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The intentionality of implementing Artificial Intelligence and the respective impact on the environmental sustainability of companies

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Abstract

Artificial Intelligence (AI) has been playing an essential role in transforming the business environment, showing its potential to enhance businesses' productivity, adaptation, and competitiveness. In a period where environmental matters become a concern on top of worldwide agendas, AI is pointed to have the potential to be deployed and implemented to enhance green performances for companies and help mitigating their environmental impacts.

This investigation aims to assess the factors influencing managers' intentionality of implementing AI based systems in their companies to boost environmental sustainability. This study also intends to analyze to what extent these drivers are different between managers based in Portugal and managers based in other European countries. For this purpose, both topics were thoroughly considered through literature review and then, further developed through a qualitative approach where interviews were conducted.

The interviews conducted showed that the main drivers of success for the implementation relate with the perception of AI as a key tool to help companies moving towards environmental targets and potential the tool can bring to businesses performances. The main drivers of unsuccess for the implementation related with the complexity and time it takes to develop and implement a system that is capable to run properly, and the initial investment and costs required. Overall, both Portugal based managers and managers based abroad believe in AI as a reliable tool to potentialize environmentally friendly businesses but highlight different aspects as the biggest constraints.

Keywords: Artificial Intelligence, Sustainability, Decarbonization, Energy Efficiency

JEL Classification:

Q010 – Sustainable Development

O320 – Management of Technological Innovation and R&D

Resumo

A Inteligência Artificial (IA) tem vindo a desempenhar um papel essencial na transformação do setor empresarial, mostrando o seu potencial para aumentar a produtividade, adaptação e competitividade das empresas. Num período em que as questões ambientais se tornam uma preocupação nas agendas mundiais, a IA é apontada como tendo o potencial para ser implementada e explorada para melhorar desempenhos ecológicos e ajudar a mitigar impactos ambientais.

Esta investigação visa avaliar os fatores que influenciam a intencionalidade dos gestores na implementação de sistemas baseados em IA nas suas empresas para impulsionar a sustentabilidade ambiental. Este estudo pretende também analisar até que ponto estes fatores são diferentes entre gestores sediados em Portugal e gestores sediados noutros países europeus. Para este efeito, ambos os tópicos foram cuidadosamente considerados através de uma revisão bibliográfica e, posteriormente, desenvolvidos através de uma abordagem qualitativa onde foram realizadas entrevistas.

As entrevistas realizadas mostraram que os principais fatores de sucesso para a implementação estão relacionados com a percepção da IA como uma ferramenta chave para ajudar as empresas nos seus objetivos ambientais e o potencial que a ferramenta apresenta no desempenho das empresas. Os principais fatores de insucesso relacionam-se com a complexidade do processo e o tempo necessário para desenvolver e implementar um sistema capaz de funcionar corretamente, bem como o investimento e os custos necessários. Em geral, tanto gestores sediados em Portugal como gestores sediados no estrangeiro acreditam na IA como uma ferramenta fiável para potencializar negócios mais verdes, mas destacam diferentes aspectos como os maiores constrangimentos.

Palavras-chave: Inteligência Artificial, Sustentabilidade, Descarbonização, Eficiência Energética

Classificação *JEL*:

Q010 – *Sustainable Development*

O320 – *Management of Technological Innovation and R&D*

General Index

ABSTRACT I

RESUMO III

INDEX OF TABLES VII

INDEX OF FIGURES IX

LIST OF ABBREVIATIONS XI

CHAPTER 1 – INTRODUCTION 1

1.1. Theme Framework 1
1.2. Research Problem 2
1.3. Objectives of the dissertation 2
1.4. Structure of the Dissertation 3

CHAPTER 2 - LITERATURE REVIEW 5

2.1. Artificial Intelligence 5
2.1.1. The concept and components of AI 5
2.1.2. AI Applications in Business Sectors 8
2.1.3. AI Challenges 12
2.2. Sustainability 13
2.2.1. Origin and evolution of the concept of Sustainability 13
2.2.2. Sustainable Development 15
2.2.3. Sustainable Development, Energy Efficiency and Decarbonization 16
2.3. Artificial Intelligence, Energy Efficiency and Decarbonization 17
2.3.1. AI applications towards Energy Efficiency and Decarbonization 18
2.3.2. Challenges of AI applications for Energy Efficiency and Decarbonization 19

CHAPTER 3 - THEORETICAL APPROACH 21

CHAPTER 4 – METHODOLOGY 25

4.1. Research Model 25
4.1.1. Data collection method 28
4.1.2. Interview's procedure 30
4.2. Sample characterization 31

CHAPTER 5 – DATA ANALYSIS AND DISCUSSION 35

5.1. Success factors of the implementation 35
5.2. Downsides of the implementation 39
5.3. Drivers of the implementation 40
5.4. Drivers of the implementation between different countries 46

CHAPTER 6 – CONCLUSION **55**

6.1. Final Considerations 55
6.2. Limitations 59
6.3. Suggestions for Future Research 60

REFERENCES **61**

ANNEX A - INTERVIEW SCRIPT **68**

ANNEX B – SUSTAINABLE DEVELOPMENT GOALS **70**

Index of Tables

Table 2.1 - Summary of AI applications and impact on business sectors 11

Table 4.1 - Relationship between literature review, the objectives, and the research questions 26

Table 5.1 – Success factors of the implementation considering the pros of Artificial Intelligence based systems 36

Table 5.2 – Success factors of the implementation considering the most relevant features and areas for AI implementation 38

Table 5.3 – Downsides of the implementation considering the main challenges raised by the interviewees 39

Table 5.4 – Main drivers of the implementation considering the perspective of Environmental Sustainability within the company strategy 41

Table 5.5 – Main drivers of the implementation considering the perspective of AI as a reliable tool to potentialize Environmental Sustainability of the Business 42

Table 5.6 - Main drivers of the implementation from the perspective of those who have AI systems in the company 43

Table 5.7 - Main drivers of the implementation from the perspective of those who do not have AI systems in the company 45

Table 5.8 - Main drivers of the implementation considering the perspective of the relevance of Environmental Sustainability within the company and of AI as a reliable tool to potentialize it from interviewees based in Portugal 47

Table 5.9 - Main drivers of the implementation considering the perspective of the relevance of Environmental Sustainability within the company and of AI as a reliable tool to potentialize it from interviewees based in other European countries 47

Table 5.10 - Main drivers of the implementation considering the opportunities highlighted by interviewees based in Portugal 49

Table 5.11 - Main drivers of the implementation considering the opportunities highlighted by interviewees based in other European countries 50

Table 5.12 - Main drivers of the implementation considering the challenges raised by interviewees based in Portugal 52

Table 5.13 - Main drivers of the implementation considering the challenges raised by interviewees based in other European countries 53

Index of Figures

Figure 2.1: AI types and AI techniques 8
Figure 4.2. a): Categorization and codification of the interview for qualitative analysis . 29
Figure 4.2. b): Categorization and codification of the interview for qualitative analysis . 30
Figure 4.3: Companies' Country of Activity 32
Figure 4.4: Companies' Sector of Activity 32
Figure 4.5: Interviewees Current Position within the Company 33
Figure 4.6: Years of Experience working in the current position 33

List of Abbreviations

AI – Artificial Intelligence

ANN – Artificial Neural Networks

CO_2 – Carbon Dioxide

CV – Computer Vision

DL – Deep Learning

EU – European Union

GDP – Gross Domestic Product

GHG – Greenhouse Gas

IoT – Internet of Things

ML – Machine Learning

NLP – Natural Language Processing

RPA – Robotic Process Automation

SDGs – Sustainable Development Goals

SMEs – Small and Medium Enterprises

TBL – Triple Bottom Line

UN – United Nations

Chapter 1 – Introduction

1.1. Theme Framework

Over the last decades, socio-economical-environmental issues and digitalization have been taking part in the agendas of worldwide governments. Considering the current context, where the world is facing huge pressing global challenges on environmental changes and economic crisis, while still trying to recover from the COVID-19 pandemic and now trying to reshape its economy under the consequences of the war in Ukraine, it turns easily understandable how the progress towards the achievement of the Sustainable Development Goals was dramatically hampered. This, in turn, leads to growing awareness and discussions on such topics. Considering also the European Green Deal as "a roadmap for making the EU's economy sustainable by turning climate and environmental challenges into opportunities across all policy areas and making transition just and inclusive for all", it is obvious how each entity should take an important role on it.

At the same time, growing attention has been paid to the implementation of intelligent systems in organizations as it starts to proof a positive impact in businesses' performance and innovation has always been a key improvement factor throughout history. Terms such Internet-of-Things (IoT), Big Data and Artificial Intelligence (AI) stand for emerging technologies around the world of which it is possible to hear about almost every day. Technological growth and developments have been enabling machines to realize tasks that would normally require human intelligence. Such digital disruption has been showing to be capable of enhancing the productivity, adaptation, and competitiveness of enterprises (Ashok *et al.*, 2022) while requiring a constant corresponding evaluation of Business Models to enable its implementation and sustained viability (Ashok *et al.*, 2022).

Although these may seem to be emerging concerns, these topics date back to the 20th century. Sustainability is a paradigm dating back to the Brundtland Commission in 1987, the United Nations' "World Commission on Environment and Development", where it was conceptualized as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN. Secretary-General & World Commission on Environment and Development, 1987). Artificial Intelligence dates back to the World War II. Since then, as a result of the of its immeasurable evolution, this is a concept that has been receiving different definitions that should be understood as the set of techniques that allows systems to receive and interpret external data correctly, to learn from such data and use it to perform tasks and achieve specific goals that are naturally assigned to humans (Haenlein & Kaplan, 2019).

1.2. Research Problem

AI has become a constant element affecting social, economic, and environmental aspects of the world. Among these, environmental changes and climate crises arise as complex issues that require technological expertise to develop urgent and long-term solutions (Nishant *et al.*, 2020). These calls for technical innovations led researchers and experts to explore the role of AI on achieve the environmental goals of carbon neutrality (Bolton *et al.*, 2021).

Although most companies are optimistic about the future development of this technology and its applications, they remain cautious with regard to the challenges it may pose. Nonetheless, according to authors like Gailhofer *et al.*, (2021), AI has the potential to be deployed for several applications to promote the European Green Deal, towards which not only governments, but also companies and everyone is invited to actively assume their responsibility. Therefore, considering this, it is important to analyze and debate these topics and the possibility to merge it towards a greener environment and a more digitalized Europe, as the European Commission aims for 2030.

Considering the existing literature on the areas, the present study aims to relate the sphere of Artificial Intelligence with Environmental Sustainability at companies, focusing on the implementation of AI to enhance greener performances. More concretely, the purpose of this investigation is to uncover the drivers for this implementation, the characteristics of this technology that can be beneficial for more environmentally friendly businesses, as well as the main limitations of these systems that may lead to challenges in the implementation of AI. Having exposed the identified variables, the goal is to understand how each one may influence the implementation of AI towards Environmental Sustainability of businesses and to what extent these drivers vary between countries.

1.3. Objectives of the dissertation

In this sense, the theoretical objective of this study is to investigate the intentionality of implementing Artificial Intelligence and the respective impact on the Environmental sustainability of companies. In turn, the goal is to contribute to the development of the state of art on the impact of AI in businesses' environmental sustainability, discussing the possibility of bridging two emerging concerns across the European Union.

More specifically, this investigation aims to understand the real impact of implementing Al systems to manage and control environmental impacts of businesses, and to better understand the factors that lead to managers' reaching a decision on the implementation of AI as a tool as this, has potential to transform companies towards a greener environment. Further, this investigation also aims to understand if what drives and influences this possibility varies between countries. For this purpose, this investigation focuses on four main questions:

RQ1) What are the success factors of implementing Artificial Intelligence towards Energy Efficiency and Decarbonization?

RQ2) What are the possible down-sides of implementing Artificial Intelligence towards Energy Efficiency and Decarbonization?

RQ3) What are the factors influencing the intentionality of managers to implement AI systems towards Energy Efficiency and Decarbonization?

RQ4) To what extent do the drivers influencing the intentionality of managers to implement AI systems towards Energy Efficiency and Decarbonization differ between countries?

1.4. Structure of the Dissertation

This investigation will be conducted throughout six chapters with specific purposes.

Chapter 1 presents an introduction for the study that provides the theme framework, explains the research problem and objectives of the dissertation.

Chapter 2 regarding the literature review draws on the state of art about Artificial Intelligence, Environmental Sustainability and the existing research bridging these two main topics.

Chapter 3 explains the theoretical approach that led to the research questions to be further developed.

Chapter 4 explains the methodology applied to answer to the research questions and provides the sample characterization.

Chapter 5 presents the results derived from the methodology applied and the corresponding discussion with the authors referred throughout the literature review aiming to compare perspectives and further develop the existing knowledge.

The last chapter, Chapter 6, draws the main conclusions of the investigation, its limitations, and suggestions for future research.

Chapter 2 - Literature Review

2.1. Artificial Intelligence

2.1.1. The concept and components of AI

In an era where Artificial Intelligence (AI) is currently expanding beyond mechanical and repetitive to analytical and thinking (Huang *et al.*, 2019), it has been dominating recent headlines and business agendas, with its promises, challenges, risks, successes, and failures (Floridi, 2019). Nevertheless, it should not be considered such a recent topic. AI roots to the 1940s decade, when the English mathematician Alan Turing developed *"The bomb"*, the code breaking machine used by the British Government to fight the German forces in World War II, that was able to decipher the Enigma code.

However, it was only in 1956 that the term "Artificial Intelligence" was officially coined, during the 1956 Dartmouth summer research project, organized by John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon (McCarthy *et al.*, 2006; Haenlein & Kaplan, 2019), bringing together researchers from various fields related with building machines able to simulate human intelligence (Haenlein & Kaplan, 2019). AI technology has a long history that has been actively changing, across which it has been receiving several definitions. Despite, Kelly L. Williams, (n.d.) defends that a common theme among such definitions is that AI must emulate intelligent human behaviors or be able to perform tasks that would normally require human intelligence.

Authors like Russel & Norvig (n.d.), define AI as the study of agents that receive information from the environment and perform actions; systems that monitor cognitive functions related to human attributes such as learning, speech and problem solving (Dwivedi *et al.*, 2021). In a more detailed way, according to Shabbir & Anwer, (2018), in the context of the modern and digitalized world, AI is the property of machines, computer programs and systems to perform the intellectual and creative functions of a person, independently find ways to solve problems, be able to draw conclusions and make decisions. Shortly, Kaplan & Haenlein (2019) present AI as a system's capability to receive and interpret external data correctly, to learn from such data and use it to perform tasks and achieve specific goals.

Altogether, current AI paradigms still satisfy the classic definition provided by John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon in their founding document and event that established the new field of AI: "for the present purpose the AI problem is taken to be that of making a machine behave in ways that would be called intelligent if a human were so behaving" (Quotation from the 2006 re-issue in (McCarthy *et al.*, 2006), (Floridi, 2019). This classic definition presents AI as a growing and interactive, autonomous, and self-learning system, capable of dealing with tasks that would otherwise require human intelligence and action to be performed successfully (Floridi, 2019).

By being able to learn and improve from different types of data, AI is distinguished among previous generations of information technology. Kaplan & Haenlein (2019) also present AI as a system's ability to collect external data, correctly interpret it, learn from it, and use such learnings to successfully achieve goals and tasks through flexible adaptation. AI has advanced rapidly from being mechanically capable to being increasingly thinking capable and while learning from various types and massive amounts of data (i.e., big data) and being able to update thoughts or actions is what makes one consider a machine to be intelligent (Huang *et al.*, 2019).

It is not possible to talk about AI without referring to data and learning methods. AI relies on the external information it gathers as the input to identify rules and patterns that allow it to perform tasks that would normally require human intervention. The mechanisms through which AI learns from data and develops from it respect to several mathematical algorithms and computational methods (Kaplan & Haenlein, 2019). Within AI, machine learning and deep learning are usually referred as especially powerful techniques. However, other important techniques also include computer vision, natural language processing (NLP), and robotics (Liengpunsakul, 2021), as well as artificial neural networks (Haenlein & Kaplan, 2019; Dwivedi *et al.*, 2021). All these related topics are to be understood as follows:

Machine Learning (ML) is a sub-level of AI that allows systems or machines to learn from data without the need of being explicitly programmed (Lee & Shin, 2020). ML uses algorithms (mathematical methods) to detect patterns in datasets, recognize relationships or correlations between different aspects, learn from it, and make assumptions on their behaviour for new similar situations (Güngör, 2020; Khan & Al-Habsi, 2020; Liengpunsakul, 2021). Examples of this technique may be YouTube suggestions of videos to be played or Netflix recommendations (Shabbir & Anwer, 2018; Güngör, 2020; Dwivedi *et al.*, 2021).

Within ML, there is a distinction between three types of learning processes: supervised learning, unsupervised learning, and reinforcement learning (Kaplan & Haenlein, 2019; Khan & Al-Habsi, 2020; Lee & Shin, 2020).

Supervised machine learning relates with labeled data meaning that algorithms are trained using labeled datasets (inputs and correct outputs) to classify data, predict outcomes accurately and produce the desired outputs. The model is fed with these inputs and correct outputs, allowing it to learn over time as the algorithm adjusts itself comparing the calculated and desired outputs until error is minimized. Once an acceptable level of accuracy is achieved, the learning process is said to be finished.

Unsupervised learning is another sub-level of ML that focuses on identifying patterns with no labeled input data. In this case, the algorithms analyze and cluster unlabeled datasets, aiming to find patterns or group data based on similarities or differences detected. The outputs are derived by the algorithms itself and not explicitly labeled as in supervised machine learning.

Reinforcement learning is the third of ML sub-levels, where algorithms learn and generate a corresponding action or output by trying to maximize the rewards that can be received for their action (Kaplan & Haenlein, 2019; Güngör, 2020; Lee & Shin, 2020).

Moving to another field, Deep Learning (DL) should be highlighted another major field in AI, being the main responsible for the development of this technology (Liengpunsakul, 2021). Deep Learning is an AI technology inspired by the human brain that combines algorithms and computational models to emulate its activity and the relation between the biological neural networks. DL algorithms known as Artificial Neural Networks (ANN) derive conclusions as human brains would do by constantly analyzing and comparing data based on a logical structure (Güngör, 2020; Jakhar & Kaur, 2020). Simply, ANN are a replication of biological neurons, emulating the way they communicate and establish relations between one another, and reflecting the human brain behaviour. ANN systems rely on algorithms to recognize patterns in data and infer conclusions and possible outputs, being capable of learning from observations and generalize conclusions (Halkiadis, n.d.).

Among all the AI approaches, it is also worth to enhance natural language processing, computer vision and robotics. Natural language processing refers to the machines' ability to understand and process written or spoken human language through the combination of statistical and ML methods (Lu *et al.*, 2018). Great examples of this AI technology may be Google Translate, or the virtual agents Alexa by Amazon and Siri by Apple.

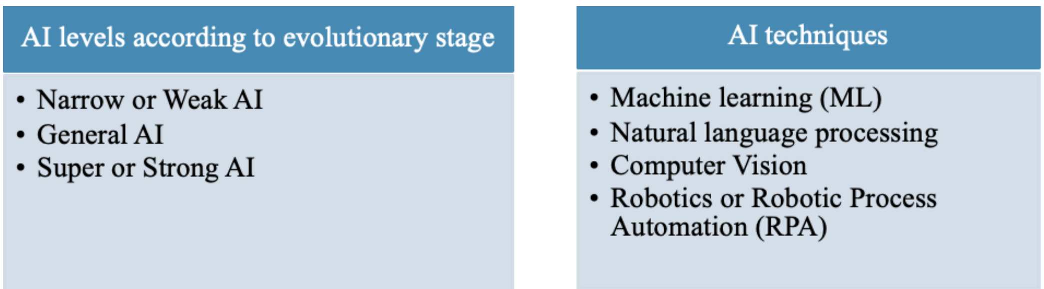
Computer vision (CV) is still one emerging field of AI's capability to replicate human cognition as it aims to analyze and understand real-world visual scenes (Klette, 2014). CV allows machines to infer meaningful information from digital information as images, videos, or other visual inputs and extrapolate outputs for it, emulating the human vision. For instance, AI algorithms try to breakdown images to be able to study it, define patterns and draw conclusions for it (Khan & Al-Habsi, 2020).

Robotics or Robotic Process Automation (RPA) combines human cognition, emotions and thinking to perform human actions, using software and algorithms to automate repetitive human and computer-based actions, aiming to provide efficient business processes. In the current days, this AI method is especially used in tasks that would be too expensive or inefficient if performed by a human being (Lu *et al.*, 2018).

Nowadays, AI comprises not only all these approaches as it can also be distinguished in three broad types, depending on the evolutionary stage: narrow or weak AI; general AI; and super or strong AI (Wirth, 2018; Güngör, 2020; Hole & Ahmad, 2021). According to these authors, narrow AI is a set of mathematical algorithms designed to perform specific and well-defined problems or tasks in one domain. It outperforms or equals humans in that specific area, but it cannot autonomously solve problems in other areas. Siri's and Alexa's capacity to recognize voices and respond accordingly and Tesla's self-driving cars can be mentioned as an example of this AI stage. General AI has not been achieved yet, but it covers systems capable of reasoning, planning and solve problems, learning and acting intelligently across varied problems or tasks, as powerful and flexible as human brains. As narrow AI systems, general AI systems also outperform or equal human intelligence, but in several areas. Super or strong AI refers to the cases when AI is applicable to any area and outperforms human brains and actions in all areas.

Figure 2.1summarizes the AI types and techniques described throughout this chapter.

Figure 2.1: AI types and AI techniques



Source: Self-elaborated

2.1.2. AI Applications in Business Sectors

As AI has been at the top of public agendas for decades, studies in the field and its applications have also been increasing significantly across business sectors and management domains (Cubric, 2020). AI has been allowing people and businesses to improve their performance on daily activities over time (Shabbir & Anwer, 2018), as the systems, computer programs, or machines' ability to perform tasks that would normally require human intelligence, finding ways of solving problems, extrapolate conclusions and even make decisions, while learning from such being capable of learning from such processes. In the eyes of Dwivedi *et al.*, (2021), the developments in AI have not only empowered the transformation of tasks and processes as they could also lead to businesses' growth and even to the potential replacement of human works in both industrial, intellectual, and social applications.

The developments on machine learning, deep learning, and predictive analysis intent to exploit planning, learning, reasoning, thinking, and action taking capability (Shabbir & Anwer, 2018) and are already impacting processes across several industry sectors in relation to high levels of performance and efficiency. Further, AI systems, and especially machine learning enables costs reduction through the optimization of resources and waste reduction, while improving customer service (Lee & Shin, 2020). Authors like Shabbir & Anwer, (2018), believe that AI will be key for competitive advantage as a new production factor that can skyrocket business profitability, for which many solutions were already implemented throughout several sectors such as finance, healthcare, manufacturing, retail, supply chains, engineering, and utilities.

On our daily lives, one of the major AI applications can be seen on self-driving cars where computer vision provides the interpretation of the surrounding environment (Elliott *et al.*, 2019) and robotics allows an efficient controlling of gas emissions, speed, and traffic without the constant monitoring of the drivers. Self-driving cars, also known as autonomous cars, comprise several sensors in different parts and a sophisticated software that processes all the input data from these sensors and produces the required outputs for the car to act and react (Tofangchi *et al.*, 2021) by itself. As Bini, (2018) states, another example of AI applicability in our daily lives could be the natural language processing technology applied in Google Translate where a set of ML algorithms enable the understanding and processing of human language to produce translations.

Businesswise, numerous studies provide insights on how some companies across different sectors have already been applying AI techniques. Supported by big data which has the capability of accessing and storing large amount of heterogenous data at high velocity (de Luca *et al.*, 2021), Artificial Intelligence has been impacting industries worldwide. AI and big data are currently deeply used over different aspects of businesses, being pointed as drivers of costs reduction, speed up of effortful work, increasing profits, and thus, business growth (Ghimire *et al.*, 2020).

This transformation of industries is also known as “Industry 4.0” or “The Fourth Industrial Revolution” and can be described as “the increasing digitization and automation of the manufacturing environment, as well as the creation of digital value chains to enable communication between products, their environment and business partners” (Lasi *et al.*, 2014). Overall, Industry 4.0 consists in a transformation comprising several technologies and concepts such as interconnectivity, digitalization and automation that should be applied to intensify the competitiveness of companies (Woschank *et al.*, 2020). More specifically, it comprises manufacturing systems with information, communication, and intelligence technologies capable of controlling, planning, and forecasting data, which in turn lead to more intelligent production systems and more efficient results (Bai *et al.*, 2020).

In manufacturing, AI robotics, integrating Computer Vision techniques, Natural Language Processing, and AI decision-making capabilities, facilitates production processes, and enhances efficiency, quality, and cost-effectiveness, which, in turn, provide environment-friendly services for users and consequently, and improves market competitiveness within the sector (Li *et al.*, 2017). In the agricultural sector, AI can generate intelligent production systems, as its techniques enable to forecast weather conditions and analyze plants, providing reliable inputs to engineers, and increase productivity of the farmers (Liengpunsakul, 2021).

In the financial sector, machine learning techniques can be applied to detect frauds. Ghimire *et al.*, (2020) explain that fraud detection techniques can be divided in two different categories: anomaly detection and misuse detection. The former learns the regular transaction behavior of a customer and whenever any new transaction occurs, the system classifies it as regular, or irregular based on the customer behavior data it knows. The later uses labelled data sets from the customers and any suspicious activity is detected according to the general fraudulent patterns. Additionally, AI has already transformed trading with the automatization of the trading process through the application of learning algorithms used to predict stock prices and ultimately lead to profit generation.

In healthcare, machine learning enables better diagnosis, and better treatments for the patients, while robotics can become a great allied during surgeries (Dwivedi *et al.*, 2021). Furthermore, machine learning contributes to scientific investigations, to find new health problems and develop new medicines (Shabbir & Anwer, 2018). In education, among many other things, AI enabled the automation of tests and homework corrections, providing recommendations to close gaps in the learning process of students and allowing the creation of personalized learning processes.

In retail, Amazon Go stores use several recognition sensors throughout its shelves to detect what customers are picking up and automatically charge them. This way, customers can do their shopping without checking out as in traditional retail stores (Ghimire *et al.*, 2020). Furthermore, machine learning can also be used to perceive and analyze consumer purchasing habits and suggest products according, and at the best prices (Shabbir & Anwer, 2018). The developments potentialized by AI across the different business sectors are summarized in Table 2.1.

Table 2.1 - Summary of AI applications and impact on business sectors

Manufacturing	AI systems leverage manufacturers efficiency while allowing them to reduce their costs of machine failure. AI technology can calculate the potential downtime or forecast the failure of equipment and schedule its repair before the failure even occurs, providing the reduction of maintenance costs.
Agriculture	AI applications can forecast weather conditions and analyze plants, providing reliable inputs to engineers and managers to build intelligent production systems, and increase productivity of the farmers.
Financial Markets	Enabled by the availability of data, ML models can identify patterns and relationships beyond humans' capabilities, driving firms' competitive advantage and efficiency by reducing costs and increasing the quality of financial services products provided. Among several examples, AI applications in asset management and credit intermediation can be highlighted.
Healthcare	By applying algorithms and deep learning, AI allows faster and more accurate diagnosis, along with personalized medical treatment. AI systems can also support and enhance the development of new medicines as BioXcel Therapeutics proved by developing the "Most Innovative Healthcare AI Development of 2019".
Education	Among may other things, AI enabled the automation of tests and homework corrections and providing recommendations to close gaps in the learning process of students.
Retail	Recognition sensors and algorithms allow digital shopping experiences without checking out as in the traditional process. AI systems can also analyze the purchasing behaviour and make suggestions according to consumers preferences.

Source: Self-elaborated

Overall, AI implementation can help managers and organizations in the decision-making process by providing a faster processing of data, the generation of new information and patterns, and forecasts of what the future can be based on the existing data and patterns (Shrestha *et al.*, 2019). As (Rosa *et al.*, 2022) share throughout their research, AI can be seen as a competitive advantage tool that provides strategic information, allowing to improve strategies, exploit innovation and generate differentiation among the competitors. Nevertheless, and despite all the opportunities that AI represents for businesses, economies and societies, some challenges also arise with it.

2.1.3. AI Challenges

The implementation of AI technologies indeed represents an opportunity for business growth. However, as AI techniques implementation and their potential are intensively exploited, they also represent significant challenges for managers, governments, and organizations. According to Lee & Shin, (2020); Dwivedi *et al.*, (2021); Ashok *et al.*, (2022) and many other authors, the challenges can be grouped into different categories explained as follows:

Data Challenges: challenges related with data quality and integrity along with transparency and reproducibility are highlighted (Dwivedi *et al.*, 2021). AI relies on large amounts of data as its basis for learning. It builds patterns, makes predictions, and extrapolates possible outcomes from this historical data. However, as Nishant *et al.*, (2020) explain, historical datasets may become of limited value because of unpredictable human variables which are difficult to integrate into ML models. Following this difficulty of integrating all the possible real-world problems, AI applications appear to be limited to specific problems or contexts (Lu *et al.*, 2018). Additionally, a wrong contextualization and interpretation of the data is pointed as one of the biggest barriers for organizations (HRNews, 2017).

Technological Challenges: technological challenges around AI relate with the architecture and design of the systems themselves. Currently, AI systems do not have the human intelligence essence, they do not understand the human cognitive flexibility and specially, they do not process moral insights (Baldassarre et al., 2017). Further, authors as Sun & Medaglia (2019), focus on challenges related with the lack of transparency of algorithms used at the base of AI systems and the respective difficulties in processing unstructured data. As an example, the authors refer their study in the healthcare sector, where hospital managers and doctors pointed as a challenge the fact that when analyzing unstructured data like medical imaging, AI systems still need to be complemented with the human experience, impacting the medical confidence in technology. Lastly, the still limited pool of investigators prepared and able to work with AI is also stated as a technological challenge.

Organizational and Managerial Challenges: at management levels, resistance to data sharing is pointed as a difficulty for AI in the sense that data is the basis for AI systems. Authors like Sun & Medaglia (2019); Dwivedi *et al.*, (2021) also mention the lack of strategic planning for AI implementation and developments within organizations. On the organizational level, challenges around human resources as threatening of human workforce replacement and lack of skilled employees for AI technology are highlighted.

Ethical and social challenges: as AI basis requires datasets, different data must be gathered from individuals and organizations. However, considering the feeling of lack of transparency on the AI designs, individuals, and organizations lack trust towards the real usage of their data (Sun & Medaglia, 2019). The usage of AI is also likely to challenge cultural norms to the extent that currently it still does not integrate the human emotional intelligence neither the unpredictable actions from human hand as it only relies on historical data to train that may lead to biased outputs. Ultimately, Sun & Medaglia (2019) express unrealistic expectations and lack of knowledge on the advantages of AI as factors influencing societies and rising barriers about the implementation of this technological development.

2.2. Sustainability

2.2.1. Origin and evolution of the concept of Sustainability

Sustainability is a paradigm that dates to the Brundtland Commission in 1987, the United Nations' "World Commission on Environment and Development", chaired by Gro Harlem Brundtland, then Norwegian Prime Minister. In this Commission, "sustainability" was conceptualized as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN. Secretary-General & World Commission on Environment and Development, 1987). In this perspective, environment, economy, and society are highlighted as the three interrelated pillars that contribute to achieve sustainability (Olawumi & Chan, 2018). Moreover, sustainability is perceived as a long-term goal, a concept that reflects about the future, enhancing the pursuit of quality of life, and relying on the equilibrium between societal, environmental, and economic factors (UNESCO, 2021).

The "Triple Bottom Line" concept was firstly coined in 1994 by the business writer John Elkington, as he claimed that the traditional way of measuring business success just through the net income and other financial signs was not enough. John Elkington defended the idea that a company could be financially successful and yet harmful to the social or ecological environment in which it was embedded. Hence, as an attempt to solve the issue on how to tackle the performance of organizations in this context, the author added the social and environmental spheres to the traditional economic way of analyzing the performance of organizations (Hourneaux Jr *et al.*, 2018). Through this new approach, Elkington suggested to expand the way of evaluating business performance by adding two other "bottom lines" to the economical one, understanding the organization's contribution to social equality and welfare as well as the organization's ideas towards ecological environment. Although studies around sustainability have been gaining momentum over the years, the definition of the TBL as a model that "captures the essence of sustainability by measuring the impact of an organization's activities on the world…including both its profitability and shareholder values and its social, human, and environmental capital" is the most generally accepted (Slaper, n.d.)

Businesswise, the Davos Manifesto 2020, released by the World Economic Forum, comprising a set of ethical principles to guide companies in the age of Industry 4.0, states that "the purpose of a company is to engage all its stakeholders in shared and sustained value creation. In creating such value, a company serves not only its shareholders, but all its stakeholders – employees, customers, suppliers, local communities, and society at large". In turn, this philosophy follows the TBL perspective (Slaper, n.d.)

In this scope, social sustainability relates with the social well-being of the population in and outside companies. It focuses on organizations' actions and behavior that affect both shareholders and all employees as well as customers, suppliers, governments, and communities. As so, social sustainability can be analyzed from internal and external approaches within organizations. The internal approach aims to understand the social impact of the companies' policies on its own employees in the sense of human resources management. The external approach deals with factors outside the company, but still related with it, that affect the economy such as the employment rate and its demand and supply conditions (Digital Product-service innovation and sustainability). Overall, social value is about generating socio-economic benefits by impacting societies at the individual, community, institutional, national, and even sometimes, at the international level.

Economic sustainability considers financial indicators as the profitability of organizations. Moreover, it aims for maximizing market value and increasing operational profits through the efficient allocation of resources (Olawumi & Chan, 2018; Tofangchi *et al.*, 2021), without disproportionately threaten future generations (Morelli, 2011).

According to Morelli (2011), environmental sustainability can be defined as *"meeting the resource and services needs of current and future generations without compromising the health of the ecosystems"* in the sense of strict the human activity in organizations within the carrying capacity of the ecosystem. Furthermore, environmental sustainability concerns topics about raw materials, land-use and water sustainability, sustainable agriculture, renewables, and energy use, among many others (Olawumi & Chan, 2018).

Ultimately, sustainability concerns the design of a favorable environment for citizens, organizations, governments, and all entities to develop their full potential considering the humanity's socio-economic well-being. It comprises the improvement of citizens' well-being, protection of the natural environment, and promotion of economic growth that build the three pillars of sustainability which are known as the 3P's: people, planet, and profit (Slaper, n.d.).

2.2.2. Sustainable Development

Sustainable Development is the encompassing paradigm of the United Nations (UN) and represents the various processes and paths to achieve the needs of the present without jeopardizing the ability of future generations to meet their own needs. Moreover, sustainable development is an ideal concept as it should enable the fulfilment of basic needs, while improving human well-being without threatening the ecological limits (Prerna, 2020).

Hence, the UN presented the Sustainable Development Goals (SDGs), a leading global framework for international cooperation that comprises an agenda to end poverty, protect the planet, and ensure all people enjoy peace and prosperity (Miller *et al.*, 2020), as a plan to tackle the world's most pressing problems. Aiming for an inclusive and sustainable future for the planet and societies, the sustainable development agenda relies on the Triple Bottom Line Model of Sustainability, focusing on the three core dimensions: economy, society, and environment (de La Calle *et al.*, 2021; Liengpunsakul, 2021).

As stated by the International Institute for Sustainable Development, the first Brundtland Commission has been inspiring other conventions and summits, where sustainability is at the foundation of several protocols and agreements, such as the 1992 Earth Summit in Rio de Janeiro and the Kyoto Protocol in 1997. More recently, in 2015, the United Nations General Assembly set the SDGs, also known as the 2030 Agenda for Sustainable Development, as the roadmap for the *"future we all want"* (Bolton *et al.*, 2021). Despite broader in scope, the Sustainable Development Agenda comprises the 17 SGDs explained in table 2.2, in annex B.

2.2.3. Sustainable Development, Energy Efficiency and Decarbonization

Considering the principles above, and the current global context, where the world is facing huge pressing global challenges from environmental changes and economic crisis, the progress towards the achievement of the Sustainable Development Goals has been dramatically hampered. Indeed, the 2020 UN SDGs' report states that the current pace of activity of countries is not sufficient to meet the goals by 2030.

In this scope, sustainable development should be understood towards the preservation of the planet through the optimization of resources and energy systems, circular modes of production and waste reduction (Denicolai *et al.*, 2021). Within this, the study Pathways to Net Zero: The Impact of Clean Energy Research (n.d.), highlights the importance of distinguishing between different concepts as carbon neutrality, net zero and climate neutrality.

According to the authors, carbon neutrality, can also be referred as "zero carbon" or "decarbonization", and should be understood as the attempt to balance emissions of carbon dioxide (CO_2) resulting from the human activity, aiming to remove it from the atmosphere. Net zero refers to the same but comprises all greenhouse gas (GHG) emissions and climate neutrality represents the ideal state whereby human activities would have no net effect in the climate system as whole. Anyhow, these three concepts relate to each other in the sense that *"achieving such a state as climate neutrality requires balancing residual emissions with CO_2 emissions removal as well as accounting for regional or local bio geophysical effects of anthropogenic activities that, for example, affect surface albedo or local climate".*

In December 2019, the urgency for action in this scope, led the European Commission to launch the European Green Deal as *"a roadmap for making the EU's economy sustainable by turning climate and environmental challenges into opportunities across all policy areas and making transition just and inclusive for all".* The European Green Deal represents the ultimate attempt to mitigate climate change, calling for action among all the economic sectors, but especially industries, energy, agriculture, and transport as the main responsible for gas emissions. Henceforward, not only governments, but also companies and every social entity are invited to actively assume their responsibility towards this deal and its goals. Under the increasing pressure of global warming effects and GHG emissions, along with skyrocketing fuel prices, energy efficiency and energy transition arise as ideas with great potential to meet the targets set by the European Commission.

The Environmental and Energy Study Institute define energy efficiency as the elimination of energy waste, by using less energy to perform the same task and consequently enabling the reduction of GHG emissions, reducing both demand for energy imports and energy costs for both citizens and enterprises. The European Commission presents energy efficiency as the path towards a more effective conversion, transmission, and distribution of energy that ultimately leads to costs and energy savings. Within these ideas, energy efficiency is highlighted as a priority in the European Green Deal, as one of the key pillars to fight climate change and meet the environmental goals. Considering the European Green Deal, the European Commission set as key targets for 2030 the reduction of GHG to at least 40%, an increase in renewables share of 32% and an improvement in energy efficiency of at least 32.5%. According to the EU Commission, each EU country must design a plan that shows how it intends to address such targets, known as the National Energy and Climate Plans.

The Climate Action Steering Committee calls for enterprises' actions to focus on net-zero business strategies and set targets aiming for such delivery. In their recent project on "The New SWOT for a Sustainable World", Pereira *et al.*, (2021) point out that in such a complex and challenging business environment, subjects as sustainability and environmental issues are indeed gaining more notoriety among organizations. However, some companies still see these issues as obligations or even just deceptive ways of achieving their goals and do not consider them yet among their strategies.

2.3.Artificial Intelligence, Energy Efficiency and Decarbonization

The implementation of intelligent systems in businesses' strategies has been receiving growing attention as it starts to proof a positive impact in business' performance. As Andy Wyckoff, the Director of OECD Directorate for Science, Technology, and Innovation emphasizes, innovation has always been a key improvement factor throughout history: *"from the invention of the wheel to cars, computers and internet, medicines and diagnosis techniques, innovation can be assured as the symbol of progress".* Innovation should be understood as the creation and development of new processes and methods that lead to change and ultimately generate new businesses, new business models and cleaner environments.

Technological developments have been enabling machines to realize tasks that would normally require human intelligence such as learning, problem-solving and decision-making. Digital disruption has been proofing to be capable of enhancing the productivity, adaptation, and competitiveness of enterprises by providing better and smart machinery and equipment while empowering the intellectual property of firms and requiring a constant corresponding evaluation of Business Models to enable its implementation and sustained viability (Ashok *et al.*, 2022).

More specifically, AI is becoming a constant element affecting social, economic, and environmental aspects of the world. Among these, environmental changes and climate crises arise as complex issues that require technological expertise to develop urgent and long-term solutions (Nishant *et al.*, 2020). Such calls for technical innovations led researchers and experts to explore the role of AI on energy efficiency to achieve the goals of carbon neutrality, and ultimately impacting the achievement of the SDGs (Bolton *et al.*, 2021).

"Digital technologies have the potential to enable a 20% reduction of global CO2 emissions by 2030, in particular, in the following sectors: energy, transport, agriculture, and manufacturing" (DIGITALEUROPE, n.d.)

2.3.1. AI applications towards Energy Efficiency and Decarbonization

AI represents a powerful tool for sustainability, integrating thousands of data-driven, connected, and automated applications that can help to solve the most complex problems. Being often conceived as a key technology for future growth, AI has the potential to be deployed for several applications to promote the European Green Deal (Gailhofer *et al.*, 2021). AI technologies can help to promote an efficient integration of renewal energy, while supporting decarbonization and reducing energy consumption. Overall, AI systems allow entities to be less dependent on energy, ultimately providing them a decrease on energy costs while making them less vulnerable to the related price changes. How AI Can Enable a Sustainable Future, (n.d.) show that AI applications among key sectors as energy, transport, industry, and agriculture can reduce global GHG by 1.5% - 4% by 2030 along with the potential to boost global GDP by 3-1% - 4.4.%.

More specifically, in the energy sector, AI systems can be integrated into electric grids making those grids capable of regulating and shifting the demand of electrical power to optimal times when renewable electricity is available by means of data collection and processing. It can also identify patterns in energy consumption and between the environment and social interactions such as varying demand for energy resources depending on the time of the day or weather conditions (International Energy Agency, 2017; Vinuesa 2020), resulting in optimized energy consumptions, reduced energy costs and CO_2 emissions. Additionally, AI can increase power plant conversion efficiency by getting more energy from the same unit of input, reducing semiconductor manufacturing energy and water usage, or, in several sectors, helping manufacturing facilities increase output (Floridi, 2019).

As far as it concerns energy efficiency applications and results, AI systems can provide autonomous grid management, accurate predictions of renewable energy production, optimization of energy usage and consumption through its capability of continuously collect and process large amounts of data that enables to conceptualize the consumer behaviour and accurately predicting renewable energy production that in turn deploy energy management and maintenance of infrastructures.

In the transport sector, AI applications provide a better understand the behaviour of transport users and mobility patterns, which in turn, enhance the planning of transport services and infrastructures. AI systems can build patterns on the users' behaviour and forecast transport demanding, allowing to reduce unnecessary traffic and optimize vehicle routing and occupation. Additionally, AI systems enable the design and production of energy-efficient vehicles and provide better battery and charging management of those vehicles. Companies like Siemens and BMW are already using AI techniques to provide sustainable mobility and build energy-efficient vehicles respectively (Gailhofer *et al.*, 2021).

In the agricultural sector, AI techniques facilitate the analysis of the soil and provide a more efficient management of resources like water and nutrients, along with the capability to detect crop diseases, control harmful agricultural pesticides and pollution effects (Jha *et al.*, 2019). Overall, AI systems allow to develop intelligent production systems, as its techniques enable to forecast weather conditions and an efficient exploration of soils and plants along with resources management.

In the industrial sector, research has presented how AI applications can significantly improve energy efficiency by enhancing more appropriate allocation of resources throughout the production and operation processes, enabling to detect and predict machine failures, saving energy and maintenance costs, reducing energy wastes, and providing an efficient management of energy usage. AI techniques provide intelligent decision-making and a better management of processes, from machine operationalization to resources management (Liu *et al.*, 2022).

2.3.2. Challenges of AI applications for Energy Efficiency and Decarbonization

Despite all the promising opportunities of AI application towards energy efficiency, challenges related with new environmental and social risks arise.

From an environmental point of view, AI systems derive their results from strongly energy-intensive algorithms, relying on largely energy-consuming datasets and big data centers and thus, creating an impressive carbon footprint (Nishant *et al.*, 2020; Gailhofer *et al.*, 2021). In an era where AI technologies keep evolving and its applications are expected to increase in the future, more data volumes will also be generated and consequently higher energy consumptions (Aghion *et al.*, 2017). Thus, it may become questionable if AI is part of the solution to environmental concerns or rather part of the environmental sustainability problem (Kopka & Grashof, 2021).

When it comes to social concerns, data privacy and cybersecurity arise as big challenges for AI systems implementation. The application of AI systems requires the integration of data from several data owners, in different formats and structures, which raises concerns about the risk of cyberattacks, and generates lack of trust from the consumer side to share such detailed information and lack of knowledge on the exact purpose of the usage of these data that is collected and stored by many interconnected systems and devices.

Chapter 3 - Theoretical Approach

Considering the literature review carried out through the previous chapter, and the several insights from different authors on artificial intelligence and the impact of environmental actions towards Sustainable Development Goals, it was possible to derive 4 research questions that will be further developed along this chapter. The economic effects of AI are already being discussed controversially, however different possible applications and the impacts of AI systems on environmental sustainability and more specifically towards the reduction of businesses' environmental impacts remain largely unanswered (Khakurel *et al.*, 2018).

Businesswise, COVID-19 has brought digital transformation as key to keep business run and even grow and in turn, this digitalization is pointed as a major opportunity to advance on the achievement of the SDGs. Within this, AI is pointed by several authors, and even Global Entities, as a strategic element to bridge digital and environmental targets while its applications have been studied throughout different sectors (Khakurel *et al.*, 2018; Miller *et al.*, 2020; Denicolai *et al.*, 2021; Gailhofer *et al.*, 2021; Kopka & Grashof, 2021).

At the same time, energy topics are highlighted as a crucial factor towards a sustainable economy. As far as companies are concerned, both large and small and medium enterprises (SMEs) are called for action to mitigate environmental challenges and help countries meet the targets on sustainability goals. Among this, SMEs, as the backbone of most economies, are considered essential players. The European Union Commission defines small enterprises as companies that employee less than 50 collaborators and that present an annual balance sheet or annual turnover that does not exceed EUR 10 million. Medium-sized enterprises employee fewer than 250 people and present an annual turnover that does not exceed EUR 50 million or a balance sheet smaller than EUR 43 million (European Commission, 2020).

According to data from the European Commission, SMEs represent 99,8% of Europe's private companies, while accounting for more than two thirds of the employment among the European Union countries and contributing to more than 50% of the European GDP (Koirala, n.d.). Nonetheless, at the same time SMEs contribute to 60-70% of industrial pollution worldwide and 60% of carbon emissions (European Commission, 2015). Research held by the European Commission's Observatory also shows that 90% of SMEs did not adopt yet any energy-efficiency measure to control its energy consumption and related carbon emissions (Cagno & Trianni, 2013). Hence, digital transformation and sustainability arise as increasingly intertwined challenges for SMEs.

Further, Denicolai *et al.*, (2021) defend AI as one of the most interesting technologies to analyze as far as it concerns the impact on sustainable growth and emphasize that despite all the studies that have been carried out about SMEs' digitalization, SMEs' sustainability readiness has been kept aside. Starting with what inspired me to develop my first research question, in *"The role of Artificial Intelligence in the European Green Deal",* Gailhofer *et al.*, (2021) refer to some studies from PwC and Microsoft that quantify the impact of AI on global GHG into a possible decrease of 1.5% – 4%.

Following the purpose of this work, I consider to be relevant to focus on the energy, transport, manufacturing, and agricultural sectors. As Nishant *et al.*, (2020); Gailhofer *et al.*, (2021); Lyu & Liu, (2021) and many other authors explain, generally, applications relate with providing energy demand estimations, monitoring, and optimization of energy consumption. AI systems can also enable the reduction of waste, stimulate resource efficiency, and consequently increase energy efficiency.

Overall, as Gerarden *et al.*, (2017) states, energy-efficient applications ultimately provide a reduction of financial costs and contribute to fight environmental challenges. While extensive research about the possible applications of AI towards sustainable growth and environmental goals have been carried out, following the insights provided by the authors in the field, it is possible to identify several benefits from implementing AI for energy efficiency management which leads me to my first research question:

RQ1) What are the success factors of implementing Artificial Intelligence towards Energy Efficiency and Decarbonization?

On the other hand, challenges related with this implementation are raised by different authors. Haenlein & Kaplan, (2019) focus on how AI systems can be influenced by any bias present in the input data provided for training as, for example, research has shown that self-driving cars are better at detecting lighter skin tones. In the same line, Baldassarre *et al.*, (2017) mention some technical challenges related with the opacity of the algorithms used in AI systems as if the system was a black box and there is still a very limited pool of experts in the area. Nishant *et al.*, (2020) point out the fact that AI data inputs used for training relate with historical information which may limit its value because those data sets do not consider unpredictable human variables as they cannot be integrated into ML models.

Further Dwivedi *et al.*, (2021) highlight ethical and social challenges related with the lack of transparency on the decision-making criteria behind AI systems, data privacy concerns and cybersecurity issues. At the basis of AI systems are data sets comprising information collected from individuals and organizations which, not only raises concerns on cyberattacks but also lack of trust to some entities in the extent to which they do not know the exact purpose of their data usage and storage.

Despite the potential benefits from AI applications to tackle environmental challenges, authors like Aghion *et al.*, (2017); Nishant *et al.*, (2020); Gailhofer *et al.*, (2021); and Kopka & Grashof, (2021) call for attention to the fact that AI systems create a large carbon footprint resulting from the dependency on energy-intensive algorithms that, in turn, rely on strongly energy-consuming datasets and big data centers.

Following the interest of understanding the success factors of implementing AI systems to achieve energy efficiency and ultimately more sustainable businesses, I believe that it is also noteworthy to understand if the challenges currently raised are still verified or if there are any new concerns that should be taken into consideration in the field. Hence, the second research question of this dissertation arises:

RQ2) What are the possible down-sides of implementing Artificial Intelligence towards Energy Efficiency and Decarbonization?

From the literature review conducted throughout this project, it was possible to understand that both opportunities and challenges regarding the application of AI systems to achieve energy efficiency have been identified. At the same time, it was also possible to see how the achievement of sustainable development goals can be related with AI applications. Especially in research carried out within the energy sector, authors like Cubric, (2020); Gailhofer *et al.*, (2021); Kopka & Grashof, (2021); Lyu & Liu, (2021) state that AI systems can be exploited to promote the environmental goals set by the European Union.

The importance of SMEs in this path is also highlighted by several authors as Cagno & Trianni, (2013), Cunha *et al.*, (2020). According to Gerarden *et al.*, (2017), energy consumption is expected to increase to more 30-50% during the next 25 years while SMEs account for 60-70% of industrial pollution worldwide and 60% of carbon emissions. Being the backbone of Europe's economy while representing 99% of all the business in the EU, research conducted by Cagno & Trianni, (2013) showed that 90% of SMEs did not adopt yet any energy-efficiency measure to control its energy consumption and related carbon emissions. Studies developed by the European Commission reveal that sectorial adoption plans of AI technologies are on average of only about 20%.

Hence, while advantages from energy efficiency measures have been studied, there is still an existing gap between this potential of AI systems on energy efficiency and its actual implementation which is frequently named as "the energy efficiency gap", coined by Brown, (2001) as *"the difference between the actual level of investment in energy efficiency and the* *higher level that would be cost-beneficial from the consumer's (i.e.t, the individual's, or firm's) point of view"*.

Considering the urgency towards environmental sustainability and given that energy efficiency and decarbonization have been taking part in all political agendas, we become aware of the importance of understanding the factors influencing the implementation of energy efficiency and decarbonization measures as the usage of AI applications. Further, while there is extensive literature about the technical implications of AI systems, literature is still scarce on the major drivers of managerial decision towards AI applications. As this, my third question arises as:

RQ3) What are the factors influencing the intentionality of managers to implement AI systems towards Energy Efficiency and Decarbonization?

Socio-economical-environmental issues and digitalization have been taking part in the agendas of worldwide governments. Growing attention has been paid to digitalization in organizations and AI has been pointed as a key tool for business growth and to tackle environmental challenges, by the European Commission, and authors like Kopka & Grashof, (2021); Liengpunsakul, (2021); Lyu & Liu, (2021) and many others.

Considering the international dimension of the topic and focusing on the different regional characteristics under institutions and political measures as well as economic structures, Mattes *et al.*, (2015) draw attention to the fact that different developments should not be analyzed under one individual scale.

Hence, considering the utmost interest of understanding the success factors from implementing AI applications, and at the same time the possible down-sides along with the factors influencing the intentionality of managers to implement AI systems to achieve energy efficiency, my main motivation to develop the fourth question arises as aiming to understand to what extent these factors between regions. As so, my fourth research question is:

RQ4) To what extent do the drivers influencing the intentionality of managers to implement AI systems towards Energy Efficiency and Decarbonization differ between countries?

Chapter 4 – Methodology

4.1. Research Model

Research is the systematic and logical search for new and useful knowledge on a specific issue. According to Tarski, (1977) research methodology is a field derived from logic, with the objective to study the scientific method. The scientific method, in turn, reflects the procedures approved by the scientific community to be applied for the exposition and confirmation of a certain theory that can lead. Following this, according to Vergara, (2005) and Manuel Da *et al.*, (n.d.) the classification of the methodology used to develop research documents can be distinguished in two ways, in terms of the ends and in terms of the means. The ends are related with applied and exploratory research, while the means are related with the field study and bibliographic research.

As far as it concerns this research, it has an exploratory dimension, since the digital transformation and environmental goals still have a big space for exploration. Moreover, the factors impacting and influencing the possibility and intentionality of managers to implement Artificial Intelligence systems to empower their green transformation and manage their environmental impacts is not yet well explored. From what I could have access to, this is the first investigation focusing on understanding and exploring the perceptions of managers regarding the Application of Artificial Intelligence to potentialize greener actions on their businesses and potentialize their green transformation both in Portuguese companies and foreign ones, among the European Union.

Having this, it was decided that a qualitative study would be the best technique to fulfill the current investigation's goal because it lays a higher emphasis on the interpretation of phenomena. For instance, "qualitative research is a form of study of society that focuses on how people interpret and make sense of their experiences and the world in which they live" (Vilelas, 2020). Albeit the reply and accession to the interviews was satisfactory, the conclusions of this investigation must be read carefully and always taking into consideration that it is based in a relatively small sample, which implies the impracticality of generalizing. This is presented as one of the main limitations of this investigation, together with the gap in the literature review, although both limitations were already predicted in the beginning of this study.

In Table 4.1, it is possible to observe the relationship between the research objectives, the research questions elaborated in the theoretical approach chapter that derived from the literature review conducted before and so, the respective link to the literature review as well as the data analysis method used.

Table 4.1 - Relationship between literature review, the objectives, and the research questions

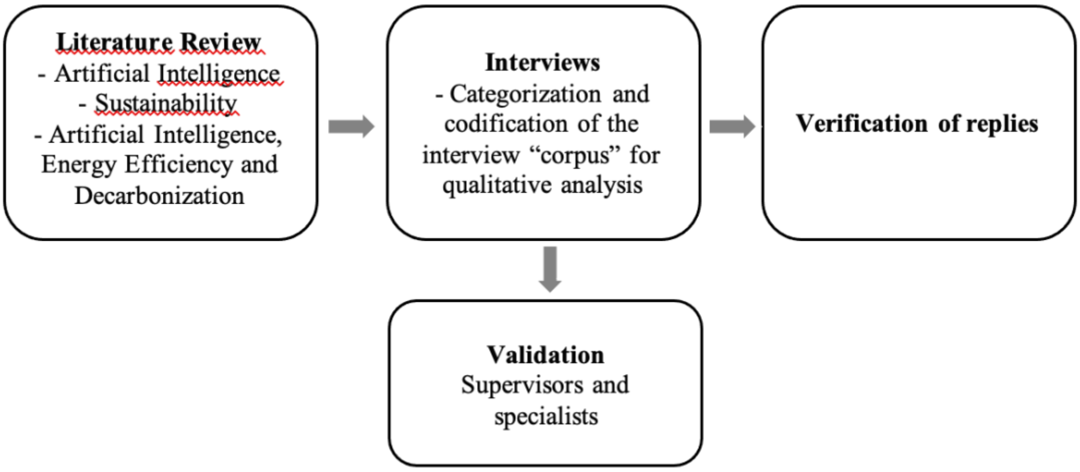
Objectives	Research Questions	Literature Review
(O1) Understand the real impact of implementing AI systems to manage and control their environmental impacts, and understand the factors influencing the possibility and intentionality of companies implementing AI as the tool to potentialize their green transformation	(RQ1) What are the success factors of implementing Artificial Intelligence towards Energy Efficiency and Decarbonization?	Gerarden *et al.*, (2017); International Energy Agency, (2017); Khakurel *et al.*, (2018); Floridi, (2019); Jha *et al.*, (2019); Miller *et al.*, (2020); Nishant *et al.*, (2020); Vinuesa, (2020); Denicolai *et al.*, (2021); Gailhofer *et al.*, (2021); Kopka & Grashof, (2021); Lyu & Liu, (2021); Liu *et al.*, (2022)
	(RQ2) What are the possible down-sides of implementing Artificial Intelligence towards Energy Efficiency and Decarbonization?	Aghion *et al.*, (2017); Baldassarre *et al.*, (2017); Haenlein & Kaplan, (2019); Sun & Medaglia, (2019); Nishant *et al.*, (2020); Dwivedi *et al.*, (2021); Gailhofer *et al.*,

		(2021); Kopka & Grashof, (2021)
	(RQ3) What are the factors influencing the intentionality of managers to implement AI systems towards Energy Efficiency and Decarbonization?	Brown, (2001); Cagno & Trianni, (2013); Gerarden *et al.*, (2017); Cubric, (2020); Cunha *et al.*, (2020); Gailhofer *et al.*, (2021); Kopka & Grashof, (2021); Lyu & Liu, (2021); Pereira *et al.*, (2021); Rosa *et al.*, (2022)
(O2) Understand if the drivers influencing the possibility and intentionality of implementing AI systems to potentialize the green transformation of companies varies between countries	(RQ4) To what extent do the drivers influencing the intentionality of managers to implement AI systems towards Energy Efficiency and Decarbonization differ between countries?	Mattes *et al.*, (2015); Kopka & Grashof, (2021); Liengpunsakul, (2021); Lyu & Liu, (2021)

Source: Self-elaborated

In summary, the present investigation was divided into four phases, namely: the first stage, which was based on bibliographic research and processing of the existing information on the topics; the second, which consisted of transferring the theoretical construct to the field of observation, in order to obtain the best possible confidence in terms of results; the third, which concerns fieldwork and the data collection through interviews and, finally, the fourth step, which consisted of the qualitative analysis of the data collected from the interviews. Figure 4.1 shows the research model applied in the present investigation.

Figure 4.1: Research Model



Source: Self-elaborated

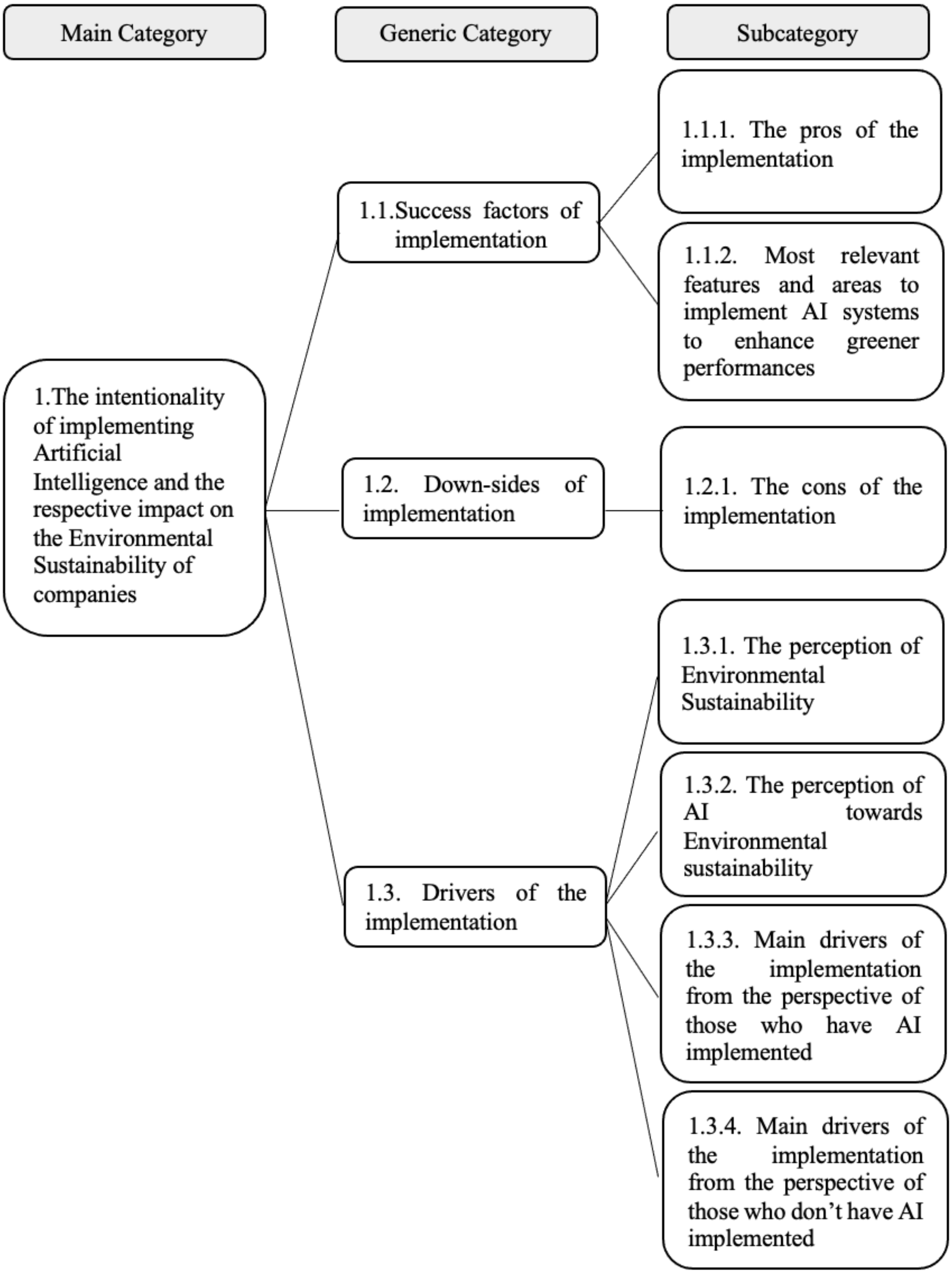
4.1.1. Data collection method

The data collection was carried out through one-to-one semi-structured interviews, conducted from a non-probabilistic convenience sample constituted according to the availability and accessibility of the elements addressed (Manuel Da *et al.*, n.d.), and considering the job position of the target interviewees as the aim is to understand the perspectives from persons with a medium to high decision power and strategic know-how within the organization.

According to Vilelas, (2020), the number of interviews to be carried out for the study to have an acceptable degree of reliability must be between 15 to 20 interviews. At the end of 13 interviews, it was possible to notice a certain degree of repetition of ideas by the interviewees and by adding this factor to the criterion defined by Vilelas, (2020), no further interviews were carried out after 15. However, despite the number of interviews carried out meet the authors' request, it is necessary to bear in mind that the conclusions of this study must be read with the due caution from a small sample.

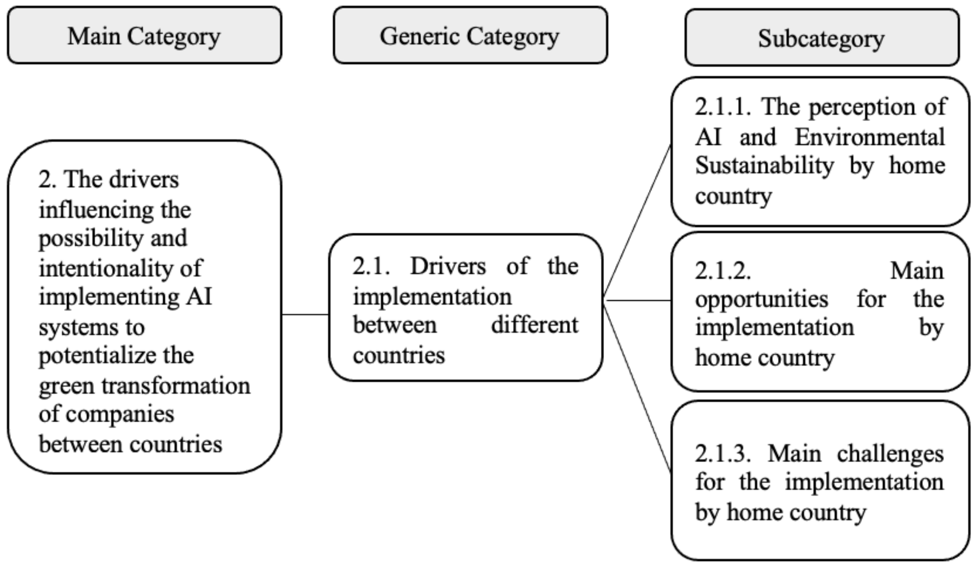
Considering the main purpose of this investigation, it was decided to conduct semi-structured interviews. The decision to conduct semi-structured interviews was based on the idea of not limiting the participants to the script that channels them to the answers, aiming to get more developed answers which allow to different types of information that would not be acquired otherwise. The research followed a pragmatic or inductive character which means it does not focus on reaching true or false conclusions, but to analyze a set of phenomena and facts that allow comparisons to be made and to explore correlations between them. In Figure 4.2, it is possible to analyze the categorization and codification of the interview *corpus*.

Figure 4.2. a): Categorization and codification of the interview for qualitative analysis



Source: Self-elaborated

Figure 4.2. b): Categorization and codification of the interview for qualitative analysis



Source: Self-elaborated

According to Bardin, (2018), content analysis must face three phases, starting with a pre-analysis. That is, organization and systematization of ideas form the interviews. Afterwards, the exploration of material or content should be carried out. At this stage, the material is coded and categorized. Finally, the treatment of the results obtained, and their respective interpretation should be carried out. In this investigation, the content analysis of the information resulting from the interviews, was carried using MAXQDA 2020.1 MAXQDA 2020.1 is a professional software for qualitative data analysis which provides the transcription and analysis of the interviews and allows to categorize relevant information using codes.

4.1.2. Interview's procedure

One very important stage of the research was planning the interview and creating the respective script. The interview script built was organized in two groups: the first one, including 4 questions prepared with the aim of characterizing the sample, the second one, including questions that aim to achieve the study main objective, which is to analyze the intentionality and possibility of implementing Artificial Intelligence towards greener businesses, addressing the pros and cons and then considering the suitability and the relevance of the implementation of these systems, with this objective.

The interviewees were contacted through LinkedIn app and website, or via email, to participate in a research project that aims to understand the factors influencing managers and business strategies regarding the implementation of AI techniques to make them greener, improving their energy efficiency, productivity and, ultimately, sustainability. The interviews were conducted via Zoom platform, Microsoft Teams or by telephone.

The interviews were performed from the July 1, 2022, until July 22, 2022, they took around 20 minutes and were all audio recorded, bearing in mind that in each one, personal data would always be kept into absolute confidentiality. At the beginning of each interview, the goal of the investigation was always clarified and the importance of knowing cases of companies that didn't have any progress in the field was also highlighted, due to the importance of trying to understand why, what are the obstacles and if there is any project or intention to adopt such strategy in the future. For the data analysis, all the 15 audio interviews were carefully transcribed and most of them translated to English.

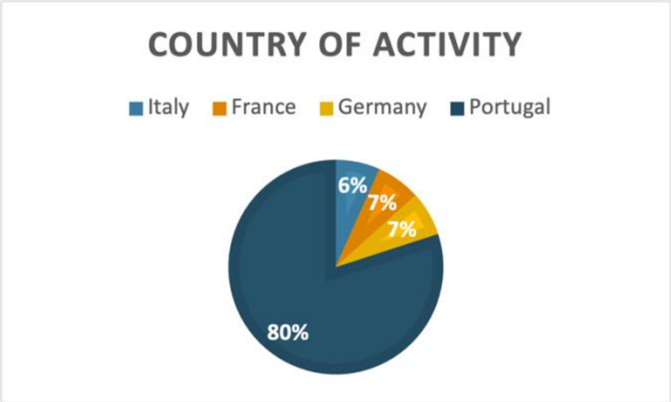
4.2.Sample characterization

This investigation was conducted over a probabilistic sample, as the individuals were chosen from a specific population. In this case, and considering the purpose of this study, the population was related with the sectors of activity which are pointed as key to bridge digitalization and green transformation, according to several studies and reports like DIGITALEUROPE, (n.d.).

Hence, to allow the sample characterization, parameters like country and sector of activity, current position in the organization and the numbers of years of experience were considered. Parameters like gender were not considered because the majority of the participants asked for complete confidentiality.

As Figure 4.3 shows, from the 15 professionals interviewed, 80% was from companies based in Portugal. The remaining interviewees, 7% are from France, 7% from Germany and 6% from Italy.

Figure 4.3: Companies' Country of Activity



Source: Self-elaborated

Within this, as presented in Figure 4.4, the majority were from the agricultural sector (53%), and 40% were related with the industry sector, and among the remaining, 7% were from the retail sector.

Figure 4.4: Companies' Sector of Activity

Source: Self-Elaborated

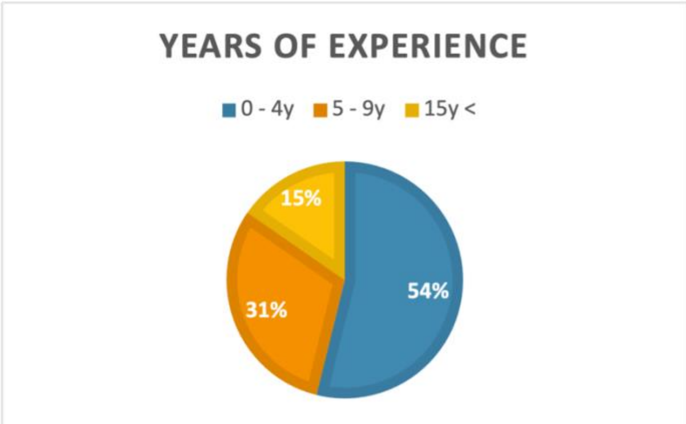
Regarding the current position within the firms, as Figure 4.5 shows, the interviewees were in their majority Sustainability Managers (40%), 33% were CEOs, 20% were Project Managers and the minority were AI Specialists.

Figure 4.5: Interviewees Current Position within the Company

Source: Self-elaborated

Finally, as far as it concerns the years of experience working the current position, the majority of the interviewees, 54%, has been in the current position for less than 4 years, while 31% already has between 5 and 9 years of experience and only 15% has more than 15 years in the current position, as described in Figure 4.6.

Figure 4.6: Years of Experience working in the current position



Source: Self-elaborated

Chapter 5 – Data Analysis and Discussion

In this chapter, it will be done an analysis of the data gathered form the interviews and discuss it accordingly with the literature conducted throughout Chapter 1, about the implementation of Artificial Intelligence and the Businesses' Environmental Sustainability. More precisely, we will be discussing the intentionality of implementing AI and its respective impact on mitigating environmental challenges for companies.

5.1. Success factors of the implementation

For the purpose of this investigation, the first research category aimed to explore the success factors of the implementation of Artificial Intelligence to potentialize Businesses' Environmental Sustainability. To do so, the pros of applying systems and machines AI based were explored, considering a broader perspective of the tool and finally, considering the most relevant features of this technology, along with the areas where its implementation could have a significant impact.

Table 5.1 shows some of the principal arguments mentioned by the interviewees regarding the success factors of the implementation of AI systems. Authors like Denicolai *et al.*, (2021); Kopka & Grashof, (2021); Liu *et al.*, (2022) mentioned the capability of AI to help building more efficient processes both in relation to machine operationalization, and to resources management. Generally, as it can be seen in Table 5.1, most of the participants recognize that the implementation of AI based systems provides indeed the optimization of processes along with a greater consistency over the production chain. Further, the great majority of the interviewees also highlighted how the application of AI techniques brings advantages such as optimization of resources and utilities usage, time sparing on production processes, increased productivity and consequently, costs reduction as the International Energy Agency, (2017); Gerarden et al., (2017); Vinuesa, (2020); Denicolai *et al.*, (2021) and Kopka & Grashof, (2021) defended.

Ultimately, this leads us to the reallocation of the human resources from repetitive and tasks that can be painful to more added-value ones that some interviewees state it as a key factor, confirming what Floridi, (2019) emphasizes regarding AI as an interactive and self-learning system, capable of dealing with tasks that would otherwise require human intelligence and action to be performed. In a broader perspective, this analysis confirms that this disruptive technology is becoming an element constantly affecting social, economic, and environmental aspects of businesses as many authors like Nishant *et al.*, (2020) have been presenting.

Table 5.1 – Success factors of the implementation considering the pros of Artificial Intelligence based systems

Text	Generic Category	Subcategory	Times mentioned	Interviewees
Optimized processes with better allocation of resources and efficient management of utilities, and increased consistency over production.	1.1.	1.1.1	12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 14, 15
Time spared, increased productivity and costs reduction.	1.1.	1.1.1	10	1, 2, 3, 4, 5, 6, 7, 9, 14, 15
Reallocation of human resources from painful and monotonous tasks to more added value ones.	1.1.	1.1.1	5	3, 4, 9, 10, 12

Source: Self-elaborated

Khakurel *et al.*, (2018) defended that different possible applications and the impacts of AI systems towards the reduction of businesses' environmental impacts remain largely unanswered. Considering the most relevant areas for AI implementation and its most relevant features towards more environmentally sustainable businesses, Lyu & Liu, (2021); Nishant *et al.*, (2020); Gailhofer *et al.*, (2021) explained that AI can be implemented to create efficient buildings and facilities, monitoring, and optimizing energy consumption, and increase energy efficiency and environmental performance of the business by reducing wastes and emissions. As represented in Table 5.2, most of the interviewees recognize that AI could be applied in their companies to turn their offices and factories or wineries, depending on the sector of activity, into efficient buildings, capable of efficiently integrate energy, optimize energy consumption, reducing wastes and emissions.

Floridi, (2019) explained that AI can be applied in manufacturing facilities to get more energy from the same unit of input, helping these types of businesses to increase their outputs, reducing their energy and water waste and consequently, becoming more energy efficient. Further, the author emphasized that AI systems can provide accurate predictions of energy demands and optimize energy usage based on the capability to continuously collect and process large amounts of data to conceptualize consumer behaviour and provide energy according to those patterns.

Liu *et al.*, (2022) showed that AI based applications can detect and predict machine failures, saving energy and maintenance costs and reducing energy wastes, which significantly improves energy efficiency for the business. Ultimately, AI provides intelligent decision-making systems and a better management of processes. From Table 5.2, it is possible to see that the majority of participants also mention these AI features and emphasize that implementing AI throughout production processes, on a commercial side, would provide sales and order predictions, reducing production wastes and providing higher controls over production processes. On a more operational and environmental perspective, the interviewees support the fact that this technology can be helpful to detect and predict machine failures, which in turn, reduces maintenance costs and energy wastes and provides optimized processes.

Considering this, more than half of interviewees highlighted that implementing AI techniques in the decision-making processes or tasks would help to turn into greener supply chains and even to innovate and develop greener products, explaining that with all the data the systems can integrate it could help deciding on the greener solutions for packaging, for example, or as far as it concerns distribution solutions.

Jha *et al.*, (2019) defended that, in the agricultural sector, AI enable weather forecasting and an efficient exploration of soils, helping with tasks like soils' analysis and enhancing the management of resources like water, nutrients, the control of pesticides and its pollution effects. Hence, according to authors, AI techniques allow to develop intelligent production systems which promote environmental sustainability of the business. As Table 5.2, some of the participants stated that AI would allow to have systems and machines on the field. These machines would provide more accurate analysis of the soil, information about plantations and vineyards down to the minute, and help with climate control, based on the ability to forecast weather. This provides more efficient and greener business models by enabling a more efficient management of resources like water and agricultural products.

Additionally, to what is raised by the authors, some participants also shared that the possibility to put machinery on the field, capable of doing what would otherwise require human hands, would enable to allocate people to value-added tasks, making them more motivated and not so exposed to harmful situations.

Table 5.2 – Success factors of the implementation considering the most relevant features and areas for AI implementation

Text	Generic Category	Subcategory	Times mentioned	Interviewees
Will allow to build energy efficient buildings and create intelligent systems that can be implemented to help managing utilities usage, increasing energy efficiency, and reducing emissions.	1.1.	1.1.2	12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13
Will be useful in production processes because it will allow to create solid predictions for orders and sales, reducing production waste and providing a higher control over the process.	1.1.	1.1.2	11	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 13
Will be helpful for predictive maintenance (detecting and predicting machine failures), reducing maintenance costs and energy waste and providing optimized and greener production processes.	1.1.	1.1.2	9	3, 4, 6, 7, 9, 10, 11, 14, 15
Will be helpful in decision-making, providing a better management of processes and helping to generate greener supply chains and even greener products.	1.1.	1.1.2	7	5, 6, 7, 8, 10, 11, 15
Will allow to have systems and machines on the field that facilitate analysis of the soil, control plantations and vineyards, forecast weather and help with climate control.	1.1.	1.1.2	6	1, 2, 3, 4, 8, 9
Will allow to put machinery on the field enabling people to do more value-added tasks, making them more motivated.	1.1.	1.1.2	5	3, 4, 9, 10, 12

Source: Self-elaborated

5.2. Downsides of the implementation

The second research category aimed to explore the possible downsides of the implementation of Artificial Intelligence to potentialize Businesses' Environmental Sustainability. To do so, the main challenges emphasized by the interviewees related with the implementation of AI based systems and machines were considered, while trying to understand their perspective towards the challenges raised by many authors.

Table 5.3 – Downsides of the implementation considering the main challenges raised by the interviewees

Text	Generic Category	Subcategory	Times mentioned	Interviewees
AI is still on a very low level of maturity. It is only as good as the assumptions we give it, requiring constant monitorization. It works the best the more standardized the processes are.	1.2.	1.2.1	9	1, 2, 3, 6, 7, 9, 11, 14, 15
It is hard and takes a long time to develop a software, implement it and make it run correctly.	1.2.	1.2.1	7	1, 3, 4, 6, 10, 12, 13
The huge investment and initial costs	1.2.	1.2.1	7	1, 3, 4, 6, 9, 10, 12
The lack of know-how	1.2.	1.2.1	5	1, 2, 6, 8, 9
The resistance of human resources to accept change and automation is always the biggest barrier.	1.2.	1.2.1	4	2, 6, 7, 8
This kind of technology requires lots of data and is based on extra giant servers which carry a huge ecological impact	1.2.	1.2.1	2	1, 9
It can depend on the activity sector, but this technology can raise many concerns regarding data privacy	1.2.	1.2.1	1	6

Source: Self-elaborated

Table 5.3 shows that during the interviews different challenges were highlighted among which the low level of maturity of AI was one of the most noted. A great part of the participants emphasized that AI systems are more helpful the most standardized processes are because the technology is not developed enough to integrate unpredictable variables, being still very dependent on information provided by human workforce and requiring constant monitorization as Haenlein & Kaplan, (2019); Nishant *et al.*, (2020) and Dwivedi *et al.*, (2021) alerted. Furthermore, interviewees stressed the lack of know-how that still exists regarding AI and how hard it is and how long it takes to develop and implement an AI based software or machine that will run properly, supporting the challenges raised by Baldassarre *et al.*, (2017) related with the opacity of these systems and pointed the limited pool of experts that still exists in the area.

This leads to the concern of required investment and initial costs required to develop and implement this kind of applications which was raised by some of the participants on top of the challenges explored by many authors in the area. The interviewees explained that the equipment or mechanisms must be tested to ensure it is working properly but also to evaluate to what extent it brings benefits to the company which is something that requires spending time and very high costs. Likewise, the resistance of human resources to accept change and automation was underlined as the biggest barrier as Sun & Medaglia, (2019) and Dwivedi *et al.*, (2021) considered. Nonetheless, some interviewees emphasized that this should not be a real threat and the human resources should be educated upon to understand this replacement as a complementary work that only allows them to become of more added-value in tasks that require human intelligence and soft-skills as Sun & Medaglia, (2019) defended.

Two interviewees recognized the fact that AI systems carry a huge ecological impact derive their results and outputs are derived from giant servers and datasets which are strongly energy-consuming like Aghion *et al.*, (2017); Nishant *et al.*, (2020); Gailhofer *et al.*, (2021) and Kopka & Grashof, (2021) emphasized. Concerns on cyberattacks and the luck of trust by some entities regarding the usage of data collected and storage raised by Dwivedi *et al.*, (2021) were raised by only one interviewee.

5.3. Drivers of the implementation

The third research category of this investigation aimed to understand the drivers of the implementation of Artificial Intelligence to potentialize Businesses' Environmental Sustainability. For this purpose, it was considered the perception of the interviewees regarding environmental sustainability and its importance within the company. It also considers the perspective of those who already have AI techniques implemented in their businesses and the perspective of those who still don't have it implemented and their perceptions on it. Finally, it also explores to what extent AI is seen as a reliable tool to manage environmental impacts.

Table 5.4 – Main drivers of the implementation considering the perspective of Environmental Sustainability within the company strategy

Text	Generic Category	Subcategory	Times mentioned	Interviewees
Sustainability is a source of competitive advantage	1.3.	1.3.1	12	1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 14, 15
The market, our customers and investors are demanding sustainability practices incrementally	1.3.	1.3.1	12	1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14
Being aligned with the Paris Agreement, becoming energy efficient and carbon neutral	1.3.	1.3.1	9	1, 2, 3, 5, 8, 9, 10, 14, 15

Source: Self-elaborated

Table 5.4 summarizes the perception of the interviewees regarding the relevance of environmental sustainability practices and concerns within their companies. Pereira *et al.*, (2021) conceptualized that sustainability and environmental issues are topics of growing attention within companies. As it can be seen, 13 out of 15 interviewees consider sustainability as a source of competitive advantage, among one of them states that *"sustainability issues are undoubtedly, at this moment, a concern of the whole business world"*. However, the interviewee also highlighted that it may be just for a matter of looking good in the market. Indeed, most of the interviewees raised the fact that both investors and customers are increasingly demanding sustainability practices and deliverables. Nonetheless, most of the interviewees also emphasized the desire to be aligned with the Paris Agreement as a driver on their business.

Table 5.5 – Main drivers of the implementation considering the perspective of AI as a reliable tool to potentialize Environmental Sustainability of the Business

Text	Generic Category	Subcategory	Times mentioned	Interviewees
It should be understood as the strategic tool to support in this green transition	1.3.	1.3.2	7	1, 3, 4, 5, 9, 10, 12
If we have artificial intelligence implemented, we can be even more efficient in the use of resources.	1.3.	1.3.2	7	3, 4, 5, 9, 10, 14, 15
It will be a key tool to meet environmental targets once it is fully developed	1.3.	1.3.2	3	2, 7, 11
Digitalization is mandatory for us to be able to deliver the values that our investors are looking for	1.3.	1.3.2	2	6, 13

Source: Self-elaborated

Table 5.5 reflects the perceptions of the interviewees regarding the reliability of AI to potentialize the Environmental Sustainability of their businesses, from which it is possible to see that all the participants perceive the tool as a key element towards the environmental goals as Cubric, (2020); Gailhofer *et al.*, (2021); Kopka & Grashof, (2021); Lyu & Liu, (2021) and Rosa *et al.*, (2022) defended. Only 3 of the interviewees highlighted that firstly it must be fully developed to become a key tool in the green transformation of businesses which is a new concern to add to what has already been raised my authors in the field.

Table 5.6 - Main drivers of the implementation from the perspective of those who have AI systems in the company

Text	Generic Category	Subcategory	Times mentioned	Interviewees
We already have AI systems implemented in the company that ultimately reflect more efficient performances	1.3.	1.3.3	7	5, 6, 7, 10, 11, 13, 14
The overall balance is positive. It provided us more control over our operations and a more efficient business	1.3.	1.3.3	4	6, 7, 10, 14
We have it implemented for decision-making purposes. It gathers data that helps us making greener choices for the business, and provides solid order prediction which helps reduce production wastes	1.3.	1.3.3	4	6, 7, 11, 14
We have it implemented in our office buildings. We have systems that manage utilities automatically	1.3.	1.3.3	3	5, 6, 13
We have it implemented in our production processes. It enables us to be more efficient and helps with predictive maintenance	1.3.	1.3.3	3	7, 11, 14
There are digital tools easier to implement then others. Developing and implement AI based software or machines is very complex	1.3.	1.3.3	3	7, 10, 14
We have it implemented in the field, helping with weather forecast and resources management	1.3.	1.3.3	1	10

Source: Self-elaborated

In the perspective of those who already any type of AI based system implemented in the business, Table 5.6 shows that 4 out of 7 recognize a positive balance towards more environmentally sustainable performances. Among the interviewees, AI applications are being used in decision-making processes taking advantage from the capability of gathering huge amounts of data and develop algorithms that help build greener supply chains and consequently products or services with a reduced carbon footprint. Others also have AI systems integrated that manage utilities usage in their buildings automatically or in the production processes, for predictive maintenance purposes, enabling to reduce energy wastes and maintenance costs as Gerarden *et al.*, (2017) analyzed. Only one interviewee from the agricultural sector confirmed to have AI mechanisms implemented on the field, providing information down to the minute about the farm and potentializing resources management based on that.

Regarding the biggest challenge to implement these systems, the participants mentioned the complexity of developing it, on a more technical level but also due to all the bureaucracy that is required.

Table 5.7 - Main drivers of the implementation from the perspective of those who do not have AI systems in the company

Text	Generic Category	Subcategory	Times mentioned	Interviewees
We still don't have any AI systems implemented in the company	1.3.	1.3.4	8	1, 2, 3, 4, 8, 9, 12, 15
The lack of know-how and the complexity to develop an AI based system would be a big challenge	1.3.	1.3.4	7	1, 2, 3, 4, 8, 9, 12
The most relevant areas to implement AI based systems would be related with the production processes	1.3.	1.3.4	7	1, 3, 4, 8, 9, 12, 15
The initial investment and costs required are a big constraint	1.3.	1.3.4	5	1, 3, 4, 9, 12
We are making efforts to bring this kind of technology into our company	1.3.	1.3.4	5	1, 3, 4, 8, 15
The most relevant areas to implement AI based systems would be related with decision-making processes to build models that are based on greener distribution options, raw materials less harmful to the environment	1.3.	1.3.4	3	2, 3, 15
We could use AI based systems to make our offices efficient buildings that help reduce our carbon footprint	1.3.	1.3.4	2	4, 8

Source: Self-elaborated

Brown, (2001) and Cagno & Trianni, (2013) alerted to the existing gap between the potential of AI systems on energy efficiency and its actual implementation and Pereira *et al.*, (2021) identified that despite sustainability and environmental practice are growing concerns within organizations, many of them still do not consider them among their strategies. However, from Table 5.7, in the perspective of those who do not have any AI based system implemented in the business to potentialize its Environmental Sustainability based on energy efficiency practices or decarbonization measures, 5 out of 8 participants recognized to be working to bring it to the company.

When questioned about the main reasons leading their companies to still have not adopted AI, the lack of know-how and the related complexity to develop an application that runs properly was mentioned 7 out of 8. The initial investment and the lack of funding or support was also mentioned as one the biggest challenges by almost of the participants. Nonetheless, all these interviewees noted some areas where AI based tools could be implemented to enhance their environmental performance like in production and decision-making processes. Only two of them emphasized that it could be implemented to turn facilities into intelligent and efficient buildings which ultimately helps to reduce their carbon footprint.

5.4. Drivers of the implementation between different countries

The fourth and last general research category of this investigation aimed to understand the to what extent the drivers influencing the possibility and intentionality of implementing AI systems to potentialize Businesses' Environmental Sustainability vary between home countries. To do so, the company's home country was considered as the basis for the data analysis considering the interviewees perception on AI towards Environmental Sustainability and lastly, the raised opportunities and challenges.

Table 5.8 - Main drivers of the implementation considering the perspective of the relevance of Environmental Sustainability within the company and of AI as a reliable tool to potentialize it from interviewees based in Portugal

Text	Generic Category	Subcategory	Times mentioned	Interviewees
Sustainability is a source of competitive advantage	2.1	2.1.1	7	3, 4, 6, 7, 8, 9, 13
The market, our customers and investors are demanding sustainability practices incrementally	2.1	2.1.1	6	3, 4, 7, 8, 9, 10
AI should be understood as the strategic tool to support in this green transition.	2.1	2.1.1	5	3, 4, 9, 10, 12
Being aligned with the Paris Agreement, becoming energy efficient and carbon neutral is one of our main goals for the near future	2.1	2.1.1	4	3, 8, 9, 10
AI will be a key tool to meet environmental targets once it is fully developed	2.1	2.1.1	2	7, 11
Digitalization is mandatory for us to be able to deliver the values that our investors are looking for.	2.1	2.1.1	2	6, 13

Source: Self-elaborated

Table 5.9 - Main drivers of the implementation considering the perspective of the relevance of Environmental Sustainability within the company and of AI as a reliable tool to potentialize it from interviewees based in other European countries

Text	Generic Category	Subcategory	Times mentioned	Interviewees
Sustainability is a source of competitive advantage	2.1	2.1.1	5	1, 2, 5, 14, 15
Being aligned with the Paris Agreement, becoming energy efficient and carbon neutral	2.1	2.1.1	5	1, 2, 5, 14, 15
The market, our customers and investors are demanding sustainability practices incrementally	2.1	2.1.1	3	1, 5, 14
AI should be understood as the strategic tool to support in this green transition	2.1	2.1.1	2	1, 5
AI will be a key tool to meet environmental targets once it is fully developed	2.1	2.1.1	1	2

Source: Self-elaborated

Table 5.8 and Table 5.9 present the main drivers of the implementation considering the perspective on the relevance of Environmental Sustainability within the company and on AI as a reliable tool to potentialize it from the interviewees based in Portugal and in other foreign countries, respectively. Overall, both groups highlight environmental sustainability as a concern with the companies and recognize AI as a potential and reliable tool to help towards the targets, supporting what Cubric, (2020); Gailhofer *et al.*, (2021); Kopka & Grashof, (2021) and Lyu & Liu, (2021) shared on the topic.

Nonetheless, it is interesting to underline that while Portuguese based interviewees put align the concerns regarding sustainable practices with the increasing market demands, all the interviewees from other European countries put the desire be aligned with the European Green Deal as one the main drivers of the implementation. At the same time, as far is concerned the perceptions on AI as a reliable tool to support businesses becoming greener, there are two Portuguese based participants emphasizing that digitalization, and specially AI, is mandatory to make them able to deliver the values that our investors are looking for.

Table 5.10 - Main drivers of the implementation considering the opportunities highlighted by interviewees based in Portugal

Text	Generic Category	Subcategory	Times mentioned	Interviewees
Will allow to build energy efficient buildings and create intelligent systems that can be implemented to help managing utilities usage, increasing energy efficiency, and reducing emissions.	2.1.	2.1.2	9	3, 4, 6, 7, 8, 9, 10, 12, 13
Will be useful in production processes because it will allow to create solid predictions for orders and sales, reducing production waste and providing a higher control over the process.	2.1.	2.1.2	8	3, 4, 6, 7, 9, 10, 11, 13
Will be helpful for predictive maintenance (detecting and predicting machine failures), reducing maintenance costs and energy waste and providing optimized and greener production processes.	2.1.	2.1.2	7	3, 4, 6, 7, 9, 10, 11
Will be helpful in decision-making, providing a better management of processes and helping to generate greener supply chains and even greener products.	2.1.	2.1.2	5	6, 7, 8, 10, 11
Will allow to put machinery on the field enabling people to do more value-added tasks, making them more motivated.	2.1.	2.1.2	5	3, 4, 9, 10, 12
Will allow to have systems and machines on the field that facilitate analysis of the soil, control plantations and vineyards, forecast weather and help with climate control.	2.1.	2.1.2	4	3, 4, 8, 9

Source: Self-elaborated

Table 5.11 - Main drivers of the implementation considering the opportunities highlighted by interviewees based in other European countries

Text	Generic Category	Subcategory	Times mentioned	Interviewees
Will allow to build energy efficient buildings and create intelligent systems that can be implemented to help managing utilities usage, increasing energy efficiency, and reducing emissions.	2.1.	2.1.2	3	1, 2, 5
Will be useful in production processes because it will allow to create solid predictions for orders and sales, reducing production waste and providing a higher control over the process.	2.1.	2.1.2	3	1, 2, 5
Will be helpful for predictive maintenance (detecting and predicting machine failures), reducing maintenance costs and energy waste and providing optimized and greener production processes.	2.1.	2.1.2	2	14, 15
Will be helpful in decision-making, providing a better management of processes and helping to generate greener supply chains and even greener products.	2.1.	2.1.2	2	5, 15
Will allow to have systems and machines on the field that facilitate analysis of the soil, control plantations and vineyards, forecast weather and help with climate control.	2.1.	2.1.2	2	1, 2
Will allow to put machinery on the field enabling people to do more value-added tasks, making them more motivated.	2.1.	2.1.2	2	1, 2

Source: Self-elaborated

As far as it concerns the main drivers considering the opportunities noticed by both groups of interviewees, deriving from Table 5.10 and Table 5.11, it is worth to mention that the same opportunities for implementation were identified on the basis that with the support of AI, processes could be optimized, increasing the quality of the products, and making businesses companies even more efficient with the resources used. Additionally, interviewees mention that AI can be helpful in decision-making processes to develop efficient and sustainable strategies as Rosa *et al.*, (2022) notice.

Table 5.12 - Main drivers of the implementation considering the challenges raised by interviewees based in Portugal

Text	Generic Category	Subcategory	Times mentioned	Interviewees
The huge investment and initial costs	2.1	2.1.3	6	3, 4, 6, 9, 10, 12
AI is still on a very level of maturity. It is only as good as the assumptions we give it, requiring constant monitorization. It works the best the more standardized the processes are.	2.1	2.1.3	5	3, 6, 7, 9, 11
It is hard and takes a long time to develop a software, implement it and make it run correctly.	2.1	2.1.3	5	4, 6, 10, 12, 13
The lack of know-how	2.1	2.1.3	3	6, 8, 9
The resistance of human resources to accept change and automation is always the biggest barrier.	2.1	2.1.3	3	6, 7, 8
This kind of technology requires lots of data and is based on extra giant servers which carry a huge ecological impact	2.1	2.1.3	1	9
It can depend on the activity sector, but this technology can raise many concerns regarding data privacy	2.1	2.1.3	1	6

Source: Self-elaborated

Table 5.13 - Main drivers of the implementation considering the challenges raised by interviewees based in other European countries

Text	Generic Category	Subcategory	Times mentioned	Interviewees
AI is still on a very level of maturity. It is only as good as the assumptions we give it, requiring constant monitorization. It works the best the more standardized the processes are.	2.1	2.1.3	4	1, 2, 14, 15
The lack of know-how	2.1	2.1.3	2	1, 2
The resistance of human resources to accept change and automation is always the biggest barrier.	2.1	2.1.3	1	2
The huge investment and initial costs	2.1	2.1.3	1	1
It is hard and takes a long time to develop a software, implement it and make it run correctly.	2.1	2.1.3	1	1
This kind of technology requires lots of data and is based on extra giant servers which carry a huge ecological impact	2.1	2.1.3	1	1

Source: Self-elaborated

Analyzing the main drivers of the implementation considering the challenges raised interviewees based in Portugal and in other foreign countries, from Table 5.12 and Table 5.13, allowed to understand that the same barriers are mentioned by both groups, sustaining what many authors like Baldassarre *et al.*, (2017); Haenlein & Kaplan, (2019) and Nishant *et al.*, (2020) noted. Among this, the low level of development of this technology which is still very dependent on constant control and on the data provided by human resources is one the most mentioned.

Nevertheless, the huge investments and initial costs are highlighted as the main challenges among Portuguese interviewees that say to be very difficult to get access to funds and governmental supports, while it is only mentioned by one interviewee based in another

European country. The lack of know-how is another challenge that interviewees emphasized on a balanced perspective but the complexity and the long time to develop and implement a software that runs properly is something raised by half of the Portugal based participants but by only one participant based abroad. Another interesting point is that data privacy matters were only mentioned as a challenge by one Portuguese interviewee in the whole group of participants. As Mattes *et al.*, (2015) emphasized, and considering the international dimension of the topic, different developments should not be analyzed under one individual scale.

Chapter 6 – Conclusion

6.1. Final Considerations

Following the previous analysis of the data collected from the interviewees and the corresponding discussions with previous authors have raised about Artificial Intelligence and the Businesses’ Environmental Sustainability, this last chapter aims to take final considerations from the previous results and provide the key findings of this investigation. Artificial Intelligence has been a topic on public agendas over the last decades with studies about this technology increasing meaningfully across business sectors. Further, it has been proofing to help people and business improving their performance on daily activities. At the same time, environmental challenges and climate crises have been presenting complex issues on top of public agendas.

As a starting the point, the first research question of this investigation aimed to understand the success factors associated with the implementation of AI based systems to help companies become more efficient and less harmful to the environment. From the interviews conducted, it was possible to conclude that 80% of the interviewees pointed as the biggest success factor the optimization of processes, with a more effective allocation of resources and a more efficient management of their energy usage, which is translated into an increased consistency over the production process. From this 80%, only 41,67% already have any kind of AI based system implemented in the company which means the other participants answered based on their beliefs of what the technology can do for the business. In light of this, another important factor highlighted by more than 50% of the interviewees was related with the time sparing, reduced costs, and increased productivity.

The possibility of reallocating human resources from painful and monotonous tasks to those that effectively required human action and of more added value was only mentioned by one third of the interviewees that explain that this good for the company because people would be more focused on doing a certain job and therefore would certainly do it better. Ultimately, the implementation of this tool can potentialize the creation of new job positions. These interviewees consider this of importance to be mentioned because the well-being of people is also deeply related with sustainability.

Still regarding the first research question, 80% of the interviewees noted that AI techniques could be applied in their buildings and facilities, to transform them into energy efficient infrastructures, capable of managing utilities usage automatically and helping to reduce emissions from daily operations. Additionally, in light of the most relevant features and areas for AI implementation towards energy efficiency and more environmentally friendly performances, the interviewees also noticed the possible application in production processes, for predictive maintenance purposes reflecting reduced maintenance costs and energy wastes along with optimized systems and for resources management purposes.

Half of the interviewees also considers the implementation on the decision-making processes because they believe it would allow to build greener supply, helping with decisions related with packaging process, in eco-design, and materials to use, for example.

The second research aimed at exploring the possible down-sides the implementation considering the challenges raised the interviewees. Following the conducted interviewees, it was possible to understand that the most concerning downside relates with low level of development that the tool still presents. 60% of the interviewees believe that the tool is still very dependent on human resources, being only as good as the assumptions they give it and requiring constant monitorization. Consonantly, the complexity to develop and implement any AI based software is seen as a significant constraint. Another important factor to mention is that the required initial investment and the difficulty to get financial support were referred by around 50% of the interviewees.

The lack of know-how and the resistance of human resources to accept change and automation was highlighted by approximately one third if the participants. Nevertheless, others believe that the threat of replacement should not exist because the tool is still very dependent on human resources and ultimately it will lead to the creation of new job position. Interesting is to mention that data privacy concerns were only raised by one interviewee who also admitted that it can depend on the sector of activity being affected. Lastly, the impressive ecological footprint of AI systems was only mentioned by 2 participants as a constraint of implementing this technique.

Following the purpose of this investigation, the third research question aimed to investigate the main drivers of the implementation of Artificial Intelligence to potentialize Businesses' Environmental Sustainability, exploring the relevance of environmental sustainability within the companies of the interviewees, their perception of AI as a reliable tool in the process and considering the perspective of those who already have this technology implemented in the company and the perspective of those who don't have yet.

Firstly, all the interviewees recognized sustainability and environmental matters as a concern in their companies. 80% consider this as a source of competitive advantage, on the basis that both investors and customers are demanding sustainability practices increasingly. Within this, 9 interviewees also highlighted the importance of being aligned with the Paris Agreement and European goals towards a healthier planet. Interesting to mention is that two interviewees mentioned that indeed sustainability and environmental issues are a pressing and existing concern that must be considered, however, they questioned if companies are doing it for the right reasons or just to have a good impression on the market.

Following this, when asked about the relevance of AI as a reliable tool to potentialize environmental sustainability in their businesses, around 50% of the participants believes that AI should be seen as a strategic tool to support in this green transition at the companies on the basis that if AI is implemented, they can be even more efficient using and managing their resources, reducing wastes. Further, two interviewees defended that digitalization is mandatory to make them able to deliver what investors are looking for. Overall, the participants see AI as the key technology to develop urgent solutions. Nonetheless, 3 interviewees emphasized that in their perspective, AI is still not developed until the point it can be enough to overcome environmental issues.

Considering the perspective of those who already AI based systems or machines implemented in their companies, 4 out of 7 considered the overall balance of the implementation as a positive measure explaining that it provided more control over operations and a more efficient business. AI techniques were implemented in production processes, both in factories and in farms, helping to manage resources more efficiently and reducing wastes that are harmful for the environment. 3 of the interviewees shared to also have implemented AI in their office buildings to make it efficient and reduce carbon emissions. Lastly, 3 out of 7 participants emphasized that are some digital tools easier to implement than others and that developing AI based systems and make it work properly is a very complex process.

Finally, on the perspective of those who do not have any AI technique implemented yet, the lack of know-how and the complexity to develop an AI based system were pointed by 7 out 8 interviewees as a big challenge to bring the tool to the company. Another crucial constraint pointed by 5 participants was the initial investment that is required sustained by the difficulty to get funds or any financial support. However, 5 out these 8 interviewees emphasized to be already making efforts or involved in projects to implement AI based systems in their companies to potentialize more efficient performances, financially and environmentally. Also interesting to highlight is that these employees refer the same most relevant features of AI and areas of business to implement the tool.

Considering the purpose of the investigation to also understand to what extent the drivers of implementation vary between countries, the last and fourth research question aims to tackle this by analyzing the data collected between Portuguese based interviewees and interviewees based in other European countries. From the interviewees conducted, it was possible to verify that both groups recognize environmental sustainability as a concern in their company. However, while participants based in other European countries than Portugal emphasized the importance of being aligned with the European goals, Portugal based participants emphasized the market demands on sustainability practices. Within this, both groups also recognize AI as a potential tool to support in this green transformation.

As far as it concerns the opportunities identified by participants based in Portugal and those based abroad, it is interesting to note that both mention the same factors, emphasizing that processes could be optimized, increasing the quality of the products, and making businesses companies even more efficient with the resources used.

Regarding the analysis of the main drivers considering the challenges raised by interviewees, it is worth to highlight that the same barriers are mentioned by both groups. However, Portugal based participants underline the huge investments and initial costs are highlighted as the main challenges while participants based abroad focus on the low level of development of the tool and the complexity of processes to develop and implement those systems.

Overall, considering all the content analyzed and discussed throughout this investigation, it seems clear that sustainability and environmental matters are undoubtably a concerning part of businesses' agendas nowadays while AI is being explored and studied ever more. Considering the global context, both fields arise as merging areas to tackle environmental challenges. However, the complexity of developing and implementing AI based systems and the huge initial investment that it carries arise as the biggest challenges of this strategy.

This investigation aimed to fill the gap raised by Brown, (2001) regarding the potential of AI systems on energy efficiency and its actual implementation, considering what Mattes et al., (2015); Cubric, (2020); Gailhofer *et al.*, (2021); Kopka & Grashof, (2021); Lyu & Liu, (2021) and Rosa *et al.*, (2022) shared about bridging AI and the European goals on Environmental Sustainability, for which every entity is called to take an action which resulted in the four research objectives mentioned in table 4.1 in the Methodology chapter.

The research model for this investigation emerged from its exploratory character for which the data collection demanded one-to-one semi-interviews aiming to not limit the interviewees to the interview script as it would allow to collect more information than it would be possible from structured interviews. Nonetheless, it should be noted that the sample is very reduced to make it possible to extrapolate and generalize conclusions.

Hence, the most relevant findings to keep from the first research question as the greatest success factors of implementing AI to potentialize Environmental Sustainability are related with the optimization of processes with better and more efficient allocation of resources with less wastes and, time sparing, costs reductions and increased productivity. Building smart and efficient infrastructures, production and decision-making processes were distinguished as the most relevant areas for AI implementation.

Overall, from the second research question it was possible to derive that the low level of maturity of AI based systems, constantly requiring monitorization and human resources input along was highlighted as the biggest constraint.

From the third research question, it should be highlighted that the main drivers of success for the implementation relate with the perception of AI as a key tool to help companies moving towards environmental targets and potential the tool can bring to businesses performances. The main drivers of unsuccess for the implementation related with the complexity and time it takes to develop and implement a system that is capable to run properly, and the initial investment and costs required.

In light of the fourth research question, it is worth to mention that both Portugal based interviewees and interviewees based in other European countries believe in AI as a reliable tool to potentialize environmentally friendly businesses but highlight different aspects as the biggest constraints. Portugal based participants underline the huge investments and initial costs and participants based abroad focus on the complexity of processes to develop and implement those systems and its’ continuous dependency on human resources input and monitorization, showing a low level of development.

6.2. Limitations

This investigation was conducted on existing literature on the topic and primary data collected from interviews. The main limitation of this research relates with the small size of the sample (interviewees). Despite the fact that the current study supported the existing prior research, care must be used when extrapolating the findings from the interviews data. It is also crucial to note that this is an exploratory study and that, in large part because of the study's small sample size, it should not be generalized or representative.

6.3. Suggestions for Future Research

Considering the importance and urgency of action from companies towards Sustainable Development, focusing on the environmental goals set by the European Union and the opportunity to bridge it with disruptive technologies like Artificial Intelligence, my recommendations are directed to further develop this area of study.

The first suggestion to be made meets the main limitation of the study, considering that it would be beneficial to take this topic to a considerably larger sample. Another suggestion would be to carry this topic to other activity sectors, since it would be quite interesting to understand if there are variations between other activity sectors. Following the same principle, it would be interesting to explore the topic regarding other disruptive technologies like the Internet of Things.

Finally, the last suggestion is related to one of the concerns raised some of the interviews that defended that AI is still not in such a level of development that can be totally independent and applied to this type of strategies.

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Annex A - Interview Script

1) For statistical matters, in which country do you work?
2) To what sector of activity does the company where you work belong to?
3) What is current position at the company?
4) How many years of experience do you have?
5) Are you aware of the concepts of decarbonization and energy efficiency?
6) To what extent, would you classify environmental impacts and climate changes as a concern for your company?

   At your company, do you have any strategy or plan to tackle these problems? Do you perceived it as a way of getting competitive advantage in your sector?
7) Are you aware of the concept of Artificial Intelligence?
8) Do you already have any AI techniques implemented in your workplace?
   a. If yes:
      i. Which type of activities or processes are automated?
      ii. Was it difficult to implement such automation strategies?
      iii. From your point of view, could you please share the pros and cons of implementing AI systems? Do they reflect higher productivity?
      iv. And do you think it adds value to meet energy efficiency and become more sustainable?
      v. Could you please tell me about the main challenge and main success factor of having implemented such AI systems? *Here I would like to hear about the motivations to implement it*
   b. If no:
      i. What are the main reasons leading your company to not adopt AI as a strategy to manage environmental impacts?
      ii. Are you aware if there is any ongoing project to implement such digital technologies focusing on making the company more sustainable?
      iii. From your point of view, could you please share what could be the pros and cons of implementing AI systems to manage environmental impacts of your business?
      iv. What do you think that would be the biggest challenge in implementing such type of technology?

9) Do you see AI as a potential and reliable tool to manage environmental impacts at your company?

10) In what areas of your company do you think that AI can have the greatest impact? (RQ3) *What do you think to be most important features in AI systems that potentialize energy efficiency or a greener performance?*

Annex B – Sustainable Development Goals

Table 2.2 - Sustainable Development Goals (SDGs)

SDG 1: No poverty	End poverty in all forms and everywhere
SDG 2: Zero Hunger	End hunger, achieve food security, promote sustainable agriculture, and improve nutritional conditions
SDG 3: Good Health and Well-Being	Ensure health lives and well-being for all citizens
SDG 4: Quality Education	Ensure inclusive and equitable quality education, promoting learning opportunities for all citizens
SDG 5: Gender Equality	Achieve gender equality and empower all women and girls
SDG 6: Clean Water and Sanitation (CWS)	Ensure availability and sustainable management of water and sanitation for all citizens
SDG 7: Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable, and modern energy for all citizens
SDG 8: Decent Work and Economic Growth	Promote inclusive and sustainable economic growth, employment, and decent work for all citizens
SDG 9: Industry, Innovation, and Infrastructure	Promote sustainable industrialization, foster innovation, and build sustainable infrastructures
SDG 10: Reduced Inequalities	Reduce inequality within and between countries
SDG 11: Sustainable Cities and Communities	Transform cities into inclusive, safe, resilient, and sustainable
SDG 12: Responsible Consumption and Production	Ensure sustainable consumption and production patterns
SDG 13: Climate Action	Take urgent actions to fight climate change and its impacts
SDG 14: Life Below Water	Conserve and promote the sustainable usage of oceans, seas, and marine resources

SDG 15: Life on Land	Sustainably manage forest, combat desertification, stop and reverse land degradation, fight biodiversity loss
SDG 16: Peace, Justice, and Strong Institutions	Promote justice and peaceful and inclusive societies
SDG 17: Partnerships for the Goals	Stimulate the global partnership for sustainable development

Source: United Nations, Sustainable Development Agenda