggio dei prodotti durante gli spostamenti interni alla fabbrica, monitoraggio e gestione dei mezzi di movimentazione, etc.)	☐	☐	☐	☐
Ottimizzazione della produzione (migliore preparazione del macchinario o della linea, supporto agli operatori e ottimizzazione della postazione operativa, migliore schedulazione della produzione, etc.)	☐	☐	☐	☐
Sicurezza sul lavoro (monitoraggio della posizione e degli spostamenti degli operatori all'interno della fabbrica, identificazione di condizioni ambientali di pericolo, etc.)	☐	☐	☐	☐
Energy management (monitoraggio dei consumi energetici dei macchinari, della linea, dell'impianto, etc.)	☐	☐	☐	☐
Altro (specificare nelle note)	☐	☐	☐	☐

SMART LOGISTICS & SUPPLY CHAIN	STATO DI AVANZAMENTO			
	Nessuna iniziativa	Analisi preliminare	Progetto pilota	Progetto esecutivo
Tracciabilità beni lungo la supply chain (es. sistemi RFId per la tracciabilità lungo la filiera)	☐	☐	☐	☐
Monitoraggio parametri lungo la supply chain (es. sensori che consentono ai vari attori della catena del freddo di monitorare la catena del freddo)	☐	☐	☐	☐
Gestione asset logistici (es. sistemi RFId per gestione di pallet e roll container)	☐	☐	☐	☐

Logistica distributiva (ad es. tracciabilità dei prodotti finiti in magazzino, gestione dei mezzi di movimentazione, etc.)	☐	☐	☐	☐
Gestione flotte (es. box assicurativi, tracking e monitoraggio veicoli per il trasporto merci)	☐	☐	☐	☐
Altro (specificare)	☐	☐	☐	☐

SMART LIFECYCLE		**STATO DI AVANZAMENTO**		
	Nessuna iniziativa	**Analisi preliminare**	**Progetto pilota**	**Progetto esecutivo**
Ottimizzazione del processo di **sviluppo e prodotti** (es. raccolta dati provenienti da versioni precedenti dei prodotti connessi per definire sviluppi dei prodotti esistenti o nuovi prodotti)	☐	☐	☐	☐
Gestione del **"fine vita" dei prodotti** (es. monitoraggio dei parametri per comprendere quando effettuare il ritiro del prodotto, per attivare servizi di post-vendita)	☐	☐	☐	☐
Altro (specificare nelle note)	☐	☐	☐	☐

Note:

8) In valore assoluto, come sono variati gli investimenti in progetti IoT per l'Industria 4.0 in seguito all'attuazione del Piano Transizione 4.0/PNRR?

Selezionare una sola risposta

☐ Non c'è stata nessuna variazione

☐ Sono leggermente aumentati, con percentuale compresa tra il +5% e il +10%

☐ Sono aumentati di percentuale compresa tra il +10% e il +30%

☐ Sono notevolmente aumentati, di una percentuale superiore al +30%

☐ Altro (specificare nelle note)

Note:

9) Le applicazioni IoT per l'Industria 4.0 che avete avviato, indicate nella domanda precedente, hanno previsto l'acquisto di servizi aggiuntivi da parte della sua azienda?

Selezionare una o più alternative

☐ NO, non è stato attivato alcun servizio

☐ SI, servizi di tipo **informativo**, basati sull'invio di notifiche in tempo reale in caso di eventi predefiniti (es. fermo della linea, valori anomali di temperatura dei prodotti durante il trasporto, fughe di gas)

☐ SI, servizi che prevedono il pagamento degli oggetti connessi (es. macchinari, asset logistici) non al momento dell'acquisto ma durante il loro ciclo di vita, sulla base dell'effettivo utilizzo (**pay-per-use/machine-to-machine payment**)

☐ SI, servizi di **manutenzione preventiva** (definizione anticipata dei momenti in cui effettuare la manutenzione di asset e/o macchinari)

☐ SI, servizi di **manutenzione predittiva** (ottimizzazione della scelta del momento in cui effettuare la manutenzione sulla base del reale utilizzo del macchinario o del mezzo di trasporto)

☐ SI, **coperture assicurative** degli oggetti connessi basate sul loro effettivo utilizzo

☐ SI, servizi di **energy management** che prevedono la ricezione di report/alert con l'analisi dell'andamento dei consumi energetici e consigli personalizzati su come risparmiare

☐ Altro (specificare nelle note)

☐ Non so

Note:

Se si nella 9

10) Da chi comprate questo tipo di servizi?

Selezionare una o più alternative

☐ Il produttore di parti di impianto (e.g. produttore del motore elettrico dell'impianto)

☐ Il produttore del macchinario/impianto

☐ Il produttore di sistemi produttivi complessi che integrano diversi impianti

☐ Grandi società di consulenza attive nella system integration

☐ Piccole società di consulenza (boutique) attive nel mondo dell'Industrial IoT

☐ Altro (specificare nelle note)

Note:

11) Quali sono i fattori che vi scoraggiano maggiormente ad adottare questo tipo di servizi?

Selezionare al massimo 2 alternative

☐ Nessun fattore, sono soddisfatto dell'adozione di questo tipo di servizi

☐ Vogliamo avere il controllo assoluto del macchinario e non ci interessano i servizi associati

☐ Non vogliamo concedere i dati del nostro macchinario al produttore o a terzi

☐ La funzione acquisti predilige l'acquisto di asset tramite investimenti

☐ È un tema contabile secondo cui, al momento, è meglio sostenere investimenti (CAPEX) piuttosto che costi operativi ricorrenti (OPEX)

☐ È un tema finanziario: è più difficile giustificare un "investimento in un servizio" piuttosto che in un "macchinario da acquistare su cui si ha pieno possesso"

☐ Altro (specificare nelle note)

Note:

12) Quali sono stati i principali obiettivi che hanno portato l'azienda ad avviare progetti IoT per l'Industria 4.0?

Selezionare una o più alternative (al massimo 3 risposte)

OBIETTIVI	MAX 3 RISPOSTE
Miglioramento dell'**immagine** dell'azienda	☐
Raggiungimento dei **benefici di efficienza** (es. riduzione dei costi e/o tempi)	☐
Raggiungimento dei **benefici di efficacia** (es. miglioramento qualità dei processi produttivi)	☐
Accesso agli **incentivi statali** (es. Piano Transizione 4.0/PNRR, Fondo Complementare)	☐
Guadagnare o mantenere un **vantaggio competitivo** rispetto al resto del mercato	☐

Adeguamento rispetto a vincoli di **legge** e/o obblighi normativi	☐
Necessità di allineamento rispetto all'**offerta della concorrenza**	☐
Possibilità di **sfruttare i dati** resi disponibili dagli oggetti connessi (es. reale utilizzo dei macchinari, aree con maggiori inefficienze, etc.)	☐
Possibilità di abilitare **servizi di valore** (es. manutenzione predittiva, energy management)	☐
Volontà di **sperimentare soluzioni innovative**	☐
Adeguamento rispetto a **vincoli contrattuali** e di processo rispetto alle esigenze di **committenti e business partner**	☐
Miglioramento della **sostenibilità ambientale** (es. riduzione CO_2, efficienza energetica)	☐
Adeguamento all'**emergenza Covid-19** (es. distanziamento tra i lavoratori)	☐
Altro (specificare)	☐

Note:

13) Quale figura aziendale è stata determinante fin dall'inizio per l'avvio dei progetti indicati?

Selezionare una o più alternative (al massimo 3 risposte)

☐ CEO – Amministratore Delegato

☐ CIO / responsabile sistemi IT

☐ Responsabile R&D

☐ Responsabile Operations

☐ Responsabile fabbrica

☐ Responsabile supply chain

☐ Responsabile HR

☐ Responsabile marketing

☐ Responsabile vendite

☐ Responsabile finance / amministrazione / controllo di gestione

☐ Innovation Manager

☐ Fornitore / consulente esterno

☐ Non so

☐ Altro (specificare)

Note:

14) Avete utilizzato (ed eventualmente rielaborato) i dati che avete raccolto tramite i progetti IoT per l'Industria 4.0?

Selezionare una sola risposta

☐ I dati raccolti non sono stati utilizzati dall'azienda e difficilmente saranno sfruttati in futuro

☐ I dati raccolti non sono attualmente utilizzati, ma è in programma un loro utilizzo in futuro

☐ I dati raccolti sono stati poco utilizzati dall'azienda

☐ I dati raccolti sono stati ampiamente utilizzati in forma grezza (senza rielaborazioni) dall'azienda

☐ I dati raccolti sono stati ampiamente utilizzati e rielaborati

☐ Non so

Note:

Se risposta 1,2,3 a domanda 14

14.a) Quali sono i motivi per cui i dati raccolti tramite i progetti IoT non vengono valorizzati?

Selezionare una o più alternative (al massimo 3 risposte)

☐ Mancanza di competenza e di figure specifiche per la loro valorizzazione
☐ Mancanza di strumenti IT adeguati per gestire correttamente i dati
☐ Mancanza di comprensione del reale valore dei dati
☐ Mancanza di applicazioni / casi d'uso su cui testarne l'utilizzo
☐ I dati non sono raccolti in modo adeguato (ad esempio non sono precisi e/o affidabili)
☐ I dati sono raccolti correttamente ma non sono condivisi all'interno dell'azienda
☐ Altro (specificare nelle note)
☐ Non so

Note:

Se risposta 4,5,6 a domanda 14

14.b) Per la gestione dei dati raccolti tramite progetti IoT, la sua azienda utilizza una piattaforma IoT?

Selezionare una sola risposta

☐ Sì, una piattaforma sviluppata internamente all'azienda
☐ Sì, una piattaforma sviluppata da terze parti
☐ No, non viene utilizzata alcuna piattaforma IoT
☐ Non lo so
☐ Altro (specificare nelle note)

Note:

15) I progetti avviati sono basati su tecnologie IoT cablate (wired) e/o senza fili (wireless)?

Se possibile, le chiediamo di indicare nel campo Note le tecnologie di comunicazione utilizzate nei progetti Industria 4.0 che avete avviato (es. rete cellulare, WiFi, Bluetooth, Near Field Communication - NFC, Reti Low Power Wide Area, Wireless Sensor Network).

Selezionare una sola risposta

☐ Cablate (wired)

☐ Senza fili (wireless)

☐ Entrambe

☐ Non so

Note:

16) Come valuta complessivamente i progetti IoT per l'Industria 4.0 realizzati dalla sua azienda?

Selezionare una sola risposta

☐ Molto negativamente, perché i progetti hanno presentato criticità e non hanno generato alcun beneficio

☐ Negativamente, perché le criticità sono state maggiori dei benefici

☐ Positivamente, ma i benefici generati da questi progetti sono stati contenuti

☐ Molto positivamente, i progetti hanno avuto un gran successo generando numerosi benefici all'azienda

☐ I progetti IoT non hanno avuto alcun tipo di impatto all'interno dell'azienda

Note:

Proseguire con la domanda 17 del questionario

SEZIONE DEDICATA A TUTTI

17) Quali sono le barriere (interne ed esterne) che secondo lei rallentano o impediscono l'avvio di progetti IoT per l'Industria 4.0 nella sua azienda?

Selezionare una o più alternative (al massimo 3 risposte)

BARRIERE	MAX 3 RISPOSTE
Non vi sono barriere	☐
Scarsa **conoscenza** delle tematiche relative all'Industrial IoT e/o mancanza di **competenze** interne in grado di gestire tali progetti	☐
Scarsa disponibilità di **risorse economiche**	☐
Assenza di un **servizio/prodotto finanziario ad hoc** fornito dalle banche che supporti l'azienda nel percorso di digitalizzazione	☐
Perdurare dell'**incertezza legata all'emergenza** sanitaria	☐
Problematiche legate all'**instabilità** del **contesto economico** (es. carenza materie prime, elevato costo energia)	☐
Difficoltà nell'accesso agli **incentivi statali** (es. Piano Nazionale Transizione 4.0/PNRR, Fondo Complementare)	☐
Resistenze interne (es. conflitti tra IT e OT - Operation Technology, resistenze da parte dei sindacati)	☐
Carenza di semiconduttori sul mercato	☐
Mancanza di **comprensione** del reale **valore** delle soluzioni che si intendono implementare	☐
Mancanza di **coordinamento** tra le varie strutture aziendali	☐
Mancanza di **fornitori** adeguati per realizzare il progetto	☐
Mancanza di prodotti adeguati / tecnologie **non ancora mature**	☐
Difficoltà di **integrazione** di nuovi e vecchi hardware e software	☐
Problematiche legate alle **privacy** e alla **cybersecurity** (es. dipendenti restii al monitoraggio delle proprie attività, eccessiva vulnerabilità dei dati scambiati)	☐
Altro (specificare)	☐

Note:

18) Quali fasi di un progetto Industrial IoT risultano più critiche o ne impediscono la realizzazione?

Selezionare al massimo 2 alternative

☐ Non ho mai considerato l'avvio di un progetto

☐ Identificazione delle potenzialità

☐ Definizione del piano di progetto, delle attività da eseguire e dell'organizzazione delle risorse coinvolte

☐ Attività analitica per la raccolta dei requisiti, identificazione delle specifiche, mappatura dei processi, raccolta di requisiti tecnico-funzionali

☐ Sviluppo e sperimentazione di soluzioni pilota, prototipi / proof of concept

☐ Supporto all'attività di implementazione e attività di Project management

☐ Riprogettazione dei ruoli e delle mansioni nell'organizzazione produttiva

☐ Manutenzione della soluzione implementata

☐ Altro (specificare nelle note)

Note:

19) L'azienda di cui fa parte ha in programma di avviare progetti IoT per l'Industria 4.0 in futuro?

Nel caso si intendano avviare progetti, specificare gli ambiti applicativi di interesse.

Selezionare una o più alternative

☐ Non abbiamo in programma l'avvio di progetti in futuro

☐ Sì, in ambito Smart Factory

☐ Sì, in ambito Smart Logistics & Supply Chain

☐ Sì, in ambito Smart Lifecycle

☐ Altro (specificare nelle note)

Note:

20) L'azienda di cui fa parte è interessata ad acquistare servizi aggiuntivi abilitati dalle tecnologie Internet of Things? Se sì, quali?

Selezionare una o più alternative (al massimo 3 risposte)

☐ NO, non è interessata

☐ SI, servizi di tipo **informativo**, basati sull'invio di notifiche in tempo reale in caso di eventi predefiniti (es. fermo della linea, valori anomali di temperatura dei prodotti durante il trasporto, fughe di gas)

☐ SI, servizi che prevedono il pagamento degli oggetti connessi (es. macchinari, asset logistici) non al momento dell'acquisto ma durante il loro ciclo di vita, sulla base dell'effettivo utilizzo (**pay-per-use/machine-to-machine payment**)

☐ SI, servizi di **manutenzione preventiva** (definizione anticipata dei momenti in cui effettuare la manutenzione di asset e/o macchinari)

☐ SI, servizi di **manutenzione predittiva** (ottimizzazione della scelta del momento in cui effettuare la manutenzione sulla base del reale utilizzo del macchinario o del mezzo di trasporto)

☐ SI, **coperture assicurative** degli oggetti connessi basate sul loro effettivo utilizzo

☐ SI, servizi di **energy management** che prevedono la ricezione di report/alert con l'analisi dell'andamento dei consumi energetici e consigli personalizzati su come risparmiare

☐ Altro (specificare nelle note)

☐ Non so

Note:

21) Nella sua azienda quali potrebbero essere in futuro i principali obiettivi alla base dell'avvio di eventuali progetti IoT per l'Industria 4.0?

Selezionare una o più alternative (al massimo 3 risposte)

OBIETTIVI	MAX 3 RISPOSTE
Non abbiamo in programma l'avvio di tali progetti in futuro	☐
Miglioramento dell'**immagine** dell'azienda	☐
Raggiungimento dei **benefici di efficienza** (es. riduzione dei costi e/o tempi)	☐
Raggiungimento dei **benefici di efficacia** (es. miglioramento qualità dei processi produttivi)	☐
Accesso agli **incentivi statali** (es. Piano Nazionale Transizione 4.0/PNRR, Fondo Complementare)	☐
Adeguamento rispetto a vincoli di **legge** e/o obblighi normativi	☐
Guadagnare o mantenere un **vantaggio competitivo** rispetto al resto del mercato	☐
Necessità di allineamento rispetto all'**offerta della concorrenza**	☐
Possibilità di **sfruttare i dati** resi disponibili dagli oggetti connessi (es. reale utilizzo dei macchinari, aree con maggiori inefficienze, etc.)	☐
Possibilità di abilitare **servizi di valore** (es. manutenzione predittiva, energy management)	☐
Volontà di **sperimentare soluzioni innovative**	☐
Adeguamento rispetto a **vincoli contrattuali** e di processo rispetto alle esigenze di **committenti e business partner**	☐

Miglioramento della **sostenibilità ambientale** (es. riduzione CO_2, efficienza energetica)	☐
Adeguamento all'**emergenza Covid-19** (es. distanziamento tra i lavoratori)	☐
Altro (specificare)	☐
Non so	☐

Note:

22) Crede che la sua azienda abbia valutato le giuste misure da implementare in tema di cybersecurity nei propri sistemi IT?

Selezionare una sola risposta

☐ Sì, è un tema rilevante e abbiamo fatto tutte le valutazioni necessarie
☐ Sì, è un tema rilevante ma dobbiamo ancora fare/sono ancora in corso le valutazioni necessarie
☐ No, è un tema rilevante ma non abbiamo ancora fatto le valutazioni necessarie
☐ No, non è un tema rilevante e non faremo nessuna valutazione al riguardo
☐ Non lo so

Note:

23) La sua azienda sarebbe propensa a collaborare con altri attori con il fine di creare un ecosistema di partner per realizzare progetti IoT integrati?

Selezionare una sola risposta

☐ Sì

☐ No

☐ Non lo so

Note:

Se risposta "si" alla domanda 23

24) Con quali attori vorrebbe collaborare?

Selezionare una o più alternative

☐ Utility

☐ Operatori Telco

☐ Tower company / operatori di rete
☐ Aziende private che offrono servizi di sicurezza
☐ Produttori di macchinari
☐ Produttori di hardware / software
☐ System Integrator
☐ Banche e assicurazioni
☐ Fornitori di servizi
☐ Enti pubblici / Pubbliche Amministrazioni
☐ Università e centri di ricerca
☐ Startup innovative
☐ Altro (specificare nelle note)

Note:

SOLO A CHI HA AVVIATO PROGETTI

25) Come valuta l'impatto avuto dai progetti IoT per l'Industria 4.0 nelle seguenti performance?

Selezionare un'alternativa per performance

SMART FACTORY	IMPATTO

	Molto negativo	Negativo	Nessun impatto	Buono	Molto buono
Consumo energetico (macchinari, linea, impianto, illuminazione)	☐	☐	☐	☐	☐
Efficienza utilizzo materiali (grado in cui le materie prime vengono consumate o incorporate rispetto a prima)	☐	☐	☐	☐	☐
Controllo qualità (monitoraggio della qualità della lavorazione effettuata, supporto agli operatori per ridurre gli errori, etc.)	☐	☐	☐	☐	☐
Emissioni prodotte (ad es. dai macchinari, linea, illuminazione, veicoli)	☐	☐	☐	☐	☐
Produzione rifiuti (c'è una minor quantità di rifiuti prodotti)	☐	☐	☐	☐	☐
Consumo di acqua (riguardante tutte le attività nell'ambito Smart Factory)	☐	☐	☐	☐	☐
Supporto da strumenti digitali (aumentato grazie alla maggiore disponibilità dei dati)	☐	☐	☐	☐	☐
Rischio di infortunio (ridotto grazie a una maggiore sicurezza all'interno dello stabilimento)	☐	☐	☐	☐	☐
Motivazione dei dipendenti (più flessibilità, meno stress)	☐	☐	☐	☐	☐
Produttività	☐	☐	☐	☐	☐
Ore lavorative in straordinario (Riduzione)	☐	☐	☐	☐	☐

Riduzione attività basso valore aggiunto (i dipendenti possono dedicare più tempo ad attività a maggior valore aggiunto)	☐	☐	☐	☐	☐
Lead time (es. tempo di produzione totale, minor tempo di fermi, miglior reazione alla domanda dei clienti)	☐	☐	☐	☐	☐
Costi (derivanti dall'attività di produzione)	☐	☐	☐	☐	☐
Ritorno sugli investimenti (es. maggior customizzazione, migliori decisioni di acquisto)	☐	☐	☐	☐	☐
Vantaggio competitivo dato da offerta innovativa	☐	☐	☐	☐	☐
Altro (specificare nelle note)	☐	☐	☐	☐	☐

Note:

Il questionario è concluso, la ringraziamo per la collaborazione. Qualora volesse, può aggiungere ulteriori commenti sul tema.

A.2. Start-up Database

Company name	Website	Foundation date	Cluster	Headquarter	Total financing (mln $)	Last fundung date	Last funding typology
Vdoo	www.vdoo.com	2017	Cybersecurity	Israel	70	2021	Series B
V5 Systems	v5systems.us/	2014	Cybersecurity	USA	19,1		Series A
ICSEC	www.icsec.pl	2018	Cybersecurity	Poland	10,4	2022	Series A
ShieldIOT	shieldiot.io/	2017	Cybersecurity	Israel	11	2021	Series A
Exein	www.exein.io	2018	Cybersecurity	Italy	8	2021	Series A
CogniFiber	www.cognifiber.com/	2018	Cybersecurity	Israel	8,5	2022	Series A
Dellfer	dellfer.com/	2016	Cybersecurity	USA	10	2021	Series A
Authena	authena.io	2018	Cybersecurity	Switzerland	5	2022	Series A
EcoPlant	www.ecoplant.co/	2016	AIoT	Israel	9,7	2020	Series A
ulalaLAB	www.ulalalab.com/	2011	AIoT	Korea	2,6	2018	Series A
MicroSec	www.microsec.ai	2021	Cybersecurity	Singapore			
StealthPath	www.stealthpath.com/	2016	Cybersecurity	USA	0,22	2020	seed
JSIO	www.jsio.pt	2022	Cybersecurity	Portugla			
peaq	www.peaq.io	2017	Cybersecurity	Germany	9,9	2022	seed
TXOne Networks	www.txone.com/	2019	Cybersecurity	Taiwan	93,9		Series B
Staex	staex.io/	2021	Cybersecurity	Germany	1,7	2022	pre-seed
Transparent Path spc	xparent.io	2018	Cybersecurity	USA	0,74	2022	angel
StaTwig	www.statwig.com	2016	Cybersecurity	India	0,25	2022	seed
Findaa	www.findaatech.com	2019	Cybersecurity	UK	0,25	2021	pre-seed
Poseidon Network	poseidon.network	2019	Cybersecurity	Singapore	1	2020	angel
Kognition	www.kognition.ai	2017	Cybersecurity	USA		2020	debt financing
ITM	itrustmachines.com/	2019	Cybersecurity	Taiwan		2020	seed
Block Armour	www.blockarmour.com	2017	Cybersecurity	Singapore		2020	seed
Xage	xage.com/	2017	Cybersecurity	USA	61,2		Series B
NanoLock Security	www.nanolocksecurity.com/	2017	Cybersecurity	Israel	18,2		Series B
Butlr	www.butlr.io	2019	AIoT	Taiwan			
Qube Technologies	qubeiot.com/	2018	AIoT	Canada	3	2020	grant
Oxys	www.oxyscorp.com	2016	AIoT	USA	0,94	2022	post-IPO equity
Acoustic Wells	www.acoustic-wells.com	2019	AIoT	USA	2	2020	pre-seed
LivNSense	livnsense.com/	2018	AIoT	India		2022	non-equity assistance
Seebo	www.seebo.com	2012	AIoT	Israel	46	2021	Series B
Alleantia	www.alleantia.com/	2011	AIoT	italia	0,48	2015	seed
Petasense	www.petasense.com/	2014	AIoT	USA	4,8	2018	seed
IoTFlows	www.iotflows.com	2019	AIoT		0,71	2022	pre-seed
SwitchOn	switchon.io/	2017	AIoT	India	1	2019	seed
ProAxion	www.proaxion.io	2015	AIoT	USA	2,8	2022	venture - unkonwn series
CPNet	www.cpnet.io/	2018	AIoT	USA		2020	pre-seed
Toumetis	toumetis.com	2009	AIoT	USA			
Ishitva Robotics Systems	www.ishitva.in/	2018	AIoT	India	1	2021	seed
QuantWave	quantwavetech.com/	2016	AIoT	USA	0,337	2020	grant
Prophesee	www.prophesee.ai/	2014	Metaverse	France	65,3	2022	Series C
Cerebrum Technologies	cerebrumtechnologies.com/	2020	Metaverse	Turkey	1,7	2021	seed

List of figures