INSTITUTO
UNIVERSITÁRIO
DE LISBOA

Digital Technologies for a Greener Future: Management Perspectives in Portuguese Companies

António José Lourenço Fonseca

Master in management

Supervisor:
PhD, Prof. Vasco Barroso Gonçalves, Assistant Professor,
Iscte Business School, Finance Department

October, 2023

BUSINESS SCHOOL

Digital Technologies for a Greener Future: Management Perspectives in Portuguese Companies

António José Lourenço Fonseca

Master in Management

Supervisor:
PhD, Prof. Vasco Barroso Gonçalves, Assistant Professor,
Iscte Business School, Finance Department

October, 2023

Acknowledgement

I would like to begin by expressing my utmost appreciation to my supervisor, Professor Vasco Gonçalves, for the important orientation and constructive feedback provided during this research endeavor. The knowledge and guidance provided by the Professor have played a key role in molding the outcome of this work.

I am also immensely grateful for the support and flexibility afforded to me by my work colleagues Elisabete and Joana. Their understanding and camaraderie made it possible for me to manage my academic goals alongside my professional responsibilities seamlessly.

Further extending my circle of gratitude, I would like to thank my friends and family for their constant encouragement and conviction in my abilities. A special shoutout goes to Joana, for being a constant source of emotional support.

Finally, I extend heartfelt thanks to the organizations and study participants involved in this research. Their willingness to contribute has not only enriched this work but has also provided a broader impact that goes beyond the academic sphere. Their contributions have been invaluable, laying the groundwork for future studies and discussions in this field.

Abstract

This research investigates the use of digital technologies by Portuguese companies to augment their environmental performance. The primary emphasis of this study pertains to the digital technologies that are most often used, with the aim of investigating their role in promoting environmental sustainability as a managerial approach.

Using a qualitative research methodology, we used semi-structured interviews and questionnaires to gather data from senior executives with environmental sustainability and digital technologies related roles from several industries. In response to dynamic legislative standards, shifting customer demands, and the financial implications of technological advancements, many corporations are actively incorporating sustainability as a fundamental approach, rather than just adhering to certifications or sustainability frameworks.

Persistent challenges are seen in several industries, such as retail and agriculture, mostly in the form of skills shortages and intricacies associated with the implementation of technology. It is observed that both the lack of automation and efficient analytical capabilities and the absence of universally accepted criteria for measuring sustainability are hindrances to progress in this area.

The findings of this research provide practical and implementable recommendations for company sustainability initiatives. The presence of limitations, such as a limited sample size, underscores the need for further investigation. To address these limitations, future research endeavors may consider doing more comprehensive empirical analyses of industry-specific metrics.

Keywords: Digital technologies, environmental sustainability, Portugal's sustainability landscape.

JEL: M15 Business Administration: IT Management

JEL: Q55 Environmental Economics: Technological Innovation

Resumo

Este estudo investiga a utilização de tecnologias digitais pelas empresas portuguesas para aumentar o seu desempenho ambiental. A ênfase principal deste estudo diz respeito às tecnologias digitais mais frequentemente utilizadas, com o objetivo de investigar o seu papel na promoção da sustentabilidade ambiental como abordagem de gestão.

Recorrendo a uma metodologia de investigação qualitativa, utilizámos entrevistas semiestruturadas e questionários para recolher dados de executivos seniores com funções relacionadas com a sustentabilidade ambiental e as tecnologias digitais de várias indústrias. Em resposta a normas legislativas dinâmicas, à evolução das exigências dos clientes e às implicações financeiras dos avanços tecnológicos, muitas empresas estão a incorporar ativamente a sustentabilidade como uma abordagem fundamental, em vez de se limitarem a aderir a certificações ou enquadramentos teóricos de sustentabilidade.

Em vários sectores, como o retalho e a agricultura, observam-se desafios persistentes, principalmente sob a forma de escassez de competências e de complexidades associadas à implementação da tecnologia. Observa-se que a inexistência de automação e de capacidades analíticas eficientes e a ausência de critérios universalmente aceites para medir a sustentabilidade constituem um obstáculo ao progresso nesta área.

Os resultados desta investigação fornecem recomendações práticas e implementáveis para as iniciativas de sustentabilidade das empresas. A presença de limitações, como a dimensão limitada da amostra, sublinha a necessidade de mais investigação. Para resolver estas limitações, os futuros esforços de investigação podem considerar a realização de análises empíricas mais abrangentes de métricas dentro de sectores específicos.

Palavras-chave: Tecnologias digitais, sustentabilidade ambiental, panorama da sustentabilidade em Portugal.

JEL: M15 Business Administration: IT Management

JEL: Q55 Environmental Economics: Technological Innovation

Table of Contents

CHAPTER 1

Introduction

The field of environmental performance has been a major concern for many decades, as industrialization and economic growth have led to increased pollution and resource depletion (Hawken, Lovins, & Lovins, 1999). In recent years, the need to address environmental issues has become even more pressing, with the increasing effects of climate change and the depletion of natural resources (United Nations Environment Programme, 2019). In light of the increasing sense of urgency surrounding this issue, it is evident that the current strategies have proven inadequate in mitigating the adverse environmental consequences.

The inadequacy in question is emphasized by the observation that mankind has so far been unsuccessful in attaining sustainable development. The upsurge in air and water pollution (Kyrychenko, 2021), energy consumption and increased depletion of our planet's natural and non-renewable resources represent an ultimatum to the subsistence of the human being. Research from Zachariadis (2016) found that the effects of climate can lead to different but all equally severe phenomena that can have a tremendous impact on all spheres of society. These phenomena can vary from sea-level rise, due to glacier meltdown, to ocean acidification, droughts, and increased occurrence of extreme weather such as heat waves, floods, and storms. Therefore, this problem is identified as a top priority by the public, governments, and organizations (Afshari et al., 2022).

The world is living in an ever-growing digital revolution that reshapes the entire industry and the overall business landscape (Lucas Jr. et al., 2013). Researchers Hagel & Brown (2011) claim that it is necessary to create “institutions, practices, and protocols that together organize and deliver the increasing power of digital technology to business and society.” Redefining digital technologies is a critical element in the strategic positioning of enterprises and a crucial agenda for top management (Wrede et al., 2020).

Expanding upon the ongoing digital revolution, a notable domain in which these technologies are gaining substantial traction is the realm of environmental performance. In recent years, there has been a significant advancement in digital technology, leading to exponential growth in their applications across numerous sectors like industrial, transportation, and agricultural. They provide new tools and methods for monitoring and managing natural resources, reducing emissions and waste, and increasing efficiency in various processes (Baun & Damsgaard, 2017).

In this context, digital technologies have emerged as a key tool for improving environmental performance by providing new methods for monitoring, managing, and reducing the environmental impacts of industrial and other human activities (World Economic Forum, 2019). This research aims to investigate the potential of digital technologies to enhance environmental performance and the impact of digital technologies on environmental performance across different sectors.

1.1 Problem statement

Despite the abundance of academic research examining potential of digital technologies, there exists a discernible gap in the academic literature pertaining to the practical ramifications of these technologies and in particular their implications for sustainability. Scholars prioritize the examination of theoretical advantages associated with these technologies, neglecting to consider their practical implementation in diverse sectors. Indeed, the majority of research endeavors concentrate on discrete occurrences of technology adoption, however they fail to provide a comprehensive comparison across various industries and company sizes to understand the broader implications and best practices for implementation (Schöggl et al., 2023). The existing literature neglects to thoroughly investigate the alignment between the integration of digital technologies and the sustainability goals of companies, leading to a lack of comprehensive understanding (Feroz et al., 2021).

This study, therefore, seeks to provide practical knowledge on the use of digital technology to enhance environmental performance focusing on a group of Portuguese companies from different sectors of activity.

1.2 Research objectives and questions

The primary objective of the proposed study is two-fold. First, the research aims to offer a contextual snapshot of the landscape of environmental sustainability practices within various industries. This initial investigation will help to understand which digital technologies are being increasingly adopted and are proving effective in aligning with sustainability objectives. Building on this foundation, the second objective is to fill the existing gap in academic literature by exploring the practical applications of these digital technologies across diverse industries. The study will identify best practices aimed at improving environmental performance. By sequentially addressing these objectives, the research is designed to make substantial contributions to academic discourse, while also providing firms with essential guidance in their pursuit of technological innovation aligned with sustainability goals. Therefore, this Dissertation will answer three research questions:

- **Research Question 1:** What is the current landscape of environmental sustainability practices within different sectors?
- **Research Question 2:** What digital technologies are being adopted and have been effective in enhancing environmental performance?

- **Research Question 3:** How do these technologies align with broader environmental sustainability goals within organizations?

1.3 Research framework

The present research is organized into five main chapters, aiming to provide a comprehensive examination of the relationship between digital technologies and environmental sustainability in organizational contexts. Chapter 2 offers an extensive examination of the existing body of literature, including the fundamental principles of sustainable development and the significant influence exerted by digital technology. Chapter 3 provides a comprehensive overview of the study methodology, including the research design, sample methodologies, and the methods used for data collecting and analysis. This chapter is specifically adapted to suit the unique characteristics of the modern Portuguese business environment. Chapter 4 is devoted to the exposition of findings, which are systematically categorized into several parts that critically examine the ramifications of digital technologies on the sustainability of organizations, including both strategic and operational viewpoints. The study is concluded in Chapter 5, which serves to summarize the significant results, address the research's limitations, and suggest potential directions for further research.

CHAPTER 2

Literature Review

The literature review begins in section 2.1 by presenting the concept of sustainable development and the main drivers that make it essential for company performance, particularly regarding the environment. The main frameworks available for evaluating the results of implementing sustainable practices are also considered. The development of sustainable business models is also seen as fundamental to enhancing the environmental performance of business activities.

Section 2.2 focuses on recent studies identifying and characterizing the main digital technologies and section 2.3 analyses the potential impact of these technologies on companies' environmental sustainability.

At the end of this chapter Figure 1.1 reflects the conceptual model used in the literature review.

2.1 Corporate environmental sustainability

2.1.1 Sustainability drivers and assessment frameworks

"Sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations" (World Commission on Environment and Development, 1987). This designation of sustainable development, the most broadly acknowledged, highlights two key concepts: needs and limitations. The World Commission on Environment and Development (1987) underlines that the search to satisfy our needs should not compromise forthcoming generations. How society achieves these goals depends on how it can manage its limitations imposed by environmental resource consumption and capacity to absorb emissions from human activities to the biosphere. Therefore, these boundaries are not absolute but directly linked to the existing technology and societal organization.

The boundaries of businesses have been expanding and including a more comprehensive range of direct and indirect stakeholders (Warhurst, 2005). According to the same researcher, businesses have a pivotal role in society, and the stakeholders expect these to follow responsible practices and provide solutions to humanitarian crises and endemic problems. Corporate Social Responsibility (CSR) has been around since the 1950s and 1960s, when the first notions of business responsibilities were constructed (Agudelo et al., 2019). In recent years, Carroll (2015) revised its previous work on this concept to include the sustainable trajectory. The revised research now includes concepts such as "corporate citizenship, corporate stewardship, business ethics, stakeholder management, conscious capitalism, creating shared value, and sustainability" to be aligned with the modern business vocabulary (Carroll, 2015).

Moreover, recent studies identified that stakeholders focus on non-financial activities. According to empirical studies, there has been a shift from the 1980s and 1990s, when the keywords related to sustainability were "sacrifice", "morality", and "values". In distinction, currently, these shifted to "stakeholders", "activism", and "financial performance" (Talan & Sharma, 2019). This change reflects the value allocated to the firms that undertake a firm position in creating a more sustainable world and the economic importance, investment-wise, attributed to leading this change (Talan, 2019).

Stakeholder pressure is a significant determinant of environmental performance inside corporations regarding CSR and green innovation (Shahzad et al., 2020). The significance of responsible environmental management is being progressively emphasized by stakeholders, including customers, investors, and community. The stakeholder theory posits that corporations possess an obligation not just towards shareholders, but also towards a wider range of individuals or groups that are affected by the company's activities (Freeman & McVea, 2001). Kassinis and Vafeas (2006) have provided empirical data indicating that corporations tend to enhance their environmental policies and practices in response to demands exerted by stakeholders. Bansal and Roth (2000) conducted pioneering research which revealed that companies that exhibit a high level of responsiveness to stakeholder concerns are more inclined to embrace proactive environmental initiatives. The most sustainable practices being imposed being environmental disclosure and transparency such as sustainability reporting (Almagtome et al., 2020; De Villiers et al., 2022) and sustainable supply chain management (Meixell & Luoma, 2015).

Regulatory forces are a strong influential factor. The proliferation of laws and regulations related to environmental protection has seen significant growth, prompting corporations to allocate resources towards the adoption of environmentally friendly technology and practices to adhere to these requirements (Darnall et al., 2010). In research conducted by Kassinis and Vafeas (2006), it was shown that companies have a greater propensity to comply with environmental norms and even surpass them when faced with rigorous regulatory measures. The perspective known as the "Porter Hypothesis" also lends credence to this assertion, positing that stringent environmental restrictions may serve as a catalyst for innovation and enhance overall performance (Porter & van der Linde, 1995).

There is a noticeable trend among customers to move away from a mere focus on price and instead consider a range of considerations, such as environmental effect, when making purchasing decisions (D'Souza et al., 2006; Yeng et al., 2015). The current situation is exerting supplementary pressure on corporations to enhance their environmental performance. According to Wang et al. (2016), empirical research has shown that companies that provide clear carbon footprint information and transparent data are more inclined to achieve a competitive edge.

The need for corporations to adopt sustainable practices is clear, as a significant fraction of Chief Executive Officers recognize the essential nature of sustainability for the enduring profitability of their enterprises. However, the evaluation and measurement of the impacts and value of sustainability provide a substantial challenge. Merely 38% consider they can measure with precision the value of their sustainable performance (Maas et al., 2016). Guidelines are required for top managers to define a clear path. This necessitates the development of detailed rules and frameworks that may successfully steer decision-makers.

In this regard, many frameworks, such the Double Materiality Principle, Science-Based Targets Initiative (SBTI), Carbon Disclosure Project (CDP), Global Reporting Initiative (GRI), and ISO 14001, might serve as guiding principles. The ISO 14001 standard is widely acknowledged on a global scale as a benchmark for the implementation and maintenance of environmental management systems (Salim et al., 2018). Although its primary purpose is not reporting, it functions as the fundamental framework for executing and overseeing sustainability endeavors. The framework in question serves as a valuable addition to existing frameworks. It offers an internal structure that facilitates the management and attainment of reporting and performance objectives (Salim et al., 2018). Organizations that possess ISO 14001 certification often exhibit a heightened capacity to enhance their Environmental, Social, and Governance (ESG) ratings, since this accreditation serves as a globally acknowledged validation of proficient environmental management practices.

The Double Materiality is the guiding principle for the other frameworks that promotes the notion that firms should consider not just the effects of sustainability challenges on their company, but also the implications of their business on society and the environment (Baumüller & Sopp, 2021). The primary objective of the Science-Based objectives Initiative is to establish ambitious business objectives for the mitigation of greenhouse gas emissions by sector, aligning them with the scientifically determined requirements outlined by climate science (Giesekam et al., 2021). The primary objective of the Carbon Disclosure Project is to establish environmental reporting and risk management as a standard practice within the corporate community. The goal of this initiative intends to enhance transparency, support informed decision-making, and promote proactive efforts that contribute to the development of a sustainable economy (Giesekam et al., 2021). The Global Reporting Initiative (GRI) is widely recognized as the primary standard-setting institution in the field of sustainability reporting. It focuses on the dissemination of comprehensive information pertaining to sustainability, including economic, environmental, and social aspects (Halkos & Nomikos, 2021).

These frameworks have the potential to provide a more detailed, evidence-based, and uniform methodology for addressing sustainability. The criteria and standards provided by these goals complement the wider and ambitious United Nations Sustainable Development Goals (SDGs) as well as the increasing significance of ESG scores. They provide a means for firms to assess their performance in a precise manner. For example, the Sustainable Business Transformation Initiative (SBTI) offers a viable approach towards attaining the Sustainable Development Goals (SDGs) connected to climate change. Similarly, the Carbon Disclosure Project (CDP) plays a substantial role in shaping a company's ESG score by providing concrete measurements pertaining to environmental responsibility.

The European Sustainability Reporting Standards (ESRS) and the International Financial Reporting Standards (IFRS) Foundation are seeking to be prominent within the dynamic realm of sustainability reporting, but with distinct emphases and extents of coverage. The ESRS, a compulsory legislation recently implemented in the European Union (EU), seeks to provide a uniform approach to sustainability reporting (Questions and Answers on the Adoption of European Sustainability Reporting Standards, 2023). This standard will exhibit strong congruence with globally acknowledged frameworks such as the Global Reporting Initiative (GRI), to avoid double reporting. The legislation is mandatory for firms located inside the European Union that employ more than 500 individuals and intends to create sector-specific standards. These enterprises are required to fulfill reporting obligations starting from the financial year 2024, with the first statements anticipated to be submitted in 2025. In contrast, the IFRS Foundation is venturing into the realm of sustainability reporting standard-setting with the objective of furnishing investors with data pertaining to the socioeconomic and environmental effects on firms engaged in reporting (De Villiers et al., 2022).

Through the integration of these frameworks, organizations may get a more comprehensive understanding of their sustainability performance, therefore providing investors and shareholders with quantifiable measures. These frameworks may function as a means of linking sustainability activities with quantifiable outcomes, so reinforcing the idea that sustainability is not just a moral decision but also a crucial aspect of corporate strategy.

2.1.2 Sustainable business models and the environment

Due to pollution's impact on sustainable development, external and internal stakeholders increasingly focus on private organizations' environmental performance (Jasch, 2006). Research led by Rahdari & Anvary Rostamy (2015) intended to identify, using a bottom-up approach, the most common sustainable indicators. This study intended to narrow down the vast selection of indicators and facilitate the construction of frameworks for further research on the topic. The results attained showed that these had proximity to the ESG model. Regarding the environmental side, the following table (Table 2.1) will highlight the most common environmental sustainability indicators based on the mentioned research.

Table 2.1. Review of the most common environmental sustainability indicators.

KPI/indicator	Indicators
Assessment of Environmental Risk	Objectives for Reduction; Total Environmental Effect.
Environmental literacy	Digital Solutions for Environmental Benefits.
Environmental Information Disclosure	Openness about Environmental Measures; Reporting on Water, Trash, and Carbon.
Adaptation and Mitigation for Climate and Carbon	Tactics to Address and Adapt to Climate Changes; Metrics related to Sales per CO2 Emissions; Transparency in Carbon Initiatives.
Conservation of Land, Biodiversity, and Ecosystems	Comprehensive Environmental Conservation Investments.
Waste Management	Efficiency of Waste Creation; Total Amount of Handled Dangerous Waste.
Pollution and Emission Metrics	Polluting Substances Released; CO2 Output; Various Significant Air Pollutants.
Sustainable Management Protocols (e.g., ISO norms)	Adoption of Environmental Management Systems; Goal setting and Oversight; In-house Environmental Guidelines.
Efficiency in Energy Use	Sales per Energy Unit Consumed; Power Consumption per Resident; Renewable Energy Usage.
Management of Water Resources	Indicators for Water Scarcity; Reduced Water Consumption; Metrics for Recycled Water Use; Intensity Metrics related to Sales.
Environmental Impact of Goods & Services	Environmental Footprint of Products; Services' Environmental Costs.
Supply Chain Emissions	Overall Environmental Effects of Supply Chain; Third parties' Emissions.

Source: Rahdari & Rostamy (2015).

The Triple Bottom Line (TBL) concept is crucial for aligning business strategy with sustainability (Samajdar, 2014). According to Elkington (1999). TBL refers to the environmental, social, and economic equilibrium needed to run businesses. So far, the environmental aspect of sustainability has been the most researched by investigators; however, few studies reflect the connection between economic, social, and ecological sustainability. A real example of this connection can be found with environmental policies to diminish car usage and ownership that result in lower carbon dioxide emissions, less traffic and noise, converging on a superior quality of life and well-being in high-density areas (Hildebrandt et al., 2018).

A business model (BM) illustrates an enterprise's primary tactic to engage in profitable business. However, modern research has proved that profit-driven business models represent an obstacle to sustainable development since they are not sustainable by default (Upward & Jones, 2015). Therefore, a comprehensive approach to how non-profitable components - environmental and social - combined with the profitable logic affect a company's practices and respective business models is required (Laasch, 2018).

The concept of Sustainable Business Models (SBM) has been gaining traction. According to Zachariadis (2016), "sustainable business models are theorized to consist of an interrelated set of components that depict a venture's value creation activities." Sustainable business models aim primarily for sustainable consumption and production, generating a new perspective for industries and economic systems. However, there is no final design on how a company should withstand a sustainable business model (Man & Strandhagen, 2017). According to Osterwalder (2005), customers turn to companies whose value proposition suits their needs. Most customers, however, do not usually see product durability as a direct connection to sustainability. Consequently, it is not likely that the demand for such products will increase in the following years. It is unclear how a business can stay competitive and successful through remarkable voluntary and social performance, as the effects are not visible in the short term. Complying with regulations and maintaining good sustainable performance indicators does not represent immediate success or financial benefits.

In conclusion, businesses must proactively differentiate themselves and seek new paths for value creation (Möller & Schaltegger, 2005). Digital technologies are one key element for sustainable business models to succeed. For instance, digital technologies aid in designing new pathways for a more integrative environment for stakeholders and co-creation (Gregori & Holzmann, 2020). Early-on technological enhancements were seen as an essential aspect of sustainable business model research and, simultaneously, as a vital piece to improving environmental sustainability and reducing waste and pollution (Schaltegger et al., 2016). Boons & Lüdeke-Freund (2013) affirm that sustainable innovation on its own has no value if not integrated through a particular business model. Consequently, understanding business models allows one to comprehend how sustainable innovation is marketed.

In line with the concept of Sustainable Business Models, the Circular Economy business model has been increasingly adopted by businesses. This concept defines its pillars as rethink, reduce, reuse, recycle, and repair. According to The Circular Business Model (2021), "businesses create supply chains that recover or recycle the resources used to create their product—shrinking their environmental footprint, trimming operation waste, using expensive resources efficiently." Therefore, achieving low input, low consumption, low emission, and highly efficient features is consistent with sustainable economic development (Shao-ping & Yun-Jie, 2010). This business model is contrary to the traditional linear economy characterized by the "take-make-dispose" model, where resources are extracted, consumed, and disposed of at the end of the lifecycle (Lieder & Rashid, 2016).

Information technology promotes further innovation in business models and enables businesses to harness better sustainable performance (Hildebrandt et al., 2018). As a new technological revolution is at our doorstep, further analysis of concepts such as digital technologies is crucial to understanding this phenomenon and its impact on society and businesses. Sullivan & Hussain (2020) highlight how enterprises like the H&M Group and Danone have utilized innovative technology to minimize the side effects of their value chain, namely the waste and pollution caused by the production of goods (Wynn & Jones, 2022).

2.2 Digital technologies

By technical definition, digital technologies are "electronic tools, automatic systems, and technological devices that can generate, process and store information" (Wynn & Jones, 2022), which is converted into a binary system (Johnson, 2021). Some examples are websites, smartphones, blockchain, cryptocurrency, cloud computing, and 5G.

According to Camodeca & Almici (2021) digital technologies result from combining digital artefacts, digital infrastructure, and digital platforms. The first concept refers to the attributes of a new product designed to create additional value (Camodeca & Almici, 2021). Digital infrastructure is the ability for communication to flow (Tilson et al., 2010). Digital platforms are interconnected sets hosted through shared services such as Apple's iOS (Tiwana et al., 2010).

Other research led by Lanzolla et al. (2020) recognized the existence of four different groups in digital technology. The researchers Camodeca & Almici (2021) summarized the groups identified from the previous authors' study into "efficiency technology (e.g., cloud), connectivity technology (e.g., the Internet of Things), trust disintermediation technology (e.g., blockchain), and automation technology (e.g., big data)." In contrast, Sebastian et al. (2017) appoints the existence of six different groups that follow the "SMACIT" acronym for Social, Mobile, Analytics, Cloud and Internet of things.

Digital technologies' influence multiple areas of sustainability, ranging from inclusiveness and global productivity to environmental protection. A recent study published ("The European Double up A Twin Strategy That Will Strengthen Competitiveness.," 2021) to assess which technologies were the most sought after to improve sustainable performance has shown that most European companies intend to adopt the following five digital technologies: Artificial Intelligence (40%), Cloud Based Enterprise Resource Planning (ERP) (37%), 5G (36%), Internet of Things (35%), and Big Data (35%). While Camodeca & Almici (2021) state that the technologies most suitable for the sustainable transition are Artificial Intelligence (AI), including its branch Machine Learning, Big Data, Blockchain, Cloud, 5th Generation Internet, Internet of Things (IoT), and Virtual Reality Systems.

The 5th generation mobile network can reshape and connect multiple market areas such as the manufacturing industry, health, automotive and utilities (Wang et al., 2022) whilst enhancing user experience (Holslin, 2022). 5G is characterized by low latency, peak data speeds, higher connection density per the number of connected devices, and reduced energy consumption (Wang et al., 2022). Compared to the 4th generation mobile generation, the 5th generation can have data speeds up to one hundred times faster, handling multiple IoT devices and machine-to-machine communication simultaneously. This technology is set to enable secure and flexible networks, harnessing their virtualization and cloud technology (Barman & Hallur, 2022). Furthermore, combining cloud computing and 5G networks promotes a generic IoT popularization and intelligent device usage caused by the more efficient use of smart mobile devices (Liu et al., 2022).

Cloud computing has seen an increase in research due to its capability for scale elasticity, speed, and flexibility for applications, such as hosting servers and workflow integration (Petri et al., 2018). According to Hofmann (2008), cloud computing is the interconnectivity between distributed, parallel and grid computing and virtualization technology that results from service patterns and application development. Cloud computing allows a business to "rent" an IT resource instead of acquiring it. In other words, the cloud is an on-demand self-service that resorts to resource pooling and multi-tenancy to provide flexible and ubiquitous access (Modisane & Jokonya, 2021).

The proliferation of communication technology, advancements in the semiconductors sector, and the rising significance of software have been instrumental in driving the broad adoption of the Internet of Things (Jankowski et al., 2014). IoT combines physical networks and intelligent connected devices with sensors and software capable of exchanging data via the Internet (Oracle, 2020) and adjusting to new data sources. Everyday objects have gradually evolved to encompass new functionality through connectivity sensors and control systems. From bells to refrigerators, the Internet of Things has been playing an increasingly present role in the day-to-day life of ordinary consumers and industrial operations. Through collecting, processing, and analyzing data sets, IoT identifies patterns and provides humans with insights to make knowledgeable assessments (Leiting et al., 2022). The same rationale is applied to businesses, resulting in better product offerings and more efficient processes that give light to higher profit margins because of less operational costs (Greenhalgh & Rogers, 2010). Moreover, IoT has opened doors for new value creation and the rise of new business models as it enabled companies not to focus solely on physical and on-demand products but digital services as a revenue stream (Metallo et al., 2018). Examples are Uber, Airbnb and Paypal (Leiting et al., 2022).

The internet phenomenon, along with the proliferation of corporate applications, social media platforms, and smart gadgets, has led to a substantial increase in the volume of data being created. Big data provides scalable data storage and the ability to extract useful information from vast amounts of data and transform it into valuable knowledge to top managers, stakeholders, and business users to help (Patel, 2019). Big data analytics not only focuses on providing information but interpreting it and treating it into actionable insights that give businesses a competitive advantage. Consequently, this technology became crucial in determining a company's financial performance, strengthening its market positioning accordingly to the market trends and volatility (Suoniemi et al., 2020). Big data analytics can also be considered "a new generation of technologies and architectures, designed to economically extract value from very huge of a wide variety of data, by enabling high-velocity capture, discovery, and analysis" (Mikalef et al., 2019). Modern research highlights different takes on this technology, focusing on information processing along the value chain, data generation within ecosystems and its usage in sustainability, ethics, data privacy and digital transformation (Mikalef et al., 2020).

Artificial intelligence (AI) has been gaining immense relevance in modern research, partly because of the crushing success of Large Language Models such as OpenAI's ChatGPT. John McCarthy, broadly recognized as the "father" of Artificial Intelligence, pictures this technology as "the science and engineering of making intelligent machines, especially intelligent computer programs." AI is a multi-faced technology and has solved many business issues, such as labor shortages, by automating tasks while enhancing sustainable performance, IT and business network processes, and user experience. It is essential to mark out what this technology is and how it is interchangeable and disparate from interconnected concepts such Machine Learning (ML), amongst many others, which are branches of this technology. Artificial Intelligence is usually referred to as an umbrella term to represent them (Park et al., 2020).

Machine learning, a sub-field of AI, can be simply described as enabling machines which can learn and improve autonomously using training algorithms without being programmed. For this reason, it can be considered "the automation of knowledge" (Chui et al., 2020). Although, it requires more human intervention to segment data into categories. The existence of three types of machine learning types is widely acknowledged: supervised, unsupervised, and semi-supervised. Supervised learning demands providing training samples with input datasets of known classification labels for the algorithm to sort the data according to similarities and differences (Nguyen & Vo, 2022). Unsupervised learning uses algorithms to identify arrangements from the input data for a specific outcome. They are usually used to solve complex computational problems or to deal with unlabeled data. At last, semi-supervised learning is a mixed type of machine learning, with the data inputs being composed of labelled and unlabeled data.

This technology has significant promise for business executives seeking to formulate new strategies and create additional streams of income. The technology to convert data into well-informed decisions is essential for organizations to thrive (Sandeep et al., 2022). By eliminating human error, misinformation and fraud, enterprises have trustworthy information on products, services, and customers, which increases the company's brand value (Sandeep et al., 2022).

Blockchain, first emerging in 2008 primarily for cryptocurrency, has evolved into a multifaceted technology that disrupts traditional information flow and transaction methods (Kamble et al., 2018; Jović et al., 2020; Pan et al., 2020). Defined as a "decentralized information technology based on shared immutable, distributed ledgers" (Lu, 2018), it offers benefits like cost reduction, efficiency (Zheng et al., 2017), transparency, traceability, and security (Saberi et al., 2018). The technology has shown promise in enhancing supply chain operations by fostering interconnectedness between suppliers and customers (Kamble et al., 2018).

Within the business sphere, the use of digital fabrication technologies, such as 3-D printing, has become progressively indispensable for the purpose of expediting the prototype process and enhancing the efficiency of supply chains, reducing waste (Nadagouda et al., 2020). The use of mobile computers and applications has become an essential aspect of modern communication and workflow enhancement through user-friendly solutions (Emmanouilidis et al., 2009). Social media platforms serve as a potent instrument for business branding and consumer interaction (Kietzmann et al., 2011). Virtual Reality (VR) and Augmented Reality (AR) provide considerable promise in the realm of staff training (Frigo et al., 2016) and consumer engagement (Bonetti et al., 2017), hence revolutionizing conventional business practices and enhancing client interactions.

According to Vial (2019), the concept of digital transformation encompasses the incorporation of digital technology into an organization's current products, processes, and strategies with the aim of enhancing overall performance. This process leverages disruptive technology (Karimi & Walter, 2015) and provides significant business enhancements such as improved customer experience (Morakanyane et al., 2017) and streamlined operations. It also enables new ways of doing business (Capgemini et al., 2013) while contributing to community development and broader stakeholder integration.

2.3 The impact of digital technologies on sustainability

This section presents the results of recent studies on the impact of digital technologies on sustainability. Their research context and design are summarized in Table 2.2.

According to ElMassah & Mohieldin (2020) digitalization is actively used to achieve Sustainable Development Goals (SDGs), with technologies directly influencing 103 of the 169 SDG targets. These technologies aid in ecosystem preservation and reducing waste and emissions (Bohnsack et al., 2014; Demartini et al., 2019). The academic focus on environmental aspects of production is providing actionable insights for businesses launching new sustainable products (Camodeca & Almici, 2021; Feroz et al., 2021).

To further understand the link between sustainability and digital transformation in the corporate scenario, specific business cases were studied using a unique technology or a combination of technologies. Yalina & Rozas (2020) researched how digital workplace implementation could improve and cloud technology could enhance environmental sustainability. El Hilali et al. (2020) believe that for enterprises to achieve sustainability in a digital era, there are three main areas to strengthen: customer focus, data analysis capabilities and innovative business models.

Further scholars believe in the impact of smart technologies on sustainable business models (Fiorentino et al., 2020). On the other hand, many seem to share the opinion that blockchain will have a significant role in the transition to a sustainable digital, especially in affecting the supply chain (Di Vaio & Varriale, 2020) and removing barriers to the creation of circular economies (Kumar & Chopra, 2022).

Most researchers seem aligned with the idea that sustainability and the digital transformation phenomenon have a close relationship and form a positive correlation (Camodeca & Almici, 2021). Balogun et al. (2020) undertook nine-case study research in multiple countries on how Big Data and IoT improved environmental performance. Feroz et al. (2021) studied how Artificial Intelligence, Big Data analytics, Cloud computing, and the Internet of things disrupted organizations and improved environmental sustainability. Demartini et al. (2019) studied how Digital Technologies improved resource waste and increased sustainability in the industrial sector.

Combining digital technologies can increase environmental and economic performance (Pirola et al., 2020). Voulgaridis et al. (2022) researched how digital technologies could remove barriers to implementing circular economies and the direct utility of each digital technology. Smart sensors allow for data collection and sharing amongst stakeholders, monitoring, analysis and predictive maintenance of the production equipment and the products. Artificial Intelligence and Machine Learning's automatic functions during manufacturing led to optimized industrial systems and processes while providing feedback for decision-making. Big data supported automated processing for reuse purposes and business evaluation. Blockchain allowed for transparency and smart contracts amongst stakeholders. Finally, cloud computing aided in achieving successful resource management.

In contrast, some scholars disagree that digital transformation can harness environmental and social sustainability (Scholz et al., 2018; Kuntsman & Rattle, 2019). Beier et al. (2020) acknowledged the benefits of the digital transformation phenomenon -efficiency gains, higher production standards and economic development. However, they emphasized the downside of producing and running these technologies as they can require high energy consumption, generate a high carbon footprint, and have strict recycling utility. In line with this argument, Kuntsman & Rattle (2019) made the concept of "unsustainable digital sustainability" familiar. The material aspect of digital communication should be considered, from the depletion of resources due to the non-stop production caused by the increased demand for digital services to toxic e-waste disposal. Finally, Akande et al. (2019) point out that there is no clear evidence of the direct connection between digitalization and sustainable development, with their research showing that cities using information and communications technology do not represent sustainability on their own and vice-versa.

Table 2.2 Review of previous studies: Digital technologies and environmental sustainability performance.

Reference	Research Context	Research Design
(Yalina & Rozas, 2020)	The contribution of digital workplaces to empower environmental sustainability.	Analyzing data collected from three cases retrieved from UIN Sunan Ampel Surabaya.
(El Hilali et al., 2020)	Examine the correlation between digital transformation and sustainable business practices within the context of small and medium-sized organizations (SMEs).	Conceptual framework using survey data collected from 41 SMEs in Morocco.
(Fiorentino et al., 2020)	Air navigation service provider on how to create sustainable SBM through smart technologies.	Empirical analysis through a case study approach.
(Di Vaio & Varriale, 2020)	Examines the potential ramifications of blockchain technology in supply chain management within the airport business.	Examination of the financial accounts, non-financial reporting, and website of a critical airport infrastructure located in southern Italy.
(Kumar & Chopra, 2022)	Blockchain and smart contract technologies implications on CE.	Systematic literature review on five barrier categories: Technological, Financial, Infrastructure, Institutional, and Societal.
(Camodeca & Almici, 2021)	Digital transformation contribution to meet the 2030 Agenda's SDGs in Italian listed firms.	Textual analysis of Italian firms' digitalization efforts, followed by a regression analysis of the ESG scores of the selected firms.
(Balogun et al., 2020)	Digitalization as a means to facilitate climate change adaption and promote sustainable development within urban areas.	Nine case studies in cities across various continents.
(Feroz et al., 2021)	Digital transformation and environmental sustainability.	A systematic literature review focused on four categories: organizational capabilities, performance, digital transformation, and environmental sustainability.
(Demartini et al., 2019)	Digitalization Technologies for industrial sustainability.	A conceptual framework with evidence from various case studies of manufacturing companies.

(Pirola et al., 2020)	Digital Technologies in product-service systems	Semi-systematic literature analysis that identifies and examines five distinct research streams within the field. These streams include product-service systems (PSS) design, digital servitization, assessment tools for PSS decision-making, knowledge management, and sustainable business models (SBMs).
(Voulgaridis et al., 2022)	The future industry 5.0 and digital circular economy.	Collection and examination of research trends on digital Circular Economy models.
(Kuntsman & Rattle, 2019)	Environmental (un)sustainability of digital communication.	Systematic literature review and future agenda setting.
(Scholz et al., 2018)	Unintended side effects of digital transformation.	Cluster-based content analysis of an expert round table of European scientists and theoretical analysis.
(Beier et al., 2020)	Green digitalized economy: the environmental impacts of digital transformation.	Trend analysis.
(Akande et al., 2019)	Technology and the environmental sustainability of European cities.	A Principal Component Analysis combine six European cities into a two-dimensional ICT index, followed by cluster analysis on the ICT index and Carbon dioxide (CO_2) emissions.

Source: Own elaboration.

Even though there is an extensive number of publications, sustainability performance evaluation remains dispersed over different approaches (Büyüközkan & Karabulut, 2018). The current literature lacks a comprehensive portrait of the digital transformation's nature and implications (Vial, 2019). Additional research is required to determine how enterprises can effectively and realistically increase their environmental and economic performances based on digital technologies. Feroz et al. (2021) claimed that additional literature is required to diminish the gap between the digital transformation phenomenon and environmental sustainability. Pagoropoulos et al. (2017) identified that the significant gap in the existing research was "the limited technological perspective" and recommended that researchers focus on this limitation and "create more empirical results by evaluating the application of digital technologies in actual case studies."

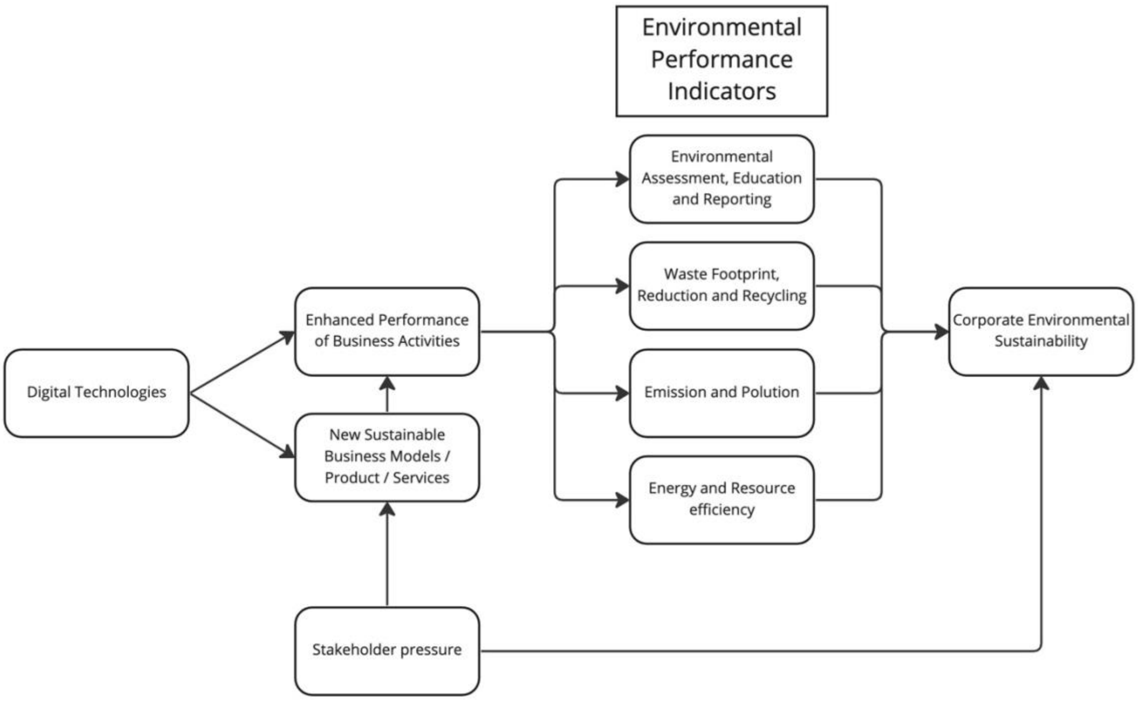

Figure 1.1 Conceptual Model: How digital technologies impact environmental sustainability.

Source: Own elaboration.

CHAPTER 3

Methodology

This chapter outlines the research design and sampling methodology adopted to address the existing research gap in understanding the impact of digital technologies on sustainable environmental performance within the contemporary Portuguese corporate landscape.

3.1 Research design

The research design employs a semi-structured interview and questionnaires framework, using a blend of predetermined and open-ended inquiries to provide a well-rounded approach in gathering data. The decision to use a semi-structured interview and questionnaire, was motivated by its inherent flexibility and capacity for in-depth exploration. This methodology enables the acquisition of qualitative data, which plays a crucial role in comprehending the intricate and subtle aspects of digital technology and sustainability within organizational contexts. The use of this approach has significant merit in acquiring a comprehensive comprehension of the study inquiries (Miles & Gilbert, 2005). The interviews, which were the primary data collection method, and questionnaires, which served as a fallback option for those unable to participate in interviews, were structurally identical.

Ethical considerations such as participant consent and data anonymity have been accounted for in the design. To promote open and honest replies while protecting the anonymity of individuals and organizations, particular names are anonymized, while still providing information about generic organizational characteristics and functions.

The interviews and questionnaires started with asking general inquiries with the objective of comprehending fundamental organizational characteristics, such as the company sector, the workforce size, and the interviewee's position within the firm (Part I).

The last round of the interview (Part II) delved more into the use of digital technology and sustainability practices inside the firm. Participants were provided with the opportunity to make selections from a range of multiple-choice alternatives, in addition to providing more elaboration on their choices via open-ended questions. As an example, the inquiry "What digital technologies are employed within your organization?" presented a systematic array of choices such as "5th Generation Internet," "Analytics & Big Data," and "Artificial Intelligence," among other answers.

Respondents were further inquired about the aims and metrics linked to these devices, along by prompts designed to stimulate detailed responses. The participants were also asked questions on sustainable practices, and they were given the opportunity to choose from predetermined choices or offer more elaboration. As an example, the inquiry "What sustainable practices does your organization currently employ or intend to implement in the foreseeable future?" contained choices such as "Energy Efficiency" and "Adoption of Environmental Management Systems," while also permitting more elaboration.

To avoid any language barriers, the interviews were carried out in Portuguese, which is the predominant language of the target market sample. To enhance the study's scope and promote comprehensibility, the gathered data was afterwards translated into English while preserving the original context and subtleties. The interview's guide and questionnaire, as well as the summary of the interviews and questionnaires conducted can be found in the appendix.

3.2 Data collection and sampling

To meet the research objectives, interviews were conducted with experts from seventeen distinct companies across various industries. These interviews took place between October 2022 and August 2023. The selection of these companies and experts was not random but was instead based on pre-established criteria.

This dissertation used purposive sampling. This type of sampling is the most common for non-probabilistic samples (Guest et al., 2006), in qualitative methods when analyzing real-life cases (Nikolopoulou, 2022), and effective in multiple-case studies (Schoch, 2020). Purposive sampling allows examples of significant contributions to the research from interviewees knowledgeable on the topics (Palinkas et al., 2013).

The enterprises selected for this study represented a diverse range of industries and varied in organizational scale. This strategy aimed to provide a comprehensive understanding of the subject, minimize research bias and to ensure that the findings were generalizable to a wider population of companies in terms of size and sector.

The respondents held senior executive roles with direct involvement in digital technologies and environmental sustainability, or equivalent positions, within the actual operational contexts of their respective companies. These organizational positions were closely tied to the variables studied and had a broader vision of the company's strategy. Therefore, enabling a holistic view of the subjects at hand and the Portuguese corporate context.

The research targets Business Council for Sustainable Development Portugal members and firms linked to both sustainability and digital tech, ensuring relevance to the Portuguese context and deep insights into sustainability-digital innovation interplay. .

CHAPTER 4

Results

This chapter explores the many dimensions of organizational sustainability and examines the impact of digital technology in enhancing it. Commencing with an elucidation of the involved companies and the generic roles of interviewees in Section 4.1, the chapter proceeds to examine the assortment of environmental sustainability methods in Section 4.2. The subsequent divisions under section 4.2 provide a comprehensive examination of both strategic and operational aspects. In Section 4.3, the examination of the adoption and consequences of digital technology across several industries is presented. Sections 4.4 and 4.5 critically examine the workflow and sustainability concerns associated with these digital technologies, respectively. Section 4.6 of the chapter provides an analysis of the factors that motivate and hinder the use of digital technology for the goal of promoting sustainability.

4.1 Organization characterization and interviewees roles

The companies selected for the interviews belong to different areas of activity (sectors), which have been grouped by type of activity sector (industry group), to differentiate the nature and relevance of the respective environmental impacts (see Table 4.1).

Table 4.1 Overview of the organizations studied by organization profile (sector and industry group) and size

Code	Organisation profile	Company size
i. Industrial		
a. Commercial Services & Supplies		
C1	Packaging Life Cycle Management	Small
b. Professional Services		
C2	Sustainability and Social Responsibility Consulting	Small
C3	Energy and Environmental Management Services	Small
c. Construction and Engineering		
C4	Technical Services Provider in the Areas of Digital and Energy	Large
C5	Construction, Promotion and Operation of Buildings	Large
C6	Engineering, Environment, Energy, Transport and Mining Services	Large
ii. Materials		
a. Paper & Forest Products		

C7	Integrated Forest, Pulp and Paper, Tissue, and Energy Producer	Large
C8	Cellulosic Fiber Producer	Large
b. Containers & Packaging		
C9	Production of Glass Containers	Large
iii. Utilities		
a. Independent Power Producers & Energy Traders		
C10	Renewable Energies	Medium
b. Electric Utilities		
C11	Grid Operator	Large
iv. Consumer Staples		
a. Food & Staples Retailing		
C12	Food Retail	Large
C13	Food Retail	Large
b. Food Products		
C14	Commercialization of Cooking Oils and Olive Oil	Large
v. Information Technology		
a. IT Consulting		
C15	IT Consulting	Large
C16	Artificial Intelligence Service Provider	Micro
vi. Healthcare		
a. Pharmaceuticals		
C17	Pharmaceutical Industry	Large

Source: Own elaboration.

Industries that are resource-intensive and whose profits are heavily reliant on operational efficiency and resource utilization exhibited a high level of participation in the study. Due to the immediate and substantial influence on their bottom line, they consider digital technologies that improve sustainability to play a crucial role in their operations. C7, C8 and C9 in the materials sector, companies engaged in construction and engineering, such as C4, C5 and C6 from the industrial sector, and C17, pharmaceutical, are examples of such industries.

Companies whose primary activities are explicitly associated with environmental performance were also well-represented. This was especially true for small businesses such as C1, a packaging lifecycle management organization, and C2 and C3, sustainability consulting firms. Due to their involvement in sustainability consulting and recycling, respectively, both companies recognize the importance of such studies, as their respective services are intrinsically linked to the research topics. C15 and C16 also participated actively, highlighting the inherent connection between IT consulting services and digital technology-enhanced environmental performance.

During our interviews across various industries, sectors such as the Financial and Communications appeared underrepresented despite their sustainability commitments, as evidenced by their association with the Business Council for Sustainable Development. The interviewee from C3 suggested that operational efficiency in some sectors may not be as directly linked to environmental concerns, stating, “this might be because these sectors' operational efficiency may not be as tangibly linked to environmental concerns.” The interviewee from C15 corroborates this reasoning pointing out a different dynamic in the service sector. According to this source, “the service sector's primary carbon emissions come from transportation.” This starkly contrasts with resource-intensive industries, where the focus is more on minimizing resource consumption rather than transportation-related emissions. These sectors might thus lean more towards CSR strategies that align with their unique operational needs and stakeholder demands (Lee, 2011). Regulatory constraints also differ among industries, affecting their participation in sustainability studies. In essence, while sectors like Financial and Communications Services might prioritize different sustainability approaches, it doesn’t indicate a lesser focus on sustainability. As the C3 interviewee stated, “there is not a necessarily direct correlation between the extent of a sector’s resource-intensity and its level of environmental consciousness.” Their strategies simply cater to their specific operational challenges, which were not aligned with the focus of our interviews.

The business's size scale encompasses many categories, including micro, small, medium, and big. A micro company is characterized by having less than 10 people, while a small company has fewer than 50 employees. A medium-sized firm is defined as having fewer than 250 employees, and a large company is distinguished by having more than 250 employees. The sample includes organizations ranging from small businesses with less 10 employees to large corporations with up to around 45,000 employees. This diversity in scale allows for investigating how operational size may impact the application and effectiveness of digital technologies for environmental performance enhancement.

Larger corporate entities with more explicitly defined policies and metrics were found to be among the most responsive. As discussed in the literature review and supported by Maas et al. (2016), these policies and metrics are significantly influenced by regulatory pressures, stakeholder expectations, and reputational risks. These organizations face stringent regulations due to their scale and potential for environmental impact. As the interviewee from C13 noted, “We are already preparing for the mandated European Sustainability Reporting Standards starting in 2025, currently employing seven different reporting methodologies to meet the needs of shareholders, regulatory bodies, clients, and other stakeholders.” This is even more pronounced for resource-intensive industries due to their amplified environmental impact, resulting in increased reporting obligations, compliance costs such as environmental management software systems, and regular inspections and audits. Therefore, large corporations, especially those in high-environmental-impact industries, place a significant emphasis on sustainability, which influences their propensity to conduct relevant research on the topics studied.

Table 4.2 Interviewee's generic roles within the company and the number of participants in each interview.

Code	Interviewee's generic tag within the company	Number of participants
C1	Senior Technology Manager	One
C2	Operations Manager	One
C3	Sustainability Manager	One
C4	Senior Environmental Sustainability Manager	One
C5	Senior Sustainability Manager	One
C6	Senior Environmental Sustainability Manager	One
C7	IT Department and Sustainability Manager	Multiple
C8	Senior Technology Manager and Sustainability Manager	Two
C9	Sustainability and Digital Technology Manager	One
C10	Senior Sustainability Manager	One
C11	Senior Operational Sustainability Manager	One
C12	Senior Sustainability Manager	One
C13	Senior Technology Manager and Senior ESG Manager	Two
C14	Senior Sustainability Manager	One
C15	Sustainability Manager	One
C16	Senior Scientific Manager	One
C17	Senior Sustainability Manager	One

Source: Own elaboration.

Table 4.2 lists interviewees' generic roles, for anonymity purposes, and their count from each company. Most interviewees hold managerial positions, aligning with the study's goal to gain insights from decision-makers. While most companies had one representative, C7, C8, and C13 had more, indicating diverse perspectives from these organizations due to the varied roles of interviewees.

4.2 Environmental sustainability practices

Table 4.3 provides a comprehensive overview of sustainable practices in several industries, including data obtained from interviews and firm sustainability reports. Practices are denoted as "Yes" when they have been implemented, "-" when they have not been implemented, and "N.A." when they are not relevant to the firm. The objective of the table is to assess the level of dedication to environmental sustainability among various businesses.

Table 4.3 A cross-sectoral overview of sustainable practices and their implementation in different industries.

Sector and Industry Group	Industrial						Materials			Utilities		Constumer Staples			Information Technology		Health-care
	i. a	i. b		i. c			ii. a		ii.b	iii.a	iii.b	iv. a		iv. b	v. a		vi. a
Sustainable Practices	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17
i. Environmental policy disclosure	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ii. Preparation of environmental risk assessment reports.	Yes	-	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
iii. Adoption of Environmental Management Systems.	Yes	-	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes
iv. Energy efficiency.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
v. Cooperation and collaboration with partners in reducing environmental impact in the value chain.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
vi. Production or purchase of recycled or high percentage recycled material products.	Yes	Yes	-	Yes	Yes	Yes	-	N.A.	Yes	-	Yes	Yes	Yes	Yes	N.A.	-	Yes
vii. Adapting the business model.	Yes	Yes	N.A.	Yes	Yes	Yes	Yes	N.A.	N.A.	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes
viii. Recycling of goods and packaging within the organization.	Yes	Yes	-	Yes	Yes	Yes	Yes	N.A.	Yes	-	Yes	Yes	Yes	Yes	Yes	N.A.	Yes
ix. Encouraging product and/or packaging reuse by the end consumer.	Yes	Yes	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Yes	-	Yes	Yes	Yes	Yes	N.A.	N.A.	N.A.

x. Production of new products or services that improve environmental performance.	N.A.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-	N.A.	Yes	Yes	Yes	Yes	Yes	Yes
xi. Optimization of product return process.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	-	N.A.	Yes	N.A.	Yes	Yes	Yes	Yes	N.A.	N.A.	N.A.
xii. Promotion of environmental education among stakeholders.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: Own elaboration.

4.2.1 Strategic oversight and risk management

4.2.1.1 Environmental reporting and transparency

While the majority of organizations have common practices, company size and core business activities influence their approach. All companies, except for C2, C3 and C16, have environmental risk assessment reports, have adopted EMS, especially aligned with the ISO14001 framework, and have disclosed their annual sustainability reports where they lay out their environmental strategy, metrics and policies. C2, C3 and C16 while not directly adopting the mentioned practices due to their size, engage in business activities geared towards assisting their clients in monitoring and crafting their sustainability reports. As previously mentioned, larger corporations, in response to stricter regulations and heightened public scrutiny, typically adopt more extensive and transparent sustainability practices (Jasch, 2006). As highlighted by C13, "Medium and large organizations, as well as publicly traded companies, will be obliged to report in accordance with ESRS standards starting in 2025," underlining the growing regulatory pressures on larger corporations. Conversely, smaller companies such as C2, C3, and C16 exhibit a more constrained approach due to comparatively lower regulatory pressures. Nevertheless, these smaller entities still make contributions that are commensurate with their respective scale and scope.

The diverse timeframes seen in the adoption of sustainability reporting may primarily be ascribed to the initial legislative demands and sector-specific environmental implications. One notable example is the company C9, in the materials business. C9 has shown a consistent commitment to transparency on its sustainability policies over a period exceeding twenty years. The enduring dedication to this cause may be attributed to the first regulatory scrutiny that the materials industry saw as a result of its significant impact on the environment. The validity of this notion is further supported by the operational strategies used by different firms inside the same sector, shown as C8. C8 displays its further commitment to openness by offering "environmental invoices" to its customers. According to the interviewee, "such reports and disclosures aim to provide transparency about the company's activities to stakeholders, demonstrating compliance and commitment to sustainability."

On the other hand, it is noteworthy that companies in the industrial and service sector, C4, C5 and C15, have only recently started the dissemination of such reports in Portugal. The increasing demands in Portugal are driving industries that were not previously seen as having significant environmental effect to adopt more transparency on their environmental performance.

Considering the evolving regulatory pressures and stakeholder expectations, companies are presented with both challenges and opportunities for disclosing their sustainability metrics. According to the interviewee from C13, "currently, companies can choose from various reporting models like GRI, SASB, United Nations Global Compact, and ESGs to disclose their sustainability metrics the one that best suits their needs and business activities." However, this is set to change since, as previously stated, companies within the European Union by 2025 will be obliged to report in accordance with the ESRS to achieve a transparent and harmonious sustainability reporting across its borders. This represents a significant regulatory shift and underscores the urgency for companies to align their reporting mechanisms with the forthcoming ESRS guidelines.

4.2.1.2 Environmental performance indicators

Incorporating crucial environmental indicators into corporate operations has become increasingly important. These indicators encompass metrics like energy consumption, water use, waste management, greenhouse gas emissions, and transportation monitoring (Rahdari & Anvary Rostamy, 2015). In the Portuguese organizational landscape, these performance indicators are widely adopted. A notable focus lies on transportation, which is monitored not only from an operational standpoint but also in terms of employee commuting, especially in the services sector. Companies involved in activities requiring waste handling must also track metrics such as water and land pollution and hazardous waste, as mandated by law. The interviewee from C4 states that ISO14001 serves as a pivotal framework, guiding companies in establishing and maintaining these environmental KPIs and ensuring compliance with relevant legal requirements.

The emphasis on carbon emissions as a primary industry-agnostic metric for assessing environmental impact is a widespread practice among corporations, a point corroborated by C5. As stated, "presently, the majority of corporations often refer to and evaluate their environmental performance by quantifying their carbon emissions." This approach aligns with global efforts to reduce carbon footprints in the organization's scopes, established by the Science-Based Targets Initiative (SBTi), with each organization focusing on their industry's primary source of carbon emissions. As stated by C15, "the ultimate objective is a comprehensive understanding and documentation of all carbon footprints linked to our activities, be they direct or indirect." Many of these companies are extremely focused on achieving their carbon neutrality goals formulated by the European Union, reach net zero by 2050, further highlighting the importance of this particular environmental aspect.

There are, however, issues related to assessing and subsequently disclosing the third scope of the Science Based Targets initiative (SBTi) as highlighted by companies C4, C11 and C15. This scope evolves a diverse range of activities from distribution, transportation and even the usage of products by end consumer, making it hard to coordinate and harmonize data from multiple suppliers. Moreover, there is a lack of standardized metrics or methodologies to calculate Scope 3 emissions, making it difficult to compare performance across companies.

Nevertheless, in the foreseeable future, businesses want to establish supplementary industry-specific environmental performance indicators to tackle difficulties or provide a totally comprehensive outlook on their endeavors towards sustainability.

4.2.1.3 Strategic integration of sustainability

Considering the escalating environmental crisis, organizations are increasingly adopting the Triple Bottom Line methodology, which balances economic, environmental, and social performance indicators. By embedding sustainability into their strategic planning, these organizations are recognizing its equal importance alongside traditional financial metrics.

Organizations such as C6 and C11 are actively promoting sustainability as a fundamental element of their strategic planning. The organization in question adheres to the twofold materiality analysis framework, as established by the Task Force on Climate-related Financial Disclosures. This approach requires companies to not only report on how their operations impact the environment (inside-out materiality) but also assess how environmental issues could resonate back on the business itself (outside-in materiality). To materialize this commitment, C6 has gone a step further by issuing sustainability bonds, financial instruments that are intrinsically tied with the organization’s sustainability performance. Such a proactive financial strategy aligns closely with the Triple Bottom Line methodology, emphasizing the interdependence of economic, environmental, and social facets (Samajdar, 2014).

On the consumer empowerment front, C11 strongly advocates for the dissemination of comprehensive information about product sustainability. This incorporates lifecycle assessments for commonplace items. C11 contends that "the inability to access sustainability costs for simpler items like t-shirts obstructs consumers from making truly informed decisions," and champions technology as the solution to this information gap.

Similarly, C12 identifies an increasing stakeholder demand for detailed and holistic sustainability information on products, from raw material sourcing to final product certifications. In their view, stakeholders are becoming increasingly attentive, wanting a complete understanding of a product’s ecological footprint, which perfectly aligns with the Triple Bottom Line's emphasis on transparency and accountability.

C13 anticipates a paradigm shift in how business success metrics are formulated. "While organizations have traditionally measured performance in economic terms, the future will require accounting for a range of environmental and social aspects" notes C13. They believe that digital technologies will play a transformative role, converting these multi-faceted metrics into a common language that is as auditable and accessible as traditional financial reports.

Finally, to augment the strategic incorporation of sustainability, it is noteworthy to acknowledge the significance of fostering the creation of new products or services with the objective of enhancing environmental performance. Providing such advancements not only serves as a distinguishing factor in the marketplace, but also represents a significant step towards enhancing the environmental performance of their clients. The use of product development and product return optimization strategies has been especially notable in consumer staples sector. Companies in this sector such as C12, C13, and C14, which engage in direct customer interaction, have exceptional proficiency in implementing product return strategies. On the other hand, C9 makes an indirect contribution because of its business-to-business orientation exclusively. Energy companies engage in the practice of sharing surplus power with the grid, which may be seen as a kind of "product return." This strategy allows them to optimize energy use.

4.2.2 Operational efficiency and impact mitigation

4.2.2.1 Water and energy management

Across all industries, many companies are investing in green energy and favor environmental-friendly energy sources such as solar, wind and hydro. Some even explore the creation of green hydrogen from green energy sources. Moreover, most companies also have the certification ISO50001 for energy efficiency. C3 focuses on helping clients bolster their energy efficiency, underlining the burgeoning demand for such solutions. The transition from fossil-fueled vehicles to hybrid or electric alternatives is also in progress, although cost remains a barrier. Moreover, most companies have already implemented Smart LEDs to improve energy efficiency.

Water management is another area of emphasis. All organizations measure their water waste, however companies with activities dependent on water management go a step further. C8 focuses on post-use water quality enhancement, C14 employs closed-circuit systems for water conservation, and C16 monitors river water in real-time to ensure its purity.

4.2.2.3 Materials and products recycling and lifecycle management

The purchase of recycled products and recycling of packages and goods within the organization are widespread practices across all sectors. However, which recycled materials are prioritized and product lifecycle management varies notably across different sectors. The Construction and Engineering sector, with firms like C4, C5, and C6, prioritizes circularity, particularly in construction equipment and future material repurposing, as seen with C5. The Materials sector, where C8 stands out for its sustainable energy practices from by-products and responsible forest management, and C9 focuses extensively on end-consumer recycling through technology that enables total glass recycling. Utilities, exemplified by C11, adopt a multifaceted approach that advocates both product longevity and the repurposing of technical wear. Consumer Staples companies such as C12, C13, and C14 research intensely into eco-design, recyclability of products by the end-consumer and circular in-house packaging. The Pharmaceutical industry represented by C17, focus extensively in purchasing recycled materials, packaging recycling and eco-friendly products.

4.2.2.4 Sustainable business models

Businesses with traditional economies characterized by the "take-make-dispose" model developed by (Lieder & Rashid, 2016) like C12, C13 and C17 are modifying their business models for enhanced sustainability. C12 and C13, in the retail sector, offers bulk items and C12 is planning on introducing second-hand clothing stores. While C5 in the construction business, started offering repurposed solutions using modular designs that can easily be disassembled.

Companies have notably shifted towards rental over the purchase, ensuring “take-back” provisions. In other words, their products are later recycled and repurposed by their suppliers. This model minimizes the waste and lowers the overall carbon footprint, eliminating the need of production and distribution for new products.

Over an extended period, the Industrial and Materials sectors have shown leadership in the adoption of circular economy principles, successfully capitalizing on by-products and improving economic efficiency. This strategic approach aims to both reduce waste and provide supplementary sources of income. In recent times, several sectors have begun to embrace full circular processes across their operations, therefore establishing a systematic approach to waste reduction that aligns with both environmental objectives and financial advantages. Notably, C4 and C11 have extended their circular economy practices beyond by-products to include full lifecycle management of their construction equipment.

C11 also advocates for the integration of nature-based solutions in their operations, as these can prove to be both cost-effective and environmentally friendly. One such example is the restoration of autochthonous species to maintain the landscape and reduce mechanical labor. As the interviewee from C11 points out “the naturalization of species can help maintain the landscape and reduce the need for mechanical or manual labor in those areas.” This solution is both environmentally friendly and cost-effective. Similarly, C8 sets a precedent in the Materials sector by managing its own forest, which is their primary material, in a sustainable manner. C8 believes that by "managing responsibly the supply of our primary product not only boosts environmental conservation but also offers cost-effectiveness, supply chain resilience, and long-term business viability."

4.2.2.5 Supply chain and cooperation with partners

Collaboration is paramount in sustainability endeavors. All surveyed companies across all sectors emphasize aligning with partners to minimize environmental impact across the value chain. Notably, C4, C8 and C12 meticulously evaluates potential suppliers' sustainability based on certifications, such as ISO14001, and alignment with the ESG principles based on third-party audits and C11 enforces a sustainable code of practice for suppliers. This assessment is crucial to monitor and reduce the carbon footprint related to the third scope of the SBTi. Companies such as C3, C14, C15 and C17 engage in collaborative ventures with suppliers to refine operations and reduce emissions, especially imparting environmental knowledge further upstream in their operations. As C4 notes, "for large companies with extensive supplier networks, implementing sustainable practices can be a complex endeavor, especially when it comes to smaller suppliers who may lack the resources and infrastructure for accurate environmental assessments." Most of the organizations studied are partnered with the Business Council for Sustainable Development (BCSD) and other sustainability-related organizations to improve their environmental performance by leveraging collective knowledge.

4.2.2.6 Stakeholder education

As previously mentioned, companies are making efforts towards transparency in their activities and environmental impact. However, many companies also emphasize the relevance in educating their stakeholders. Concerning their employees and clients, numerous organizations are focusing on teaching sustainability using practical methods. For instance, some provide seminars on how employees can reduce their environmental footprint, while others have opted to use gamified applications to promote more sustainable practices.

4.3 Digital technologies

Table 4.4 presents a comprehensive summary of the adoption and use of digital technologies throughout the sectors and industry groups of the companies selected for analysis. This information is based on the interviews conducted and reflects the interviewees' knowledge of technology adoption within their respective companies. It aims to give a holistic view of how digital technologies are shaping businesses across sectors. Digital Technologies are denoted as "Yes" if they have been adopted, "-" if they have not been adopted.

Table 4.4 provides valuable insights about the adoption of Digital Technologies throughout various industries and industrial groupings, allowing for some noteworthy findings to be made. First and foremost, it is apparent that the use of Blockchain technology remains limited across several industries. This observation may indicate a perceived lack of practicality or concerns about the maturity of the technology. Furthermore, the use of 3D Printing or Digital Fabrication remains limited, mostly seen in the Industrial sector.

However, it is evident that Analytics & Big Data, Cloud, Internet of Things, Mobile Computing and Apps, and Social Media have been widely embraced in almost all industries and industrial segments. This implies that these technologies have become fundamental components in current corporate operations. The use of these digital technologies seems to be widespread across several sectors, highlighting their wide-ranging applicability and usefulness.

Table 4.4 Sector and industry group-wise adoption of digital technologies.

Sector and Industry Group	Industrial						Materials			Utilities		Constumer Staples			Information Technology		Health-care
	i. a	i. b		i. c			ii. a		ii.b	iii.a	iii.b	iv. a		iv. b	v. a		vi. a
Digital Technology	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**	**C17**
i. 5th Generation Internet	-	Yes	-	Yes	-	Yes	Yes	Yes	Yes	-	-	Yes	Yes	Yes	Yes	-	-
ii. Analytics & Big Data	Yes	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
iii. Artificial Intelligence	-	-	Yes	-	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	Yes	Yes	-
iv. Blockchain	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
v. Cloud	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
vi. Digital Fabrication/3-D Printing	-	-	Yes	-	Yes	Yes	Yes	-	-	-	-	-	-	-	-	-	-
vii. Internet of Things	-	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes
viii. Mobile Computing/Apps	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	Yes	Yes
ix. Social Media	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
x. Virtual Reality Systems/Augmented Reality	-	-	-	-	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	-	-	Yes	-	Yes

Source: Own elaboration.

4.4 Digital workflow

During the interviews, a notable interconnection between various technologies emerged, forming a cohesive digital workflow, backed by the literature review, which is detailed below in an illustrative diagram (Figure 4.1). This workflow is amplified by 5G's speed and connectivity properties. The technological workflow starts with data collection sources such as IoT, ERP systems, and Social Media platforms (Patel, 2019). With IoT's sensorization properties being instrumental in capturing real-time data from the organization's operations. This raw data, often stored and managed in the cloud, ensures scalability, accessibility, and real-time data exchange (Petri et al., 2018). The cloud-hosted data then flows into analytics and big data infrastructures where it is processed and refined (Patel, 2019). Following this refinement, the data is passed on to AI systems. The AI processes this data to generate predictions, highlight significant data points, detect anomalies, and self-evaluate its performance. This feedback not only refines the analytics process but also provides actionable insights. These insights are then relayed to various cloud-based end-user interfaces, like apps and dashboards, enabling both autonomous data-driven decisions and informed human decision-making. Insights and refinements from the AI and analytics phase can be sent back to the initial data sources to optimize and adjust their operations, ensuring a dynamic, constantly improving systems (Voulgaridis et al., 2022). For example, C4 integrated a seamlessly example of this digital workflow in the form of an automatic water irrigation system. Sensors deployed in the field can capture and transmit real-time measurements of soil moisture levels to a cloud-based platform. Upon undergoing processing and analysis, artificial intelligence (AI) algorithms ascertain the required amount of water to be deployed and the ideal timetable for optimal irrigation, afterwards implemented automatically by the system. The closed-loop mechanism continually improves itself, hence offering a dynamic and efficient watering system, conserving water, and energy resources.

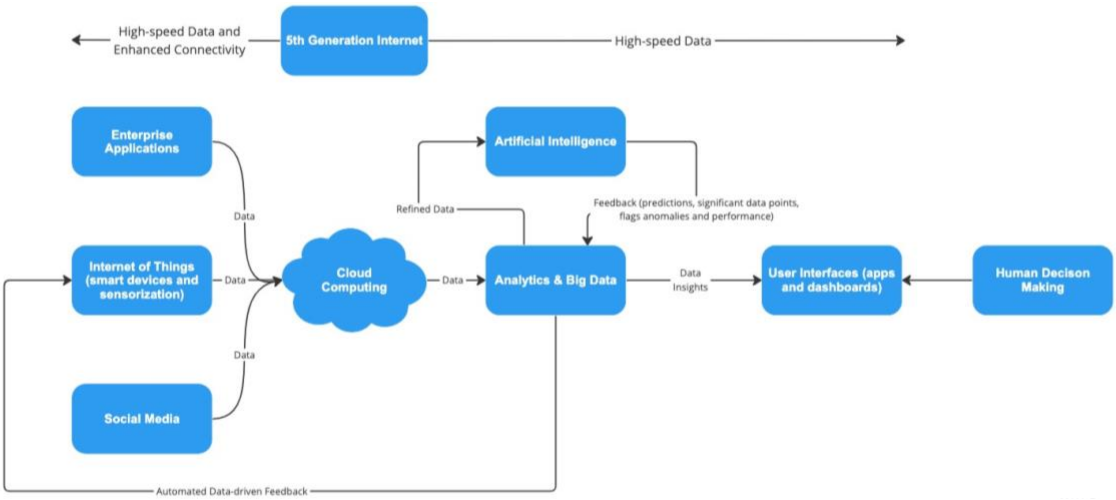

Figure 4. 2 Diagram of the integrated digital ecosystem workflow.

Source: Own elaboration.

4.5 Impact of digital technologies on sustainability

Table 4.5 provides a snapshot of how digital technologies intersect with environmental sustainability practices, based on interviewee insights. The presence of a (*) denotes that the technology is acknowledged for its capacity in promoting sustainability, although that sustainable practice is currently not adopted. The presence of a (**) indicates that while the organization is not already using the technology, it recognizes the potential of this technology in tackling that specific sustainability concern.

Accordingly to the analysis presented in the Table 4.5, Analytics and Big Data, as well as Cloud Computing, are widely used in many industries and play a crucial role in several sustainability initiatives, such as the development of environmental risk assessment reports and the enhancement of energy efficiency.

Artificial Intelligence (AI) is recognized for its selective but influential involvement in domains such as the formulation of environmental risk assessment reports and the implementation of Environmental Management Systems. Mobile computing and applications, together with the Internet of Things (IoT), are flexible technologies that are used in many sustainability initiatives, including energy efficiency and reduction of material waste.

However, the direct applications of 5th Generation Internet in the context of sustainability practices are noticeably lacking, suggesting that its potential contribution to environmental sustainability has not been adequately recognized or used.

Despite not being adopted by the researched companies for sustainable practices, Blockchain technology shows promise in some areas, notably supply chain transparency and traceability.
In a similar vein, the adoption of Digital Fabrication/3-D Printing remains limited, although it has significant potential for industries that prioritize material efficiency and waste reduction, as this technological advancement enables the practice of manufacturing on-demand.

Technologies such as Social Media and Mobile Computing and Apps have shown notable efficacy in facilitating stakeholder engagement practices, particularly in the realm of promoting environmental education.

In general, the implementation of digital technologies for the purpose of sustainable practices exhibits sector-specific variations, suggesting that the selection of technology is often contingent upon the distinct problems and prospects inherent to each sector.

Table 4.5 Matrix of digital technologies and their application in environmental sustainability practices.

	Digital Technologies									
Environmental Sustainability Practices	i. 5th Generation Internet	ii. Analytics & Big Data	iii. Artificial Intelligence	iv. Blockchain	v. Cloud	vi. Digital Fabrication/ 3-D Printing	vii. Internet of Things	viii. Mobile Computing/ Apps	iv. Social Media	x. Virtual Reality Systems
i. Environmental Policy Disclosure	-	-	-	-	-	-	-	C4, C12, C14, C17	All	-
ii. Preparation of environmental risk assessment reports	-	C5, C6, C7, C8, C9, C11, C17	C11, C15, C16	-	C5, C6	-	C5, C6, C7, C8, C9, C11, C14, C16, C17	C4, C5	-	-
iii. Adoption of Environmental Management Systems.	-	C4, C5, C6, C7, C8, C9, C10, C11, C12, C14, C15, C17	C11, C15, C16(*)	C8(**), C12(**), C13(**), C17(**)	C6	-	C5, C6, C7, C8, C9, C11, C12, C14, C15(**), C16, C17	C4, C5	-	-
iv. Energy efficiency.	-	C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C14, C15, C16, C17	C3, C6, C7, C8, C9, C11, C12, C14, C16	-	C1, C3, C4, C5, C6, C7, C8, C11, C15, C16, C17	-	C3, C5, C6, C7, C8, C9, C10, C11, C12, C14, C16, C17	C3, C4, C5, C6, C8, C9, C10, C14, C15, C16, C17	-	-
v. Material Efficiency and Waste Reduction	-	C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C14, C15, C16, C17	C3, C6, C7, C8, C9, C11, C12, C14, C16	-	C2, C3, C4, C5, C6, C7, C8, C11,	C3, C5, C6, C8(**)	C3, C5, C6, C7, C8, C9, C10, C11,	C3, C4, C5, C6, C8, C9, C10, C14, C15, C16, C17	-	C5, C11, C12, C17

	Digital Technologies									
Environmental Sustainability Practices	i. 5th Generation Internet	ii. Analytics & Big Data	iii. Artificial Intelligence	iv. Blockchain	v. Cloud	vi. Digital Fabrication/ 3-D Printing	vii. Internet of Things	viii. Mobile Computing/ Apps	iv. Social Media	x. Virtual Reality Systems
					C15, C16, C17		C12, C14, C16, C17			
vi. Cooperation and collaboration with partners in reducing environmental impact in the value chain.	-	C3, C5, C6, C8, C10, C11, C12, C14, C15, C16	C3, C15	C8(**), C12(**), C13(**), C17(**)	C5, C8, C10, C16, C17	-	C3	C3, C4, C5, C6, C8, C10, C11(**), C12, C14	-	-
vii. Production or purchase of recycled or high percentage recycled material products.	-	-	-	C8(**), C12(**), C13(**), C17(**)	-	-	-	C12	-	-
viii. Adapting the business model.	-	-	-	-	C3(*)	-	-	C4, C12	-	-
ix. Recycling of goods and packaging within the organization.	-	-	-	C8(*)(**), C12(**), C13(**), C17(**)	-	C5	C12	C14	-	-
x. Encouraging product and/or packaging reuse by the end consumer.	-	-	-	C8(**), C12(**), C13(**), C17(**)	-	-	C12	C4, C12, C14, C17	-	-
xi. Production of new products or	-	C3, C6, C12, C15, C16	C3, C5, C15, C16	-	C12, C15	-	C12, C16	C15	-	-

	Digital Technologies									
Environmental Sustainability Practices	i. 5th Generation Internet	ii. Analytics & Big Data	iii. Artificial Intelligence	iv. Blockchain	v. Cloud	vi. Digital Fabrication/ 3-D Printing	vii. Internet of Things	viii. Mobile Computing/ Apps	iv. Social Media	x. Virtual Reality Systems
services that improve environmental performance.										
xii. Optimization of product return process.	-	-	-	C8(*)(**), C12(**), C13(**)	-	-	-	C12	-	-
xiii. Promotion of environmental education among stakeholders.	-	C4, C17	C6	-	-	-	C11	C4, C12, C14, C17	All	-

Source: Own Elaboration.

4.5.1 5th generation internet

The complete use of 5G technology in industrial environments remains largely unadopted due to existing constraints in deployment, particularly pertaining to infrastructure limitations. However, the predominant effects of 5G are mostly seen in mobile networks and office environments. Companies capitalize on the improved connection offered by 5G technology, however they do not explicitly establish a clear correlation between 5G and sustainability. In the context of remote work, the 5G network's dependable and fast connectivity serves to mitigate the need of traveling, hence resulting in a reduction of carbon emissions (Wang et al., 2022). Companies, such as C14, have made significant progress in using the enhanced data transmission capabilities of 5G technology to facilitate the implementation of real-time analytics. Although the technology itself does not possess an intrinsic emphasis on sustainability, its capacity to provide real-time data facilitates improved energy and resource management, so making a valuable contribution to the promotion of sustainable operations. As stated by C13, "5G's main sustainable advantage lies in its enhanced connectivity capabilities rather than a direct impact on environmental sustainability."

4.5.2 Analytics & Big Data

The use of Analytics & Big Data is prevalent and exhibits considerable variation across diverse industries, with each industry using the technology to address distinct operational difficulties and capitalize on possibilities. As noted by C13 in our interviews, "The most significant contribution to environmental sustainability comes from Analytics & Big Data. This technology integrates data from various and sometimes unrelated sources, like stock management systems, to support environmental management. It also provides actionable insights, such as identifying reasons behind varying consumption rates across stores."

Analytics and Big Data are used in the manufacturing industry to enhance supply chain optimization and minimize wastage. Conversely, in the healthcare sector, the emphasis is placed on maximizing patient care and effectively managing resources. In the retail industry, as emphasized by C13, these technologies has the capability to monitor consumption rates across multiple stores, hence providing valuable information on optimal stock management strategies to minimize wastage. In the energy sector, the use of these technologies is of utmost importance in facilitating real-time monitoring of energy usage, hence aiding in load balancing and enhancing overall energy efficiency.

Although the direct correlation between Analytics & Big Data and environmental sustainability may not be immediately apparent, there is an increasing recognition of its crucial significance among organizations, including C3, C7, C10, and C12. These technologies provide a strong foundation for decreasing consumption and improving overall operating efficiency. Organizations such as C5 are use these technologies to optimize procurement processes, evaluate suppliers, and identify environmental risks. The use of Analytics & Big Data by organizations such as C12 and C3 to monitor operational parameters, including production and waste emissions, to enhance their sustainability efforts, is corroborated by recent study conducted by Mikalef et al. (2020). The adoption and implementation of Analytics & Big Data across several sectors exemplify the extensive and impactful potential of these technologies in advancing sustainable practices.

4.5.3 Artificial Intelligence

The use of artificial intelligence is getting more essential across diverse industries. Within the professional services industry, there is a growing trend among smaller organizations, such as C3, to use artificial intelligence (AI) to effectively manage energy consumption in buildings. This strategic approach not only aims to save costs but also seeks to mitigate environmental consequences associated with energy usage. Within the materials industry, prominent organizations such as C7 and C8 implement artificial intelligence (AI) techniques to effectively manage their carbon footprints. Additionally, C9 leverages predictive capabilities to proactively mitigate the risk of fires in their manufacturing facilities.

Within the utilities industry, organizations such as C11 are using machine learning algorithms to proactively predict a range of environmental events, including forest fires. In the realm of consumer staples, AI is used to optimize the production of cooking oils by C14, with the goal of better aligning their operations with sustainability goals.

In the realm of construction and engineering, prominent organizations such as C5 are venturing into the domain of material science with the objective of using AI to develop building materials that are more environmentally friendly. The use of machine learning for predictive analytics is prevalent in the technology industry, where prominent consulting companies such as C15 and specialist AI providers like C16 are actively involved. This application extends to other domains, including the anticipation of water quality concerns, including both operational and environmental aspects.

The increasing abundance of data is expected to contribute to the broadening of AI's potential applications in sustainability across several industries. These applications may include but are not limited to predictive maintenance, resource allocation, real-time monitoring, and automated decision-making. The adaptability of this entity guarantees its increasing significance in enhancing operational efficiency and promoting sustainability efforts, hence reinforcing its applicability across many sectors.

4.5.4 Blockchain

The recognition of blockchain technology's ability to significantly transform transparency within supply chains is becoming more prevalent across several industries. It is worth mentioning that some firms, such as C8, C12, C13, and C17, recognize the potential of this technology to improve traceability and security. However, the widespread adoption and use of this technology still pose challenges and none of the companies has yet fully adopted it. As the interviewee from C17 notes, "the reluctance to adopt it is not due to skepticism about its capabilities, but rather because of the lack of well-established networks, that are necessary for the technology to yield its full benefits."

Within the specific setting of Portugal's economic environment, which is characterized by a diverse range of main suppliers, many of whom are small to medium-sized enterprises, the establishment of a unified network necessary for the successful adoption of blockchain technology presents a notable obstacle. The lack of this network makes the considerable investment required for blockchain difficult to justify.

However, the investigative endeavors conducted by corporations such as C8, C12, and C13 pertaining to sustainable sourcing serve to emphasize the potential benefits of blockchain technology. C8 has undertaken an examination of its use within their wood supply chain with the aim of enhancing security measures and minimizing interruptions. This initiative highlights the potential for favorable outcomes, particularly in intricate supplier-customer dynamics within a supply chain context.

4.5.5 Cloud

Cloud technology is a very adaptable instrument that is used throughout various sectors, exerting a significant influence on every firm under examination. It is essential to acknowledge that the "Cloud" is of wide scope, embracing diverse applications ranging from the total migration of on-premises databases to the cloud, to the facilitation of collaborative workspaces.

For organizations seeking to mitigate their ecological footprint, the capacity to flexibly adjust storage resources is advantageous, since it obviates the need for superfluous hardware and equipment. Prominent suppliers of cloud services are actively advancing their efforts in the realm of environmental sustainability, as seen by Google's pledge to entirely rely on carbon-free energy for their operations by the year 2030.

The practicality of using cloud storage for data access is shown by C4's use of cloud technology in their due diligence procedures. Additionally, the use of cloud technology enables the establishment of remote work settings, therefore augmenting operational adaptability and concurrently mitigating the carbon emissions associated with everyday transportation. The use of cloud-based solutions facilitates the transition to paperless operations, so presenting an additional channel through which cloud technology plays a crucial role in advancing sustainability (Yalina & Rozas, 2020).

4.5.6 Digital fabrication and 3-D Printing

In the realm of Construction and Engineering, particularly in prominent corporations such as C5. The use of digital manufacturing and processes by C5 enables accurate control of materials, leading to waste reduction and strategic planning for the repurposing of such waste in other building endeavors. While allowing for efficient prototyping. This exemplifies the potential of digital manufacturing as a prominent catalyst for sustainability, especially within industries characterized by substantial waste generation.

On the other hand, organizations operating in the Professional Services sector, such as C3, exercise prudence. C3, a company specializing in Energy and Environmental Management Services, argues that the use of these technologies needs to be restricted to prototype development. This caution mostly stems from apprehensions over the substantial use of resources associated with the application of these technologies in wider production contexts.

4.5.7 Internet of Things

Organizations across all industries have expressed challenges in acquiring data of high-quality that encompasses a broad spectrum of operations. According to a representative from C12, "the use of sophisticated technological tools, such as sensorization and analytics, has been important in effectively quantifying sustainability indicators."

Numerous firms across various sectors, such as Professional Services (represented by C3) and Consumer Staples (exemplified by C12), heavily rely on the sensorization capabilities offered by Internet of Things (IoT) devices. The devices include a spectrum of functionalities, ranging from basic temperature and humidity sensors to advanced instruments designed for the assessment of air quality or soil moisture levels. Within the Information Technology industry, entities such as C15 and C16 are increasingly adopting advanced machine-learning algorithms capable of analyzing data obtained from a diverse range of sensors, including but not limited to motion detectors and infrared cameras.

Despite the extensive proliferation of Internet of Things (IoT) technology, it is commonly acknowledged that the whole capabilities of IoT remain untapped. Numerous businesses across all sectors are now prioritizing the development of sensorization capabilities to facilitate data collecting. However, there is a relatively smaller proportion of firms that are actively exploring the more intricate analytics and machine learning functionalities, which have the potential to provide more profound insights.

The irrigation system used by C14 incorporates advanced sensor technology, which includes soil moisture sensors and weather prediction algorithms, to efficiently manage water consumption. In the Construction and Engineering industry, C5 utilizes air quality sensors in conjunction with Internet of Things (IoT)-enabled vibration and tilt sensors to oversee the structural soundness of building constructions. In the field of Utilities, companies like as C10 and C11 use energy consumption sensors and smart meters in order to enhance the management of electrical grids.

The emphasis on sensorization is consistent with research findings indicating that just 36% of chief executive officers (CEOs) have shown trust in their ability to effectively evaluate their organization's sustainability performance (Maas et al., 2016). The use of these sensors enables accurate measurements, hence drawing attention to limitations within the supply chain and operational inefficiencies.

Through the analysis of sensor data, organizations can formulate plans aimed at enhancing energy efficiency and optimizing resource use. This is consistent with the prevailing patterns observed in the industry, where there is a growing emphasis on leveraging insights derived from the Internet of Things (IoT) to make well-informed decisions (Leiting et al., 2022).

4.5.8 Mobile computing and Apps

Mobile computing and apps have become critical tools for enhancing sustainability across diverse sectors. Industrial firms like C1 and C4 use software and apps to manage resource allocation and environmental metrics. Materials companies like C8 and C9 are shifting towards paperless operations and real-time quality control. Utilities like C10 and C11 rely on digital solutions for efficient energy management. Consumer staples organizations like C12, C13, and C14 utilize real-time data and gamification to reduce waste and promote recycling. In the tech sector, companies like C15 and C16 advocate for remote work and use AI analytics to improve sustainability. Finally, healthcare companies like C17 are using mobile technologies for regulatory compliance and safe disposal methods. Across the board, mobile technologies are streamlining operations, reducing waste, and enhancing sustainability initiatives.

4.5.9 Social Media

Social media has emerged as a crucial medium for firms operating in many sectors to exhibit their environmental projects and initiatives, cultivate public participation, and enhance transparency and communication with stakeholders. Companies across several industries using social media platforms to disseminate sustainability reports and policy, therefore informing stakeholders about their environmentally conscious endeavors. These platforms prioritize using the educational potential of social media to foster awareness and comprehension of environmental sustainability. C11 distinguishes itself by its unique strategy, aiming to incorporate more digital technologies into its social media platforms to provide additional value. C11 utilizes live feeds from its monitoring cameras to provide the public with a real-time visual representation of local animals and ecosystems, therefore augmenting transparency and fostering active involvement from relevant stakeholders. The rapid accessibility and significant impact of social media platforms are increasingly recognized as essential resources for corporations, enhancing their endeavors in promoting environmental sustainability and fostering a shared sense of accountability.

4.5.10 Virtual Reality (VR) and Augmented Reality (AR)

Various industries, including construction and engineering (C5), electric utilities (C11), food and basics retailing (C12), and pharmaceuticals (C17), have a shared need to enhance production efficiency and minimize resource wastage. The pursuit of this common objective has prompted these businesses to allocate resources towards the use of Virtual Reality (VR) technology in their training initiatives. The immersive characteristics of these technologies speed up acquiring knowledge, thereby enabling the efficient accomplishment of tasks and fostering sustainability by enhancing the use of resources.

Furthermore, a respondent from C13 highlighted the prospective future applications of virtual reality (VR) and augmented reality (AR), emphasizing their potential for environmental education. These technologies provide the potential to serve as influential instruments in fostering environmental consciousness. This may be achieved via the incorporation of educational initiatives that effectively disseminate information with the wider public.

4.6 Driving forces and challenges for the implementation of digital technologies for sustainable purposes

Within the dynamic state of digital technology and sustainability, organizations across many industries are confronted with obstacles and motivations. C9 has identified a recurring theme in the form of insufficient automation and a shortage of knowledgeable workers regarding digital technologies. The key impediment identified by the firm is a severe lack of knowledge, which is comparable to the technical expertise gap noted in connection to the Portuguese market by C13. Conversely, digital technologies are seen as avenues to enhance operational efficiency, a perspective that is also endorsed by C10, who highlights that digital technology enables the optimization of resources and facilitates enhanced communication. Nevertheless, C10 also raises a cautionary note over the carbon footprint associated with this technology and its potential use of vital raw resources. This echo worries expressed by other corporations regarding the environmental ramifications of digital solutions.

Within the domain of sustainability measures, corporations such as C11 are progressively using intelligent meters and centralized systems to monitor energy use. The level of data granularity has shown signs of improvement; however it has not yet reached an optimal state. C12 supports this viewpoint by highlighting the potential of sensorization and Internet of Things (IoT) technologies in augmenting the process of data collecting. These technologies have the benefit of incorporating additional layers of information that were previously overlooked. There is an increasing desire for transparency, especially in relation to the provision of product lifecycle information. The integration of digital and sustainability indicators necessitates regulatory control, as emphasized in the context of C16’s reality. AI systems need to shift from being “black box” entities to transparent entities to enable thorough audits.

The cost factor seems to be a prominent obstacle in the adoption of technology, as shown by C14's reference to the expensive nature of SAP software and C15's recognition of the financial challenges associated with the implementation of LED and smart lighting systems. C16 is particularly concerned about the financial obstacle, particularly in relation to the deployment of sensors that are specifically built for monitoring certain environmental indicators. C17 asserts that while cost continues to be a substantial obstacle, the increasing stringency of legislation pertaining to carbon footprints is making sustainable efforts more attractive.

CHAPTER 5

Conclusions, Limitations and Future Research

5.1 Major conclusions

5.1.1 Emerging trends and challenges in corporate sustainability

Due to evolving legal requirements, technological advances, and changing consumer preferences, sustainability has become a crucial focus for companies. This shift in consumer behavior is compelling companies to disclose their sustainability metrics, making transparency a key differentiator.

Corporations, especially large ones, adhere to established environmental standards like ISO14001 and produce annual sustainability reports based on frameworks like the GRI and SBTi. Regulatory changes by 2025, including ESRS requirements and IFRS Foundation standards, are expected to unify reporting across sectors (De Villiers et al., 2022).

Financial considerations, including the costs of digital technology, are a challenge for companies, yet many are committed to balancing economic, environmental, and social metrics. Investments in green energy and technologies, such as electric cars and Smart LEDs, are part of companies' operational strategies, along with strategic and financial emphasis on sustainability, such as sustainability bonds to make organizations accountable for their footprint.

A significant transition is taking place from traditional "take-make-dispose" models to circular economies, with leaders in the industrial and materials sectors showing the way. These changes are part of a broader trend toward comprehensive lifecycle management, alternative income streams, second-hand shopping, modular building, and upcycling to reduce waste.

Certifications like ISO14001 and ESG principles are being integrated into supply chains. Stakeholder engagement has evolved beyond transparency to include educational initiatives like seminars and gamification techniques. Collaboration with sustainability councils enhances these efforts.

5.1.2 Interplay of digital technology and sustainability

The famous quote from Peter Drucker, "You can't manage what you can't measure," mentioned by multiple interviewees perfectly depicts the need for precise metrics in managing sustainable performance, a requirement increasingly felt in the Portuguese corporate landscape. While several organizations are using modern technology such as process automation and analytics to monitor sustainability and leverage real-time decision making, both human or automated data-driven feedback, a significant number of corporations continue to depend on antiquated approaches like Excel spreadsheets and intuitive judgment. The conventional methods and lack of alignment between different sources are proving inadequate and time-consuming in fulfilling emerging regulatory demands and stakeholder expectations, emphasizing the increasing significance of prompt and precise data analytics for the purpose of sustainable development.

Two crucial technologies that constitute the core of this revolution are the Internet of Things (IoT) and the integration of Analytics with Big Data, the most widely adopted technologies by the companies studied. These technologies are not only optional additions, but rather indispensable instruments for contemporary sustainability management in several industries within Portugal. Through the provision of real-time data collecting and analytics, these technologies provide the groundwork for a new era characterized by efficient, data-centric operations and environmentally conscious corporate practices which is aligned with previous academic research by El Hilali et al. (2020).

Cloud technologies provide inherent sustainable benefits via the reduction of in-house physical server infrastructure requirements. Therefore, there is a decrease in both energy use and carbon emissions. Cloud computing is recognized for its ability to support digital remote workspaces and paperless operations (Yalina & Rozas, 2020), making it a scalable and environmentally conscious alternative.

Artificial Intelligence (AI) enhances the analytical process by introducing sophisticated predictive skills. Illustrative examples are the use of artificial intelligence algorithms for the purpose of forecasting industrial machine malfunctions, carbon emissions, wildfires, and weather. This facilitates the implementation of proactive and efficient approaches to sustainable management regarding environmental pollution control, waste management and sustainable production (Feroz et al., 2021).

The emergence of Mobile Computing and Apps improves organizational efficiency via the provision of real-time monitoring and reporting capabilities. These technologies enable the prompt and effective gathering of crucial sustainability measures, often in mobile environments, so contributing to the overarching objectives of corporate sustainability.

Although many technologies may not prioritize sustainability as a core feature, their applications might nonetheless provide indirect advantages in terms of sustainability. The implementation of 5th Generation Internet may indirectly result in increased efficiency in remote work and the potential to decrease the need of commuting and business traveling. Consequently, this has the potential to contribute to a reduction in carbon emissions. The construction industry is being transformed by the advancements in Digital Fabrication and 3D Printing technologies, which provide a high level of precision in resource use and efficient prototyping, resulting in less waste and improved sustainability (Nadagouda et al., 2020).

Social media platforms are increasingly recognized as excellent instruments for firms to promote their sustainability initiatives and interact with the public. These platforms function as channels for promoting transparency and facilitating educational outreach, so enhancing the overall comprehension of sustainable methods. Virtual Reality (VR) and Augmented Reality (AR) technologies have been introduced, allowing immersive training experiences that enhance performance and minimize resource inefficiencies (Frigo et al., 2016) and, potentially, stakeholder education though its consumer engagement properties.

Finally, the use of Blockchain technology has the capacity to significantly augment transparency and guarantee the traceability of both products and services (Saberi et al., 2018). Despite its potential benefits, the use of Blockchain technology in Portuguese enterprises encounters substantial obstacles, namely the need for network effect. The successful execution of this initiative necessitates not only a substantial financial commitment but also a significant advancement in technology, which has not yet been verified in the Portuguese corporate context.

5.1.3 Sector-specific and sector-agnostic challenges

Through our study, we conducted interviews across many industries, revealing a multifaceted set of difficulties, many of which were sector-specific while others were sector-agnostic. For instance, those who were interviewed within the industrial sector placed significant emphasis on the challenges associated with the integration of Internet of Things (IoT) devices for the purpose of real-time resource monitoring. The industry in question encounters a significant learning curve that extends beyond the mere procurement of hardware, including comprehensive software administration as well.

The respondents from the retail industry provided insights into the intricate and labor-intensive process of implementing sustainable supply chain management systems. This complexity arises from the engagement of numerous suppliers. In the field of agriculture, it is important to recognize that the problem at hand extends beyond technical advancements. It is essential for agricultural systems to possess the capability to adaptive and flexible technologies to effectively address the changing environmental conditions.

The respondents emphasized that in the context of sustainability and digital transformation, the IT sector is confronted with significant challenges, including the increasing need for strong data governance frameworks, ethical artificial intelligence techniques, and proficient multidisciplinary teams.

Nevertheless, there were issues of a general nature that beyond the bounds of certain sectors. One often mentioned concern was to the existing skills gap, where organizations across several industries expressed dissatisfaction with the scarcity of individuals with deep expertise in both digital technologies and sustainable practices.

5.2 Limitations to the research

While the study's sample size of seventeen enterprises is limited and does not fully represent all sectors in Portugal, it provides valuable preliminary insights into the relationship between digital technologies and sustainability within the Portuguese business landscape. One potential limitation to consider is that our approach to recruiting participants may have been more appealing to certain sectors and types of companies, thereby biasing the types of industries represented in our sample. This is especially noteworthy as some sectors are extremely fragmented, making it difficult to generalize our findings broadly. Despite these limitations, the research offers enough coverage to identify critical patterns and issues within specific industries.

The rapid expansion of digital technology and sustainability practices is another notable restriction in the current landscape. The dynamic nature of the environment under investigation has the potential to swiftly make the outcomes of this research obsolete, so posing a significant obstacle to the enduring application and pertinence of the study's results.

The study primarily utilizes interviews as the principal approach for data gathering, hence incorporating a degree of subjectivity into the obtained results. In addition, most organizations were examined through the lens of one respondent who had expertise in either environmental matters or digital technology. While several respondents have experience in both domains, others lacked such exposure, which might result in a potentially biased perspective that may not faithfully reflect a company's comprehensive endeavors in the realms of digital technology and sustainability. Despite these constraints, it is crucial to acknowledge that all participants in the interviews occupy positions of leadership and hold significant expertise within their respective domains, therefore offering a holistic and high-level perspective on their enterprises.

The research highlights a broad correlation between digital technologies and sustainability; however, it is crucial to acknowledge that not all technologies exhibited a direct or unequivocal association with sustainability results. For example, the use of 5th Generation Internet or Virtual Reality Systems technology, despite its potential as described in the existing scholarly literature by Camodeca and Almici (2021), could not demonstrate a conclusive and unequivocal beneficial effect on the promotion of environmental sustainability inside the examined businesses.

5.3 Future research

It is of utmost importance to comprehend consumer behavior within the context of digital technology and sustainability. The research may center on examining the effects of transparency tools and technologies, such as blockchain or IoT, on consumer decision-making processes and purchasing patterns. The growing accessibility of digital platforms necessitates more investigation into the impact of sustainability information sharing on customer trust and its role in promoting sustainable choices. Considering the existing literature has shown deficiencies in understanding the effects of digital technologies, such as Virtual Reality, on sustainability, it is imperative to investigate the potential influence of these emerging technologies on consumer behavior.

Another essential area for further exploration is the influence of public policy and regulatory frameworks. The potential impact of the European Sustainability Reporting Standards (ESRS) for the year 2025 on enterprises' use of digital technology within their sustainability strategies is noteworthy. The ESRS has the potential to function as a facilitator by establishing explicit norms and promoting openness, or as an impediment by imposing excessive reporting obligations that redirect resources from tangible sustainable initiatives.

A comparative analysis of one singe sector may provide significant insights into the distinct obstacles and possibilities that the studied sector encounters when using digital technology for the purpose of achieving sustainability. Considering the sample size and multi-sector focus of the study, there is a need for fresh research to pursue a more in-depth investigation, hence facilitating a deeper comprehension of specific sectors.

In-depth examinations of certain technologies, specifically those appointed as having a more promising impact on the future like the Internet of Things (IoT), Blockchain, and Artificial Intelligence, have the potential to provide valuable insights into their respective roles in promoting sustainability and enhancing environmental performance. The absence of use cases where blockchain is already in place for product and service transparency emphasizes the need for focused research in this area. Hence, it's essential for future research endeavors to prioritize the exploration of strategies that enhance the integration of these promising technologies with sustainability goals.

Finally, the use of a multi-methodological strategy is recommended for future research endeavors, using both case studies and empirical research. The integration of qualitative and quantitative data may enhance the empirical robustness and provide a more exhaustive comprehension of the intricate relationship between digital technologies and sustainability. As qualitative results can provide essential context and depth, quantitative data can confirm the study conclusions.

References

Afshari, H., Agnihotri, S., Searcy, C., & Jaber, M. (2022). Social sustainability indicators: A comprehensive review with application in the energy sector. *Sustainable Production and Consumption*, *31*, 263–286. https://doi.org/10.1016/j.spc.2022.02.018

Agudelo, M., Jóhannsdóttir, L., & Davídsdóttir, B. (2019). A literature review of the history and evolution of corporate social responsibility. *International Journal of Corporate Social Responsibility*, *4*(1). https://doi.org/10.1186/s40991-018-0039-y

Akande, A., Cabral, P., & Casteleyn, S. (2019). Assessing the Gap between Technology and the Environmental Sustainability of European Cities. *Information Systems Frontiers*, *21*(3), 581–604. https://doi.org/10.1007/s10796-019-09903-3

Almagtome, A., Khaghaany, M., & Önce, S. (2020). Corporate governance quality, stakeholders' pressure, and sustainable Development: an Integrated approach. *International Journal of Mathematical, Engineering and Management Sciences*, *5*(6), 1077–1090. https://doi.org/10.33889/ijmems.2020.5.6.082

Balogun, A. L., Marks, D., Sharma, R., Shekhar, H., Balmes, C., Maheng, D., Arshad, A., & Salehi, P. (2020). Assessing the Potentials of Digitalization as a Tool for Climate Change Adaptation and Sustainable Development in Urban Centres. *Sustainable Cities and Society*, *53*, 101888. https://doi.org/10.1016/j.scs.2019.101888

Bansal, P., & Roth, K. (2000). WHY COMPANIES GO GREEN: a MODEL OF ECOLOGICAL RESPONSIVENESS. *Academy of Management Journal*, *43*(4), 717–736. https://doi.org/10.2307/1556363

Barman, P. P., & Hallur, G. (2022). A Study on the impact of 5G on the Banking Industry: An Economic Impact Perspective. *2022 International Conference on Decision Aid Sciences and Applications (DASA)*. https://doi.org/10.1109/dasa54658.2022.9765085

Bassen, A., & Kovács, A. M. (2008). Environmental, Social and Governance Key Performance Indicators from a Capital Market Perspective. *Zeitschrift Für Wirtschafts- Und Unternehmensethik*, *9*(2), 182–192. https://doi.org/10.5771/1439-880x-2008-2-182

Baumüller, J., & Sopp, K. (2021). Double materiality and the shift from non-financial to European sustainability reporting: review, outlook and implications. *Journal of Applied Accounting Research*, *23*(1), 8–28. https://doi.org/10.1108/jaar-04-2021-0114

Beier, G., Fritzsche, K., Kunkel, S., Matthess, M., Niehoff, S., Reißig, M., & Van Zyl-Bulitta, V. (2020). A green digitalized economy? Challenges and opportunities for sustainability. *IASS Fact Sheet*, *1*. https://publications.iass-potsdam.de/pubman/faces/ViewItemOverviewPage.jsp?itemId=item_6000196

Bocken, N., Short, S., Rana, P., & Evans, S. (2014). A literature and practice review to develop sustainable business model archetypes. *Journal of Cleaner Production*, *65*, 42–56. https://doi.org/10.1016/j.jclepro.2013.11.039

Bohnsack, R., Pinkse, J., & Kolk, A. (2014). Business models for sustainable technologies: Exploring business model evolution in the case of electric vehicles. *Research Policy*, *43*(2), 284–300. https://doi.org/10.1016/j.respol.2013.10.014

Bonetti, F., Warnaby, G., & Quinn, L. (2017). Augmented reality and virtual reality in physical and online Retailing: A review, Synthesis and research agenda. In *Springer eBooks* (pp. 119–132). https://doi.org/10.1007/978-3-319-64027-3_9

Boons, F., & Lüdeke-Freund, F. (2013). Business models for sustainable innovation: state-of-the-art and steps towards a research agenda. *Journal of Cleaner Production*, *45*, 9–19. https://doi.org/10.1016/j.jclepro.2012.07.007

Büyüközkan, G., & Karabulut, Y. (2018). Sustainability performance evaluation: Literature review and future directions. *Journal of Environmental Management*, *217*, 253–267. https://doi.org/10.1016/j.jenvman.2018.03.064

Camodeca, R., & Almici, A. (2021). Digital Transformation and Convergence toward the 2030 Agenda's Sustainability Development Goals: Evidence from Italian Listed Firms. *Sustainability*, *13*(21), 11831. https://doi.org/10.3390/su132111831

Carroll, A. (2015). Corporate Social Responsibility (CSR) is on a Sustainable Trajectory. *Journal of Defense Management*, *05*(02). https://doi.org/10.4172/2167-0374.1000132

Chui, M., Manyika, J., & Miremadi, M. (2020, February 13). *Where machines could replace humans—and where they can't (yet)*. McKinsey & Company. Retrieved September 17, 2022, from https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/where-machines-could-replace-humans-and-where-they-cant-yet

Darnall, N., Henriques, I., & Sadorsky, P. (2009). Adopting proactive environmental strategy: the influence of stakeholders and firm size. *Journal of Management Studies*, *47*(6), 1072–1094. https://doi.org/10.1111/j.1467-6486.2009.00873.x

De Villiers, C., La Torre, M., & Molinari, M. (2022). The Global Reporting Initiative's (GRI) past, present and future: critical reflections and a research agenda on sustainability reporting (standard-setting). *Pacific Accounting Review*, *34*(5), 728–747. https://doi.org/10.1108/par-02-2022-0034

Demartini, M., Evans, S., & Tonelli, F. (2019). Digitalization Technologies for Industrial Sustainability. *Procedia Manufacturing*, *33*, 264–271. https://doi.org/10.1016/j.promfg.2019.04.032

Di Vaio, A., & Varriale, L. (2020). Blockchain technology in supply chain management for sustainable performance: Evidence from the airport industry. *International Journal of Information Management*, *52*, 102014. https://doi.org/10.1016/j.ijinfomgt.2019.09.010

D'Souza, C., Taghian, M., Lamb, P., & Peretiatkos, R. (2006). Green products and corporate strategy: an empirical investigation. *Society and Business Review*, *1*(2), 144–157. https://doi.org/10.1108/17465680610669825

El Hilali, W., El Manouar, A., & Janati Idrissi, M. A. (2020). Reaching sustainability during a digital transformation: a PLS approach. *International Journal of Innovation Science*, *12*(1), 52–79. https://doi.org/10.1108/ijis-08-2019-0083

Elkington, J. (1999). Cannibals with forks: the triple bottom line of 21st century business. *Choice Reviews Online*, *36*(07), 36–3997. https://doi.org/10.5860/choice.36-3997

ElMassah, S., & Mohieldin, M. (2020). Digital transformation and localizing the Sustainable Development Goals (SDGs). *Ecological Economics*, *169*, 106490. https://doi.org/10.1016/j.ecolecon.2019.106490

Emmanouilidis, C., Liyanage, J. P., & Jantunen, E. (2009). Mobile solutions for engineering asset and maintenance management. *Journal of Quality in Maintenance Engineering*, *15*(1), 92–105. https://doi.org/10.1108/13552510910943903

Feroz, A. K., Zo, H., & Chiravuri, A. (2021). Digital Transformation and Environmental Sustainability: A Review and Research Agenda. *Sustainability*, *13*(3), 1530. https://doi.org/10.3390/su13031530

Fiorentino, R., Grimaldi, F., Lamboglia, R., & Merendino, A. (2020). How smart technologies can support sustainable business models: insights from an air navigation service provider. *Management Decision*, *58*(8), 1715–1736. https://doi.org/10.1108/md-09-2019-1327

Freeman, R. E., & McVea, J. (2001). A stakeholder approach to strategic management. *Social Science Research Network*. https://doi.org/10.2139/ssrn.263511

Frigo, M. A., Da Silva, E. C. C., & Barbosa, G. F. (2016). Augmented Reality in Aerospace Manufacturing: A review. *Journal of Industrial and Intelligent Information*. https://doi.org/10.18178/jiii.4.2.125-130

Giesekam, J., Norman, J., Garvey, A., & Betts-Davies, S. (2021). Science-Based targets: on target? *Sustainability*, *13*(4), 1657. https://doi.org/10.3390/su13041657

Greenhalgh, C., & Rogers, M. (2010). Innovation, Intellectual Property, and Economic Growth. *Princeton University Press*. https://doi.org/10.1515/9781400832231

Gregori, P., & Holzmann, P. (2020). Digital sustainable entrepreneurship: A business model perspective on embedding digital technologies for social and environmental value creation. *Journal of Cleaner Production*, *272*, 122817. https://doi.org/10.1016/j.jclepro.2020.122817

Guest, G., Bunce, A., & Johnson, L. (2006). How Many Interviews Are Enough? *Field Methods*, *18*(1), 59–82. https://doi.org/10.1177/1525822x05279903

Halkos, G., & Nomikos, S. (2021). Corporate social responsibility: Trends in global reporting initiative standards. *Economic Analysis and Policy*, *69*, 106–117. https://doi.org/10.1016/j.eap.2020.11.008

Hildebrandt, B., Hanelt, A., & Firk, S. (2018). Sharing Yet Caring. *Business &Amp; Information Systems Engineering*, *60*(3), 227–241. https://doi.org/10.1007/s12599-018-0532-6

Hofmann, P. (2008). ERP is Dead, Long Live ERP. *IEEE Internet Computing*, *12*(4), 84–88. https://doi.org/10.1109/mic.2008.78

Holslin, P. (2022, July 29). *4G vs 5G | What's the difference?* HighSpeedInternet.com. Retrieved September 17, 2022, from https://www.highspeedinternet.com/resources/4g-vs-5g

Jankowski, S., Covello, J., Bellini, H., Ritchie, J., & Costa, D. (2014). The Internet of Things: Making sense of the next mega-trend. In *https://www.goldmansachs.com/insights/pages/internet-of-things/iot-report.pdf*.

Jasch, C. (2006). Environmental management accounting (EMA) as the next step in the evolution of management accounting. *Journal of Cleaner Production*, *14*(14), 1190–1193. https://doi.org/10.1016/j.jclepro.2005.08.006

Johnson, K. (2021, March 18). *What Is Digital Technology? 25 Best Examples*. Honest Pros and Cons. Retrieved September 16, 2022, from https://honestproscons.com/what-is-digital-technology-25-best-examples/

Jović, M., Tijan, E., Žgaljić, D., & Aksentijević, S. (2020). Improving Maritime Transport Sustainability Using Blockchain-Based Information Exchange. *Sustainability*, *12*(21), 8866. https://doi.org/10.3390/su12218866

Kamble, S., Gunasekaran, A., & Arha, H. (2018). Understanding the Blockchain technology adoption in supply chains-Indian context. *International Journal of Production Research*, *57*(7), 2009–2033. https://doi.org/10.1080/00207543.2018.1518610

Kassinis, G. I., & Vafeas, N. (2006). Stakeholder Pressures And Environmental Performance. *Academy of Management Journal*, *49*(1), 145–159. https://doi.org/10.5465/amj.2006.20785799

Kietzmann, J., Hermkens, K., McCarthy, I. P., & Silvestre, B. S. (2011). Social media? Get serious! Understanding the functional building blocks of social media. *Business Horizons*, *54*(3), 241–251. https://doi.org/10.1016/j.bushor.2011.01.005

Kumar, N. M., & Chopra, S. S. (2022). Leveraging Blockchain and Smart Contract Technologies to Overcome Circular Economy Implementation Challenges. *Sustainability*, *14*(15), 9492. https://doi.org/10.3390/su14159492

Kyrychenko, O. (2021). Environmental Regulations, Air Pollution, and Infant Mortality in India: A Reexamination. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3939238

Laasch, O. (2018). Beyond the purely commercial business model: Organizational value logics and the heterogeneity of sustainability business models. *Long Range Planning*, *51*(1), 158–183. https://doi.org/10.1016/j.lrp.2017.09.002

Lanzolla, G., Lorenz, A., Miron-Spektor, E., Schilling, M., Solinas, G., & Tucci, C. (2020). Digital Transformation: What is New if Anything? Emerging Patterns and Management Research. *Academy of Management Discoveries*, *6*(3), 341–350. https://doi.org/10.5465/amd.2020.0144

Lee, M. J., Wong, W. Y., & Hoo, M. H. (2017). Next era of enterprise resource planning system review on traditional on-premise ERP versus cloud-based ERP: Factors influence decision on migration to cloud-based ERP for Malaysian SMEs/SMIs. *2017 IEEE Conference on Systems, Process and Control (ICSPC)*. https://doi.org/10.1109/spc.2017.8313020

Leiting, A. K., De Cuyper, L., & Kauffmann, C. (2022). The Internet of Things and the case of Bosch: Changing business models while staying true to yourself. *Technovation*, 102497. https://doi.org/10.1016/j.technovation.2022.102497

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, *115*, 36–51. https://doi.org/10.1016/j.jclepro.2015.12.042

Liu, T., Wang, C., Fu, H., & Lei, T. (2022). Fusion Modeling and Heterogeneous Simulation of Big Data Technology in 5G Communication Network. *2022 4th International Conference on Smart Systems and Inventive Technology (ICSSIT)*. https://doi.org/10.1109/icssit53264.2022.9716554

Lu, Y. (2018). Blockchain and the related issues: a review of current research topics. *Journal of Management Analytics*, *5*(4), 231–255. https://doi.org/10.1080/23270012.2018.1516523

Maas, K., Schaltegger, S., & Crutzen, N. (2016). Integrating corporate sustainability assessment, management accounting, control, and reporting. *Journal of Cleaner Production*, *136*, 237–248. https://doi.org/10.1016/j.jclepro.2016.05.008

Man, J. C. D., & Strandhagen, J. O. (2017). An Industry 4.0 Research Agenda for Sustainable Business Models. *Procedia CIRP*, *63*, 721–726. https://doi.org/10.1016/j.procir.2017.03.315

Meixell, M. J., & Luoma, P. (2015). Stakeholder pressure in sustainable supply chain management. *International Journal of Physical Distribution & Logistics Management*, *45*(1/2), 69–89. https://doi.org/10.1108/ijpdlm-05-2013-0155

Metallo, C., Agrifoglio, R., Schiavone, F., & Mueller, J. (2018). Understanding business model in the Internet of Things industry. *Technological Forecasting and Social Change*, *136*, 298–306. https://doi.org/10.1016/j.techfore.2018.01.020

Mikalef, P., Boura, M., Lekakos, G., & Krogstie, J. (2019). Big data analytics and firm performance: Findings from a mixed-method approach. *Journal of Business Research*, *98*, 261–276. https://doi.org/10.1016/j.jbusres.2019.01.044

Mikalef, P., Pappas, I. O., Krogstie, J., & Pavlou, P. A. (2020). Big data and business analytics: A research agenda for realizing business value. *Information &Amp; Management*, *57*(1), 103237. https://doi.org/10.1016/j.im.2019.103237

Miles, J., & Gilbert, P. (2005). *A Handbook of Research Methods for Clinical and Health Psychology* (Illustrated). Oxford University Press.

Modisane, P., & Jokonya, O. (2021). Evaluating the benefits of Cloud Computing in Small, Medium and Micro-sized Enterprises (SMMEs). *Procedia Computer Science*, *181*, 784–792. https://doi.org/10.1016/j.procs.2021.01.231

Möller, A., & Schaltegger, S. (2005). The Sustainability Balanced Scorecard as a Framework for Eco-efficiency Analysis. *Journal of Industrial Ecology*, *9*(4), 73–83. https://doi.org/10.1162/108819805775247927

Morakanyane, R., Grace, A., & O'Reilly, P. (2017). Conceptualizing Digital Transformation in Business Organizations: A Systematic Review of Literature. *Digital Transformation – From Connecting Things to Transforming Our Lives*. https://doi.org/10.18690/978-961-286-043-1.30

Nadagouda, M. N., Ginn, M., & Rastogi, V. (2020). A review of 3D printing techniques for environmental applications. *Current Opinion in Chemical Engineering*, *28*, 173–178. https://doi.org/10.1016/j.coche.2020.08.002

Nguyen, Q. P., & Vo, D. H. (2022). Artificial intelligence and unemployment:An international evidence. *Structural Change and Economic Dynamics*, *63*, 40–55. https://doi.org/10.1016/j.strueco.2022.09.003

Nikolopoulou, K. (2022, September 6). *What Is Non-Probability Sampling? | Types & Examples*. Scribbr. Retrieved September 25, 2022, from https://www.scribbr.com/methodology/non-probability-sampling/

Oracle. (2020, June 3). *What is IoT?* oracle.com. Retrieved September 17, 2022, from https://www.oracle.com/pt/internet-of-things/what-is-iot/

Osterwalder, A., Pigneur, Y., & Tucci, C. L. (2005). Clarifying Business Models: Origins, Present, and Future of the Concept. *Communications of the Association for Information Systems*, *16*. https://doi.org/10.17705/1cais.01601

Pagoropoulos, A., Pigosso, D. C., & McAloone, T. C. (2017). The Emergent Role of Digital Technologies in the Circular Economy: A Review. *Procedia CIRP*, *64*, 19–24. https://doi.org/10.1016/j.procir.2017.02.047

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2013). Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research. *Administration and Policy in Mental Health and Mental Health Services Research*, *42*(5), 533–544. https://doi.org/10.1007/s10488-013-0528-y

Pan, X., Pan, X., Song, M., Ai, B., & Ming, Y. (2020). Blockchain technology and enterprise operational capabilities: An empirical test. *International Journal of Information Management*, *52*, 101946. https://doi.org/10.1016/j.ijinfomgt.2019.05.002

Park, S. H., Mazumder, N. R., Mehrotra, S., Ho, B., Kaplan, B., & Ladner, D. P. (2020). Artificial Intelligence-related Literature in Transplantation: A Practical Guide. *Transplantation*, *105*(4), 704–708. https://doi.org/10.1097/tp.0000000000003304

Patel, J. (2019). An Effective and Scalable Data Modeling for Enterprise Big Data Platform. *2019 IEEE International Conference on Big Data (Big Data)*. https://doi.org/10.1109/bigdata47090.2019.9005614

Petri, I., Zamani, A. R., Balouek-Thomert, D., Rana, O., Rezgui, Y., & Parashar, M. (2018). Ensemble-Based Network Edge Processing. *2018 IEEE/ACM 11th International Conference on Utility and Cloud Computing (UCC)*. https://doi.org/10.1109/ucc.2018.00022

Pirola, F., Boucher, X., Wiesner, S., & Pezzotta, G. (2020). Digital technologies in product-service systems: a literature review and a research agenda. *Computers in Industry*, *123*, 103301. https://doi.org/10.1016/j.compind.2020.103301

Porter, M. E., & Van Der Linde, C. (1995). Toward a new conception of the Environment-Competitiveness relationship. *Journal of Economic Perspectives*, *9*(4), 97–118. https://doi.org/10.1257/jep.9.4.97

Questions and Answers on the Adoption of European Sustainability Reporting Standards. (2023, July 31). European Commission - European Commission. Retrieved September 8, 2023, from https://ec.europa.eu/commission/presscorner/detail/en/qanda_23_4043

Rahdari, A. H., & Anvary Rostamy, A. A. (2015). Designing a general set of sustainability indicators at the corporate level. *Journal of Cleaner Production*, *108*, 757–771. https://doi.org/10.1016/j.jclepro.2015.05.108

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2018). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, *57*(7), 2117–2135. https://doi.org/10.1080/00207543.2018.1533261

Salim, H. K., Padfield, R., Hansen, S. B., Mohamad, S. E., Yuzir, A., Syayuti, K., Tham, M. H., & Papargyropoulou, E. (2018). Global trends in environmental management system and ISO14001 research. *Journal of Cleaner Production*, *170*, 645–653. https://doi.org/10.1016/j.jclepro.2017.09.017

Samajdar, C. (2014). Triple bottom line strategy for sustainable steel industry. *2014 2nd International Conference on Business and Information Management (ICBIM)*. https://doi.org/10.1109/icbim.2014.6970964

Sandeep, S., Ahamad, S., Saxena, D., Srivastava, K., Jaiswal, S., & Bora, A. (2022). To understand the relationship between Machine learning and Artificial intelligence in large and diversified business organisations. *Materials Today: Proceedings*, *56*, 2082–2086. https://doi.org/10.1016/j.matpr.2021.11.409

Schaltegger, S., Lüdeke-Freund, F., & Hansen, E. G. (2016). Business Models for Sustainability. *Organization &Amp; Environment*, *29*(3), 264–289. https://doi.org/10.1177/1086026616633272

Schoch, K. (2020). Case study research.: Research design and methods: An applied guide for the scholar-practitioner. *SAGE Publications*, 245–258.

Schöggl, J., Rusch, M., Stumpf, L., & Baumgartner, R. J. (2023). Implementation of digital technologies for a circular economy and sustainability management in the manufacturing sector. *Sustainable Production and Consumption*, *35*, 401–420. https://doi.org/10.1016/j.spc.2022.11.012

Scholz, R., Bartelsman, E., Diefenbach, S., Franke, L., Grunwald, A., Helbing, D., Hill, R., Hilty, L., Höjer, M., Klauser, S., Montag, C., Parycek, P., Prote, J., Renn, O., Reichel, A., Schuh, G., Steiner, G., & Viale Pereira, G. (2018). Unintended Side Effects of the Digital Transition: European Scientists' Messages from a Proposition-Based Expert Round Table. *Sustainability*, *10*(6), 2001. https://doi.org/10.3390/su10062001

Sebastian, I., Moloney, K., Ross, J., Fonstad, N., Beath, C., & Mocker, M. (2017). How big old companies navigate digital transformation. *MIS Quarterly Executive*, *16(3)*, 197–213.

Shahzad, M., Qu, Y., Zafar, A. U., Ding, X., & Rehman, S. U. (2020). Translating stakeholders' pressure into environmental practices – The mediating role of knowledge management. *Journal of Cleaner Production*, *275*, 124163. https://doi.org/10.1016/j.jclepro.2020.124163

Shao-ping, X., & Yun-jie, H. (2010). The Research of the Development Principles and Development Model of Circular Economy. *2010 International Conference on Challenges in Environmental Science and Computer Engineering*. https://doi.org/10.1109/cesce.2010.141

Sullivan, J., & Hussain, B. (2020, May 19). *How technology unlocks new value from the circular economy | Greenbiz*. Retrieved September 13, 2022, from https://www.greenbiz.com/article/how-technology-unlocks-new-value-circular-economy

Suoniemi, S., Meyer-Waarden, L., Munzel, A., Zablah, A. R., & Straub, D. (2020). Big data and firm performance: The roles of market-directed capabilities and business strategy. *Information &Amp; Management*, *57*(7), 103365. https://doi.org/10.1016/j.im.2020.103365

Talan, G. (2019, January 11). *Doing Well by Doing Good: A Systematic Review and Research Agenda for Sustainable Investment*. MDPI. Retrieved September 8, 2022, from https://www.mdpi.com/2071-1050/11/2/353

Talan, G., & Sharma, G. (2019). Doing Well by Doing Good: A Systematic Review and Research Agenda for Sustainable Investment. *Sustainability*, *11*(2), 353. https://doi.org/10.3390/su11020353

The Circular Business Model. (2021, June 15). Harvard Business Review. Retrieved September 19, 2022, from https://hbr.org/2021/07/the-circular-business-model

The European double up: A twin strategy that will strengthen competitiveness. (2021). In *https://www.accenture.com/_acnmedia/PDF-144/Accenture-The-European-Double-Up.pdf#zoom=50*. Accenture. Retrieved September 16, 2022, from https://www.accenture.com/us-en/insights/strategy/european-double-up

Tilson, D., Lyytinen, K., & Sørensen, C. (2010). **Research Commentary**—Digital Infrastructures: The Missing IS Research Agenda. *Information Systems Research*, *21*(4), 748–759. https://doi.org/10.1287/isre.1100.0318

Tiwana, A., Konsynski, B., & Bush, A. A. (2010). **Research Commentary**—Platform Evolution: Coevolution of Platform Architecture, Governance, and Environmental Dynamics. *Information Systems Research*, *21*(4), 675–687. https://doi.org/10.1287/isre.1100.0323

Upward, A., & Jones, P. (2015). An Ontology for Strongly Sustainable Business Models. *Organization &Amp; Environment*, *29*(1), 97–123. https://doi.org/10.1177/1086026615592933

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, *28*(2), 118–144. https://doi.org/10.1016/j.jsis.2019.01.003

Voulgaridis, K., Lagkas, T., & Sarigiannidis, P. (2022). Towards Industry 5.0 and Digital Circular Economy: Current Research and Application Trends. *2022 18th International Conference on Distributed Computing in Sensor Systems (DCOSS)*. https://doi.org/10.1109/dcoss54816.2022.00037

Wang, S., Qin, J., Qi, X., Yan, Z., He, M., & Liu, Y. (2022). Discussion on 5G Business Model in Power Industry. *2022 IEEE 5th International Electrical and Energy Conference (CIEEC)*. https://doi.org/10.1109/cieec54735.2022.9846465

Warhurst, A. (2005). Future roles of business in society: the expanding boundaries of corporate responsibility and a compelling case for partnership. *Futures*, *37*(2–3), 151–168. https://doi.org/10.1016/j.futures.2004.03.033

World Commission on Environment and Development. (1987). *Our Common Future*.

Wynn, M., & Jones, P. (2022). Digital Technology Deployment and the Circular Economy. *Sustainability*, *14*(15), 9077. https://doi.org/10.3390/su14159077

Yalina, N., & Rozas, I. S. (2020). Digital workplace: digital transformation for environmental sustainability. *IOP Conference Series: Earth and Environmental Science*, *456*(1), 012022. https://doi.org/10.1088/1755-1315/456/1/012022

Yeng, F., Yazdanifard, R., & Wong. (2015). Green marketing: A Study of Consumers Buying Behavior in Relation to Green Products. *Global Journal of Management and Business Research*, *15*(5). https://globaljournals.org/GJMBR_Volume15/2-Green-Marketing-A-Study.pdf

Zachariadis, T. (2016). Climate Change Impacts. *SpringerBriefs in Environmental Science*, 25–49. https://doi.org/10.1007/978-3-319-29688-3_3

Zheng, Z., Xie, S., Dai, H., Chen, X., & Wang, H. (2017). An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends. *2017 IEEE International Congress on Big Data (BigData Congress)*. https://doi.org/10.1109/bigdatacongress.2017.85

Annexes

Annex A. Interview's guide

INTERVIEW

A. Introduction

The purpose of the interview will be to collect information on the implementation of digital technology in organizations, as well as on its relationship with environmental sustainability. The information collected in it will serve as a source for the preparation of a Master's Thesis and its publication in the Repository of Iscte - Instituto Universitário de Lisboa. The interview should take up to 30 minutes.

B. Anonymization

The identities of all organizations and participants will be anonymized.

C. Consent to Recording

The audio recording will be requested during the course of the interview for later transcription and analysis of the content collected.

If you have any problems or questions about the interview, do not hesitate to contact:

- Email: ajlfa@iscte-iul.pt

RESEARCH CONTEXT

Recent studies indicate a lack of understanding, through practical cases, of how digital technologies enable the creation of value in order to promote environmental sustainability in organizations. This Master's Thesis seeks to bridge this gap in the academic literature through an analysis of best practices and environmental sustainability initiatives using digital technologies.

This study will analyze companies in each sector and in different business areas, therefore, not all the options presented may be suitable for the activities of your Organization.

Research objectives:

1. Understand which are the Digital Technologies that are being most used in Organizations and their respective purpose;
2. Understand how Digital Technologies allow to improve or create environmental sustainability initiatives in an Organization;
3. Specify how you can obtain these results and identify which environmental metrics are used to measure them.

QUESTIONS

Part I – Characterization of the Organization

1. Briefly, what is the business area or main activity of your organization?
2. How many employees does your organization have?
3. What is your position in your organization?

Part II – Digital Technologies and Sustainable Practices

4. What are the digital technologies that are used in your Organization?

Suggestions:

i. 5th Generation Internet
ii. Analytics & Big Data
iii. Artificial Intelligence
iv. Blockchain
v. Cloud
vi. Digital Fabrication/3-D Printing
vii. Internet of Things
viii. Mobile Computing/Apps
ix. Social Media
x. Virtual Reality Systems

5. Clarify the use and purpose of digital technologies, which you identified in the previous question, in your Organization. Try to specify the areas of the company in which they operate.

6. What are the sustainable practices that your Organization carries out or intends to carry out in the near future?

Suggestions:

i. Disclosure of environmental policies (example: sustainability reports).
ii. Preparation of environmental risk assessment reports.
iii. Adoption of Environmental Management Systems (example: ISO 14000).
iv. Energy efficiency (examples: reduction of energy consumption, use of renewable energy sources, etc.).
v. Cooperation and collaboration with partners in reducing the environmental impact in the value chain (example: transition to circular economy).
vi. Production or purchase of recycled products or with a high percentage of recycled material.
vii. Adapt the business model (example: rental contracts instead of purchasing products, etc.).
viii. Recycling of goods and packaging within the organization.
ix. Encourage the reuse of the product and/or packaging by the final consumer.
x. Production of new products or services that improve environmental performance.
xi. Optimization of the product return process.
xii. Promotion of environmental education with stakeholders.

7. For the digital technologies identified above, or for combinations of these, identify how they promote the environmentally sustainable practices you just mentioned.

Suggestions:

i. 5th Generation Internet

ii. Analytics & Big Data
iii. Artificial Intelligence
iv. Blockchain
v. Cloud
vi. Digital Fabrication/3-D Printing
vii. Internet of Things
viii. Mobile Computing/Apps
ix. Social Media
x. Virtual Reality Systems

8. What metrics does your organization use to measure the impact of digital technologies on environmental performance?

Suggestions:

i. Production of goods or services (kg, items, etc.).
ii. Consumption of natural resources and raw materials (total tons of raw materials used).
iii. Energy consumption (e.g. energy consumption per unit output, energy efficiency, etc.).
iv. Water consumption (e.g. water consumption per unit of output, employee, etc.).
v. Waste emitted (e.g. waste emitted per unit of output, employee, etc.).
vi. Greenhouse gas emissions (e.g. CO2 emissions per unit of output, collaborator, etc.).
vii. Water and land pollution (e.g. total waste disposal per cubic metre, etc.).
viii. Hazardous waste (total tonnes of hazardous waste generated).
ix. Transportation (e.g., proportion of employees commuting by car to work, etc.).

9. In your opinion, what are the favorable factors and barriers to the application of digital technologies?

10. If applicable, add more relevant information about the use of digital technologies and environmental sustainability in your Organization.

Annex B. Summaries of the interviews

Interview C1 (Senior Technology Manager)

Digital Technology Adoption

Digital technologies in use include Analytics & Big Data for cross-organizational analysis (comparing packaging in the market versus recyclability costs), Cloud services through Office 365, and Social Media for marketing campaigns and its outcomes.

Adopted Environmentally Sustainable Practices

The organization has already implemented several sustainable practices. These include public disclosure of environmental policies, risk assessment reports, an Environmental Management System (e.g., ISO 14000), and energy efficiency measures. They also cooperate with partners to reduce environmental impact and focus on the recycling and reuse of goods and packaging. Environmental education is also promoted among stakeholders.

Digital Technology's Role in Enhancing Environmental Sustainability

Cloud technology is used to reduce local energy consumption. Social Media is used for raising awareness and educating society about sustainable environmental practices. Analytics & Big Data aren't perceived to directly relate to environmental sustainability.

The organization acknowledges that digital technologies have helped in reducing paper usage, printing, and physical travel, while also increasing productivity.

Measurement Metrics

Various metrics are used to measure the impact of digital technologies on environmental performance, including consumption of natural resources and raw materials, energy consumption, water consumption, waste emissions, and greenhouse gas emissions. Metrics like production of goods, water pollution, and hazardous waste are not being measured.

Main Challenges and Incentives to Digital Technology Implementation

The main incentives for applying digital technologies include the need for them and the competitiveness they bring. Barriers include a lack of specialized knowledge and resources, as well as high costs.

Interview C2 (Operations Manager)

Digital Technology Adoption

The organization adopts a mix of digital technologies including 5th Generation Internet for remote work, Cloud for server hosting, Microsoft Apps for mobile computing, and Social Media platforms like LinkedIn and Instagram for marketing. However, Analytics, AI, Blockchain, Digital Fabrication, IoT are not being utilized.

Adopted Environmentally Sustainable Practices

While they have not formalized environmental policies through documentation, the organization has adopted a variety of sustainable practices. These include energy efficiency, collaboration with partners for reducing environmental impact, using recycled products, recycling goods and packaging, encouraging reusability, and environmental education among stakeholders.

Digital Technology's Role in Enhancing Environmental Sustainability

Cloud technology has been employed to reduce paper usage in the office, while social media platforms like LinkedIn and Instagram are used for promoting good environmental practices.

Measurement Metrics

The organization does not have any specific metrics in place to measure the impact of digital technologies on environmental performance. All possible categories such as goods production, resource consumption, water consumption, waste emitted, greenhouse gas emissions, amongst others, are considered as "Not Applicable" in their business context. While the organization itself does not maintain environmental metrics, their co-working office space does have several environmental metrics, hinting at the potential for future adoption and measurement.

Main Challenges and Incentives to Digital Technology Implementation

The main favorable factor for digital technology adoption is noticeable improvements in processes. The key challenge is resistance to change within the organization.

Interview C3 (Sustainability Manager)

Digital Technology Adoption

C3 is a company that leverages a variety of digital technologies including Analytics & Big Data, Artificial Intelligence, Cloud, Digital Fabrication, Internet of Things, Mobile Computing/Apps, and Social Media. These technologies are used to enhance energy efficiency and resource management in their operations. The company utilizes sensorization capabilities to gather data that is later transformed into models. These models provide real-time information which can be displayed in mobile applications as alerts or integrated into systems such as lighting and irrigation systems. This use of technology ultimately reduces electricity and resource consumption by enhancing efficiency.

Adopted Environmentally Sustainable Practices

The interviewee emphasizes that his company primarily focuses on carbon reduction due to the nature of the services they provide. Among the organization's initiatives are transitioning their fleet of vehicles from fossil fuel to electric, switching their lighting to LEDs, and promoting recycling. They have made substantial impact on their clients' operations, helping them reduce primary electricity consumption by 40% to 50%. Primary electricity refers to energy directly generated from primary sources such as wind, solar, and hydropower. Apart from their own practices, C3 also aids their clients in drafting and disclosing their environmental policies. The company collaborates with its suppliers to enhance the utilization of HVAC systems through sensorization. Moreover, they frequently host webinars and talks to educate their clients' employees on individual-level carbon footprint reduction.

Digital Technology's Role in Enhancing Environmental Sustainability

The interviewee shares an example of a project in which sensorization and intelligent algorithms were employed to adapt and enhance energy consumption according to the specific requirements of a building, leading to savings of up to 30% on electricity costs. The interviewer highlighted that a variation exists across industries - both resource-intensive and non-resource-intensive - in terms of understanding and implementing technologies and practices for enhancing environmental performance. However, it was made clear that there is not necessarily a direct correlation between the extent of a sector's resource-intensity and its level of environmental consciousness or the adoption rate of these technologies. The interviewee believes in the interconnectedness of various technologies like 5th Generation Internet, Analytics & Big Data, Cloud, Internet of Things, and Mobile Computing/Apps. These technologies are integral to carrying out comprehensive analysis of the company's operations. Data is gathered through IoT devices, transmitted via the Cloud, and analyzed using analytics on a 5G network. The interviewee mentions that in most cases, simple analysis can yield significant results and aid decision making without needing to delve into complex analytics. Furthermore, even without replacing existing equipment, the application of these technologies can dramatically improve environmental performance. These technologies play a crucial role in Industry 4.0 by centralizing information, making it easier for users to analyze data and make decisions. Looking to the future, the interviewee sees Industry 5.0 as a new era where humans and robots coexist and collaborate rather than working in isolation. The interviewee also notes the role of 5G networks in facilitating fast data transmission, especially from sensors, for real-time decision-making. Digital Fabrication/3-D Printing is utilized for prototypes but phased out in the later stages due to plastic waste concerns. Lastly, Social Media is leveraged to promote environmentally sustainable practices and facilitate communication.

Measurement Metrics

The organization has established metrics related to the production of goods and services, energy consumption, water consumption, greenhouse gas emissions, and transportation, as these factors are directly linked to their business activities.

Main Challenges and Incentives to Digital Technology Implementation

Knowledge sharing among companies is a key incentive that helps overcome potential barriers to finding solutions. The rapidly evolving technological landscape, however, creates a challenge for companies to keep up with advancements. Other hurdles include the availability of hardware components due to travel restrictions in Asia, a major hardware provider, and the scarcity of skilled labor in Portugal. The biggest obstacle, according to the interviewee, is the lack of mainstream sustainability software and solutions that are affordable and accessible for small companies, not just for large corporations capable of making significant investments.

The Future of Digital Technologies and Sustainability

Looking forward, the interviewee envisions Industry 5.0 as a time when the relationship between humans and machines becomes even more symbiotic, with increasing incorporation of human feedback into algorithms. As performance increases and the cost of technologies such as solar panels decreases, the interviewee believes every household will have the opportunity to reduce their environmental impact and carbon footprint, making sustainability a common practice.

Interview C4 (Senior Environmental Sustainability Manager)

Digital Technology Adoption

The company is piloting projects that involve implementing 5th generation internet technology. Cloud technology is utilized, offering protection against cyber-attacks among its many benefits. Data gathered through Analytics and Big Data are automatically integrated into their management systems, enhancing the management of their construction projects. The parent organization uses Mobile Computing/Apps to create personalized applications for various businesses and operations within the company. Examples include apps for logging personal expenses, reporting environmental accidents, tracking carbon footprint, and promoting circular economy practices, such as selling subproducts and equipment that are byproducts of the main activity. Additionally, the organization has dedicated teams to manage the social media presence of its brands and publish environmental programs and reports.

Adopted Sustainable Environmentally Practices

In 2022, the company released its inaugural sustainability report, covering areas like ethics, compliance, corruption, innovation, security, and safety. Environmental metrics are followed as established by the Global Report Institute (GRI), with plans to measure more material KPIs increasingly. The interviewee mentions that the company assesses their environmental risks in all their operational activities as mandatory per their ISO14001 certification. The company positions itself in the middle level of the Business Council for Sustainable Development (BCSD) framework, which suggests they are still understanding their environmental impact to define a strategy and action plan. For ESG maturity diagnosis, the BCSD uses a tool called C-MORE. Energy efficiency is linked directly to their core business activity and is implemented internally. The company is investing in photovoltaic panels, contributing to green hydrogen production, charging their vehicle fleet, and supplying the national grid with clean energy. They are transitioning their fleet to hybrid and electric vehicles and are implementing digitalization to provide more sustainable and efficient solutions to clients, such as installing smart LEDs.

The company practices circular economy strategies, selling subproducts and equipment via an app after their use in projects, extending product life cycles, and encouraging employee or charitable product ownership after a certain age. They are also imposing stricter rules on carbon-intensive upstream suppliers and collaborating for more sustainable products. However, implementing these rules can be challenging with smaller suppliers. They utilize a carbon footprint app and waste management programs, promoting proper and sustainable waste management practices.

Digital Technology's Role in Enhancing Environmental Sustainability

Analytics and Big Data are employed to analyze the data inserted through mobile apps, visualizing data on a dashboard to aid in consumption monitoring and decision-making. They use gamification to educate employees about environmental sustainability and reducing their carbon footprint. Social media is used to promote environmental awareness.

Measurement Metrics

All metrics, the interviewee stated, could be referred to in their sustainability report.

Main Challenges and Incentives to Digital Technology Implementation

The primary challenge is the centralized and automated updating of information about environmental metrics and certifications to ease information access. One of the main obstacles is the centralization and automatic update of information regarding environmental metrics and certifications, making it easier to have access to information.

The Future of Digital Technologies and Sustainability

The interviewee highlighted a project focused on creating 12 public dashboards, each one dedicated to a different natural heritage area. The goal is to educate stakeholders and provide information to the public of the richness and significance of these natural heritage sites. These dashboards will serve as real-time information platforms offering a range of data relevant to each site. The metrics provided will include elements such as biodiversity indices, geo-referencing data of flora and fauna, cultural dimensions and artifacts, historical relevance, and potential environmental impact indicators. These data points are aligned with the core themes of the 12 biospheres, a term suggesting the company's recognition of different ecological and environmental zones.

Interview C5 (Senior Sustainability Manager)

Digital Technology Adoption

C5's construction projects have incorporated sensorization capabilities, marking a shift towards industrialized construction. This has enhanced both traceability and the sensor-based monitoring of their projects. To support this transition, the organization is piloting an Augmented Reality program to train their teams, ensuring they are adept at using these advancements on-site. The cloud serves as a backbone for information centralization, facilitating a collaborative environment. Mobile and computing applications further support construction endeavors, consolidating information like project designs and logging essentials like energy, water, and fuel consumption. As a testament to their commitment to modernization, C5 has transitioned to a paperless environment. While they are still enhancing their capabilities in Analytics & Big Data, current analytics already provide insights from their sensor-based systems. Additionally, they utilize artificial intelligence in secondary operations, for instance, in billing processes through third-party platforms. Digital fabrication and 3-D printing are also integrated into their operations for creating building models. Furthermore, the organization leverages Social Media platforms for a wider reach and engagement.

Adopted Environmentally Sustainable Practices

C5 recognizes its societal responsibility, ensuring their operations are both sustainable and community-friendly. They have institutionalized environmental reporting, holding the ISO14001 certification, and make their environmental risk assessments transparent. Partnering with third parties, they are amplifying their energy efficiency, increasingly relying on renewable energy sources like solar power.

Their primary objective is minimizing water consumption. With a largely internal supply chain, sharing their environmental concerns becomes more cohesive. Notably, they've pioneered sustainable construction through the circular economy: structures built from concrete and wood that can later be repurposed. Their investment in recycling is evident, not just in procurement but also in their innovative approaches to material utilization. Their commitment to eco-friendliness extends to transitioning to electric vehicles. Metrics have been set to ensure a high percentage of recycled materials in their operations. They are champions of creating products with enhanced environmental performance and are proactive in promoting sustainable practices through webinars for their stakeholders.

Digital Technology's Role in Enhancing Environmental Sustainability

In C5's perspective, technology is pivotal to operational efficiency. Using Analytics & Big Data, they assess supplier reliability and discern environmental risks. This data also aids in evaluating the progression of construction projects, correlating time investments with environmental factors. Artificial intelligence is on the horizon for C5, with plans to employ it for creating sustainable product mixes. The move to a paperless operation was streamlined using cloud-based solutions, wherein even event expenses and designs are digitized. Digital Fabrication reduces waste by optimizing material use, and plans are in place to repurpose this waste for various projects. IoT plays a pivotal role through sensorization, for instance, in monitoring air quality, thereby integrating into the building management systems for enhanced performance. Social Media amplifies their sustainability messaging, while Augmented Reality provides immersive training experiences, aiming to heighten productivity and limit wastage.

Measurement Metrics

Although C5 doesn't yet possess a unified system for sustainability metrics, their detailed sustainability report bridges this gap. This report encapsulates their construction ventures and the materials required, with digital technology automating data collection. With a proprietary brand dedicated to tracing their energy efficiency, they're also integrating smart building management systems. However, waste emissions still require manual tracking. While they measure CO_2 emissions (scope 1 and 2), scope 3 remains a future goal. Regulatory adherence ensures the safe disposal of hazardous waste, even though it's outsourced and doesn't necessitate internal tracking. Commuting efforts are documented, and the organization encourages the use of shared services to minimize carbon footprints.

Main Challenges and Incentives to Digital Technology Implementation

One of the most formidable challenges C5 faces is the knowledge gap in software utilization, especially in the construction sector where digital literacy may not be widespread. This, combined with perceived inadequacies of available ESG tracking softwares and high costs, particularly challenges smaller enterprises.

The Future of Digital Technologies and Sustainability

In the realm of construction, the future is undeniably digital. Harnessing these technologies will be essential to optimize operations and derive more from fewer resources. The expectation is for sustainable solutions and software to become commonplace, with costs becoming more accessible for companies of all scales. With increasing industrialization in construction, processes will become streamlined, resembling efficient factories. In this evolution, digital technologies will undeniably play a foundational role.

Interview C6 (Senior Environmental Sustainability Manager)

Digital Technology Adoption

C6 is currently transitioning to the 5th generation of the internet, although not fully adopted yet. They actively employ Analytics & Big Data throughout the company, utilizing data from both internal sources and third parties. This allows them to benchmark against other industry players. They have incorporated artificial intelligence in marketing, notably in voiceovers for promotional videos and video development. Additionally, they have platforms powered by AI algorithms. While Blockchain isn't used currently, C6 utilizes SAP platforms to monitor and record the materials and their components. This ensures transparency across their supply chain. The organization primarily stores its data on cloud platforms. Moreover, C6 has ventured into digital fabrication and 3D printing and employs the Internet of Things to monitor employees' fatigue levels for safety purposes. They are developing mobile apps to streamline internal processes and make use of social media for various purposes. They are also piloting projects in Virtual Reality Systems to recreate building scenarios, with the aim to enhance employee training.

Adopted Environmentally Sustainable Practices

With a significant presence in 23 countries, C6 holds ISO certifications for environment, safety, and quality. However, they face challenges in standardizing methodologies across these nations due to varying regulations. There's a particular emphasis on aligning company-wide reporting on transversal ESG metrics like carbon footprint. Collating this data was a challenge, leading the company to adopt the Cority platform, facilitating automated, centralized, and real-time data monitoring. This enhances real-time decision-making and reporting capabilities. They also stress the importance of data quality and are taking measures to improve environmental literacy. This year marked the first-time sustainability was positioned as a top pillar in defining the company's strategic direction. The strategy report outlines specific KPIs and goals, formulated based on double materiality analysis. This assesses both the company's environmental impact and the environmental factors influencing the business. The company has also launched sustainable bonds, linking the bond returns to their sustainability performance. Collaborative efforts are underway with organizations specializing in carbon footprint assessment to further reduce their environmental impact. C6 is proactive in recycling and reusing materials, exemplified in their railway projects. They prioritize renting equipment over buying, and actively promote environmental awareness among various stakeholders.

Digital Technology's Role in Enhancing Environmental Sustainability

Digitalization offers a dual benefit to C6. Firstly, it's leading the company towards a paperless environment. Secondly, it aids in efficient and accurate data collection, empowering real-time decision-making. They utilize technology to simulate environmental crises and understand potential impacts on their business and the environment.

Measurement Metrics

C6 diligently measures resource consumption across projects. They also align with metrics from the Global Report Institute, which serves as a guideline for sustainable corporate practices. The company tracks waste emissions per contract and assesses the carbon footprint of each project. Reports are prepared on potential natural disaster impacts, and studies are being conducted to evaluate the carbon footprint implications of commuting.

Main Challenges and Incentives to Digital Technology Implementation

Change management emerges as a significant barrier to technology adoption, along with the associated costs. These investments can be particularly daunting for SMEs. However, the benefits are clear: technologies enable more precise data collection, leading to better outcomes.

The Future of Digital Technologies and Sustainability

C6 believes that a company's purpose should guide its sustainability journey. They recognize their obligations to stakeholders and the planet. The company's mission should reflect a commitment to a positive impact. Engaging stakeholders in discussions is vital to collaboratively chart the company's path forward.

Interview C7 (IT Department and Sustainability Manager)

Digital Technology Adoption

The organization utilizes a wide array of digital technologies across various departments. This includes 5th Generation Internet for industrial PoCs, Analytics & Big Data in logistics and industry, Artificial Intelligence for RPAs and robotization, Cloud services through AWS and Azure, Digital Fabrication/3-D Printing for PoCs, IoT for operational support, mobile computing/apps for employee portals, Social Media for communication, and Virtual Reality Systems for industrial maintenance.

Adopted Environmentally Sustainable Practices

The organization has a robust set of sustainable practices, including environmental policy disclosures, risk assessment reports, ISO 14000 environmental management systems, and energy efficiency measures. They also cooperate with partners on minimizing environmental impact and are adapting their business model accordingly. However, they don't produce or buy recycled products and certain practices like encouraging reusability are not applicable.

Digital Technology's Role in Enhancing Environmental Sustainability

Specific digital technologies like Analytics & Big Data, Artificial Intelligence, and the Internet of Things are leveraged for reducing resource consumption and increasing efficiency. However, the roles of other technologies in sustainability are not specified.

Measurement Metrics

All metrics mentioned could be identified in the organization’s sustainability report.

Interview C8 (Senior Technology Manager and Sustainability Manager)

Digital Technology Adoption

C8 employs a variety of digital technologies such as Analytics & Big Data, Artificial Intelligence, and 5G internet, which are woven into its operational fabric. Their operations rely heavily on sensorization, allowing them to glean critical insights from a wealth of data. Although they don't currently apply blockchain technology to their wood supply chain, its implementation is on the horizon due to the rising demand for transparency, security, and product traceability from clients. Transitioning from on-premise tools to Cloud-based solutions is another strategic move made by the company. Despite Digital

Fabrication and 3D printing not being directly applicable within the company, these technologies are frequently used among its suppliers. Mobile Computing also plays a significant role, providing application mobility and facilitating the digitalization of information, which subsequently helps the company transition to paperless operations. This strategy improves operational flexibility and efficiency, notably within their supply chain processes and customer interactions. Further enhancing their technological portfolio, the organization also utilizes Social Media for communication purposes and Augmented Reality for operational support.

Adopted Environmentally Sustainable Practices

In addition to transparently communicating its environmental practices, the organization produces a sustainability report to inform stakeholders of its initiatives. Holding an Environmental Management Certificate (ISO 14001) and an Energy Efficiency Certificate (ISO 50001), the company is deeply committed to environmental sustainability, with energy efficiency being a cornerstone of its performance. It sources over 90% of its operational power from renewable sources like biomass boilers and photovoltaic panels. The company ensures that the entire value chain is sustainable by scrutinizing the sustainable certifications and practices, including ESG topics, of its suppliers. Additionally, the company provides customers with an “environmental invoice,” documenting environmental metrics related to the products purchased. This commitment to positive environmental impact is further seen in their fabric manufacturing, which includes the reuse of river effluent and a focus on returning cleaner effluent to the river. Additionally, the organization manages sustainability their own forest, which is their primary material.

Digital Technology's Role in Enhancing Environmental Sustainability

The organization recognizes technology as a vital tool for driving sustainability and continually explores ways to leverage it for enhancing environmental performance. Sensorization, in particular, is instrumental in collecting large and ever-increasing volumes of data from across the company. These data, in turn, are transformed into actionable insights using technologies like Big Data Analytics and AI, influencing high-level decision-making and bolstering operational efficiency. These enhancements contribute to financial sustainability, asserting the crucial link between successful operations and business survival. The company remains committed to the sustainable and effective use of these digital technologies.

Measurement Metrics

The company measures a broad range of metrics, as mentioned in the interview questionnaire. It is also initiating a project to align its reporting with the Global Reporting Initiative (GRI) metrics, in addition to its pre-existing goals for 2030. The interviewee highlighted that these metrics are increasingly being utilized for operational purposes, as inefficient resource usage leads to decreased efficiency and increased costs. Therefore, operational efficiency and environmental sustainability are inextricably intertwined in their business model.

Main Challenges and Incentives to Digital Technology Implementation

The use of technology enables the company to measure and control its key operations, providing insights that can improve efficiency and offer stakeholders extensive product information. The interviewee emphasized that there are simple technologies that can yield significant and immediate impact, provided that companies have a clear understanding of the value proposition of the technologies they aim to adopt. Interestingly, the interviewee pointed out that the digital capabilities of a company might be a significant factor in attracting younger generations of employees, a vital consideration for industrial companies with significant machinery work, which is not attractive for younger generations.

Interview C9 (Sustainability and Digital Technology Manager)

Digital Technology Adoption

The organization C9 uses all the technologies mentioned in the guide except for Blockchain and Digital Fabrication/3-D Printing. They have a department dedicated to the digital transformation of their operations and rely on these technologies for improvements. For example, Analytics & Big Data are used for predictive methods of their operational performance, aiming to prevent deviations. Internet of Things is used for its sensorization capabilities, gradually incorporating more intelligent sensors into its operations. The organization also has various apps utilizing Analytics and are applicable to various departments like sales, HR, and others. They also have a presence on Social Media and use Virtual Reality systems for maintenance and virtual assistance.

Adopted Environmentally Sustainable Practices

The organization has been publishing its annual sustainability report for over 20 years. In this report, the organization outlines its strategies, results, and environmental policies, including environmental risk reports. These risk reports are aligned with the guidelines from the Carbon Disclosure Project (CDP). The organization aims to achieve carbon neutrality by 2035 and is ISO14001 certified. Energy efficiency is also highly emphasized, including a four-year ongoing project aimed at reducing energy consumption. Although they strive to be powered by photovoltaic panels installed in their factories, they still can't supply their entire operations but plan to continue heavily investing in green energy implementation. Additionally, the organization is able to fully recycle their product, therefore they aim to collaborate with their clients, such as retailers, to promote the recycling by the end consumer.

Digital Technology's Role in Enhancing Environmental Sustainability

The interviewer mentions the use of smart sensors, like those installed in chimneys to monitor gas emissions. This data is automatically transmitted to a cloud database for subsequent analysis using Analytics tools, enabling informed decision-making. Social media plays a role in stakeholder education and promotion, while artificial intelligence is used for predictive methods like fire prevention.

Measurement Metrics

The organization analyzes all metrics mentioned in the questionnaire, except for water and land pollution, which is not applicable in their context.

Main Challenges and Incentives to Digital Technology Implementation

One of the main challenges, as pointed out by the interviewer, is the lack of automation in the entire data processing procedure, thereby avoiding manual tools like Excel and subsequently preventing manual errors. The main barrier is a lack of skilled people with specialized know-how. Change management is another relevant issue, particularly due to some employees having limited digital literacy and resistance to change. On the other hand, digital technologies allow for a significant increase in operational efficiency, drastically reducing any kind of deviation and loss.

The Future of Digital Technologies and Sustainability

The interviewer states that it is still complex to monitor the environmental performance of their organization. The CO_2 emission reports take a long time to be generated and rely on underlying data sources as well as the know-how and judgment of the people preparing them. Therefore, the interviewer believes there's a need for tools and expertise to align information across various sources, including different companies. More importantly, there should be European-level benchmarks to guide organizations in their sustainable transition. The interviewer also mentions that lack of funding is a hindrance to investing in green technologies, particularly for large companies.

Interview C10 (Senior Sustainability Manager)

Digital Technology Adoption

The organization selectively employs digital technologies for specific functions. Analytics & Big Data are used for data analysis and monitoring for better performance in the value chain. Cloud and Internet of Things (IoT) technologies support due diligence processes, while Mobile Computing/Apps enhance team communication and agility. Social Media is used for external communications. Notably absent are technologies like 5th Generation Internet, Artificial Intelligence, Blockchain, Digital Fabrication/3-D Printing, and Virtual Reality Systems.

Adopted Environmentally Sustainable Practices

The organization is involved in several sustainable practices such as disclosure of environmental policies, risk assessment reports, ISO 14000 environmental management systems, energy efficiency measures, and stakeholder environmental education. However, it does not engage in the recycling of goods or encourage the reuse of products and packaging by the end-user.

Digital Technology's Role in Enhancing Environmental Sustainability

Analytics & Big Data are used to improve organizational performance in terms of electricity consumption and use of raw materials. Mobile Computing/Apps contribute to sustainability by reducing paper usage and optimizing time and resource management.

Measurement Metrics

The organization employs a comprehensive set of metrics for measuring the environmental impact of digital technologies, including the production of goods or services, consumption of natural resources, energy and water usage, waste emissions, greenhouse gas emissions, land and water pollution, and hazardous waste generation.

Main Challenges and Incentives to Digital Technology Implementation

According to the questionnaire, the favorable factors for applying digital technologies include resource optimization and better communication. However, barriers exist such as the carbon footprint associated with technology and the consumption of critical raw materials like lithium with a high environmental impact.

Interview C11 (Senior Operational Sustainability Manager)

Digital Technology Adoption

The organization leverages Artificial Intelligence capabilities for asset management, alongside utilizing Big Data. It also makes use of cloud technology for storing parking data. In the domain of IoT, the organization demonstrates sensorization capabilities, with ongoing development projects including the deployment of nano sensors in their electrical and gas grid. The company employs Social Media as a communication channel. Augmented reality is used to support operations, and a pilot project involving virtual reality systems is underway to create training scenarios for jobs that involve working at heights.

Adopted Environmentally Sustainable Practices

The interviewee articulated that sustainability, when viewed holistically, often translates into measurable terms as carbon footprint. In relation to the ESGs, the environmental pillar of the organization tackles deforestation, biodiversity, circular economy, decarbonization of electrical and gas systems and their fleet, installation of electrical production systems for self-consumption, nature-based solutions, and reforestation with indigenous species. C11 publicizes their environmental policies. The organization aims to reduce its carbon footprint by 50% by 2030 (compared to 2019) for scope 1 and 2 as defined by the Science Based Target Initiatives, with the objective to achieve total carbon neutrality by 2040 - a decade before the general target for carbon neutrality. As for scope 3, the organization is working on regulating their supplier's code of practice concerning sustainable practices. They have evaluated the environmental impact of their supply chain and intend to favor more sustainable suppliers. An integrated report focusing on sustainability as a company strategy, along with their usual annual report, is being released. The company assesses environmental impacts and risks to the business, adhering to the guidelines of the Task Force on Climate-related Financial Disclosures (TCFD). It has ISO Certifications for sustainability, continuity management, and innovation, and aims to achieve certification for asset management. As an enabler for national level energy transition, the company also has a roadmap to enhance their energy efficiency at the infrastructure and operations level. A pilot project for a circular economy was initiated this year, impacting due diligence, engineering processes, and construction. The organization is building a quantified circular economic strategy, and while not entirely restrictive, it has informed suppliers that preference will be given to those with sustainable certifications. Efforts are being made to identify and extend the lifecycle of their products, promoting a circular economy. For instance, they've repurposed technical suits, which would typically be sent to landfill, by reusing the components and offering them as useful objects to their employees. C11 is mapping their material flows to identify points of intervention in the supply chain. The organization makes use of nature-based solutions that enhance operational efficiency and allow cost reductions. The interviewee believes that the naturalization of species is gaining importance, partnering with local or environmental authorities to plant native or "autochthonous" species, which can help maintain the landscape and reduce the need for mechanical or manual labor in those areas.

Digital Technology's Role in Enhancing Environmental Sustainability

The interviewee expressed that there are many steps yet to be taken concerning the integration of digital technologies in sustainability, with the field being in its initial stages. However, digital solutions have already been implemented that enhance sustainability. For example, the company has an electrical grid of 9,400 km, 60% of which is located in forested areas. They have installed sensors and cameras capable of detecting temperature and monitoring wind intensity and direction to predict forest fires and their development, thereby preventing environmental damage. Furthermore, the company is committed to making their electrical grids animal-friendly, having installed cameras to monitor various species in these forested areas, with live feeds available to the public via social media. Construction service providers harness digital technologies to quantify the carbon footprint associated with the use of mechanical means in construction. The interviewee emphasized that companies must align sustainability with their assets to gain a competitive advantage, utilizing digital technologies for monitoring purposes.

Measurement Metrics

The interviewee mentioned the use of smart meters to gather data and update centralized systems for monitoring, with an emphasis on energy consumption among other metrics. Historically, annual reports were primarily financial, but demand for ESG metrics, such as carbon footprint of the car fleet, percentage of electric/hybrid vehicles, and intelligent building systems, is growing. Data quality and granularity are improving, but the process is not yet fully mature. The company is particularly interested in the consumption of natural resources and raw materials, especially for circular economy strategies where each asset will have its own identification card displaying not only technical properties like energy consumption, but also sustainable metrics such as composition, carbon footprint, among others. This will allow for lifecycle assessments of assets, providing partners with real-time asset information for selling purposes, and improving the ability to monitor products and buildings in real time. Although water consumption is measured, it is not particularly relevant for their analysis. On the other hand, waste emissions are especially relevant and strictly regulated. The company also monitors greenhouse gas emissions, water and land pollution, and hazardous waste.

Employee commute metrics such as means of transportation and vehicle type are tracked, and initiatives to encourage sustainable habits are being promoted.

The Future of Digital Technologies and Sustainability

The interviewee observed a significant push for sustainability by stakeholders due to increased public awareness. They believe it is essential to empower consumers with information about the sustainability of products to enable informed decision-making. Examples of similar initiatives include the introduction of energy consumption labels for electronics and nutritional information on food products. The interviewee feels that product lifecycle disclosures need to be expanded through tighter regulations and public policy. Currently, it is possible to obtain a lifecycle assessment for sophisticated products like smartphones and laptops, but not for simpler items like a t-shirt. The inability to access sustainability costs for such items - including transportation, materials used, pesticides, water consumption, among other metrics - prevents consumers from making informed decisions. The interviewee believes that technologies can have a profound impact by providing customers with this information, thereby allowing individuals to understand their personal carbon footprint.

Interview C12 (Senior Sustainability Manager)

Digital Technology Adoption

C12 employs a wide range of digital technologies listed in the questionnaire, except for Digital Fabrication 3D Printing. The utilized technologies encompass the 5th Generation Internet, Analytics & Big Data, Artificial Intelligence, Blockchain, Cloud, Internet of Things, Mobile Computing/Apps, Social Media, Virtual Reality Systems, and Augmented Reality. Despite its non-utilization of 3D printing, the interviewee acknowledges its considerable sustainability potential in other industries, such as electronics, especially for creating replacement parts and minimizing resource consumption. Even though the company widely uses these technologies, they are not exclusively used for sustainability.

Adopted Environmentally Sustainable Practices

The company's environmental sustainability efforts are grouped into four primary sectors: climate change, value chain (sustainable sourcing), circular economy, and responsible supply. In the climate change sector, the company is dedicated to improving its energy, transportation, and fluorinated gases performance, considering the significant pollution caused by cold technologies. In sustainable sourcing, the company's focus is on the preliminary stages of their business, specifically their products and suppliers. Here, they utilize criteria like sustainability practices, product certifications, and deforestation prevention measures during the supplier selection process. The circular economy sector focuses on the circularity of products, packaging, services, and overall resources. Responsible supply initiatives aim to promote more sustainable habits among customers, either through visible measures such as awareness campaigns and color-coded nutrient labeling, or indirectly by modifying the content of their own brand products.

The interviewee emphasizes that the organization consistently carries out several sustainable practices, including environmental policy disclosure, environmental risk assessment reports, Environmental Management Systems adoption, energy efficiency, cooperation and collaboration with partners, and recycling within the organization, among others. Regarding their business model, it has not been entirely adapted but has been adjusted in specific areas to enhance sustainability.

Digital Technology's Role in Enhancing Environmental Sustainability

The company leverages technology to bolster sustainable actions and elevate its environmental performance. The primary technologies used for this purpose include Analytics & Big Data, Cloud, Internet of Things, and Social Media. IoT and sensorization technologies facilitate accurate measurements of energy and water consumption and reveal supply chain and operational inefficiencies. In the future, these technologies will also underpin a recycling program offering clients an incentive for product package returns.

Measurement Metrics

To assess its environmental impact, the company utilizes a variety of metrics, including the production of goods or services, consumption of resources and raw materials, energy and water usage, waste emissions, greenhouse gas emissions, pollution, and transportation. In some cases, proxies are used to estimate impact, while in others, sensorization and IoT technologies are employed. These technologies provide the advantage of incorporating previously unconsidered information.

Main Challenges and Incentives to Digital Technology Implementation

The main hindrances to employing these technologies are the disparate information sources that need centralization and the relative immaturity of technologies like blockchain and 3D printing.

The Future of Digital Technologies and Sustainability

According to the interviewee, the increasing demand for transparency from clients and detailed ecological product information is growing. Stakeholders are increasingly seeking detailed information on product composition, including the sourcing and processing of raw materials. They are also interested in the sustainability of the product's supply chain, tracing the product's journey from raw material extraction to its arrival on store shelves. Lastly, they wish to have access to product certifications, environmental impact data, and details on packaging recyclability, all of which provide a comprehensive view of the product's ecological footprint. Technologies such as Big Data, Artificial Intelligence, and Blockchain will be instrumental in interconnecting diverse data sources, transforming the data, and centralizing the information. Blockchain will be specially required to centralize data and make the information transparent. Moreover, the increasing digitalization and accessibility of such information are in high demand. This could involve developing apps that scan QR codes to provide detailed product information, certifications, and other relevant data.

Interview C13 (Senior Technology Manager and Senior ESG Manager)

Digital Technology Adoption

5G internet is currently used in a limited capacity, focusing primarily on mobile networks without significant operational impact. Analytics and Big Data play a crucial role in both consumer-facing and operational aspects of the organization. Artificial Intelligence (AI) is also deployed in various functions. While pilot projects involving Blockchain have been initiated, they are not yet effectively integrated into operations. The organization also leverages cloud computing resources. Additional technologies in use include the Internet of Things (IoT), mobile computing/apps, and social media.

Adopted Environmentally Sustainable Practices

The interviewee, who specializes in environmental matters, outlined the key challenges organizations face regarding environmental sustainability. Currently, companies can choose from various reporting models like GRI, SASB, United Nations Global Compact, and ESGs to disclose their sustainability metrics. However, starting in 2025, European-based medium and large companies, as well as publicly traded firms, will be mandated to use the European Sustainability Reporting Standards (ESRS). The interviewee also acknowledges ongoing efforts by the International Financial Reporting Standards (IFRS) to develop new sustainability reporting models. The interviewee highlighted the absence of sector-specific reporting software to meet this reporting demands, identifying this as a significant business opportunity.

The organization in question is already preparing for this change, as it currently employs seven different reporting methodologies. This aims to meet the different needs of shareholders, regulatory bodies, clients, and other stakeholders, each of whom may require information to be presented in a particular format.

Most of the organization's industries are ISO14001 certified, and their stores employ technical systems for energy efficiency. Cooperation extends to suppliers to minimize environmental impact, such as food waste management.

The organization is transitioning to an electric vehicle fleet and predominantly leases equipment from service providers. It encourages recycling and has a tracking system for water, energy, and material consumption across all operational activities. This system also prompts suppliers when it's time to collect materials for recycling or reuse.

In addition, the organization promotes circularity in its operations. For example, one of its companies has developed a closed-loop system for packaging. The organization is also implementing consumer-facing solutions like filtered water stations to reduce plastic waste. Whenever a new product is launched, the organization ensures it contains recycled material and is reusable or recyclable.

To maintain transparency and foster commitment, the organization disseminates environmental management meeting reports to stakeholders and runs educational campaigns on social media.

Digital Technology's Role in Enhancing Environmental Sustainability

The interviewee, an expert in digital technologies, discussed the limited impact of 5G internet on sustainability efforts. The most significant contribution comes from Analytics & Big Data. This technology integrates data from various and sometimes unrelated sources, like stock management systems, to support environmental management. It also provides actionable insights, such as identifying reasons behind varying consumption rates across stores.

Artificial Intelligence (AI) is occasionally used and its deployment is expected to rise as data volume increases and machine learning models improve. This will automate the data analysis process, making it more efficient.

Blockchain technology has been tested but is not currently in active use within the organization. The reluctance to adopt it is not due to skepticism about its capabilities, but rather because of the lack of well-established networks, or "chains," that are necessary for the technology to yield its full benefits. Blockchain essentially operates on a network of stakeholders and suppliers who must all participate for the technology to work effectively. In the current business landscape of Portugal, which is characterized by a fragmented array of primary suppliers, many of whom are small to medium-sized businesses, building such a cohesive network poses a significant challenge. Without this network, the substantial investment needed to implement blockchain is difficult to justify. However, in specific contexts like an industry association that wants to certify a particular product, blockchain could serve as a powerful verification tool, assuming a well-defined network of stakeholders is involved.

Cloud computing doesn't directly impact sustainability. The Internet of Things (IoT) plays a critical role in data collection and parameterization, enabling real-time adjustments in areas like lighting to correct deviations. Mobile Computing and Apps serve data collection and awareness-raising functions. Virtual Reality, although not in use, could potentially enhance stakeholder awareness.

The organization employs SAP for sustainability metrics collection. SAP's customizable and editable features allow for the integration of new filters tailored to environmental monitoring, enabling more efficient and accurate reporting.

Measurement Metrics

In an industrial context, the organization measures all the metrics mentioned in the questionnaire, including those that are mandatory. On the other hand, in an urban store reality, metrics such as water and land pollution and hazardous waste are not measured because they are not fully applicable.

Main Challenges and Incentives to Digital Technology Implementation

One major factor driving sustainability initiatives is the growing recognition of environmental responsibility as a core component for organizations. Technology plays a critical role in achieving this, fueled by pressure from customers, suppliers, and shareholders. Additionally, technological innovation—both digital and otherwise—offers ways to perform tasks more efficiently and reliably, leading to enhanced monitoring and environmental performance across the value chain.

However, there are challenges specific to the Portuguese market, including a general lack of technological expertise. The high upfront costs of implementing these advanced technologies also deter investment, especially since the return on investment isn't immediate. Market uncertainty about reporting standards further complicates matters. Blockchain technology has the potential to solve traceability issues, but its adoption would necessitate a significant technological upgrade across the entire supply chain.

The Future of Digital Technologies and Sustainability

Interviewees say that digital technologies are extremely interconnected. Previously, organizations were accustomed to measuring in euros, but the way forward means that they will have to measure various environmental aspects that will be equally relevant. Digital technologies play a key role here, as they make it possible to parameterize these metrics and translate them into common language so that everyone has access to the information. This information will also be audited in the same way as the accounts reports.

Interview C14 (Senior Sustainability Manager)

Digital Technology Adoption

The organization has been effectively leveraging a variety of digital technologies, including the 5th generation internet, analytics & Big data, artificial intelligence, cloud computing, Internet of Things, mobile computing/apps, and social media.

Adopted Environmentally Sustainable Practices

To optimize both environmental performance - concerning water, energy, and fertilizers - and operational efficiency, the organization has deployed these digital technologies. They emphasize using organic fertilizers to curtail carbon emissions and strive for closed-circuit water and energy systems. A significant portion of electricity, accounting for 10-15% of their fabric production needs, is generated via solar panels, while the rest is sourced from other green methods.

Investments are made to boost environmental performance through systems that can predict potential leaks or malfunctions, allowing preemptive action to prevent significant waste, particularly electrical. The organization also collaborates with their suppliers to lessen their collective carbon footprint, opting for more efficient transport, and procuring recycled resources whenever possible.

In terms of packaging, recycled materials have been introduced, and eco-design has been emphasized by tweaking packaging weight and pigmentation. The organization strives to promote biodiversity and resource optimization to foster ecosystem growth while improving their olive groves. To avoid biproduct waste and conserve energy, biomass boilers have been deployed using olive oil and sunflower husk as fuel.

To display transparency, the company has published an environmental policy report annually for the last three years, outlining the organization's footprint across its many domains. Moreover, an environmental risk assessment has been made available for regulatory compliance and insurance purposes. The company also holds an ISO14001 certification. In order to avoid asset redundancy, rental contracts for equipment and machinery have been preferred. Additionally, the circularity of assets is promoted through the reuse of pallets, which are returned to suppliers. Partnerships are in place for waste management, including recycling card and plastic materials, and handling hazardous waste.

Through in-house initiatives, C14 encourages environmental sustainability, focusing on improving individual environmental performance. For instance, special seminars are organized where experts discuss primary energy consump tion sources in everyday homes.

Digital Technology's Role in Enhancing Environmental Sustainability

C14 has an advanced watering system that leverages sensor technology, satellite imaging, drone data, and meteorological information to optimize water use. This system adjusts the water supply based on the plant's hydration needs, soil conditions, seasonal water cost fluctuations, and weather predictions. This approach helps in conserving water and energy by minimizing waste.

In the agricultural sector, similar sensor technology, alongside analytics, big data, and artificial intelligence, is used to forecast the emergence of pests and extreme weather conditions that could potentially damage the olive trees and impact the company's operations. This enables the company to take preventive actions, thus safeguarding their assets and preventing further damage or waste.

C14 is also collaborating with other firms to develop mobile apps aimed at enabling consumers to recycle the product’s packaging. This is achieved using gamification and promoting environmental initiatives.

Measurement Metrics

C14 tracks emissions related to scope 1, 2, and 3, enlisting the help of a service provider for this purpose. Despite the system being in a nascent phase, it covers the company's entire activity. The company also measures energy efficiency and consumption in terms of energy per kilo of product and the quantity of pesticide and water per kilo of product. They utilize their partners' apps to log and manage waste residuals. The organization also uses sensors to monitor water and land pollution levels, a prerequisite for their certifications. In terms of material usage, SAP software is used to measure the quantity of materials used per kilo of product. In the future, the organization plans to track the environmental impact of their employees' commuting habits and manage their product transportation emissions and costs.

Main Challenges and Incentives to Digital Technology Implementation

The primary incentive to implement digital technology is to centralize real-time information in a user-friendly app. This eliminates human error and facilitates better, more accurate decision-making. The key challenges faced include the high cost of environmentally-friendly options and recycled materials, making it difficult to offer competitive prices to consumers. There's also a high cost associated with certain technologies, such as SAP software, which can be prohibitive for smaller companies. Furthermore, there is an overwhelming variety of available technologies, which complicates the selection process. Additionally, access to finance for sustainability purposes is still limited, impeding many from adopting better technologies.

The Future of Digital Technologies and Sustainability

With increasing demands for businesses to report more environmental metrics, digital technologies will become even more indispensable for reliable reporting and monitoring. This will inevitably lead to broader adoption of such technologies and their incorporation into sustainability practices.

Interview C15 (Sustainability Manager)

Digital Technology Adoption

The organization is making significant advancements in Virtual Reality Systems, particularly focusing on the metaverse. Moreover, they have a robust presence on Social Media platforms. The interviewer highlighted that remote work has greatly contributed to reducing carbon emissions, aligning with the company's net-zero goal by 2024. Technologies such as Microsoft Teams and Cloud services - which the organization offers - have been instrumental in this shift. Artificial Intelligence (AI) is also being employed internally, assisting in resource profile searches, and matching them with existing demands. Furthermore, AI is utilized to quantify the carbon footprint.

Adopted Environmentally Sustainable Practices

The organization aims to become net-zero by 2040. This means that the company plans to reduce its equivalent CO2 emissions across all its operations by ninety percent by the set year. Achieving this goal necessitates the adoption of innovative tools, projects, and methodologies.

The Science Based Target Initiative (SBTi) attracts many large organizations due to increasing regulatory stringency. The interviewer stated that such initiatives enhance organizational transparency and combat greenwashing. The interviewer explained that the third scope of sustainability receives the most emphasis due to the organization's nature. Their procurement policies emphasize collaboration with suppliers, for instance, in developing sustainable computers from both material and usage perspectives. However, it's challenging to analyze and measure since it considers the company's entire value chain. In this context, the procurement department ensures the products and services acquired align with the organization's sustainability metrics, especially carbon footprint. Yet, not all suppliers provide this information. Here, artificial intelligence plays a crucial role in accounting for and auditing these metrics.

The company's national environmental report details its sustainable practices, aiming to transparently inform stakeholders of its initiatives and environmental contributions. The organization also focuses on reducing waste sent to landfills and promotes environmental education among stakeholders.

Digital Technology's Role in Enhancing Environmental Sustainability

Digital technologies provide solutions for real-time data collection and carbon footprint calculations, which would be otherwise impossible manually. Analytics & Big Data play an essential role has the company receives around 15,000 data points to be analyzed and provide solutions through simple user interfaces.

Internal tools, such as the carbon calculator, gauge the carbon footprint of each project, while the carbon accounting tool tracks emissions from operations, including electricity, fuel, water, waste, and transportation. In this context, artificial intelligence plays a crucial role in accounting for and auditing these metrics.

Measurement Metrics

The organization tracks carbon production per service, water and energy consumption, waste, and hazardous emissions associated with their devices. It also closely monitors transportation data, both for business trips and commuting.

Main Challenges and Incentives to Digital Technology Implementation

The organization undergoes energy efficiency audits every four years. These audits typically identify actions like transitioning to LEDs and smart lighting systems to optimize illumination based on space requirements. However, such transitions are currently costly. Transport-related emissions represent the bulk of their CO2 output, with air travel accounting for 49.84% and vehicles contributing 39.42%. The main barrier to implementing these technologies remains their cost.

The Future of Digital Technologies and Sustainability

The organization provides cloud services, facilitating data migration to the cloud and thus positively impacting sustainability. They intend to leverage the Internet of Things (IoT) for creating intelligent office systems based on sensors, which would provide real-time data-driven insights to minimize wastage. The interviewee emphasized that the organization's main sustainability impact lies in commuting and travel. Contrarily, resource-intensive industries prioritize materials' consumption.

Interview C16 (Senior Scientific Manager)

Digital Technology Adoption

Companies today are increasingly integrating advanced digital technologies into their environmental sustainability strategies. One prominent example is how Analytics & Big Data are interconnected with

Artificial Intelligence. Through leveraging neural networks, companies can create intricate models. These models can then be visualized via user-friendly interfaces, like dashboards, utilizing the power of analytics. Furthermore, the Internet of Things (IoT) operates in tandem with Cloud technologies. The role of IoT in this partnership is to capture and transmit real-time data, while the Cloud facilitates data storage and processing.

Adopted Environmentally Sustainable Practices

While the organization does not explicitly release their environmental policies or detailed reports, they employ a proactive approach to environmental monitoring. This includes real-time analysis of river pollution and pinpointing sources of contaminants. Furthermore, they monitor the energy efficiency of structures, providing insightful recommendations for companies to enhance their building's environmental performance.

Digital Technology's Role in Enhancing Environmental Sustainability

The organization relies on IoT for real-time monitoring of water, air, and soil quality. They utilize biomarkers and other metrics to swiftly identify and address potential contamination. While such technological solutions are still nascent in certain markets like Portugal, there's a growing cognizance of contamination issues. As an illustrative point, the organization cites water treatment facilities that employ their technology to assess water quality both before and after the treatment process. Additionally, they've designed web applications that relay real-time water quality data to users in an easily digestible format. This initiative fosters greater transparency about environmental impacts, benefiting both nature and society. The organization's strategy focuses on affordability, employing cost-effective sensors to measure water or soil parameters, and leveraging neural networks to make predictions based on historical data.

Measurement Metrics

To gain an in-depth understanding of environmental health, the organization employs an array of biomarkers and metrics. These tools are not limited to water analysis but extend to soil examinations. They assess nutrient balance, contamination levels, and the amount of CO_2 trapped within the soil. The overarching goal is to cultivate a harmonious environment where nature thrives in equilibrium, minimizing the disruption of native species and guarding against invasive entities. In urban settings, they also monitor CO_2 levels at various city locales to study environmental patterns.

Main Challenges and Incentives to Digital Technology Implementation

A significant hurdle in deploying these advanced technologies lies in the financial realm. Sensors, especially those designed for specific markers, come with a hefty price tag. To get a comprehensive understanding of an environment, a multitude of these sensors needs to be installed, which compounds the cost.

The Future of Digital Technologies and Sustainability

As the digital realm and sustainability further intertwine, the interviewee underscores the importance of regulatory oversight and public discourse surrounding Artificial Intelligence. They envision a future where humans and AI collaborate, pairing human ingenuity with AI's computational prowess. For this synergy to be effective, AI systems need to transition from being enigmatic "black boxes" to transparent "white boxes," ensuring that these tools can undergo rigorous audits when necessary.

Interview C17 (Senior Sustainability Manager)

Digital Technology Adoption

C17 has embraced a suite of digital technologies, including Analytics & Big Data, Cloud, Internet of Things, Mobile Computing/Apps, and Social Media. The incorporation of Cloud technology is pivotal for fostering collaborative work environments and centralizing information. Additionally, they are exploring the potential of virtual systems designed to facilitate training scenarios, particularly for the handling of hazardous chemicals.

Adopted Environmentally Sustainable Practices

C17 is transparent about its commitment to the environment, regularly disclosing environmental policies and conducting environmental risk assessments. The company has institutionalized environmental management systems and undergoes audits to ensure adherence to sustainability standards. Their dedication is also evident in their procurement strategies, preferring green energy from suppliers. Collaborative efforts with partners aim at minimizing environmental footprints in the supply chain. C17’s business model has evolved to champion sustainability, evident in their initiatives like purchasing recycled materials, in-house recycling, launching eco-friendly products or services, and spearheading environmental education campaigns for stakeholders.

Digital Technology's Role in Enhancing Environmental Sustainability

C17's drive for sustainability is backed by the smart use of technology. Sensorization combined with analytics plays a pivotal role in gauging the energy efficiency of their infrastructure. Analytics further amplifies the reach and impact of their sustainable campaigns, driving stakeholder engagement. Mobile apps, designed with elements of gamification, incentivize sustainable behavior among their stakeholders.

Measurement Metrics

Metrics form the backbone of C17's sustainability approach. They emphasize the importance of maintaining a comprehensive masterfile for metrics, which aids in enhancing data accuracy and streamlining report generation.

Main Challenges and Incentives to Digital Technology Implementation

While digital integration offers immense potential, cost remains a significant barrier, especially when immediate return on investment isn't apparent. However, the anticipated tightening of regulations regarding carbon footprints makes initiatives like achieving net zero more appealing. Market trends further serve as incentives, steering businesses towards sustainable practices.

The Future of Digital Technologies and Sustainability

Peering into the future, the interviewee envisions a landscape where data transparency is paramount, necessitating centralized access across the supply chain. They predict blockchain will play a crucial role in this centralization, where a singular digital key could unlock comprehensive product information, encompassing sustainability aspects. Such transparency would be instrumental in combating greenwashing, ensuring a more honest portrayal of sustainability efforts. C17 is also transitioning towards paper-less labs, marking a significant step in their journey towards full digitalization.