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Innovation Technologies and the Green Transition in the Italian Energy Sector

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1. Introduction

The energy sector is at the center of attention for any research aimed at establishing the responsibility for climate change and searching solutions for reaching net zero targets. It is the problem and the solution to the current climate crisis, accounting for more than two-thirds of global greenhouse gas (GHG) emissions (International energy agency, 2022). Innovation technologies are increasingly considered to be the key to climate action due to their ability to effectively accelerate the green energy transition in any industry, and need to be a crucial part of any corporate strategy. Artificial intelligence, Internet of Things, cloud computing to blockchain all have the potential to help address climate change without compromising economic growth. Italian energy companies, including Enel, Eni, A2A and Terna, have all played a significant role in driving and pioneering green innovation strategies globally. With abundant renewable energy investments and advanced innovation initiatives, these companies have the potential to revolutionize the energy industry.

In this light, this thesis aims to identify how Italian energy companies integrate Industry 4.0 technologies in their innovation practices to rapidly reach net-zero targets. The focus of this paper will be on identifying, classifying, analyzing and assessing the innovation technology initiatives by Italian energy companies in order to define and to determine strategies that could guarantee their success. The comprehensive and multidimensional analysis will help to identify possible gaps and key success factors for green innovation initiatives.

In order to answer the research question, this study aims to first review the literature on how to define, classify, analyze and assess innovations in general and green innovations in order to develop a comprehensive framework for the research. Based on the literature review, I will propose a framework to identify, classify and assess green innovations that will be applicable to the energy industry in Italy. After this, I will proceed to introduce and review the energy industry in Italy, explaining its relevance, and then analyze the Italian energy companies' efforts to adopt and create innovation technologies aimed at helping them to cut emissions and switch to renewable resources. Finally, I will apply the elaborated framework to the energy industry in Italy to assess the companies' efforts and then discuss the key findings from applying the green innovations framework.

I will follow a number of steps to conduct the study. In the second section of the thesis, in order to evaluate the types, value and impact of green innovations and innovations in general, I will undertake a thorough analysis of the most pertinent academic literature. First, I will delve into the literature covering Industry 4.0 and the types of innovation technologies coming with it, which will later serve for determining which Italian innovation projects to analyze. Secondly, I will examine the most popular definitions of green innovations to identify their core characteristics later to be used in the framework and its application. After that, I will review the relevant literature to determine the typology of green innovations, which will provide a systematic and structured way to categorize and understand different types of innovations. Following this part, I will discuss how innovation may spur social and environmental change in addition to economic progress and go through some of the fundamental theories of innovation explaining why it is important to take into account. I will also review different theories to define the key internal capabilities that scholars consider important for innovative firms. As the last part of literature review, I will analyze theories vindicating the importance of the holistic approach to sustainable innovation, collaboration, and stakeholder engagement, as well as determine the key success factors that could be used to assess green innovations. Overall, the literature review on how to analyze innovations in general and green innovations in particular will serve the main purpose of this section aimed at developing a framework for the research.

At the end of the literature review section, I will suggest a framework for recognizing, classifying, and evaluating green innovations based on thorough theory research. This framework will then be utilized to analyze GIs in the Italian energy industry. The framework will attempt to provide a systematic approach to analyzing the adoption of innovative technologies in the context of sustainability and consist of four steps: identifying green innovations based on their characteristics; categorizing them based on their types, novelty, and levels of collaboration; analyzing them based on their economic, social, and environmental impacts; and evaluating them based on their alignment with sustainability principles, potential to contribute to sustainable development, and potential to create value for stakeholders.

In the third section of the thesis, I apply the previously developed theoretical framework to the Italian energy companies to analyze their innovation activities and answer the main research question. I will first start by introducing the energy sector explaining its key role in the global energy transition, as well as the relevance of Italian companies in these efforts. This analysis will guarantee a comprehensive understanding of such a complex and multidimensional topic and provide a foundation to analyze the companies' innovative practices targeted at green transitioning. Then, I will proceed to apply the framework to specific innovation initiative cases by Italian energy firms. Since the present study cannot cover all of the Industry 4.0 technologies, I will choose innovation technologies that are most widely used and accessible information-wise, and present examples of initiatives by various companies. I will present and analyze the data before applying the previously created framework to the particular cases.

In the following section, I will discuss the key takeaways from Section 3 to analyze how Italian energy companies use innovation technologies to drive the green energy transition. Before analyzing the main results from the examination of the different innovation practices by different firms, I will first explore the strengths and limitations of the constructed framework. Then, I will explain what the insights of my analysis mean for energy companies and researchers.

In the conclusion of this thesis, I will use the results of the previous chapters to discuss the main topics that I have explored. I will suggest some potential solutions for guaranteeing the success of green innovation practices.

2. Literature review

As we delve into this section, I will conduct a systematic analysis of the most relevant academic literature seeking on green innovations (GIs) and innovations in general. Through this study, I intend to identify and review the relevant theories and frameworks that may be used to define, classify, analyze and assess the innovation adoption initiatives for environmental purposes in the Italian energy companies. The results of the analysis should provide a comprehensive understanding of the notions, characteristics and criteria around GIs used in research. Based on this, I will suggest a framework that can be utilized to identify, categorize, analyze and evaluate the green innovation efforts undertaken by Italian energy companies.

In order to guarantee a comprehensive and systematic review of the literature, I have followed the structure detailed in Figure 1.

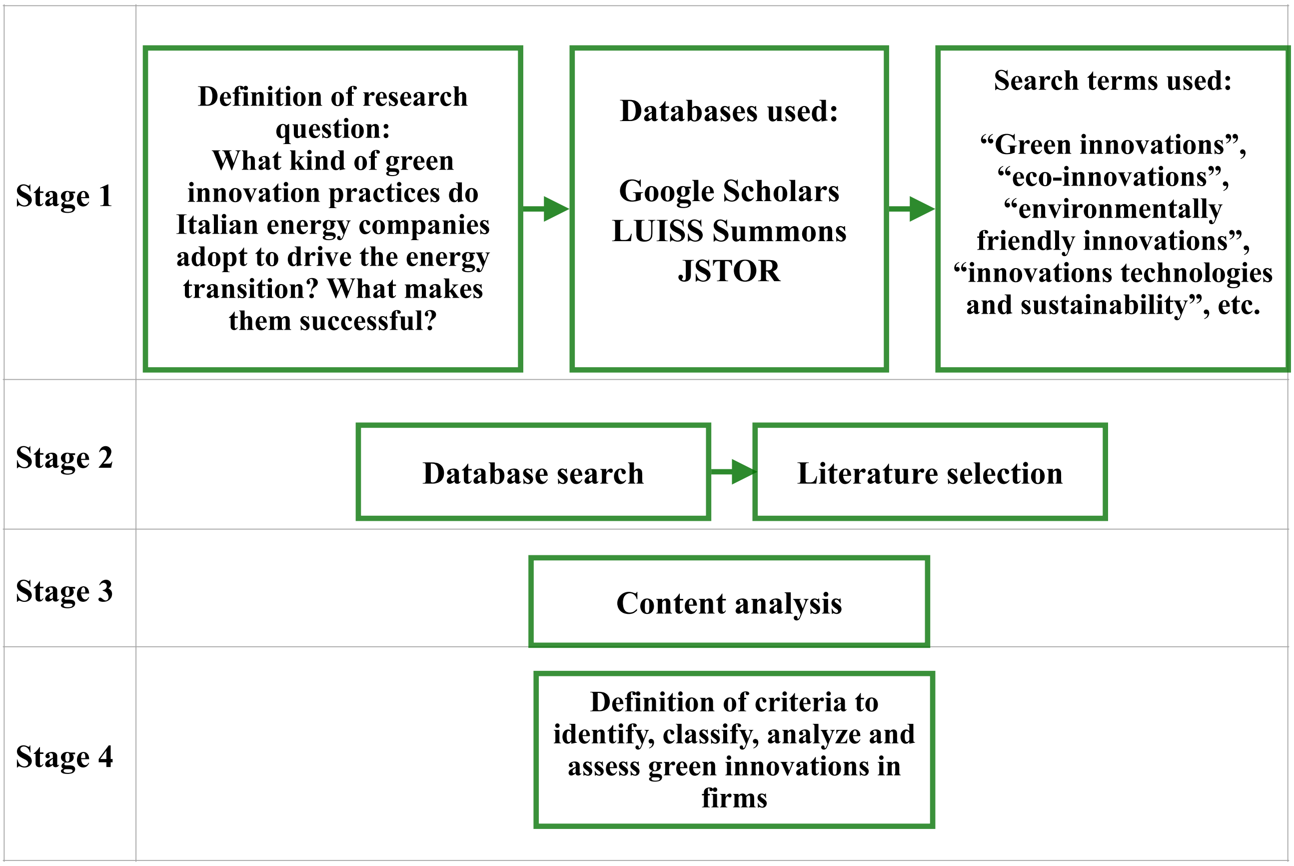


Figure 1. Methodology for literature review

2.1. Literature on innovation and green innovation

2.1.1. Industry 4.0. and sustainable innovation

In this section, I will review the notions of Industry 4.0 key to the study and its relation to sustainable development goals. I will identify some of the most popular innovation technologies that can be later used while choosing the specific company cases.

SDG9 is a target set by the United Nations (UN) 2030 Agenda that intends to change how firms build infrastructure, advance industrialization, and foster Industry 4.0 innovation. It claims that in order to prepare for the future challenges, humanity needs to promote innovative sustainable technologies while also ensuring universal access to the relevant know-how. Innovation in processes, products, and integrated inter-entity sustainability efforts must all be put in place to develop a sustainable production system. A product-service ecosystem, which includes cleaner production strategies aimed at cutting energy consumption, minimizing waste generation, controlling pollution, and conserving material resources, is currently one of the dominating trends in manufacturing industries. Klaus Schwab (2017) coined the term "Industry 4.0" to refer to a number of cutting-edge industrial innovations, including sensor networks, the Internet of Things (IoT), robotics, Big Data, cloud manufacturing, artificial intelligence, and augmented reality (AR). Carvalho et al. (2019) provided a comprehensive categorisation of the Industry 4.0 technologies used for environmental goals, including cyber-physical systems, cloud manufacturing, Big Data analytics, augmented reality, smart sensors, location detection, IoT, and additive manufacturing. Such digitalization technologies are indispensable for organizations striving to implement environmentally friendly innovations. Figure 2 summarizes some of the most common types of innovation technologies used for environmental purposes found in the literature.

	Technology	**Description**
1	**Artificial Intelligence (AI)**	Development of intelligent systems that can perform tasks typically requiring human intelligence. AI technologies enable systems to perceive, reason, learn, and make decisions (Wu et al., 2021).
2	**Blockchain**	A decentralized and distributed digital ledger technology that records transactions across multiple computers. It provides transparency, security, and traceability, making it useful for energy trading, peer-to-peer energy transactions, and ensuring the integrity of data in energy systems (Borkovcová et al., 2022).
3	**Internet of Things (IoT)**	Intelligent and interoperable network of physical devices embedded with sensors, actuators, and connectivity, allowing them to collect and exchange data over the internet anywhere and at anytime. IoT enables the connection and communication of objects, generating real-time data for monitoring, control, and analysis (Carvalho et al., 2019; Ali et al., 2015).
4	**Cyber-Physical Systems (CPS)**	Computational collaboration systems that integrate the relationship between people, data and information, machines and equipment. They streamline the process of receiving and sharing data, analysis, interpretation, and decision-making by connecting the physical and digital worlds (Carvalho et al., 2019).
5	**Cloud computing**	It utilizes remote servers to store, manage, and process data, enabling on-demand access to computing resources and reducing the need for local infrastructure. It supports various applications and services, providing scalability, flexibility, and cost-efficiency (Carvalho et al., 2019).
6	**Big Data analytics**	The process and tools used to extract insights from large volumes of data. It involves organizing data, analyzing it, and visualizing and presenting insights to enable data-driven decision-making (Carvalho et al., 2019).

7	**Augmented reality**	Computer graphics technique that blends the real environment with virtual objects, providing various applications in transmitting knowledge, work activities, product design, and logistic routes (Bekaroo, 2018).
8	**Smart sensors**	Key elements of the future smart grid, enabling remote monitoring and real-time assessment of system performance. They provide insights and help identify errors and respond to internal and external needs for adaptation or change in the network (Carvalho et al., 2019).
9	**Location detection**	Systems that help identify the location of users or objects in physical spaces, using various methods such as fixed sensors, tags, or infrastructure (WiFi or Bluetooth). They provide control over resources and processes, optimizing their utilization and ensuring they are directed to the right location (Carvalho et al., 2019).
10	**Additive manufacturing**	A technique that builds complex geometries and structures by printing successive layers of materials based on a 3D model. It has applications in various industries such as biomechanics, prototyping, and construction, transforming manufacturing and logistics processes (Carvalho et al., 2019).
11	**Robotics**	The design, development, and use of robots for various applications in the energy industry. Robotics technologies can perform tasks autonomously or assist humans in hazardous or repetitive tasks, improving efficiency, safety, and productivity in energy production, maintenance, and inspection processes (Iqbai et al., 2019).
12	**Digital Twin**	Virtual replica of physical assets or systems that provides real-time data and simulation capabilities, enabling monitoring, analysis, and optimization (Fuller et al., 2022).

Figure 2. Main types of innovation technologies.

Most of the SD goals can be achieved in combination with each other. Apart from SDG9, companies have to consider SDG7 aimed at ensuring access to affordable, reliable and sustainable energy for all, SDG12 targeted at sustainable consumption patterns, SDG13 related to combating climate change and its impacts, and SDG11 linked with making human settlements safe, resilient and sustainable. All of these goals are closely related to the global energy sector, which sooner or later needs to take into account the aforementioned conditions. As pointed out before, most of these global challenges can be tackled with the help of innovation technologies.

The examples of the application of such technologies for environmental means are growing exponentially amid the innovation technology boom. Sensor networks are used for smart building systems to optimize energy consumption by adjusting lighting, heating, cooling based on the information they get in real time (Santos, 2021). IoT has been successfully used in smart agriculture systems to monitor moisture, crop health, and weather conditions, enabling farmers to use resources more efficiently and reduce waste (Rezk, 2021). Autonomous robots can perform tasks such as cleaning up trash and debris from oceans and rivers, assisting in waste management and reducing pollution (Rue, 2023). Predictive analytics models based on big data use machine learning algorithms to optimize energy consumption in buildings, transportation systems, and industrial processes, reducing carbon emissions and improving efficiency (Ghasemkhani, 2022). Advanced manufacturing networks utilize cloud-based technologies to share design and production data, allowing for more efficient use of resources and reducing waste (Fisher, 2018). Artificial intelligence (AI) is omnipresent in different fields nowadays and is often used in combination with the aforementioned technologies. AI has been of great benefit in smart grid management for GHG emission reduction, precision agriculture for crop optimization and waste management, sustainable transportation, green building and many other applications (Chi, 2022; Nti, 2022).

Innovation technologies are also progressively used in the energy sector, with companies signing new deals and registering more patents related to artificial intelligence and other innovative technologies. For example, Siemens AG is spearheading globally the application of artificial intelligence among other firms in the power industry. The company has launched in 2022 the Tech for Sustainability ideation campaign aimed at tackling modern challenges in the nexus of sustainability and technology through collaboration (Siemens, 2023). It is actively using and promoting its innovative approached based on digital industry technologies, for decarbonization, industrial energy efficiency and resource efficiency. In the energy realm, it has developed the Siemens Xcelerator digital business platform which supports companies in decarbonizing through optimizing production processes digitally (Siemens, n.d.).

The key takeaways from this section include a review of the concept of Industry 4.0 and the identification and definition of some of the innovation technologies that can be used for environmental purposes. This section explains what SDG9 is and why it is important for addressing future challenges with sustainable technologies. Moreover, it describes some of the main types of innovation technologies, such as artificial intelligence, blockchain, IoT, and robotics, and gives examples of how they are applied in different fields and industries. It concludes that innovation technologies are increasingly used in the energy sector and provides an overview of how Industry 4.0 can contribute to achieving SDGs and creating a sustainable production system.

2.1.2. Identification of green innovation

In this section I will attempt to analyze relevant literature to determine the key characteristics of green innovations, which can later be used for the construction of the theoretical framework.

With the evolution of innovation studies, more academics concur that, even though profit matters, the creation of value for the society by innovation is equally important. The innovation driven by firms facilitates market growth, which in turn fosters employment and leads to higher quality of life. Many scholars argue that the primary objective of business is to create novel, cutting-edge products and services that boost the economy, provide sustainable competitive advantages in the long-term while simultaneously providing significant social benefits (Ahlstrom, 2010). Moreover, environmentally sustainable innovation is crucial to fulfilling the 17 Sustainable Development Goals (SDGs) by Agenda 2030, including the SDG9. From the marketing point of view, implementing environmentally friendly innovations assists firms in aligning themselves with consumers that are increasingly conscious about climate change (Paparoidamis et al., 2019). Such efforts, therefore, improve the reputation of the company stakeholders.

Ahlstrom (2010), in particular, argues that innovative businesses can contribute to society in several ways, including by developing products and services that address social and environmental challenges, promoting ethical and sustainable business practices, and supporting education and training programs to help build the skills of the workforce. At the same time, Ahlstrom highlights the need for businesses to adopt a broader perspective that takes into account the impact of their actions on society as a whole and the importance of creating a supportive regulatory environment to avoid ecological repercussions of economic growth.

Taking this into account, it is of paramount importance to assess innovations in the light of their implications for the society and the environment. In the most recent studies, environmental issues are recognized as being at the forefront of innovations management (El Baz et al., 2022). Stakeholders are pushing businesses to integrate environmental concerns into their business decisions while also coming up with novel strategies to boost profitability through sustainable practices. This has led to the integration of eco-design, cleaner production, and life cycle assessments in supply chain management, both internally and with partners. With the growth of research on sustainability management in recent years, issues concerning sustainable organizational practices, including innovations at all stages and levels, are increasingly being raised by academics. As a result, the research concerning green innovation as a part of sustainable innovation has expanded comprehensively.

Green innovations or eco-innovations refer to the development of environmentally conscious products or processes that incorporate new or updated technologies aimed at conserving energy, preventing pollution, or managing the natural environment (Awan, 2020), hence helping companies to reach net zero goals. De Medeiros (2022) additionally points out that innovations involve not only products and processes, but also marketing methods and institutional arrangements. The prerequisite for identifying an innovation as an eco-innovation is if its usage is less detrimental to the environment than the use of pertinent alternatives (Kemp and Pearson, 2007).

Based on the analysis provided in Figure 3, the key elements of green innovation are (1) novelty, (2) environmental focus, (3) mitigation of future environmental risks, (4) improved environmental performance, (5) support for the transition to a sustainable economy, (6) knowledge and technology application, and (7) green during the full life cycle. Schiederig et al. (2012) also add that the intention can be motivated not only by ecological impulses but also economical, including the need to be competitive on the market and satisfy the demand.

	Definitions of Green Innovation	**Key Points**	**Authors**
1	"The production, assimilation or exploitation of a **novelty** in products, production processes, services or in management and business methods, which aims, throughout its lifecycle, to **prevent or substantially reduce environmental risk**, pollution and other negative impacts of resource use (including energy)".	**1. Novelty;** **2. Reduction of environmental risk.**	OECD

2	An **organization-specific novel product,** production method, service, or management strategy that can be created, adopted, or used to **reduce environmental hazards, pollution, and other negative effects** related to resource use, including energy use, throughout its entire life cycle. This is accomplished by minimizing such effects **in comparison to other solutions.**	**1. Novelty; 2. Reduction of environmental risk; 3. Higher resource efficiency compared to previous processes.**	Kemp and Pearson (2007)
3	Innovation that **improves environmental performance.**	**1. Improvement of environmental performance.**	Carrillo-Hermosillaet al. (2010)
4	**New or modified** processes, products and practices that aim to **benefit the environment** by reducing negative impacts and ultimately contribute to a more sustainable ecological balance.	**1. Novelty 2. Benefit to the environment.**	Oltra and Saint Jean(2009)
5	Innovation that plays a role in **mitigating or minimizing human-caused burdens on the environment**. It encompasses efforts to **prevent or reduce** such burdens, as well as initiatives to **address and rectify existing damage**. Additionally, innovation is utilized in the **identification and monitoring** of environmental issues for effective diagnosis and management	**1. Efforts toward anthropogenic environmental burdens; 2. Addressing existing damage; 3. Damage prevention and monitoring.**	Hemmelskamp (2000)
6	The creation and acceptance of **new concepts, technologies, and approaches** that **tackle environmental issues** and **facilitate the shift towards** an economy that is both **low-carbon and sustainable.**	**1. Novelty; 2. Tackle environmental issues; 3. Facilitate the shift toward low-carbon economy.**	Ghisetti et al. (2015)
7	The **generation, dissemination, and application of knowledge and technologies** that facilitate the **attainment of environmental objectives** and foster **sustainable development.**	**1. Generation and application of both knowledge and technologies; 2. Aimed at the attainment of environmental objectives; 3. Promote sustainable development.**	Suarez et al. (2018)

Figure 3. Definitions of Green Innovation. Adapted from Díaz-García et al. (2014).

The key takeaways from this section include the definition of key characteristics of green innovations and how they can create value for society and address environmental challenges based on the reviewed literature. The fundamental criteria for determining whether an innovation is green is summarised in Figure 3.

2.1.3. Typology of innovation and green innovation

In this section, I will explore different typologies of innovation and how they can be applied to the context of sustainability and the environment. Innovations can take different forms and have been increasingly branching out into new types with the innovation technology boom. Defining a typology framework can be an important step in classifying and assessing innovation as they support in reviewing organizational structures and strategies and predicting specific dependent variables. They are typically created with respect to certain organizational outcomes (Doty et al., 1994). Typology can also provide a systematic and structured way to categorize and understand different types of innovations in the context of sustainability and the environment. It facilitates comparative analysis among different types of green innovations and enables the identification of patterns and trends.

The categorisation of innovation can be carried out according to different criteria. One of the simplest and fundamental typology frameworks for innovations in general - *product and process innovation* - has emerged over time through the collective contributions of various researchers and scholars in the field of innovation studies. The distinction between product, process, and organizational innovation can be traced back to the work of Joseph Schumpeter (1935), who emphasized the importance of technological advancements and new product development in driving economic growth. If applied to the field of sustainability, *green product innovation* refers to the improvement or transformation of products by using eco-friendly raw materials in order to prevent the environmental effects (Amores-Salvado et al., 2014). Solar panels, electric vehicles, and energy-efficient appliances are all examples of green product innovation. Meanwhile, *green process innovation* is defined as the advancement of manufacturing equipment, along with the formulation of approaches and protocols aimed at mitigating the environmental impacts resulting from production and consumption practices (Shrivastava, 2018). In the past years, carbon capture and storage (CCS), advanced wind turbine technology, and biomass conversion have been implemented by companies to contribute to a more sustainable and low-carbon future in the production and consumption processes.

Apart from this, scholars identify *organizational innovation*, which can entail the development and implementation of new or improved organizational structures, processes, and practices within a company (Pereira and Vence, 2012). This type of innovation may include the implementation of agile workforce, digital transformation, and innovative sustainability management.

Business model innovation focuses on the development of new and innovative ways of creating, delivering, and capturing value in a business (Pereira and Vence, 2012). Business model innovation can bring adjustments to how a firm produces income, engages with consumers, and distinguishes itself in the market. Its goal is to develop new sources of competitive advantage. In the area of sustainability, it can entail the creation of new business models to increase resource efficiency, such as industrial symbiosis or new collection and recovery schemes for valuable resources. Some successful examples of such innovation in the energy industry include Energy Service Companies (ESCOs), which provide energy efficiency services, such as energy audits and energy management, financed based on energy savings (IEA, n.d.). Apart from ESCOs, there are peer-to-peer energy trading platforms through blockchain, Pay-as-You-Go (PAYG) energy solutions, and demand response and Virtual Power Plants (VPPs) (IEA, n.d.).

Another way of classifying of innovations is based on their novelty and has been developed by Tushman and Anderson (1986) who label these types *"competence-enhancing" (incremental) and "competence-destroying" (radical)*. Competence-enhancing innovations refer to significant advancements in price/performance that leverage existing knowledge and skills. They are often introduced by incumbent firms and often are aimed at improving individual components. On the other hand, competence-destroying innovations erode competencies and cause fundamental shifts in the information and abilities needed for product creation and manufacturing, making preexisting expertise irrelevant.

If we apply this to green innovations, they can be both competence-destroying and competence-enhancing, depending on the specific context and nature of the innovation. Some environmentally friendly discontinuities could substantially alter the knowledge, abilities, and procedures necessary in industries that rely largely on conventional, polluting technologies. Existing business models can be disrupted by these breakthroughs, which also make the corresponding competencies obsolete.

For example, the introduction of electric vehicles (EVs) can be considered competence-destroying for traditional automakers heavily invested in internal combustion engine (ICE) technology. EVs require new expertise in battery technology, electric drivetrains, and charging infrastructure, disrupting the existing competences of traditional automakers. In the energy sector, for conventional fossil fuel-based energy corporations, the broad adoption of renewable energy sources, like solar and wind power, might be viewed as competence-destroying. Compared to traditional power generating techniques, these renewable energy solutions demand distinct knowledge, abilities, and infrastructure. The necessity to switch to renewable energy sources may render the existing competencies of incumbent energy businesses with significant investments in fossil fuel technology obsolete.

On the other hand, many green innovations expand on previously acquired knowledge and abilities, enhancing and developing accepted practices. These innovations build on already-existing competencies to provide more sustainable solutions. For instance, improvements in renewable energy technology, such as more effective solar or wind turbines, can be viewed as competence-enhancing since they make use of already-developed grid integration and energy generating skills while strengthening performance and environmental impact.

In the case of green innovations, it is of paramount importance to take into account the context within which it is adopted, since it takes into account the environmental and social repercussions of a novel product or process. Hence, a more comprehensive typology framework that can be used for the purpose of the present study must include more extensive and all-inclusive criteria. The innovation management research has contributed to the identification of the following dimensions of innovation: *connective, structural, reflexive, and integrative innovation.* This typology categorizes innovations based on their distinct characteristics and focuses on different aspects of the innovation process and outcomes. The categorization is based on the levels of collaboration, fairness, as well as adsorption and desorption capabilities. Fairness and collaboration are the driving powers of governance, since they highlight the need engage and involve diverse perspectives and stakeholders to address systemic failures and promote inclusive innovation practices. Adsorption and desorption capabilities are related to the ability of an innovation to attract and retain attention, resources, and interest from stakeholders through agility and flexibility (Awan, 2020). Adsorption capability is based on the concepts of accumulation learning (Driessen et al., 2013) and embedding integrative routines (De Medeiros et al., 2014) and fosters collaboration aimed at eco-innovation. It can be linked to the concept of "green absorptive capacity" (Chen et al., 2015), which refers to the identification, assimilation and utilisation of external knowledge in combination with internal know-how to build green innovation practices. Meanwhile, the desorption capability relates to the ability to release or disseminate the innovation to a wider audience or context based on the learning capability (Schilke, 2014).

Connective innovation refers to the creation and use of novel technologies, systems, or practices that enhance communication and cooperation between various actors or entities (Awan, 2020). It entails building platforms, networks, and connections that promote improved collaboration, communication, and information exchange. To promote creativity and problem-solving, connective innovation strives to close gaps, improve interactions, and build synergies among various stakeholders. Connective innovation has the potential to stimulate sustainable development and economic growth by transforming existing practices in the artificial intelligence and IoT environment. This type of innovation requires high levels of collaboration and adsorption capability. According to earlier studies, IoT has the potential to improve productivity, streamline operations management, and drive organizational restructuring toward collaborative networks that present fresh opportunities for younger employees (McDonald, 2011). According to Harrington and Ladge (2009), strong management commitment is essential for fostering creative workforce management strategies, particularly those that integrate work-life views. Similar to this, the creation of sustainable products and practices is heavily influenced by a better knowledge of market demands (Awan, 2020). According to Alan (2010), IoT has led to the creation of a "green innovation environment" through enhanced connectivity, integration, interoperability, and stakeholder engagement. Smart grids, smart buildings, precision agriculture, waste management are all possible due to the Internet of Things, which allows to improve efficiency through data-driven decision-making (Dhanaraju et al., 2022).

The redesign or restructuring of current systems, structures, or processes inside a company or an industry constitutes *structural innovation.* It entails making considerable adjustments to the underlying infrastructure, governance structures, or operational frameworks. Structural innovation is crucial to tacking climate change since it directs attention to the effective sustainability management and the expansion of natural resource management to foster ecological innovation.

The proponents of structural innovation underline the significance of collaboration among stakeholders in addressing fundamental issues within the innovation system (Howells and Edler, 2011). The prerequisites for structural innovation are collaboration and desorption capability. IoT, cloud computing, and blockchain are pivotal tools in structural management. For example, the so-called “digital twin” technology, helping to create virtual replicas of physical assets with sensors and Big Data, enables organizations to simulate and optimize performance, identify energy-saving opportunities, and minimize environmental impact throughout the lifecycle of the asset. This technology backboned by IoT and advanced data analytics completely transforms the incumbent infrastructure turning it into a virtual living being (Fuller et al., 2020).

Reflexive innovation can be defined as a type of innovation where actors engage with and utilize a system of regulations, institutions, and their own capabilities to drive change and improvement (Windeler, 2018). It involves the adoption of new approaches, methods, or practices that encourage critical self-reflection and learning within an organization or system. This type of innovation focuses on creating an environment that promotes continuous questioning, evaluation, and adaptation of existing assumptions, values, and norms. Reflexive innovation aims to foster a culture of learning and responsiveness, enabling organizations to adapt to changing contexts and improve their decision-making processes. In the environmental context, this type of innovation ensures that the needs of the future generations are take into account and green practices are prioritized over brinkmanship (Awan, 2020). Reflexive innovation is crucial to building a sustainable future within organizations. This type of innovation requires fairness and desorption capabilities. For example, companies worldwide have been successfully adopting energy monitoring and feedback systems based on IoT in buildings and industrial facilities for real-time data collection and analysis of energy usage. Reflecting on the results, users can determine new ways of reducing waste and optimising energy efficiency. Environmental Management Systems, such as ISO 14001, are another example of reflexive innovations aimed at assessing the environmental impacts and developing strategies for continuous improvement. Considering the importance of cooperation, another relevant example would be collaborative networks and knowledge sharing among industry stakeholders, policymakers, researchers, and community groups.

Integrative innovation is the process of combining and integrating several technologies, fields of knowledge, or disciplines to come up with new services or goods. It entails fusing diverse components to create coherent and synergistic solutions that can handle difficult problems. Integrative innovation seeks to create new, comprehensive solutions by utilizing the advantages of many disciplines or areas of knowledge. This type of innovation often includes user innovation which helps to foster shared vision in generating new ideas. It is high on fairness and desorption capabilities. Sustainable technologies are increasingly integrated into the existing systems slowly helping organizations to transition to green economy. Innovation technologies can facilitate the implementation of circular economy principles, where resources are reused, recycled, or repurposed to minimize waste and environmental impact. Digital platforms and technologies enable efficient resource tracking, reverse logistics, and collaboration among stakeholders to create closed-loop systems. For example, smart grid integration is of great support in adding renewable energy sources into the existing power grid for better management of energy generation, distribution, and consumption. Similarly, IoT devices and sensors are employed for environmental monitoring and management to identify and address environmental issues more effectively.

For the purposes of this study, it is possible to combine different categorizations of innovation by considering multiple dimensions (type, novelty, impact) simultaneously. For example, an innovation can be categorized as a green product innovation (type of innovation) that is also competence-enhancing (novelty of innovation) and integrates various technologies and knowledge fields (integrative innovation). By combining different categorizations, this study can achieve a more comprehensive understanding of the innovation landscape in order to ensure better analysis, comparison, and identification of patterns and trends.

This section has defined four types of innovation based on their characteristics: connective, structural, reflexive, and integrative — apart from product, process, business model and organizational innovation types. It also describes two types of innovation based on their novelty: competence-enhancing and competence-destroying. By combining different dimensions of innovation, the section has managed to build the basis for a more comprehensive typology framework.

2.2. Literature on business innovation

In the following section I will discuss how innovation can drive social and environmental change, as well as economic growth, and review some of the foundational theories of innovation through different theories. I will start with the early theories of innovation, such as Schumpeter's theory of creative destruction and entrepreneurship, and their limitations in addressing the societal and environmental impacts of innovation. I will also review additional theories to define the key internal capabilities that scholars consider important for driving innovation.

2.2.1. Schumpeterian theory

Apart from being an essential driver of economic growth, innovation is critical for driving social and environmental change. Companies that tap into innovation not only gain competitive advantage and drive economic growth, but also contribute to Environmental, Social and Governance goals.

However, the first theories, despite occupying an important place in the foundations of the relevant studies, have mainly focused on the economic aspects of business. Even though the research related to innovation in business has progressed significantly in the past decades, it is still important to review the foundations of this field in order to achieve a greater understanding of the subject matter.

In the dawn of the contemporary business ethics studies, Milton Friedman famously argued against business ethics bringing forward the non-responsibility and the principal agent claims (corporate executives have responsibilities only towards their shareholders). He stated that the sole purpose and responsibility of firms was to generate profits, and most corporate social responsibility-driven actions have bad consequences on markets, and hence on individuals (Hospers, 2005).

This idea was supported by a lot of prolific academics that have either solely focused on the economic benefits of innovation or have refused to explore more in-depth the environmental and social impacts of this process. If we focus on the innovation studies, the Schumpeterian theory is undoubtedly the most established theory that provides a general understanding of the core of entrepreneurial processes aimed at generating new ideas that can be applied to secure benefits due to significant improvements (Fagerberg et al., 2012). Decades before Friedman, Joseph Schumpeter explored in his new numerous works how innovative businesses ignite creative and disruptive processes that challenge capitalistic notions. He defines innovation as "new combinations" of changes that disturb the existing equilibrium in the economic system (Schumpeter, 1940).

In his works, despite briefly mentioning the potential productivity and prosperity for the society, Schumpeter mainly focuses on the economic implications of innovation. Even though he does not reject the importance of innovation for environmental and social welfare, he does not place a strong emphasis on impacts beyond just economic growth.

Figure 4 illustrates the primary contributions of Schumpeter to innovation studies listing the key ideas of the author in his works:

	Main Schumpeterian ideas about innovation	**Explanation**
1	Creative destruction	New waves of innovation occurring in different periods of human history have led to the destruction of the old economic structures and the emergence of new ones (Schumpeter, 1942).
2	Entrepreneurship	Entrepreneurship, defined as an innate source of economic change, is the main source of creative destruction resulting in growth and success of capitalist economies (Schumpeter, 1991).
3	Forms of innovation	Innovation comes in different forms: product innovation, process innovation, business model innovation, source of supply innovation, and mergers and divestments innovation (Schumpeter, 1911).
4	Innovation as a continuous process	Innovation is an uninterrupted process of trial and error which requires risk-taking and learning from failures (Schumpeter, 1942).
5	Innovation as a driver of economic growth	Innovation is the fundamental driver of economic growth and it ultimately leads to higher levels of productivity and prosperity (Schumpeter, 1942).

Figure 4. Main Schumpeterian ideas about innovation.

Schumpeter provides one of the most comprehensive entrepreneurial innovation theories, which provides a good basis for the identification of innovation. One of the main takeaways from his works is the understanding that innovation requires “combinations” of new risky ideas that lead to radical, disruptive changes, rather than incremental improvements. Large, incumbent companies can be too bulky and risk-averse to drive the process of creative disruption, which requires additional managerial efforts to foster the innovativeness within big companies.

However, as pointed out above, there are some limitations to his works. In relation to the main subject matter of this paper, an important weak point in Schumpeter's work is lack of emphasis on the societal and environmental implications of innovation. It can be argued that his focus on creative destruction and the pursuit of profits could only ramp up the environmental degradation and social inequalities. This can be attributed to the vagueness and abstractness of most of his theories (McCraw, 2007). While providing a good framework for a generalized assessment of innovations, Schumpeter's works are not as applicable for green innovations due to the lack of a more holistic approach.

2.2.2. Internal capabilities of innovative firms

Despite some limitations, the Schumpeterian theory makes an important point — it suggests that the success of innovations often depends on certain internal capabilities of a company. It highlights one of the key elements necessary for successful innovation strategies — the risk-taking propensity. Firms are in need of dynamic capabilities that integrate different resources for effective adaptation in the ever-changing business environment (Teece et al., 1997). These capabilities, among others, are especially important for effective green innovations, which are multi-dimensional and more complex.

Pereira and Vence (2012) have developed a framework that helps to determine what affects the successful development and adoption of eco-innovation, whether it is the structural characteristics of a firm, its business strategy, technological capabilities or effective leadership.

The impact of the structural characteristics of a firm, such as age and size, are subject to debate. Some scholars argue that the probability of adopting eco-innovations is not contingent on the size of the firm (Wagner, 2008). Some researchers claim that SMEs are more prone to implementing green initiatives, claiming that incumbent firms are less likely to be innovative (Schumpeter, 1991), whereas SMEs opt for innovative solutions more often (Acs and Audretsch, 1990). On the other hand, Lin and Ho (2010) argue that, when compared to small businesses, large organizations implement eco-friendly practices more quickly by making use of their extensive resources and vital infrastructure. Bigger organizations can benefit from economies of scale, access to a large pool of highly skilled employees, immense tacit know-how and competences. Entrepreneurial dynamism, adaptability, efficiency, closeness to the market, and motivation are the main elements that have the greatest impact on small businesses' competitive advantage.

Regarding the business strategy of firms, several studies underscore the key role of visionary management in the implementation of green innovation (Paraschiv et al., 2012). Taking a long-term perspective and recognising that green innovation is a continuous process rather than a one-time initiative, managers can drive sustainable initiatives within companies. Moreover, the top management of the firm needs to have a clear commitment and focus on environmental sustainability as a core value of the business strategy. This involves integrating environmental considerations into all aspects of the organization's operations, products, and services. Corporate Social Responsibility (CSR) programs are a common and effective way for organizations to adopt eco-innovations (Cainelli et al., 2011).

Technological expertise is undoubtedly fundamental to successful green innovation initiatives. Strong technological capabilities enable businesses to create creative solutions that successfully address environmental problems because they have a deeper grasp of green technology and their application. Technological expertise is directly supported by R&D capabilities, since robust R&D competence enables firms to stay at the forefront of green innovation and maintain a competitive edge (Díaz-García, 2015).

Green innovation efforts also require strong leadership commitment to environmental sustainability and a distinct vision. In order to inspire and support green innovation activities, leaders must determine the direction, mobilize resources, and cultivate a supportive organizational culture. Leaders should also be able to foster a culture of learning and adaptability is crucial for embracing and implementing green innovation. Firms that promote continuous learning, experimentation, and the ability to adapt to changing environmental requirements, are better positioned to develop and adopt sustainable practices (Begum et al., 2022).

Based on this section, while specific capabilities may vary depending on the context, some key internal capabilities for firms to develop and adopt green innovations include technological and R&D capabilities, visionary leadership, organizational learning, age, and business strategy focused on sustainability.

2.3. Literature on sustainability and green innovation

In this section, I will review some of the literature on sustainability and green innovation, focusing on two main perspectives: the Triple Bottom Line theory and the collaboration with stakeholders with open innovation and Triple Helix models. I will aim to define what are the key characteristics that scholars find crucial for innovation and sustainability practices.

2.3.1. Triple Bottom Line Theory

It was not until 1987 that the concept of sustainable development gained more prominence through the efforts of the Brundtland report (Brundtland, 1987) by the World Commission on Environment and Development. The focus on sustainable development was further reinforced by Elkington (1997) in his Triple Bottom Line (TBL) theory. The TBL approach suggests using the economic, social, and environmental elements to evaluate sustainability efforts by organizations. It underscores the positive effects of including those elements into firms' innovation strategy and striking a balance between all the three dimensions.

The Triple Bottom Line theory takes a holistic approach towards business activities, viewing them not only as drivers of economic growth but also contributors to environmental and social areas. Instead of solely focusing on financial performance, it encourages organizations to consider the inevitable implications of their operations for the external environment. Economically, TBL considers the financial aspects of business operations, such as profitability, cost efficiency, and economic value creation. The environmental dimension places a great emphasis on sustainability and ecological stewardship. It entails evaluating how corporate operations affect environmental factors such as resource consumption, pollution, greenhouse gas emissions, and ecological sustainability. Finally, the social dimension takes into account the obligations and societal repercussions of firms' actions. It includes topics like social equality, participation in the community, worker wellbeing, respect for human rights, and ethical behaviour (Elkington, 1997).

Organizational innovation is an indispensable part of business efforts toward the improvement of all those three dimensions. It has particularly been recognized as a crucial tool for resolving issues with sustainable development (Hall et al., 2003; Boons et al., 2013). The TBL theory has been used in research on green innovation to demonstrate how such inventions may boost social welfare while promoting economic growth (Mendes, 2021). Since the triple bottom line approach allows for a comprehensive assessment of green innovation technologies by taking into account their effects on the economy, the environment, and society, it offers a bigger picture that looks beyond monetary rewards and takes into account wider sustainability concerns.

From the social perspective, the TBL approach ensures that green innovations are assessed in terms of their social implications. It encourages the evaluation of factors such as job creation, community involvement, equity, and the well-being of stakeholders affected by the innovation. It exhorts firms to take into account whether certain business practices will bing positive repercussions, like increased access to energy, job creation and energy affordability, or negative repercussions, such as job replacement, technological divide, ethical and private concerns.

Turning to the scope of this study, from the environmental impact perspective, the Triple Bottom Line theory aids in evaluating the ecological advantages of green technologies by taking the environmental component into account. It makes it possible to identify and quantify environmental advancements including reduced resource consumption, lower emissions, and improved conservation techniques. It also allows to evaluate not only positive environmental implications of green innovations, but also negative. On one hand, recent innovations in the energy industry have indeed led to higher energy efficiency, wider renewable energy integration, more efficient demand response and load management, highly accurate predictive maintenance. On the other hand, it is crucial to evaluate the reverse effects of the innovations adopted by firms, since they can impact the energy consumption levels by data centres and computing infrastructure, volumes of e-waste, demand for data storage and transmission capacity, and ethical sourcing of resources.

Overall, the TBD approach emphasizes the sustainable development's long-term outlook. It promotes the evaluation of green technologies based on their long-term benefits and potential for good legacies by taking into account the capacity of future generations to meet their needs. TBD provides a complete framework to assess green innovations in a comprehensive and balanced manner, considering their economic, environmental, and social impacts.

Assessing the potential environmental impacts of green innovation requires a comprehensive evaluation framework. The present study’s scope does not include the analysis of the existing frameworks on this topic. The assessment of innovations in the Italian energy industry on this criteria will be based on the information and feedback available in open sources. However, it is worth mentioning the most used methodologies.

Life Cycle Assessment (LCA) is one of those widely used techniques for the assessment of the environmental impacts of products, processes, or services throughout their life cycle, from the raw material extraction to distribution and use. According ISO 14040 (ISO, 2006), LCA can be applied for product development and improvement, strategic planning, public policy making and other means. LCA provides a systematic approach to evaluate the environmental burdens and potential improvements for different companies.

Another method for environmental impact assessment is called Environmental Footprinting (EV). According to the European Commission (2021), EV methods, such as carbon footprint, water footprint, or ecological footprint, are the most reliable and verifiable ways to calculate the environmental performance of companies. Moreover, this technique helps other actors to have access to such information increasing transparency and incentivising the reduction of the carbon footprint. It is important to keep in mind that the effectiveness of EV depends on various factors, most importantly the scope and accuracy of the collected data. When implemented properly, EV can contribute to not only improved environmental performance, but also supply chain transparency, stakeholder engagement and communication, and strategic decision-making.

In summary, the Triple Bottom Line theory suggests using the economic, social, and environmental elements to evaluate sustainability efforts by organizations, and clearly vindicates that innovations can substantially contribute to all those three dimensions.

2.3.2. Collaboration with Stakeholders, Open Innovation and Triple Helix Model

To further build the matrix and to build criteria to assess eco-innovations, it is important to bring about another perspective. The evaluation of firms' sustainability efforts cannot be restricted only to their organizational capabilities. Companies are also influenced by other stakeholders, benefiting from interactive processes (Caloghirou et al., 2004). Collaborative networks tend to facilitate the identification of potential opportunities for innovation and ensure improved results due to knowledge transfer and collaboration. Several scholars have emphasized that companies can execute certain plans more effectively through cooperation (Abramovsky et al., 2009). According to the research, businesses that don't communicate and share information, explicitly or implicitly, are less able to adjust to changing market conditions (Hanna et al., 2008).

The process of developing an innovation consists of three strategies, according to Navarro (2002). The first one — the "make" strategy — is linked to generating internal knowledge within the firm. This strategy depends on internal resources, knowledge, and R&D efforts aimed at providing new insights and breakthroughs. The second strategy is called "buy", in referral to acquiring information or technology from outside sources. Instead of creating information, intellectual property rights, or technologies from scratch, this strategy involves obtaining them through licensing, collaborations, or acquisitions. Cooperation with other agents, commonly known as "cooperate", is the third strategy that Navarro emphasizes. The importance of official and informal collaboration with external organizations like research institutes, business partners, suppliers, or clients is rendered crucial by this strategy. This is because collaboration enables firms to access external knowledge, skill, and resources, strengthening their capacity for innovation.

This aligns with the idea of open innovation (Chesbrough, 2003), which involves knowledge flows across organizational boundaries, for both pecuniary and non-pecuniary reasons. This includes open source innovation, crowdsourcing, IP licensing, university collaborations, startup engagement, venture capital, interfere collaboration, R&D, supplier-driven and user innovation. Firms are more likely to come up with successful innovative solutions when they resort to open innovation (Chesbrough, 2006), hence collaboration tends to enhance innovation. This is especially relevant in the context of eco innovations. Most companies do not focus their key efforts on environmental issues, which is why cooperation with third parties can be pivotal in developing sustainable practices and adopting green innovations (Melander, 2018).

The idea of collaboration is further developed in the Triple Helix Model (Etzkowitz et al., 1995), which is often compared to the model of open innovation. The Triple Helix Model (THM) insists on the importance of collaboration between the government, industry, and academia to promote innovation and societal progress (Figure 5). This is manifested in the form of university research funding by government or industry, technology transfer, special national programs (Leydesdorff et al., 2016).

	Main Triple Helix Model ideas about innovation	Explanation
1	**Collaboration among University, Industry, and Government**	The model recognizes that innovation arises through the dynamic engagement of universities, industries, and government agencies. Each helix represents distinct actors with their own roles and resources (Etzkowitz et al., 1995).
2	**Knowledge Exchange and Transfer**	The model looks into the flow of knowledge and expertise among the three helices. Universities contribute scientific research and knowledge creation, industries apply and commercialize this knowledge, and government policies and regulations facilitate the transfer and utilization of knowledge in society (Etzkowitz et al., 1995).
3	**Synergistic Relationships**	The THM suggests that innovation thrives when there is strong collaboration and synergy between academia, industry, and government. This collaboration fosters the development of new technologies, products, services, and policies that address societal challenges (Etzkowitz et al., 1995).

Figure 5. Main Triple Helix Model ideas about innovation

The THM approach is vindicated by many other theories with a similar focus. The concept of System Building (Nelson, 1993) can be used to complete and reinforce the idea of collaboration and necessary interaction with the environment. This theory calls for a radical shift in the philosophy around innovation — from an insular point of view to a more inclusive consideration of business in the context of society. Its main idea is rooted in the phrase "*doing good by doing new things with others*" (Adams, 2016). Sustainability efforts can only work on the global level and cannot pertain to just a single firm. The radical change that is required to fight climate change will only work within an interconnected system of innovations consisting of stakeholders from different areas.

As it emphasizes the significance of multi-stakeholder cooperation and information sharing in supporting sustainable development, the THM can hold great value for evaluating green technologies. Interdisciplinary strategies including the incorporation of scientific research, technical developments, business skills, and favorable governmental regulations are prerequisites for green innovations. The THM may be used to assess how well these three helices are working together and how they are influencing the creation and implementation of sustainable solutions.

It is important to add that, apart from cooperation, stakeholders can be one of the prime reasons for the adoption of green innovation practices in companies. Chen and Jiang (2023) argue that the institutional environment and the market (customer demand for green practices and competition) directly influence the top management decision to adopt green innovation initiatives. They found based on empirical evidence that this external stakeholder pressure is especially successful when the top management already has an environmental mindset.

The collaboration with stakeholders perspective provided in this section demonstrates how innovation arises through the dynamic engagement of universities, industries, and government agencies, as well as other external actors, such as customers and competitors. The key takeaway from this is the importance of collaboration and stakeholder engagement in driving innovation.

2.4.1. Sustainable Business Performance through Green Innovation

After identifying and analysing an innovation, it is necessary to evaluate it based on its alignment with sustainability principles, its potential to contribute to sustainable development and to create value for stakeholders. Ideally, the end purpose of any green innovation should be the reduction or eradication of environmental harm coming from a company's operations. In order to understand how likely an innovation is to contribute to the SDGs, several scholars have identified different success factors of innovation.

Baeshen et al. (2021) found that green absorptive capacity, or more broadly organisation learning, have a positive influence on GIs within SMEs. This implies that organizations need to identify, adapt and apply internal and external knowledge to be able to effectively manage novel green practices. This knowledge may include the understanding of sustainable technologies, environmental regulations, market trends, and consumer preferences. These elements need to be effectively identified, assimilated, interpreted and managed within the organization. Apart from information, such knowledge also includes the up-to-date know-how about new technologies, processes, and practices. Moreover, firms need to be able to adapt and recombine existing knowledge and capabilities with newly acquired knowledge in order to create innovative solutions that address environmental challenges.

Skilled human capital and environmental awareness of the top management are also important aspects that can positively affect the performance of GIs (Baeshen et al., 2021). Skilled human capital brings specialized knowledge and expertise in areas relevant to green innovation, such as environmental management. When the human resources possess such competences, they influence positively the direction of green innovation initiatives through employee activities (Huang and Kung, 2011). These intangible and tangible assets can be further reinforces by the environmental awareness and commitment of the management which sets the tone for the organization's sustainability efforts. The sustainable mindset of the management fosters a system of values completely transforming the practices in the firm by endorsing employees' eco-friendly behaviour, ensuring that employees have easy access to organizational resources, raising hiring standards, fostering organizational learning, and acquiring environmental knowledge (Lin and Ho, 2011). Overall, organisational support which fosters innovation by ensuring the availability of relevant resources significantly influences the adoption of innovation (Baeshen et al., 2021).

De Medeiros et al. (2014) identified four success factors that influence green innovation performance: “market, law and regulation knowledge”, “interfunctional collaboration”, "innovation-oriented learning”, and “R&D investments”. Firstly, firms are likelier to invest in green innovation when there is market demand and consumer interest along with relevant trends, educational campaigns, favourable laws, and government incentives (De Medeiros et al., 2014). Being aware of these aspects and effectively leveraging them is key to successful GIs. Moreover, once green initiatives are adopted, companies are likely to be rewarded by the market with differentiation, cut costs, and better reputation (Cambra-Fierro et al., 2008).

According to De Medeiros et al. (2014), the development and delivery of ecologically friendly products also requires *interfunctional cooperation*, echoing the THM and System Building concepts discussed previously. Chen (2007) found that a mix of internal and external factors, such as technology availability, development costs, consumer pressure, and governmental laws, can influence the success of green innovation initiatives. The maturity of the organization and interactions with other participants in the supply chain, such as logistics, are equally critical for the creation of sustainable products (Jabbour. 2008). GI initiatives are always more successful when important stakeholders, such as suppliers, academic institutions, and research organizations are involved. Moreover, apart from external stakeholders, market performance is positively impacted by a multi-level integration of various departments within the firm and the involvement of environmental specialists (Pujari et al., 2004). This means that the incorporation of environmental sustainability into every aspect of the business and the provision of incentives for this strategy can guarantee the effective sustainable product and process development. Overall, studies show that improved environmental practices and sustainable innovation performance are a result of concurrent engineering and proactive interactions between several fields.

De Medeiros et al. (2014) also reinforces the claim of Baeshen et al. (2021) about the importance of the organizational learning capacity. He claims that, although cultural obstacles might impede it, innovation-oriented learning is a crucial component of effective environmentally friendly product innovation. To provide excellent green product performance, businesses must build a set of green competences and embrace a proactive leadership style (Aragón-Correa et al., 2008). In order to close the gap between technology advancements and economic outcomes, proactive leadership and the capacity to consider processes from several angles are essential. De Medeiros reiterates that the organizational culture of learning encourages the integration needed to put a triple bottom line strategy into practice. Continuous learning through critical reflective analysis (the adsorptive capacity) is a top priority for businesses that concentrate on environmentally friendly solutions.

Finally, De Medeiros et al. (2014) highlight the crucial role of R&D investments based on the findings of their study. GIs are made possible by adequate production methods and technological capabilities, including competent people resources, labs, and tools (Montalvo, 2008). Professionals with more advanced skills can respond quickly to environmental demands for environmentally sustainable product creation. Together with external aspects like environmental legislation and consumer behavior, technological skills and resource availability directly affect the success of innovation initiatives. Investments in technology and equipment are favorably influenced by the control of governmental regulatory agencies, leading to favourable results in green innovation efforts.

	Success Factors for Green Innovation	Authors
1	**Green Absorptive Capacity and Innovation-Oriented Learning**	Baeshen et al. (2021); De Medeiros et al. (2014)
2	**Skilled Human Capital**	Baeshen et al. (2021)
3	**Environmental Awareness of the Management**	Baeshen et al. (2021)
4	**Market, Law, and Regulation Knowledge**	De Medeiros et al. (2014)
5	**Interfunctional Collaboration**	De Medeiros et al. (2014)
6	**R&D Investments**	De Medeiros et al. (2014)

Figure 6. Success Factors for Green Innovation

Figure 6 highlights the main factors — green absorptive capacity and organizational learning, skilled human capital, environmental awareness of top management, market, law, and regulation knowledge, interfunctional collaboration, innovation-oriented learning, and R&D investments — that contribute to the effective implementation of environmentally friendly practices and sustainable product development. All success factors identified through literature review are interconnected and have overlapping elements, emphasizing the importance of a holistic approach to green innovation. These success factors will be crucial to the assessment of GIs in the Italian energy industry in the following chapters.

2.5. Drawing the theoretical framework for identifying, categorising, analysing and assessing GIs

Based on the comprehensive literature review, this chapter will attempt to propose a framework for identifying, classifying, and assessing green innovations, which will later be used to analyse GIs in the Italian energy sector. This framework will draw on relevant theories and concepts from the literature review and provide a systematic approach to analyzing the adoption of innovative technologies in the context of sustainability (Figure 7).

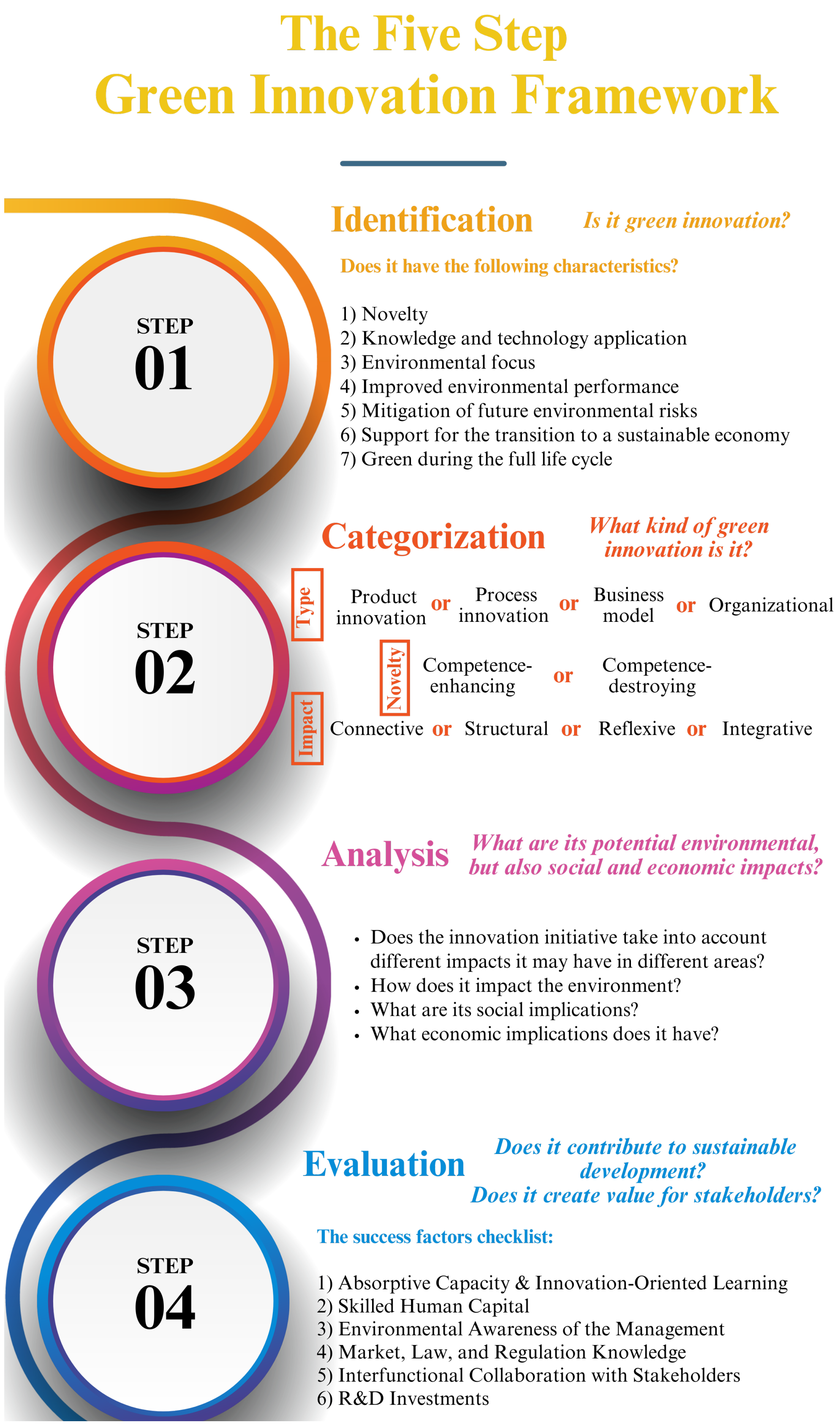


Figure 7. Framework for identifying, categorising, analysing and assessing GIs

Regarding green innovation identification, Chapter 2.1.2. has provided a comprehensive analysis of diverse definitions from the reviewed literature and define the key elements that can be utilised for

GI recognition. An innovation can be called green, if it is possesses the following characteristics: novelty, knowledge and technology application, environmental focus, improved environmental performance, mitigation of future environmental risks, support for the transition to a sustainable economy, and green during the full life cycle. By incorporating these characteristics, the definition of GIs becomes comprehensive and allows for the clear identification and classification of innovations that prioritize environmental considerations and contribute to sustainable development. It enables stakeholders to distinguish GIs from other types of innovations and focus efforts on promoting and supporting environmentally beneficial solutions. As for this study, the characteristics will act as a checklist to prove that certain innovations in the Italian energy industry are green.

Concerning the categorisation of eco-innovations, Chapter 2.1.3. distinguished three criteria for discerning different types of innovations, which can be used together due to their complementarity. Firstly, green innovations can be categorised based on their types — product, process, business model, and organizational. Secondly, innovation is traditionally categorised based on its novelty (competence-enhancing or competence-destroying). The first two methods are the basis for innovation categorisation. However, since they apply to any kind of innovation, it is important to bring in other dimensions. The main purpose of green innovations is the reduction of GHG emissions and the mitigation of environmental risks. Moreover, it is crucial to take into account other important factors, like collaboration and learning abilities of the innovative organization. The third method (connective, structural, reflexive, and integrative) is based on the levels of collaboration, fairness, as well as adsorption and desorption capabilities of a company.

Overall, understanding the type of innovation provides companies with a framework for making strategic decisions, evaluating performance, fostering collaboration, and leveraging the acquired knowledge. It enhances the company's ability to innovate effectively and achieve its innovation objectives. In regards to this study, it will become an important tool for categorising the Italian energy industry innovations.

The analysis of green innovations implies understanding their potential environmental, but also social and economic impacts. This question can be answered based on the TBL theory, which suggests a holistic approach to sustainable practices. By considering all three dimensions, companies can assess the broader impacts and outcomes of their green innovations. Environmental impacts are typically the primary focus of green innovations, aiming to reduce resource consumption, emissions, and ecological harm. However, it is crucial to also evaluate the social implications of these innovations. This includes assessing factors such as job creation, social equity, health and safety benefits, community engagement, and the well-being of stakeholders affected by the innovation. Additionally, the economic dimension, which considers cost-effectiveness, market competitiveness, profitability, and the potential for economic growth, is vital for the long-term viability and scalability of green innovations.

The final evaluation of green innovations is based on their alignment with sustainability principles, their potential to contribute to sustainable development, and their potential to create value for stakeholders. This part is based on the literature review from Chapter 2.4.1. and also takes inspiration from the overall discussion in Chapter 2. The developed criteria provide a comprehensive list of success factors ensuring that all the questions are answered. They show that it is not enough to simply analyse the innovation itself, it is crucial to evaluate the company implementing it, since the success of the initiative depends on diverse factors.

This section proposes a framework for identifying, classifying, and assessing green innovations, which will be later applied to the Italian energy sector. The framework draws on relevant theories from literature review and consists of four steps: identifying green innovations based on their characteristics, categorizing them based on their types, novelty, and levels of collaboration, analyzing them based on their economic, social, and environmental impacts, and evaluating them based on their alignment with sustainability principles, potential to contribute to sustainable development, and potential to create value for stakeholders. The section provides an overview of how this framework can help assess green innovations in a comprehensive and balanced manner.

3. Framework application: Green innovations in the Italian energy industry

In this chapter, I will apply the theoretical framework developed in the previous section to the Italian energy sector. I will start by briefly introducing the Italian energy industry, its relevance and contribution to the international arena, as well as the green innovations practices adopted by the local firms. Based on the open source data on the innovative technologies adopted by Italian energy firms to reach net-zero targets, I will use the framework to classify and assess these innovations.

3.1. Green innovations in the Italian energy industry

The global mega-trends have been completely redefining the political, economic and social aspects in a profound and structural way. Demographic and socio-economic shifts, the rapid pace of technological advancements and digitalization, as well as the increasing influence of human activities on the environment and natural resource utilization will, unless effectively regulated, result in a significantly altered world within the next three decades compared to the present. The energy sector, which is greatly responsible for a large share of GHG emissions, is deeply impacted by these trends. Technological innovation and digitization can help accelerate the energy transition towards a carbon neutral economy contributing to the SDGs adopted by the UN.

This agenda plays a crucial role for the Italian energy sector. Among the EU members, Italy is the third largest consumer of energy, coming after Germany and France (IEA, 2023), and is among the top-10 largest CO2 emitters in the world, with its total emissions soaring to 328.7 Mt in 2021 (Global Carbon Project, n.d.). Just like in most other countries, Italy is in need of a significant increase in investments in renewable energy, prompted by government incentives. The Italian authorities are strongly pro-renewables and have defined energy and climate as the cornerstones of their political agenda setting an ambitious goal with renewables of reaching 30% in total energy consumption and 55% in electricity generation by 2030 (IEA, 2023). The government has implemented a comprehensive framework that includes incentives, feed-in tariffs, and regulatory measures to drive the deployment of renewable technologies. The country has also made significant progress in diversifying its energy mix and reducing GHG emissions. According to IEA (2023), Italy currently has 22 technology collaboration programs. With the country's ambitious climate goals, the local energy companies are incentivised to increase the investment in and adopt green innovations.

Italian energy companies, including Enel, have played a significant role in driving and pioneering in green innovation strategies in the country. Leading the way is Enel which has made sustainability a core part of its business strategy by establishing Enel X and innovation ecosystem of startups, research centres, universities and clients (Enel X, n.d.). With its commitment to sustainability, prolific renewable energy investments, strategic collaborations with academia, government and other stakeholders through the Enel Innovation Hub, the company's leadership in green innovation extends beyond Italy. Italian energy companies, including major players like Enel, possess substantial industry expertise and resources due to advanced technical knowledge, research capabilities, and financial resources to invest in and support green innovation research. Their influence and market scale enable them to implement and test green innovation solutions at a large scale, providing valuable data and insights for research.

According to a literature review conducted by Schiederig et al. (2012), a lion's share of researchers actively working on green innovation are situated in Europe, particularly in Italy, along with the Netherlands and Germany. Leading with 159 publications is F. E. E. Mattei from the Italian Climate Modelling Institute, followed by Massimiliano Mazzanti from the University of Ferrara and Carlo Carraro from the University of Venice (Schiederig et al., 2012). The high number of scholars on green innovation in Italy can positively affect the success of green innovation strategies, since this can lead to innovation and environmental research and knowledge generation and subsequent implementation of cutting-edge technologies and practices through collaboration and networking between academia and business. Moreover, it contributes to the training of a new generation of professionals who possess the knowledge and skills required to drive green innovation forward.

With Italy being one of the groundbreakers in renewable energy on a global scale, is it important to analyse green innovations in the Italian energy industry to gain insights into the country's ambitious targets, technological advancements, market opportunities, and the lessons they provide for the broader global energy transition. Overall, the Italian energy companies are relevant for green innovation research due to their industry expertise, resources, market influence, access to data and infrastructure, collaboration opportunities, and policy influence.

3.3. Green innovation practices in the leading Italian energy companies

Several Italian energy companies, such as Enel and Eni, have invested heavily in renewable energy sources like solar, wind, and hydropower, contributing to the expansion of renewable energy capacity and the reduction of carbon emissions. Most of these endeavours are possible due to innovation technologies, like AI and machine learning, cloud services, IoT and others. In order to demonstrate the applicability and effectiveness of the developed framework, this section will be divided based on the different types of innovation technologies predominantly used in the energy sector. Since the types of such technologies are countless, the present study cannot cover all of them, hence I will focus on the most popular technologies with the highest accessibility of information. The analysis will include AI and machine learning, IoT, cloud services, and blockchain (Figure 2). For each type, an example of innovation practices by different companies will be presented, depending on the availability of information, relevance to the framework, significance and balance. After presenting and analysing the information, I will apply the previously developed framework to the specific cases.

3.3.1. Artificial Intelligence

Artificial intelligence is is a machine's ability to simulate or demonstrate human-like intelligent behaviour, such as learning, problem-solving, analysing, creativity (McKinsey, 2023; Russel et al., 2016). By perceiving the environment, AI can make decision to improve or maximise certain aspects. AI has the potential to accelerate the dingy transition by saving time and resources, unlocking new sources of value, and creating new business models (Mehlum et al., 2021). It can be used to integrate renewable energy sources into the grid, by forecasting demand and supply, managing load balancing, and enhancing grid resilience. By enabling smart mobility, process automation, and energy efficiency, it can lead to a significant reduction of GHG emissions. If a few year ago little effort and investment focused on next-generation digital technologies, nowadays, most Italian energy companies are actively taking advantage of AI to drive the energy transition.

Enel and Myst AI

In 2018, Enel Green Power, part of Enel, started working with Myst AI to develop AI-powered forecasts for various energy applications. Myst AI is a Google-backed timed series forecasting platform that provides companies with near-term load, renewable production and market price forecasts. It increases the accuracy of forecasting models specifically in the energy industry, since utilities like Enel heavily depend on day-ahead and intraday forecasts amid the rise of intermittent renewable energies to ensure stability of the grid. This is particularly relevant for solar and wind energy production which is highly dependent on weather conditions (Enel, 2022).

The variety of applications of Myst AI is extremely diverse. For example, Enel uses Myst AI's machine learning-powered forecasts to support the energy transition by enabling smart grid management, renewable energy forecasting, and energy efficiency improvement (Enel, 2022). More specifically, Enel uses Myst AI's forecasts to predict the electricity load by consumers and optimize the dispatch of power plants, reducing the need for fossil fuel backup generation. Enel also uses Myst AI's forecasts to predict the renewable energy production from its wind and solar plants, and to plan the optimal storage and distribution of excess energy. Moreover, Myst AI's forecasts help to identify opportunities for energy efficiency improvement in its buildings and facilities, reducing its energy consumption and costs (Blanco et al., 2021).

Furthermore, Enel uses Myst AI's forecasts to bid on asset production in intraday markets, thereby reducing imbalance costs by 5% per year, which means that the amount of energy produced matches the amount of energy demanded more closely (Myst AI, 2022). By using Myst AI's forecasts, Enel can better estimate its energy production from renewable sources and adjust its bids accordingly, minimizing the risk of imbalance.

Based on these examples, it is evident that the applications of Myst AI for environmental purposes are unlimited and present an amazing tool for Enel on the path to complete energy transition.

Framework application Myst AI by Enel		
Step 1. Identification - Is it a green innovation?		
Criteria checklist		Comments
Novelty	✓	It involves the application of a new and original technology.
Knowledge and technology application	✓	It involves the application of a new and original technology, as well as know-how about AI and energy production.
Environmental focus	✓	It is aimed at supporting the energy transition.
Improved environmental performance	✓	It leads to improves environmental performance reducing energy consumption.
Mitigation of future environmental risks	✓	It mitigates the risks with AI-powered forecasts.
Support for the transition to a sustainable economy	✓	It is aimed at supporting the energy transition.
Green during the full life cycle	?	Myst AI's environmental footprint is not definitively positive, as it depends on factors such as the data centers, servers and networks that support its cloud-based machine learning platform.
Step 2. Categorization - What kind of innovation is it?		Comments
Type	Process innovation	It involves an improved way of conducting Enel's renewable energy projects.
Novelty	Competence-enhancing innovation	It improves Enel's existing capabilities in forecasting and managing renewable energy production and consumption.

Impact	Integrative	Integrative since it combines and integrates several technologies and fields of knowledge. It also has reflexive, structural and connective characteristics.
Step 3. Analysis - What are its potential environmental, but also social and economic impacts?		
Does the innovation initiative take into account different impacts it may have in different areas?	There seems to be intentionality in Enel's initiative, aimed at supporting energy transition, cutting costs, benefitting to the society. However, open sources are not enough for comprehensive evaluation.	
How does it impact the environment?	The environmental impact of the initiative may depend on the trade-offs between its benefits and costs and how they are measured and balanced. On one hand, it supports the energy transition due to reduced energy consumption, optimized storage and distribution of excess energy, and overall, cuts GHG emissions and fossil fuel consumption. However, it may also have some negative environmental impacts, since Myst AI relies on data centres, servers and networks. Moreover, the use of renewable power plants can also have its negative effects. According to the Group's GHG Inventory, their CO2 emissions in 2021 increased by 13% in relation to 2020 (Enel, 2022). Overall, the positive implications outweigh the negative.	
What are its social implications?	More reliable and sustainable energy services contribute to the quality of life and well-being of its customers and stakeholders.	
What economic implications does it have?	In regards to Enel, it helps to reduce its imbalance costs, improving profitability and competitiveness in the energy market. On a societal level, it can support the creation of new markets, jobs and revenues, as well as improve productivity of industries. However, it may also lead to market disruption and job destruction.	
Step 4. Evaluation - Does it contribute to sustainable development? Does it create value for stakeholders?		
Success factors checklist for companies	Comments	

Absorptive Capacity & Innovation-Oriented Learning	✓	The use of Myst AI by Enel involves acquiring, adapting, and exploiting external knowledge from Myst AI's machine learning platform to optimize energy forecasts and reduce imbalance costs. On a larger scale, it involves acquiring and applying knowledge to drive the green transition.
Skilled Human Capital	✓	Enel does have skilled human capital due to a diverse and talented workforce of over 65,124 employees across more than 30 countries (Enel, n.d.) with "different experiences, unique aspirations, strong feelings of belonging and great spirit of service" (Vera, 2014). The company invests significantly in the training of its human capital, nurtures respect for human rights and focuses on the employee empowerment by focusing on their wellness, motivation and active involvement (Enel, n.d.).
Environmental Awareness of the Management	✓	Enel's management has been consistently investing in green technologies and adopting sustainable strategies. They have also committed to achieve net-zero goals by 2040 (Enel, 2021; Enel, 2020). Moreover, the company's net zero plan strives to work towards decarbonisation by promoting inclusions and equality, covering also the social aspect. Out of Enel's total power generation, renewables account for almost 50%. The company expects to increase that number to 85% by 2030 and net-zero by 2040 (Enel, n.d.).
Market, Law, and Regulation Knowledge	✓	Enel operates in a complex and competitive environment that requires constant adaptation and innovation based on such knowledge. For example, Enel has a deep knowledge of the electricity market design and the wholesale energy market regulations in the EU and other regions (Ysewyn, 2022).
Interfunctional Collaboration with Stakeholders	✓	Enel actively collaborates with external partners, such as universities, research centers, startups and innovation hubs, to access and leverage external knowledge and skills (Enel, n.d.). Moreover, the company puts a strong emphasis on open innovability, creating a platform where any user can solve a challenge or propose a new project. According to Enel's website, it has evaluated over 28000 opportunities and started more than 800 collaborations, the majority of which are with dynamic startups, SMEs, and other. The company has transformed over 300 ideas into actual business projects (Enel, n.d.).

R&D Investments	✓	Enel expects to mobilize investments of 190 billion euros in the 2021-2030 period, of which 160 billion euros will be allocated to organic growth (Enel, n.d.)

Figure 8. Framework application: Myst AI by Enel

Based on the framework analysis (Fig. 8), the use of Myst AI by Enel is an example of an effective green innovation that improves Enel's environmental, social and economic performance in the energy sector. It fully falls under the criteria for green innovation definition. Regarding the second part of the framework, it is a process innovation that enhances Enel's existing capabilities in forecasting and managing renewable energy production and consumption with machine learning and data science tools. Furthermore, the application of Myst AI can be considered integrative since it combines and integrates several technologies and fields of knowledge. Concerning the analysis part, it has positive impacts on the environment, such as reducing greenhouse gas emissions and fossil fuel consumption, as well as on society, like improving the quality of life and well-being of customers and stakeholders. It also has economic benefits, such as reducing imbalance costs and increasing profitability and competitiveness in the energy market. Moreover, this initiative by Enel contributes to sustainable development and creates value for stakeholders. The performance of Myst AI is supported by several success factors within Enel, such as absorptive capacity, skilled human capital, environmental awareness of the management, market, law and regulation knowledge, interfunctional collaboration with stakeholders, open innovation, and R&D investments. However, the framework showed some gaps in the accessible information making it impossible to evaluate whether the initiative is green through its entire life cycle and which are its negative environmental implications. Overall, it can be concluded that the use of Myst AI by Enel is an effective green innovation that supports Enel's vision of a fair and sustainable energy transition. This example positively relates to almost all the points in the framework and can be considered a prime example of a green innovation. The sole negative trade-off of this technology, which cannot be accurately assesses based on the accessible sources, is the fact that it might not be fully green throughout its life cycle, as it relies on energy used by data centres.

3.3.2. Internet of Things

The Internet of Things is another widely used innovation technology with a diverse range of applications across industries. As mentioned in the second chapter, Ali et al. (2015) define IoT is an intelligent and and interoperable dynamic network that enables connectivity of data anywhere and at anytime. The power and diverse applicability of IoT has made it an extremely in-demand technology used for "smartifying" industries. In the energy industry, it is often applied for smart metering and smart grids, as well as energy monitoring and automation of energy usage.

A2A and Smart Technologies

A2A, a multi-utility company, has become one of the most prominent Italian energy players to put IoT at the core of its operations and strategy. Working towards achieving Net Zero emissions by 2040 and significantly reducing them by 2030, the company follows strict guidelines elaborated according to the circular economy commitment and self-identification as a *Life company* (A2A, 2020). At the beginning of 2023, the non-profit organisation CDP (Carbon Disclosure Project), which owns a large global database on the environmental performance of different organisations, rated A2A's efforts in fighting climate change and ensuring water security with A-, confirming the effectiveness of the company's initiatives (CDP, n.d.). This proves that A2A is undertaking successful endeavours aimed at electrification, transition to renewables and reaching 9 TWh of electricity production from green sources by 2030.

As part of its technological innovation strategy, A2A established a separate entity called A2A Smart City which works on creating smart and digital solutions that make cities and neighbourhoods more liveable and support farmers in producing more sustainably by using technology to reduce pollution and resource use. One of the pillars of the Smart City strategy of A2A is the LoRaWAN® Ecosystem based on Semtech LoRa™ wireless RF technology, which is a network protocol which facilitates the smartification of cities with the help of IoT and interconnectivity. The company chose in 2016 to invest in LoRaWAN® due to its reliability, security and scalability by becoming a member contributor of the LoRa Alliance®, a non-profit association of more than 500 member companies that collaborate to drive the global success of the LoRaWAN standard (A2A, 2020; A2A, n.d.).

Beyond safety and liveability, A2A Smart City solutions are conducive to improved energy efficiency through energy, sound and environment monitoring, smart lighting, smart grid and smart irrigation in residential areas. The so-called "smart-metering" allows the company to collect detailed information on energy usage in households in order to offer more transparent, personalised and, therefore, more sustainable services. All of this is supported by energy automation and prediction to further optimise the energy usage and also reduce expenditures in A2A facilities. These solutions have already been implemented in new smart districts in Milan, including Figino, Cenni, Merezzate, Moneta, Rizzoli, and Quintiliano (A2A, 2020). This benefits not only the housing units where the technologies were installed but also the city overall, since A2A is contributing to the creation of smart districts, like Smart District Uptown - Cascian Merlata (A2A, 2020).

In order to reinforce these endeavours, the Italian company takes advantage of the benefits coming from innovation brokers and open innovation platforms, such as Innocentive. Nurturing and interacting with creative minds, A2A launched the WtE Challenge, directed at optimizing waste-to-energy plants, and the Networks & District Heating BUChallenge, targeted at creating underground electricity substations (A2A, 2020).

The efforts undertaken by A2A demonstrate great dedication to find innovative solutions aimed at fighting climate change, driving green energy transition and improving the livelihood of the communities around. IoT plays an indispensable role in these endeavours.

Framework application Smart City by A2A with LoRaWAN		
Step 1. Identification - Is it a green innovation?		
Criteria checklist		Comments
Novelty	✓	It involves the application of a new and original technology.
Knowledge and technology application	✓	It involves the application of a new and original technology, as well as know-how about IoT and energy production.
Environmental focus	✓	It is aimed at supporting the energy transition within the company's Circular Economy strategy.
Improved environmental performance	✓	It leads to improves environmental performance stemming from reduced energy consumption.
Mitigation of future environmental risks	✓	It mitigates the risks with the help of smart and digital solutions for urban and agricultural sectors by reducing emissions, pollution and resource use. Moreover, LoRaWAN solutions reduce also the energy consumption and carbon footprint of IoT devices (Mohamed et al., 2022).
Support for the transition to a sustainable economy	✓	It is aimed at supporting the energy transition in accordance with A2A's environmental commitments.

Green during the full life cycle	**?**	According to A2A (n.d.), LoRaWAN green IoT applications aim to be self-sufficient and environmentally friendly. Despite the lack of direct evidence, the appraisal of A2A by non-profit organisations, such as CDP, support the credibility of the company’s declarations. However, it is important to take into account the consequences of using IoT technologies which heavily rely on data centres and batteries going to landfills.
Step 2. Categorization - What kind of innovation is it?		Comments
Type	Product innovation	Th application of LoRaWan itself by A2A is a product innovation that leads to new or improved products using a novel technology. The Smart City initiative by A2A is a product, process, organisational and business model innovation, since it completely transforms the way the company conducts its operations in different aspects.
Novelty	Competence-enhancing innovation	It improves A2A's existing capabilities in managing renewable energy production and consumption. It uses an already existing concept of IoT applications and creation of smart cities.
Impact	Connective	It is mainly a connective innovations, since it entails creating new networks and connections among different devices and actors using a novel technology. Moreover, it contributes to the creation of smart cities, which encompasses the participation of different actors. It also has reflexive, structural and integrative characteristics.
Step 3. Analysis - What are its potential environmental, but also social and economic impacts?		
Does the innovation initiative take into account different impacts it may have in different areas?		There seems to be intentionality in A2A’s strategy, aimed at supporting energy transition, cutting costs, benefitting to the society and preventing the negative effects of climate change and automation on the communities involved.

How does it impact the environment?		The environmental impact of this initiative may depend on the trade-offs between its benefits and costs and how they are measured and balanced. According to the company's 2022 press release, its renewable capacity increased by 12% from the previous year (A2A, 2023). The application of the LoRaWan technology by A2A results in more efficient environmental monitoring and management in various domains. On the other hand, it may interfere with other wireless signals or devices, lead to electromagnetic radiation exposure, battery disposal or recycling issues (Ansah et al., 2020). The A2A group does not provide publicly available information on the level of its CO2 emissions.
What are its social implications?		A2A strives to improve the quality of life, health, education, or inclusion of people by enabling various applications and services for smart cities. However, it may also lead to such social risks as privacy breaches, data misuse, cyberattacks, digital divide, social exclusion, or ethical dilemmas of Industry 4.0.
What economic implications does it have?		In regards to A2A, it helps to cut the company's costs, improve its profitability and competitiveness in the energy market. On a societal level, it can support the creation of new markets, jobs and revenues, as well as improve productivity of industries. However, it may also lead to market disruption and job destruction.
Step 4. Evaluation - Does it contribute to sustainable development? Does it create value for stakeholders?		
Success factors checklist for companies		Comments
Absorptive Capacity & Innovation-Oriented Learning	✓	This use of LoRaWan and creation of Smart Cities by A2A involves acquiring, adapting, and exploiting external knowledge. On a larger scale, it involves acquiring and applying knowledge to drive the green transition. Focusing on the development of its intellectual capital, the company works towards enhancing its know-how in innovation and other domains (A2A, 2020).
Skilled Human Capital	✓	A2A places great emphasis on its human capital, ensuring the prime skills and experience of its workforce. It has developed a Digital plan designed for improving well-being and consistently strengthening the skills of the employees (A2A, 2020).

Environmental Awareness of the Management	✓	A2A's management has put SDGs, green energy transition and improvement of the overall welfare at the core of its strategy. The company employs all the tools at its disposal in order to move towards these goals.
Market, Law, and Regulation Knowledge	✓	Being one of the leading multi-utility companies, A2A has to possess all the necessary know-how to remain competitive and sustainable. Its investment in human capital further guarantees the knowledge of the market conditions, legal frameworks, and regulatory requirements that affect the innovation process and outcomes.
Interfunctional Collaboration with Stakeholders	✓	An important part of A2A's strategy is engagement in open innovation and collaboration with its stakeholders. The firms actively leverages on cooperation tools to maximise the success of its operations (A2A, 2020).
R&D Investments	✓	A2A puts SDGs at the core of its corporate strategy, focusing also on SDG17, which calls for developing investments in R&D and increasing partnerships with research centres globally. For example, it has launched the LombHe@t R&D programme targeted at heating technologies with ecologically low impact (A2A, 2020).

Figure 9. Framework application: Smart City by A2A

Based on the framework (Fig. 9), the use of LoRaWan by A2A is an example of an effective green innovation that strives to contribute to the company's green transition efforts. The framework helped to identify, classify, analyse and assess the green innovation. Firstly, the A2A initiative does meet the criteria for being a green innovation, as it has novelty, environmental focus, improved environmental performance, mitigation of future environmental risks, and support for the transition to a sustainable economy. While analysing the type of innovation, it became clear that some of the innovations may be attributed to different categories at the same time. This particular innovation initiative encompasses different characteristics of product, process, organisational, as we all as connective, integrative reflexive, and structural innovation. Despite such a result, the process of categorisation was still beneficial, since it prompted reflection on the different aspects of the innovation that might not have been covered otherwise. Due to A2A's intentional and consistent endeavours towards decarbonization and sustainability overall, the overall impression of its efforts is positive. The application of LoRaWan has potential positive impacts on the environment, society and economy, such as reducing energy consumption and emissions, improving quality of life and health, creating new markets and jobs, and cutting costs and improving profitability for A2A. At the same time, it has negative trade-offs on the environment and society, which need to be analyzed and balanced. The innovativeness of the technology is combined with the excellent characteristics of A2A, which leverages on absorptive capacity, skilled human capital, environmental awareness of the management, market knowledge, interfunctional collaboration with stakeholders, and R&D investments. Overall, the innovation by A2A possesses great potential in terms of sustainability, however the company's management needs to minimize the technology's negative impacts to guarantee the holistic success of the initiative. The main negative side of this technology, which cannot be accurately assessed based on the accessible sources, is the fact that it might not be fully green throughout its life cycle, as it relies on energy used by data centres and batteries that end up in landfills.

3.3.3. Blockchain

As mentioned in Chapter 2, as a decentralized and distributed digital ledger technology that records transactions across multiple computers, blockchain strengthens transparency, security, traceability, data auditability, privacy, value transfer, and process efficiency and automation, for all the parties involved. It has been another game-changer that has completely revolutionised how things are done across various fields. The key characteristics of blockchain can contribute to the structural changes in the current global infrastructure by ensuring visibility to alignment with SDGs for companies, unlocking new financing infrastructures and strengthening awareness and access to new market models (OECD, 2019).

Terna and Equigy

Terna, which is the largest independent electricity Transmission System Operator (TSO) in Europe, plays a central role in the energy transition in Italy and Europe overall. In March 2203, the company pledged to invest over 21 bin euros in the next ten years in the acceleration of the energy transition and the reduction of dependence on foreign suppliers (Terna, 2023). As a part of its ecological strategy, in 2020, the company launched a joint venture initiative, alongside the German, Dutch, Swiss and Austrian TSOs, called Equigy. Its objective consisted in using the developed blockchain platform for trusted data exchange. The new crowd balancing platform (CBP) would provide access to new sources of electricity from consumer-based devices, such as home batteries and electric vehicles (Terna, n.d.). This would empower and transform consumers into "prosumers", since even they would be able to play an active role in balancing the grid and contribute to ecological transition. This would accelerate the integration of renewables into the electricity system by providing safety, flexibility and balance. Equigy operates with a set of smart contracts that define rules and provide traceability.

From TSOs' perspective, Equigy provides them with flexibility, since they can utilize small-scale devices to balance supply and demand fluctuations caused by renewables energy sources. It leaks incentives operators to collaborate to share flexibility resources across Europe. In regards to aggregators, Equigy gives them access to a unified point of entry to participate in grid services and, therefore, cuts transaction costs and mitigates uncertainties with blockchain. Finally, it allows device owners to leverage their flexibility potential and monetise on it. By doing so, they can contribute to the energy transition by supporting renewable energy integration and decarbonization (Equigy, n.d.).

The efforts by Terna demonstrate how blockchain provides an opportunity for innovation and experimentation in the energy sector, leading to more decentralised, digitalised and decarbonises practices in energy production and consumption.

Framework application Equigy by Terna with Blockchain		
Step 1. Identification - Is it a green innovation?		
Criteria checklist		Comments
Novelty	✓	It involves the application of a new and original technology.
Knowledge and technology application	✓	It involves the application of a new and original technology, as well as know-how about blockchain and energy production.
Environmental focus	✓	It is aimed at supporting the energy transition among TSOs.
Improved environmental performance	✓	It leads to improved environmental performance through improved electrical storage and demand side response (DSR).
Mitigation of future environmental risks	✓	By enabling the integration of renewables and electric vehicles into the electricity system, Equigy contributes to the reduction of fossil fuel dependance, GHG emissions and overall decarbonization.
Support for the transition to a sustainable economy	✓	It contributes to the green economy model by enhancing flexibility potentials and leading to decarbonization.

Green during the full life cycle	**?**	Even though Equigy enables the integration of renewable energy sources and reduces GHG emissions, it relies on blockchain technology, which consumes large amounts of electricity and generates CO2 emissions based on the sources. Depending on how these setbacks are taken into account and weighted, the technology can be either successful or defeat its own purpose.
Step 2. Categorization - What kind of innovation is it?		Comments
Type	Process and business model innovation	As a process innovation, it involves the implementation of new and improved practices aimed at better environmental performance. It improves the efficiency and quality of the flexibility market. As a business model innovation, Equigy creates a new value proposition for TSOs, aggregators and device owners. It reconfigures the market by introducing new actors, such as prosumers and aggregators. It also integrates smart contracts as a mechanism for conducting operations.
Novelty	Competence-enhancing and competence-destroying	It is competence-enhancing for the grid and system operators, because it builds on their existing knowledge and skills. Equigy is also a competence-destroying innovation for the conventional flexibility providers, such as large-scale power plants or storage facilities, because it renders their existing knowledge and skills obsolete.
Impact	Connective and integrative	It is an example of connective innovation since it enables new connections or interactions among grid and system operators, aggregators and device owners, who can exchange data and transactions using blockchain technology. It also enables interconnection between TSOs across different countries. Equigy is also integrative because combines blockchain technology with smart meters, smart chargers, aggregation platforms, TSO systems and different devices to provide flexibility services.
Step 3. Analysis - What are its potential environmental, but also social and economic impacts?		

Does the innovation initiative take into account different impacts it may have in different areas?	Terna actively monitors the implications that Equity may have on the electricity system and the society (Terna, n.d.). The company has collaborated with TSOs across Europe to optimize and decarbonise electricity generation. However, it may not have a systematic approach to assess the different environmental, economic, social or ethical impacts Equigy may have.
How does it impact the environment?	The environmental impact of this initiative may depend on the trade-offs between its benefits and costs and how they are measured and balanced. On one hand, Equigy enables the integration of renewable energy sources and electric vehicles into the electricity system leading to decarbonization. On the other hand, the platform relies on blockchain, hence consuming electricity and generating GHG emissions. There is no sufficient information on this topic from Terna's part, however the company has repeatedly pleaded to minimize its environmental impacts by using green electricity and conducting environmental impact assessments.
What are its social implications?	Equigy empowers the society by enabling aggregators and prosumers to participate in the flexibility market and benefit from it. It also leads to innovative collaboration among TSOs across borders. However, it may create social inequality by favouring certain regions or countries that have access to cheap electricity or advanced technology. There are also security and data privacy risks linked to blockchain technology.
What economic implications does it have?	Equigy creates value for the economy by creating new sources of revenue for aggregators and prosumers. It also reduces costs for TSOs and stimulates investments in the energy sector. However, it may create competition or render obsolete conventional flexibility providers.
Step 4. Evaluation - Does it contribute to sustainable development? Does it create value for stakeholders?	
Success factors checklist for companies	Comments

Absorptive Capacity & Innovation-Oriented Learning	✓	The company demonstrates innovation-oriented learning capacities based on its investments in R&D, collaborations with other stakeholders, and use of external and internal knowledge to drive innovation.
Skilled Human Capital	✓	Terna highlights the importance of skilled and empowered human capital to promote the transition to a carbon-free energy and economic system. It has launched a cultural transformation project called NexTerna which trains the company's employees for new ways of working (Terna, n.d.).
Environmental Awareness of the Management	✓	As an energy provider, Terna puts sustainability at the centre of its values. It is committed to staking the perfect balance between consumer energy needs and the responsibility to protect the environment (Terna, n.d.).
Market, Law, and Regulation Knowledge	✓	Being the largest electricity transmission operator requires unique knowledge and capabilities to remain competitive and sustainable. Its investment in human capital further guarantees the knowledge of the market conditions, legal frameworks, and regulatory requirements that affect the innovation process and outcomes.
Interfunctional Collaboration with Stakeholders	✓	Terna sees inter functional collaboration and stakeholder engagement as one of the keys to reaching its corporate goals. The main principles of Equigy only reinforce this commitment.
R&D Investments	✓	Terna places great emphasis on its intellectual capital, development of new patents and innovation. In 2021, the company launched 69 projects and filed 8patent applications linked to robotics, digital technologies and VR (Terna, n.d.).

Figure 10. Framework application: Equigy by Terna

Based on the analysis using the framework (Fig. 10), Equigy is an excellent example of how Italian energy companies can use innovation technologies to accelerate energy transition. The framework provided a comprehensive and systematic approach to identify, classify, analyze and assess this green innovation by Terna. Firstly, Equigy by Terna meets the majority of criteria for an initiative to be called green innovation based on its novelty, knowledge and technology application, environmental focus, improved environmental performance, mitigation of future environmental risks, support for the transition to a sustainable economy and greenness during the full life cycle. Even though the last point is dubious due to the use of blockchain technology, Terna might have taken it into account using renewables in its operations. Despite not being able to answer the life cycle question definitively, the framework successfully raises the concern and urges to reflect on it. As for categorisation, the framework helped to classify Equigy as a process and business model innovation that is both competence-enhancing and competence-destroying depending on the perspective. Moreover, it is a great examples of connective and integrative innovation. The next section of the framework helped to analzye the potential environmental, social and economic impacts by asking questions about how it affects different areas and stakeholders. Overall, the implications of this green innovation can be considered positive, as long as the company takes into account the potential negative effects and minimises them. Finally, the successful performance of Equigy is supported by Terna's proclivity to innovation-oriented learning, skilled human capital, environmental awareness of the management, market and regulatory knowledge, interfunctional collaboration with stakeholders, and R&D investments. Overall, Equigy as a green innovation undoubtedly contributes to the green transition goals set by Terna. The main negative side of this technology, which cannot be accurately assessed based on the accessible sources, is the fact that it might not be fully green throughout its life cycle, as it relies on energy used by blockchain.

3.3.4. Cloud computing and Big Data

With the massive amount of data with great volume, velocity and variety produced in organisations, cloud computing is an essential tool that provides infrastructure and platform for Big Data analytics. Cloud computing and Big Data can be used for a wide variety of environmental purposes, including climate change monitoring, biodiversity assessment, resource optimisation, among many others (Sebestyén et al., 2023). Cloud services provide scalability, flexibility, and cost-efficiency to the operations (Carvalho et al., 2019).

Eni and Open-Es Platform

Eni, one of the largest oil and gas companies in Europe, is another key player in the green energy transition in Italy. The company has committed itself to supporting a just and inclusive energy transition that creates long-term value and guarantees accessible and clean energy for everyone. Its strategy is based on the pillars of long-tern carbon neutrality, operational excellence and the creation for local development (Eni, n.d.). In 2020, Eni in collaboration with the Boston Consulting Group and Google Cloud announced the creation of Open-es — a new open digital platform that allows companies to calculate their sustainability performance based on certain metrics and give different stakeholders, including customers and financial institutions, the opportunity to gain access to that data. The platform will also enable companies to compare theirs results with competitors and receive personalised plans for the improvement of their ESG performance. Open-es has over 3000 companies from all over the world across different sectors. It is available for all companies in the energy sector and industrial supply chain focused on driving the green transition.

Eni sees Open-es as a practical tool for companies that wish to improve their sustainability performance but do not possess the relevant tools to measure performance and progress along the entire chain. Due to tremendous volumes of data required for the measurements, Eni collaborated with Google Cloud, which contributed to the project with its know-how in cloud computing, Big Data analytics and AI. These innovation technologies provide a secure and scalable platform that can manage large amounts of data and enable advanced analytics and insights. Through this open and collaborative space, Eni supports a fair and sustainable energy transition by fostering transparency, innovation and value creation.

Framework application **Open-es by Eni with Cloud computing and Big Data**		
Step 1. Identification - Is it a green innovation?		
Criteria checklist		Comments
Novelty	✓	It involves the application of a new and original technology.
Knowledge and technology application	✓	It involves the application of a new and original technology, as well as Google Cloud's know-how about cloud computing, Big Data analytics and AI.
Environmental focus	✓	It is aimed at supporting the energy transition in the energy and supply chain industry.
Improved environmental performance	✓	It leads to improved environmental performance through transparency, data analytics, learning and planning.
Mitigation of future environmental risks	✓	By providing companies with a platform to measure performance and progress along the entire chain, the innovation contributes to better environmental outcomes.

Support for the transition to a sustainable economy	✓	It contributes to the green energy transition by facilitating the exchange of knowledge and best practices among different actors in the energy sector. It can help companies to identify problems and develop solution to cut GHG emissions, increase efficiency, and enhance social and environmental responsibility.
Green during the full life cycle	?	Open-es also aims to support the life cycle assessment of the energy solutions that are shared and implemented through the platform. However, it uses cloud computing which consumes large amount of electricity in data centers. Depending on how this setback is taken into account and weighted, the technology can be either successful or defeat its own purpose.
Step 2. Categorization - What kind of innovation is it?		Comments
Type	Process, business model and organizational innovation	Open-es can be considered a combination of different innovation types. Open-es is a process innovation since it proposes a new way of working and learning that leverages cloud computing, big data, and artificial intelligence to enhance efficiency and effectiveness in the energy transition. As a business model, Open-es is a new form of value creation and capture that relies on openness, transparency, and co-creation among different actors in the energy sector. It can also considered organizational innovation since it is a new network of partnerships and alliances that fosters a culture of innovation and sustainability in the energy sector.
Novelty	Competence-enhancing	It is competence-enhancing innovation since its main purpose is to improve the environmental practices within companies.

Impact	Reflexive, connective, integrative	Open-es is a prime example of reflexive innovation, since it enables the users and partners to reflect on their own practices and performance and learn from others' experiences and feedback. It is also a connective innovation — it succeeds in connecting different actors in the energy sector and facilitates the exchange of data and information among them. As an integrative innovation, Open-es integrates different types of data and information from various sources and provides a holistic view of the energy sector. It could even partly be considered structural, since it also changes the structure and dynamics of the energy sector by creating new relationships among actors and influencing their behaviour and decisions.
Step 3. Analysis - What are its potential environmental, but also social and economic impacts?		
Does the innovation initiative take into account different impacts it may have in different areas?		By adopting a stakeholder engagement approach, Eni has proven to be attentive to different aspects of its activities. Open-es involves listening to and dialoguing with the local communities and authorities, understanding their expectations and concerns, and addressing them in a transparent and responsible way.
How does it impact the environment?		Open-es aims to improve the ESG performance of the industrial and financial system by creating a synergy between sustainable transition and digital transformation. Moreover, it enables the members to exchange sustainability metrics with their stakeholders and get feedback on it. As an example of open innovation aimed at green practices, Open-es has great potential to impact positively the environment by improving the companies' practices. However, there is no available information on the direct effects of the platform. Moreover, even though the use of cloud computing and Big Data is central to the feasibility of the platform, these technologies consume a lot of energy.

<table>
<tr><td colspan="2">What are its social implications?</td><td>Promoting the sustainable development, Open-es relies on four pillars, i.e. planet, people, prosperity, and principles of corporate governance (Open-es, n.d.). The platform pledges to uphold human rights, people's health and safety, proving decent working conditions and equal pay.
By doing so, the platform has created new jobs and improved the standards of life. Moreover, it spreads awareness about the sustainable values and practices.</td></tr>
<tr><td colspan="2">What economic implications does it have?</td><td>The platform fosters growth in the business ecosystem while simultaneously ensuring that it is sustainable. It helps the companies to reduce costs, increase productivity and optimize investments and assets.</td></tr>
<tr><td colspan="3">Step 4. Evaluation - Does it contribute to sustainable development? Does it create value for stakeholders?</td></tr>
<tr><td colspan="2">Success factors checklist for companies</td><td>Comments</td></tr>
<tr><td>Absorptive Capacity & Innovation-Oriented Learning</td><td>✓</td><td>The company demonstrates these capacities, since Open-es enables Eni and other firms to access and acquire external knowledge, assimilate and integrate it, and then apply and leverage it for the sake of sustainability and economic prosperity.</td></tr>
<tr><td>Skilled Human Capital</td><td>✓</td><td>Eni and Open-es possess a diverse and empowered workforce that is provided with triaging and nurtured by the culture of innovation (Eni, n.d.). Being one of the largest companies in the energy industry, it is crucial to. Have a skilled human capital to stay afloat.</td></tr>
<tr><td>Environmental Awareness of the Management</td><td>✓</td><td>According to the company's website and several declarations, Eni is aware of the importance of mitigating the environmental impact, especially as a part of the Big Oil. It has a long-term strategy towards carbon neutrality by 2050 (Eni, n.d.).
However, being a fossil fuel company entails significant hardships and investments to truly become sustainable. Eni's GHG emissions decreased solely by 8% in 2022 in comparison with 2021 owing to the decline in gas sales (Eni, n.d.).</td></tr>
</table>

Market, Law, and Regulation Knowledge	✓	Being one of the largest energy companies in Europe requires knowledge and capabilities to remain competitive and sustainable. Eni uses the Internal Control and Risk Management System (ICRMS) to control risks through effective management. The company possesses appropriate legal, international trade, business and market knowledge (Eni, n.d.). Moreover, by collaborating and exchanging knowledge with different companies through Open-es, it further strengthens its position.
Interfunctional Collaboration with Stakeholders	✓	Eni understands the importance of collaboration with stakeholders and open innovation to succeed. The company has collaborated with Google Cloud and BCG to combine their knowledge and capabilities and set up a successful open and collaborative platform.
R&D Investments	✓	Eni sees R&D as the cornerstone for driving innovation and clean energy transition. Within the Eni ecosystem, there are R&D engineers, New Materials Researchers and other roles. The firm constantly invests in trainings and improving the facilities to be the best in the sector (Eni, n.d.).

Figure 11. Framework application: Open-es by Eni

Relying on the analysis using the framework (Fig. 11), Equigy is an excellent example of how Italian energy companies can use innovation technologies to accelerate energy transition. The framework provided a comprehensive and systematic approach to identify, classify, analyze and assess this green innovation by Terna. First of all, Open-es with the use of cloud commuting, Big Data and AI aligns with the criteria for green innovation definition. However, in order to guarantee that it is fully green across its life cycle an additional evaluation would be required using metrics and internal data from the company. Moving on to classification, Open-es can be considered process, business model and organizational innovation, as it not only creates a new way of working using cloud computing, but also presents a new opportunity for value creation and capture through organizational alliances and collaborations. It is a competence-enhancing platform that is also a great example of a reflexive innovation that drives improvement through reflections on current practices. Moreover, it can be considered connective and integrative, since it facilitates knowledge transfer between different actors in the energy industry and also integrates different technologies, data and practices. The next section of the framework helped to analzye the potential environmental, social and economic impacts of Open-es. Based on these queries, the framework showed that Open-es has a mainly positive effect on different aspects. However, as a fossil fuel company, it has to take more proactive actions to significantly reduce its environmental and social impact. Due to the alignment with all the success factors presented in the framework, Eni provides a solid basis for its innovation initiatives to reach their goals. It possesses the required absorptive capacity and innovation-oriented learning, skilled human capital, environmental awareness of the management, market and regulatory knowledge, and also invests in interfunctional collaboration with stakeholders and R&D. Overall, the framework showed that Open-es is a practical tool that fosters transparency, innovation and value creation for the energy industry on the way to sustainability.

4. Discussion

In this section, I will discuss the key findings from Section 3, where I applied the framework for identifying, classifying, analyzing and assessing green innovation initiatives in the Italian energy sector. The main purpose of this study is to analyze how Italian energy companies use innovation technologies to drive the green energy transition and to identify the best strategies based on that. The application of the previously developed framework provided a holistic review of some of the ongoing initiatives in the industry. The elaborated structure allowed to look at the innovations from different points of view and evaluate them accordingly. I will first discuss the strengths and gaps of the elaborated framework, and then proceed with the analysis of the key takeaways from the review of the four innovation practices by Enel, A2A, Terna and Eni.

In regards to the developed framework, there are several points that need to be highlighted. Overall, the framework was designed to be comprehensive and systematic. It covers a range of green innovation-related dimensions, including definition, category, impact, and success factors. Additionally, it offers precise criteria for every stage, as well as comments and questions that assist the analysis. The framework is of great value for determining each innovation practice's advantages and disadvantages, as well as potential trade-offs and difficulties. Following each step of the framework can help to raise important questions and draw attention to crucial aspects in the development of innovation technology initiatives that might be lacking. The framework itself is flexible and adaptable to different types of innovation technologies, and it is coherent in its structure and logic. Being based on relevant literature and sources that provide theoretical and empirical foundations, it can be a useful tool for developing the initial strategies for innovation projects for the corporate management. It is also of great use for researchers attempting to identify and analyze certain innovations, since it accumulates different relevant theories and studies by other scholars.

However, the application of the framework helped to identify several limitations and areas of improvement that could be tapped into in future research. First of all, the framework might not capture all the complexity and diversity of green innovation practices in the real world. For example, some innovations may not fit neatly into one type or category, as seen in the previous sections. Moreover, it may not account for the dynamic and evolving nature of green innovation practices, since some innovations may change their novelty, impact, or performance as they mature or interact with other factors in the environment. The application of the framework also demonstrated that it must be accompanied by another methodology to calculate the difference between the level of emissions before and after the implementation with internal and independent data to have precise metrics that show the contribution to energy transition.

To bridge these gaps, the textual analysis could be complemented by interviews, surveys, observations, or experiments to gain more insights and evidence on how different companies use innovation technologies for sustainability. The analysis based on the developed framework would be most successful with the involvement and consultation of different stakeholders. For example, one could solicit feedback from customers, employees, partners, regulators, or experts on how they perceive or value certain aspects of green innovation practices.

Apropos of the innovation practices analysed in Chapter 3, there are several discoveries and insights gained through the framework application. All of the cases, including Myst AI by Enel, Smart City by A2A, Equigy by Terna, and Open-es by Eni, fall under the definition of green innovations. All of them possess such characteristics as novelty, knowledge and technology application, environmental focus, improved environmental performance, mitigation of future environmental risks, and support for the transition to a sustainable economy. As for the "green during the full life cycle" criteria, the analysis showed that the framework could only assume that it is true, since the answer requires data and insights from the companies, which is not available through open sources.

The categories of GIs adopted by Italian energy companies are manifold and diverse. They range from product and process to business model and organizational innovations, from connective and integrative to reflexive and structural, depending on their goals and needs. In the cases reviewed in the previous chapter, companies use mostly competence-enhancing green innovations, which improve their existing capabilities and skills in the energy sector. However, some of their innovations may also be competence-destroying for other actors in the market, such as conventional flexibility providers in the case of Terna. Incremental nature of most of the GIs can be explained with the help of Schumpeterian theory (1962). All of the reviewed companies are incumbent firms and, therefore, can be too bulky and risk-averse to introduce radical changes that render some practices obsolete. Enel, Eni, A2A and Terna developed their GI practices based on already existing technologies from third parties, which may have initially been competence-destroying on their own. Furthermore, all of the companies' GI initiatives fall under two or more categories at the same time in terms of being connective, reflexive, integrative, or structural. The reviewed Italian energy companies use mainly connective innovations, which create new networks and interactions among different devices and actors using novel technologies, and integrative innovations, which combine and integrate several technologies and fields of knowledge. Some of their innovations may also have reflexive or structural characteristics. All four cases fall under different and multiple categories, which demonstrates that any category of innovation can be beneficial to the environmental goals, as long as its main goal is to contribute positively to the world. It shows how diverse green innovations can be and the endless room for creativity for all the actors willing to tap into them.

The analysis demonstrated that the majority of large energy companies in Italy have utilized Industry 4.0. technologies to accelerate the green transition. They consider innovation technologies to be a fundamental tool in improving their operations, and all the reviewed companies, including Enel, Eni, A2A and Terna, have incorporated innovation practices into their corporate strategy and investment plans. Green innovations proved to be one of the constituting pillars for all those companies in their longterm plans. This is explained by the fact that energy companies account for more than two-thirds of global GHG emissions (IEA, 2022), and are therefore being heavily scrutinised and pressured by the stakeholders to decarbonize. They are aware of the importance of sustainability and the energy transition for their business and society, and align their strategies with the SDGs and the Circular Economy principles. While developing the green innovation strategies, the four analyzed companies have taken into account the impacts of their actions on different dimensions. Not only do they strive to reap financial and economic rewards, but also endeavour to contribute to SDGs and mitigating and preventing climate change, while simultaneously benefitting the society by improving quality of life, health, education, or inclusion of people.

The analysis helped to establish that all of the innovation practices have become possible through different forms of cooperation between the energy companies and third parties, such as startups (Myst AI), joint ventures (Equigy), memberships in non-profit associations (LoRa Alliance), and open collaboration platforms (Open-es). This finding reiterates the point made in the literature review by Navarro (2002) about the success of "make", "buy" and "cooperate" strategies, as well as by Chesbrough (2003) regarding open innovation. All of these firms have come up with effective and unique innovative solutions because they collaborated with third parties. This point is also directly linked to the the absorptive capacity and innovation-oriented learning: companies that are capable of interacting with the outer world, acquiring relevant knowledge and then adapting and utilizing it in order to be more innovative, are more likely to develop successful green innovation solutions. All of the analyzed companies demonstrated such capabilities through the nature of their initiatives and their corporate strategies. These practices are underpinned by a skilled human capital which is actively trained and given opportunities for leaning and development. Moreover, Enel, Eni, Terna and A2A actively invest in R&D often targeted at finding innovative solutions for environmental challenges, helping to enhance their capabilities and competitiveness in the green innovation domain. Grounded on these lessons, the most valuable recommendations are to seek collaboration and partnership with other actors to create synergies and co-create value; to foster a culture of innovation and sustainability within the organization and empower employees; to actively communicate and promote the benefits and value of green innovations to investors, customers, regulators, or society in general. Openness and cooperation can strengthen the initiatives, mitigate any risk and guarantee the success for anti-climate change initiatives.

The analysis of the four cases also showed that the respective Italian energy companies face some challenges and trade-offs in adopting green innovations. Apart from balancing the environmental benefits and costs of innovation technologies, they face with challenges in ensuring data security and privacy, and addressing social and ethical issues of Industry 4.0. Based on this, several key points are to be made. Firstly, it is urgent for companies engaging with digitalization technologies to implement robust data security and privacy measures, i.e. encryption, access control, authentication, in order to protect the generated data. Moreover, all over the analyzed organizations pledged to promote social welfare, however more concrete actions should be taken and make transparent to prevent the negative social and ethical implications of the Industry 4.0. Therefore, companies should plead to address such issues as job displacement, digital divide, human-machine interaction, and social responsibility, by engaging with stakeholders, providing training and education, ensuring inclusivity and diversity, and adhering to ethical principles. All of this should be transparent and put as a top priority.

One of the most significant limitations of this analysis is linked to the fact that it relies on secondary data and information, which may not be accurate, complete, or up-to-date. It may also be biased or influenced by the sources' perspectives and interests, since a lot of the information about the initiates was covered in companies' reports which can sometimes exaggerate the organizations' feats. More information and statistics about the innovations' real performance, outcomes, and impacts in many dimensions are therefore needed in order to make more definitive and fact-based judgements on their success. As the framework showed, it is crucial to measure the carbon footprint of the companies before and after implementing the green innovation practices in order to clearly assess their contribution to the energy transition. Companies can adopt a life cycle perspective and assess the environmental benefits and costs of innovation technologies at every stage, from design and production to use and disposal. Making this data accessible to the public would not only restore and straighten the trust of the stakeholders, but also motivate the company to improve its practices in terms of their environmental impacts. It could also give the company access to feedback and recommendations from different stakeholders. Initially open access to such metrics will enhance the viability of any initiative, increase its value for stakeholders and, most importantly, guarantee more effective decarbonization.

Moreover, important stakeholders should take part by defining and agreeing upon certain standards or metrics for gauging the effectiveness of the innovation. Otherwise, it might not be feasible to clearly and transparently quantify or illustrate the companies' actual contribution to sustainable development or value generation for stakeholders. It would be of great use to compare or benchmark the green innovations with other alternatives or competitors in the market, which could provide a more objective and relative assessment of their performance and value. For example, the analysis could be more complete with some cases of GI initiatives from SMEs and startups. These recommendations can significantly decrease the risks and uncertainties coming from the market, competitors or stakeholder dissatisfaction.

5. Conclusion

The energy sector, which is one of the main culprits contributing to climate change, can become the answer to this urgent global issue by undertaking effective and timely action to accelerate the energy transition. While an increasing number of oil and gas or multi-utility companies are recognizing the imperativeness of such initiatives and searching for creative ways of achieving net zero goals, innovation technologies are becoming the vital part of any corporate strategy. Artificial intelligence, Internet of Things, cloud computing and blockchain all have the ability to help tackle climate change without sacrificing economic growth, and Italian companies, like Enel, A2A, Terna and Eni, are actively investing in them.

This study has aimed to examine the ways in which innovation technologies are used by Italian energy companies to facilitate the green energy transition and to determine strategies that could guarantee their success. In order to accomplish this, the study set the following objectives:

1. I have reviewed the literature on how to define, classify, analyze and assess innovations in general and green innovations in order to develop a comprehensive framework for the research.
2. Based on the literature review, I have proposed a framework to identify, classify and assess green innovations that will be applicable to the energy industry in Italy.
3. I have introduced and reviewed the energy industry in Italy, explaining its relevance, and the Italian energy companies' efforts to adopt and create innovation technologies aimed at helping them to cut emissions and switch to renewable resources.
4. Finally, I have applied the elaborated framework to the energy industry in Italy to assess the companies' green innovation initiatives and then discuss the key findings from applying the green innovations framework.

A comprehensive assessment of some of the current initiatives in the sector allowed to put theory to practice and to identify the most common and effective green innovation strategies adopted by Italian energy companies. Apart from assessing them, the framework also provided a methodology for the GI's definition, categorization and analysis. The in-depth review facilitated the identification of several gaps and limitations providing a better basis for recommendations.

One of the key takeaways both from the literature and the analysis is the utmost importance of collaborations, partnerships with other actors and stakeholder engagement to create synergies and co-create value. These points brought up in the literature review, reappeared with a stronger force in the case studies. All of the innovation practices would have been impossible without different forms of cooperation between the energy companies and third parties, such as startups (Myst AI), joint ventures (Equigy), memberships in non-profit associations (LoRa Alliance), and open collaboration platforms (Open-es). Therefore, firms undertaking GI initiatives should actively collaborate and engage with other actors to create synergies and co-create value and also foster a culture of innovation and sustainability within the organization by training and empowering employees. These key takeaways will ensure the success of any innovation strategy.

Keeping in mind the Triple Bottom Line theory and the importance of a holistic approach in developing green innovation strategies, energy companies should strive to promote social welfare and safety. Therefore, GI strategies need to be accompanied by ways to ensure strong data security and privacy measures, address such challenges as job loss, digital gap, human-machine interaction, and social responsibility, by engaging with stakeholders, providing training and education, ensuring inclusivity and diversity, and following ethical principles.

Innovations cannot be considered green if they do not fulfil their core goal — contribution to reduce environmental damage and use natural resources efficiently. As the framework has shown, in order to accurately assess a company's contribution to the energy transition, it is essential to analyze its carbon footprint both before and after adopting green innovation methods. Therefore, businesses may take a life cycle approach and weigh the environmental advantages and drawbacks of emerging technology at every step. Making this information available to the general public will not only help the corporations win back the stakeholders' trust but also encourage it to change its practices to have less of an impact on the environment. Additionally, it could provide the business with access to suggestions and criticism from various stakeholders. The transparency about the GIs' environmental performance will strengthen any initiative's feasibility, boost its value for stakeholders, and, finally, ensure the fulfilment of the SDGs. This could be taken a step further by engaging stakeholders in standard or metrics definition and benchmarking the initiatives against competitors to provide a more objectively positive outcome.

In conclusion, this study on green innovation technologies in the Italian energy sector has highlighted the key factors and challenges for creating and putting into practice green innovation strategies in the energy sector in Italy. It has demonstrated that guaranteeing the success and sustainability of green innovation initiatives requires a number of different factors, including cooperation, stakeholder participation, a holistic approach encompassing ecological, social and economic dimensions, and environmental performance evaluation. It has also provided some recommendations and suggestions for future research in this field. The study hopes to contribute to the advancement of green innovation knowledge and practice, as well as to inspire more energy companies to adopt innovation technologies that can help tackle climate change and promote sustainable development.

Bibliography

Books:

- Chesbrough, H. W. (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology.* Harvard Business Press.
- Chesbrough, H. W., Vanhaverbeke, W. and West, J. (2006). *Open Innovation: Researching a New Paradigm.* OUP Oxford,
- Elkington, J. (1997). *Cannibals with Forks*. Oxford: Capstone.
- Etzkowitz, H. and Leydesdorff, L. (1995). *The Triple Helix -- University-Industry-Government Relations: A Laboratory for Knowledge Based Economic Development.* Rochester, NY.
- Grasso, M. (2022). *From Big Oil to Big Green: Holding the Oil Industry to Account for the Climate Crisis*. MIT Press.
- McCraw, T. K. (2007). *Prophet of Innovation: Joseph Schumpeter and Creative Destruction*. Harvard University Press.
- Nelson, R. E. (1993). *National Innovation Systems: A Comparative Analysis.* Columbia University Press.
- Schumpeter, J. A. (1962). *Capitalism, socialism, and democracy.* Harper and Row.
- Schumpeter, J. A. (1991). *The economics and sociology of capitalism.* Princeton University Press.
- Schumpeter, J.A. (1911). *The Theory of Economic Development.* Harvard University Press.
- Schwab, K. (2017). *The fourth industrial revolution*. Portfolio Penguin.

Journal Articles:

- Abramovsky, L., Kremp, E., López, A., Schmidt, T. and Simpson, H. (2009). *Understanding co-operative innovative activity: evidence from four European countries.* Economics of Innovation and New Technology, 18:3, 243-265. doi: 10.1080/10438590801940934
- Acs, Z. J., and Audretsch, D. B. (1990). *Innovation and small firms*. Cambridge, MA: MITPress.

- Adams, R., Jeanrenaud, S., Bessant, J., Denyer, D. and Overy, P. (2016). Sustainability-oriented innovation: a systematic review: sustainability-oriented innovation. I*nternational Journal of Management Reviews*, *18*: 180-205
- Ahlstrom, D. (2010). Innovation and growth: How business contributes to society. *The Academy of Management Perspectives*, 24(3), 11-24
- Ali, Z. H., Ali, H. A., Badawy, M. M. (2017). Internet of things (IoT): Definitions, challenges, and recent research directions. *International Journal of Computer Applications*, *164*(1), 34-40. doi: 10.5120/ijca2015906430
- Amores-Salvado, J., Castro, G.M.D. and Navas-Lopez, J.E. (2014). Green corporate image: moderating the connection between environmental product innovation and firm performance. *Journal of Cleaner Production*, *83:* 356-365. doi: 10.1016/j.jclepro.2014.07.059.
- Ansah, M. R., Sowah, R. A., Melià-Seguí, J., Katsriku, F. A., Vilajosana, X., & Banahene, W. O. (2020). Characterising foliage influence on LoRaWAN pathloss in a tropical vegetative environment. *IET Wireless Sensor Systems*, *10*(5), 198–207. https://doi.org/10.1049/iet-wss.2019.0201
- Aragón-Correa, J.A., Hurtado-Torres, N., Sharma, S. and García-Morales, V.J. (2008). *Environmental strategy and performance in small firms: a resource-based perspective*. J. Environ. Manag. 86 (1), 88e103.
- Awan, U. (2020). Steering for sustainable development goals: a typology of sustainable innovation. *Industry, Innovation and Infrastructure, Salvia and Wall, Springer*. doi: 10.1007/978-3-319-71059-4_64-1
- Baeshen, Y., Soomroo, Y.A. and Bhutto, M. Y. (2021). Determinants of Green Innovation to Achieve Sustainable Business Performance: Evidence From SMEs. Frontiers in Psychology, 12:767968. doi: 10.3389/fpsyg.2021.767968
- Begum, A., Zia, E., Ali, F., Awan, U. and Ashfaq, M. (2022). Achieving green product and process innovation through green leadership and creative engagement in manufacturing. *Journal of Manufacturing Technology Management,* 33, 4: 656-674.
- Bekaroo, G., Sungkur, R. K., Ramsamy, P., Okolo, A., & Moedeen, W. (2018). Enhancing awareness on green consumption of electronic devices: The application of Augmented Reality.

Sustainable Energy Technologies and Assessments, *30*, 279–291. https://doi.org/10.1016/j.seta.2018.10.016

- Boons, F., Montalvo, C., Quist, J., and Wagner, M. (2013). Sustainable innovation, business models and economic performance: An overview. *Journal of Cleaner Production, 45*, 1-8. doi:10.1016/j.jclepro.2012.08.013
- Borkovcová, A., Cerna, M., & Sokolova, M. (2022). Blockchain in the Energy Sector—Systematic Review. *Sustainability*, *14*(22), 14793. https://doi.org/10.3390/su142214793
- Cainelli, G., Mazzanti, M., and Zoboli, R. (2011). Environmental innovations, complementarity andlocal/global cooperation: Evidence from North-East Italian industry. *International Journal of Technology, Policy and Management,* 11, 328–368.
- Caloghirou, Y., Kastelli, I. and Tsakanikas, A. (2004). Internal Capabilities and External Knowledge Sources: Complements or Substitutes for Innovative Performance. *Technovation*, 24, 29-39. https://doi.org/10.1016/S0166-4972(02)00051-2
- Cambra-Fierro, J., Hart, S. and Polo-Redondo, Y. (2008). Environmental Respect: Ethics or Simply Business? A Study in the Small and Medium Enterprise (SME) Context. Journal of Business Ethics, 82: 645–656.
- Carrillo-Hermosilla, J., Del Río, P., Könnölä, T. (2010). Diversity of Eco-innovations: Reflectionsfrom selected case studies. *Journal of Cleaner Production*,18, 1073–1083.
- Carvalho, A. M., Carvalho, A. P. P., & Carvalho, N. G. P. (2020). Industry 4.0 Technologies: What Is Your Potential for Environmental Management? *Industry 4.0.* https://doi.org/10.5772/intechopen.90123
- Chen, Y. S., Lai, S.-B. and Wen, C.-T. (2006). The influence of green innovation performance on corporate advantage in Taiwan. *Journal of Business Ethics*, *67:* 331-339.
- Chen, Y. S. (2007). The driver of green innovation and green image - green core competence. *Journal of Business Ethic*, 81 (3): 250-263.
- Chen, Y. S., Lin, Y. H., Lin, C. Y., and Chang, C. W. (2015). Enhancing green absorptive capacity, green dynamic capacities and green service innovation to improve firm performance: an analysis of structural equation modeling (SEM). *Sustainability* 7, 15674–15692. doi: 10.3390/su71115674

- Chen, Z. and Liang, M. (2023). How do external and internal factors drive green innovation practices under the influence of big data analytics capability: Evidence from China. *Journal of Cleaner Production,* 404: 1-14. https://doi.org/10.1016/j.jclepro.2023.136862
- Chi, D.-J., and Shen, Z.-D. (2022). Using Hybrid Artificial Intelligence and Machine Learning Technologies for sustainability in going-concern prediction. *Sustainability*, *14*(3), 1810. https://doi.org/10.3390/su14031810
- Dhanaraju, M., Chenniappan, P., Ramalingam, K., Pazhanivelan, A., Kaliaperumal, R. (2022). Smart Farming: Internet of Things (IoT)-Based Sustainable Agriculture. *Digital Innovations in Agriculture*, *12*(10), 1745. https://doi.org/10.3390/agriculture12101745
- Díaz-García, C., González-Moreno, A. and Sáez-Martínez, F. J. (2015). Eco-innovation: insights from a literature review. Innovation: Management, Policy & Practice, 17, 1: 6-23. http://dx.doi.org/10.1080/14479338.2015.1011060
- Drath, R., and Horch, A. (2014). Industrie 4.0: Hit or Hype? [Industry Forum]. *IEEE Industrial Electronics Magazine*, *8*(2), 56–58. https://doi.org/10.1109/mie.2014.2312079
- De Medeiros, J., Ribeiro, J., and Cortimiglia, M. (2014). Success factors for environmentally sustainable product innovation: A systematic literature review. *J Clean Prod, 65*: 76–86. doi: 10.1016/j.jclepro.2013.08.035
- Driessen, P., Hillebrand, B. (2013). Integrating multiple stakeholder issues in new product development: an exploration. *J Prod Innov Manag* 30: 364–379.
- El Baz, J., Evangelista, P., Iddik, S., Jeśli, F., Derrouiche, R., and Akenroye, T. (2022). Assessing green innovation in supply chains: a systematic review based on causal mechanisms framework. *The International Journal of Logistics Management,* 1114-1145.
- Fagerberg, J., Fosaas, M., and Sapprasert, K. (2012). Innovation: Exploring the knowledge base. *Research Policy, 41*(7), 1132-1153. doi:10.1016/j.respol.2012.03.008
- Fisher O., Watson N., Porcu L., Bacon D., Rigley M., Gomes R. (2018). Cloud manufacturing as a sustainable process manufacturing route. *J Manuf Syst*, 47: 53–68. doi.org/10.1016/j.jmsy.2018.03.005
- Friedman, M. (1970). The Social Responsibility of Business is to Increase its Profits. *New York Times Magazine (September 13),* 122–126.

- Fuller, A., Fan, Z., Day, C., and Below, C. (2020). Digital Twin: Enabling Technologies, Challenges and Open Research. *IEEE Access*, *8*: 108952-108971. doi.org/10.1109/ACCESS.2020.2998358
- Ghasemkhani, B., Yilmaz, R., Birant, D., Alp Kut, R. Machine Learning Models for the Prediction of Energy Consumption Based on Cooling and Heating Loads in Internet-of-Things-Based Smart Buildings. *Information Technology and Its Applications*, *14*(8), 1553. https://doi.org/10.3390/sym14081553
- Ghisetti, C., Marzucchi, A., and Montresor, S. (2015). The open eco-innovation mode: An empirical investigation of eleven European countries. *Research Policy,* 44(5), 1080-1093.
- Griffith, R., Huergo, E., Mairesse, L., and Peters, B. (2006). Innovation and productivity across four European countries. *Oxford Review of Economic Policy*, 22(4): 483-498.
- Hall, J., and Clark, W. W. (2003). Special issue: Environmental innovation. *Journal of Cleaner Production, 11*(4), 343-346. doi:10.1016/S0959-6526(02)00070-7
- Hanna, V. and Walsh, K. (2008). Small firm networks: a successful approach to innovation? *R&D Management,* 32, 3. https://doi.org/10.1111/1467-9310.00253
- Hemmelskamp, J. (2000). Environmental Taxes and Standards: An Empirical Analysis of the Impact on Innovation. *ZEW economic studies*, 303–329. https://doi.org/10.1007/978-3-662-12069-9_15
- Hospers, G. (2005). Joseph schumpeter and his legacy in innovation studies. *Knowledge, Technology and Policy, 18*(3), 20-37
- Howells, J., Edler, J. (2011). Structural innovations: towards a unified perspective? *Sci Public Polic*y, 38: 157– 167. doi: 10.3152/030234211X12924093660598
- Huang, C. L., and Kung, F. H. (2011). Environmental consciousness and intellectual capital management: evidence from Taiwan's manufacturing industry. Manag. Decis. 49, 1405–1425. doi: 10.1108/00251741111173916
- Iqbal, J., Al-Zahrani, A., Alharb, S. and Hashmi, A. (2019). Robotics Inspired Renewable Energy Developments: Prospective Opportunities and Challenges. *IEEE Access, 7:* 174898-174923. doi: 10.1109/ACCESS.2019.2957013.

- Jabbour, C.J.C. (2008). In the eye of the storm: exploring the introduction of environmental issues in the production function in Brazilian companies. *Int. J. Prod.* Res. 48 (1), 6315e6339.
- Leydesdorff, L. and Ivanova, I. (2016). “Open Innovation” and “Triple Helix” Models of Innovation: Can Synergy in Innovation Systems Be Measured? *Journal of Open Innovations: Technology, Market and Complexity*, 2(1), 1-12. doi:10.1186/s40852-016-0039-7
- Lin, C. Y., and Ho, Y. H. (2011). *D*eterminants of green practice adoption for logistics companies in China*. J. Bus. Ethics* 98, 67–83. doi: 10.1007/ s10551-010-0535-9
- McDonald, P. G. (2011). It’s time for management version 2.0: Six forces redefining the future of modern management. *Futures*, *43*(8), 797–808. https://doi.org/10.1016/j.futures.2011.05.001
- Medeiros, J.F., Garlet, T.B.,Ribeiro, J.L., and Cortimiglia, M. N. (2022). Success factors for environmentally sustainable product innovation: An updated review. *Journal of Cleaner Production*, Vol. 65, pp. 76-86
- Melander, L. (2018). Customer and Supplier Collaboration in Green Product Innovation: External and Internal Capabilities. *Business Strategy and the Environment, 27, 6:* 677-693. https://doi.org/10.1002/bse.2024
- Mendes, T., Braga, V., Correia, A., and Silva, C. (2021). Linking corporate social responsibility, cooperation and innovation: the triple bottom line perspective. *Innovation and Management Review*. https://doi.org/10.1108/inmr-03-2021-0039
- Mohamed, N., Al-Jaroodi, J., Jawhar, I. and Kesserwan, N. (2022). Understanding Risks in Smart City Projects. *IEEE International Systems Conference (SysCon),* 1-7. doi: 10.1109/ SysCon53536.2022.9773834.
- Moher, D., Liberati, A., Tetzlaff, J., and Altman, D.G. (2009). Reprint—preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Phys. Ther. 89*, 873–880. https://doi.org/10.1093/ptj/89.9.873
- Montalvo, C. (2008). *General wisdom concerning the factors affecting the adoption of cleaner technologies: a survey 1990-2007.* J. Clean. Prod, 16 (7): 7-13.
- Navarro, V. (2002). *La cooperación para la innovación de la empresa española desde una perspectiva internacional comparada.* Economía Industrial, (346), 47–66.

- Nti, E. K., Cobbina, S. J., Attafuah, E. E., Opoku, E., and Gyan, M. A. (2022). Environmental Sustainability Technologies in biodiversity, energy, transportation and water management using Artificial Intelligence: A systematic review. *Sustainable Futures*, *4*, 100068. https://doi.org/10.1016/j.sftr.2022.100068
- Oltra, V., and Saint Jean, M. (2009). Sectoral systems of environmental innovation: An applicationto the French automotive industry. *Technological Forecasting & Social Change,* 75, 567–583.
- Paparoidamis, N. G., Tran, T. T. H., Leonidou, L. C., and Zeriti, A. (2019). Being innovative while being green: An experimental inquiry into how consumers respond to eco-innovative product designs. *Journal of Product Innovation Management, 36*(6), 824-847. doi:10.1111/jpim.12509
- Paparoidamis, N. G., and Tran, H. T. T. (2019). Making the world a better place by making better products: Eco-friendly consumer innovativeness and the adoption of eco-innovations. *European Journal of Marketing, 53*(8), 1546-1584. doi:10.1108/EJM-11-2017-0888
- Paraschiv, D. M., Nemoianu, E. L., Langa, C. A., and Szabó, T. (2012). Eco-innovation, responsible leadership and organizational change for corporate sustainability. *Amfiteatru Economic,* 14, 404–419.
- Pereira, A. and Vence, X. (2012). Key business factors for Eco-innovation: An overview of recent firm-level empirical studies. *Cuadernos de Gestion,* 12,73–103.
- Pujari, D., Peattie, K. and Wright, G. (2004). *Organizational antecedents of environmental responsiveness in industrial new product development.* Industrial Marketing Management, 33 (5): 381-391.
- Rezk, N., Hemdan, E., Attia, A., and El-Sayed, A. (2021). An efficient IoT based smart farming system using machine learning algorithms. *Multimedia Tools and Applications,* 80(1), 773–797. https://doi.org/10.1007/s11042-020-09740-6
- Russell, S. D., & Norvig, P. (1995). Artificial intelligence: a modern approach. *Choice Reviews Online*, *33*(03), 33–1577. https://doi.org/10.5860/choice.33-1577

- Santos, B., Soares, A., Nguyen, T., Lee, J., Silva, F. (2021). IoT Sensor Networks in Smart Buildings: A Performance Assessment Using Queuing Models. *Edge and Fog Computing for Internet of Things Systems*, *21*(16), 5660. https://doi.org/10.3390/s21165660
- Schiederig, T., Tietze, F. and Herstatt, C. (2012). *Green innovation in technology and innovation management – an exploratory literature review.* R&D Management, 42, 2: 180-192. https://doi.org/10.1111/j.1467-9310.2011.00672.x
- Schilke, O. (2014). Second-order dynamic capabilities: How do they matter? *Acad Manag Perspect 28*: 368– 380.
- Schumpeter, J. A. (1935). The analysis of economic change. *Review of Economic Statistics, 17*(4), 2-10.
- Schumpeter, J. A. (1947). The creative response in economic history. *The Journal of Economic History*, *7*(2), 149–159. https://doi.org/10.1017/s0022050700054279
- Sebestyén, V., Czvetkó, T., & Abonyi, J. (2021). The Applicability of Big Data in Climate Change Research: The Importance of System of Systems Thinking. *Frontiers in Environmental Science*, *9*. https://doi.org/10.3389/fenvs.2021.619092
- Shrivastava, P. (2018). Environmental technologies and competitive advantage. *Business Ethics and Strategy*, Volumes I and II, 16: 995, 317-334. doi: 10.4324/ 9781315261102-20.
- Suarez, F. F., Rodriguez, A., and Reyes, C. M. (2018). Business models for sustainability from a system dynamics perspective: A systematic literature review. *Journal of Cleaner Production,* 172, 139-152.
- Teece, D.J., Pisano, G. and Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, 18, 509–533.
- Wagner, M. (2008). Empirical influence of environmental management on innovation: Evidencefrom Europe. *Ecological Economics,* 66, 392–402.
- Windeler, A. (2018). Reflexive Innovation. *Innovation Society Today* (pp. 65–105). Springer.
- Wu, C., Raghavendra, R., Gupta, U., Acun, B., Ardalani, N., Maeng, K., Chang, G. Y., Behram, F., Huang, J., Bai, C., Gschwind, M. K., Gupta, A., Ott, M., Melnikov, A., J, C. S., Brooks, D. J., Chauhan, G., Lee, B. R., Lee, H. S., . . . Hazelwood, K. (2021). Sustainable AI: Environmental

Implications, Challenges and Opportunities. *Cornell University.* https://doi.org/10.48550/arxiv.2111.00364

Online articles:

- Enel. (2022, April 22). MyStAI: Powering sustainable AI. *Open Innovability.* https://openinnovability.enel.com/stories/articles/2022/04/mystai-powering-sustainable-ai
- McKinsey & Company. (April 24, 2023). What is AI? *McKinsey & Company.* https://www.mckinsey.com/capabilities/quantumblack/our-insights/an-executives-guide-to-ai
- Mehlum, E., Hischier, D., & Caine, M. (2021, September 1). Here's how AI will accelerate the energy transition. *World Economic Forum.* https://www.weforum.org/agenda/2021/09/this-is-how-ai-will-accelerate-the-energy-transition/
- Palazzi, T. (2020, April 13). Enel and Myst AI: Optimizing energy forecasts. *Myst AI Blog.* https://blog.myst.ai/enel-and-myst-ai-optimizing-energy-forecasts-80eede58fe4c
- Rue, N. (2023, March 2). Robotics in waste management: A promising solution for a cleaner future. *BBN Times.* https://www.bbntimes.com/environment/robotics-in-waste-management-a-promising-solution-for-a-cleaner-future
- Siemens. (2023, April 16). Tech for Sustainability Campaign 2023 – Can we save tomorrow together? *Siemens*. https://ecosystem.siemens.com/techforsustainability/tech-for-sustainability-campaign-2023-can-we-save-tomorrow-together
- Siemens. (n.d.). Industrial Energy Efficiency – reduce emissions and costs. *Siemens*. https://www.siemens.com/global/en/products/automation/topic-areas/sustainable-industries/industrial-energy-efficiency.html
- Terna. (2023, March 15). Terna: 2023 Development Plan for the National electricity Grid Presented. *Terna*. https://www.terna.it/en/media/press-releases/detail/2023-development-plan
- Ysewyn, J., Sadrak, K., van Kruijsdijk, L. and Espinasse, A. (2022, June 1). The CJEU sets out an analytic framework on exclusionary abuses in the context of market liberalisation. *Covington Competition.* https://www.covcompetition.com/2022/06/the-cjeu-sets-out-an-analytic-framework-on-exclusionary-abuses-in-the-context-of-market-liberalisation/

Websites:

- A2A. (n.d.). *LoRa® Alliance Member. A2A Smart City.* A2A. https://www.a2asmartcity.it/
- A2A. (n.d.). *Smart Solutions. A2A Smart City.* A2A. https://www.a2asmartcity.it/
- CDP. (n.d.). *CDP responses page*. CDP. https://www.cdp.net/en/responses
- Global Carbon Project. (n.d.). *Country CO2 Emissions.* Global Carbon Project. http://www.globalcarbonatlas.org/en/CO2-emissions
- Enel. (n.d.). *Empowering Enel people.* Enel. https://www.enel.com/company/stories/articles/2020/10/empowering-enel-people
- Enel X. (n.d.). *Innovation and Sustainability. Leading the way to climate-proof technological transformation.* Enel X. https://corporate.enelx.com/en/our-commitment/innovation-sustainability
- Eni. (n.d.).
- Equigy. (n.d.) *Your role.* Equigy. https://equigy.com/about/#
- Open-es. (n.d.). *Sustainable development.* Open-es. https://www.openes.io/sustainable-development-solution
- Terna. (n.d.). *Equigy*. Terna. https://www.terna.it/en/electric-system/system-innovation/spotlight-equigy-platform
- Terna. (n.d.). *Inside the Energy Transition*. Terna. https://www.terna.it/en/about-us/inside-energy-transition

Reports:

- A2A. (2020). *A2A integrated report 2020*. A2A. https://www.gruppoa2a.it/sites/default/files/2021-04/A2A_Integrated_Report_2020.pdf
- A2A. (2023). *A2A, results as of 31 december 2022*. A2A. https://www.gruppoa2a.it/en/media/press-releases/a2a-results-31-december-2022

- Enel. (2022). *GHG Inventory. Quantification and reporting of greenhouse gas emissions in accordance with the Corporate GHG Protocol.* Enel. https://www.enel.com/content/dam/enel-com/documenti/investitori/sostenibilita/2021/ghg-inventory-2021_en.pdf
- Enel. (2021). *Sustainability report 2020.* Enel. https://www.enel.com/content/dam/enel-com/documenti/investitori/sostenibilita/2021/05/enel-sustainability-report-2020.pdf
- Enel. (2020). *Zero emissions ambition: Enel's path to decarbonization.* Enel. https://www.enel.com/content/dam/enel-com/documenti/investitori/sostenibilita/2020/11/zero-emissions-ambition-report.pdf
- International Energy Agency. (2022). *CO2 Emissions in 2022*. International Energy Agency. https://iea.blob.core.windows.net/assets/3c8fa115-35c4-4474-b237-1b00424c8844/CO2Emissionsin2022.pdf
- International Energy Agency. (2022). *World Energy Outlook*. International Energy Agency. https://iea.blob.core.windows.net/assets/830fe099-5530-48f2-a7c1-11f35d510983/WorldEnergyOutlook2022.pdf
- OECD. (2009). *Sustainable Manufacturing and Eco-Innovation. Framework, Practices and Measurement. Synthesis Report.* OECD. https://www.oecd.org/innovation/inno/43423689.pdf
- Kemp, R., & Pearson, P. (2007). *Final report of the MEI project measuring eco innovation.* UMMerit Maastricht. https://www.oecd.org/env/consumption-innovation/43960830.pdf
- Siemens, Reuters Events. (2022). *The role of artificial intelligence in sustainable infrastructure. Managing grids and buildings for a climate-friendly future.* Siemens. https://assets.new.siemens.com/siemens/assets/api/uuid:09392f9a-84cc-4e81-b988-99daf2b87324/reuters-ai-whitepaper.pdf
- Terna. (2021). Decarbonising the energy system. Terna. https://www.terna.it/en/about-us/inside-energy-transition/collaborations-shared-challenge/spotlight-tso-paper-decarbonisation

Official documents:

- ISO. (2006). *ISO 14040:2006. Environmental management — Life cycle assessment — Principles and framework.* ISO. https://www.iso.org/standard/37456.html

- ISO. (2014). *Environmental management — Life cycle assessment — Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006.* ISO. https://www.iso.org/standard/61103.html

- EU Directorate-General for Environment. (2021). Recommendation on the use of Environmental Footprint methods. European Commission. https://environment.ec.europa.eu/publications/recommendation-use-environmental-footprint-methods_en

Interviews:

- Vera, E. (2014). Elio Vera interviews Maurizio Bezzeccheri. Cross Cultural Management: An International Journal, 21 (1). https://www.emerald.com/insight/content/doi/10.1108/CCM-10-2013-0145/full/html

Case studies:

- Blanco, C., Metzner, M. and Stroehle, J. (2021). Enel: Pathways to Purposeful Transformation through Shared Value and Innovation. *Saïd Business School.* https://www.sbs.ox.ac.uk/sites/default/files/2021-04/Enel-Case-Study.pdf

- OECD. (2019). Blockchain Technologies as a Digital Enabler for Sustainable Infrastructure. *OECD*. https://www.oecd.org/finance/blockchain-technologies-as-as-digital-enabler-for-sustainable-infrastructure.htm

Datasets:

- International Energy Agency. (2023). Greenhouse Gas Emissions from Energy. International Energy Agency. https://www.iea.org/data-and-statistics/data-product/greenhouse-gas-emissions-from-energy

Thesis Summary

1. Introduction

The energy sector is the problem and the solution to the current climate crisis, accounting for more than two-thirds of global greenhouse gas (GHG) emissions (International energy agency, 2022). Innovation technologies are increasingly considered to be the key to climate action due to their ability to effectively accelerate the green energy transition in any industry, and need to be a crucial part of any corporate strategy. Italian energy companies, including Enel, Eni, A2A and Terna, have all played a significant role in driving and pioneering green innovation strategies globally. With abundant renewable energy investments and advance innovation initiatives, these companies have the potential to revolutionize the energy industry.

In this light, this thesis aims to identify, classify, analyze and assess innovation technology initiatives by Italian energy companies in order to determine strategies that could guarantee the success of similar practices. In order to answer the research question, in the second section of the thesis, I first review the literature on how to define, classify, analyze and assess innovations in general and green innovations particular in order to develop a comprehensive framework for the research. Based on the literature review, I propose the framework that will be applicable to the energy industry in Italy. In the third section, I proceed to introduce and review the energy industry in Italy, explaining its relevance, and then analyze the Italian energy companies' efforts to adopt and create innovation technologies aimed at helping them to cut emissions and switch to renewable resources. In the fourth section, I apply the elaborated framework to the energy industry in Italy to assess the companies' efforts and then, in section five of the thesis, I discuss the key findings from applying the green innovations framework.

2. Literature review

In the literature review, I conduct a systematic analysis of the most relevant academic literature seeking on green innovations (GIs) and innovations in general. Through this study, I intend to identify and review the relevant theories and frameworks that may be used to define, classify, analyze and assess the innovation adoption initiatives for environmental purposes in the Italian energy companies. The results of the analysis should provide a comprehensive understanding of the notions, characteristics and criteria around GIs used in research. Based on this, I suggest a framework that can be utilized to identify, categorize, analyze and evaluate the green innovation efforts undertaken by Italian energy companies.

2.1. Literature on innovation and green innovation

2.1.1. Industry 4.0. and sustainable innovation

In this section, I review the notions of Industry 4.0 key to the study and its relation to sustainable development goals. I identify some of the most popular innovation technologies that can be later used while choosing the specific company cases.

Industry 4.0 is a key concept to the study and its relation to sustainable development goals. The term coined by Klaus Schwab (2017) refers to a number of cutting-edge industrial innovations, including sensor networks, the Internet of Things (IoT), robotics, Big Data, cloud manufacturing, artificial intelligence and augmented reality (AR). These technologies are increasingly being used in the energy sector, with companies signing new deals and registering more patents related to them in order to accelerate the green transition without compromising the economic growth.

The section summarizes some of the most common types of innovation technologies used for environmental purposes, such as artificial intelligence, blockchain, IoT, and robotics, and gives examples of how they are applied in different fields and industries. It also provides an overview of how Industry 4.0 can contribute to achieving SDGs and creating a sustainable production system.

2.1.2. Identification of green innovation

In this section I attempt to analyze relevant literature to determine the key characteristics of green innovations, which can later be used for the construction of the theoretical framework.

Green innovations or eco-innovations refer to the development of environmentally conscious products or processes that incorporate new or updated technologies aimed at conserving energy, preventing pollution, or managing the natural environment (Awan, 2020), hence helping companies to reach net zero goals. Based on the analysis of different studies provided in this section, the key elements of green innovation are (1) novelty, (2) environmental focus, (3) mitigation of future environmental risks, (4) improved environmental performance, (5) support for the transition to a sustainable economy, (6) knowledge and technology application, and (7) green during the full life cycle. Schiederig et al. (2012) also add that the intention can be motivated not only by ecological impulses but also economical, including the need to be competitive on the market and satisfy the demand.

The key takeaways from this section include the definition of key characteristics of green innovations and how they can create value for society and address environmental challenges based on the reviewed literature.

2.1.3. Typology of innovation and green innovation

In this subsection, I explore different typologies of innovation and how they can be applied to the context of sustainability and the environment. Innovations can take different forms and have been increasingly branching out into new types with the innovation technology boom. Defining a typology framework can be an important step in classifying and assessing innovation as it provides a systematic and structured way to categorize and understand different types of innovations in the context of sustainability and the environment. It facilitates comparative analysis among different types of green innovations and enables the identification of patterns and trends.

Based on the review of pertinent literature, this section defines four types of innovation based on their characteristics: connective, structural, reflexive, and integrative — apart from product, process, business model and organizational innovation types. It also describes two types of innovation based on their novelty: competence-enhancing and competence-destroying. By combining different dimensions of innovation, the section manages to build the basis for a more comprehensive typology framework.

2.2. Literature on business innovation

In the following section I discuss how innovation can drive social and environmental change, as well as economic growth, and review some of the foundational theories of innovation through different theories. I start with the early theories of innovation, such as Schumpeter's theory of creative destruction and entrepreneurship, and their limitations in addressing the societal and environmental impacts of innovation. I also review more complete and holistic theories to define the key internal capabilities that scholars consider important for driving innovation.

2.2.1. Schumpeterian theory

The Schumpeterian theory provides a general understanding of entrepreneurial processes aimed at generating new ideas (Schumpeter, 1942; 1991). Joseph Schumpeter explored how innovative businesses ignite creative and disruptive processes that challenge capitalistic notions. He defines innovation as "new combinations" of changes that disturb the existing equilibrium in the economic system. He mainly focuses on the economic implications of innovation, but does not place a strong emphasis on impacts beyond just economic growth.

While providing a good framework for a generalized assessment of innovations, Schumpeter's works are not as applicable for green innovations due to the lack of a more holistic approach. However, despite some limitations, the Schumpeterian theory makes an important point — it suggests that the success of innovations often depends on certain internal capabilities of a company, specifically the risk-taking propensity.

2.2.2. Internal capabilities of innovative firms

Firms are in need of dynamic capabilities that integrate different resources for effective adaptation in the ever-changing business environment (Teece et al., 1997). These capabilities, among others, are especially important for effective green innovations, which are multi-dimensional and more complex.

Based on the analysis, this section establishes that while specific capabilities may vary depending on the context, some key internal capabilities for firms to develop and adopt green innovations include technological and R&D capabilities, visionary leadership, organizational learning, age, and business strategy focused on sustainability.

2.3. Literature on sustainability and green innovation

In this section, I review some of the literature on sustainability and green innovation, focusing on two main perspectives: the Triple Bottom Line theory and the collaboration with stakeholders with open innovation and Triple Helix models. I aim to define what are the key characteristics that scholars find crucial for innovation and sustainability practices.

2.3.1. Triple Bottom Line Theory

The Triple Bottom Line theory by Elkington (1997) suggests using the economic, social, and environmental elements to evaluate sustainability efforts by organizations, and clearly vindicates that innovations can substantially contribute to all those three dimensions. It emphasizes the sustainable development's long-term outlook and promotes the evaluation of green technologies based on their long-term benefits and potential for good legacies. It also takes into account the capacity of future generations to meet their needs.

2.3.2. Collaboration with Stakeholders, Open Innovation and Triple Helix Model

This subsection discusses the importance of collaboration and interaction with other stakeholders for developing and implementing eco-innovations. It presents three strategies for innovation by Navarro (2002): “make", “buy”, and “cooperate”, and explains how open innovation (Chesbrough, 2003) and the Triple Helix Model (Etzkowitz et al., 1995) can facilitate knowledge flows and synergies among different actors. It also refers to the concept of System Building (Nelson, 1993), which emphasizes the need for a holistic and societal perspective on innovation and sustainability.

The collaboration with stakeholders perspective provided in this section demonstrates how innovation arises through the dynamic engagement of universities, industries, and government agencies, as well as other external actors, such as customers and competitors. The key takeaway from this is the importance of collaboration and stakeholder engagement in driving innovation.

2.4.1. Sustainable Business Performance through Green Innovation

Ideally, the end purpose of any green innovation should be the reduction or eradication of environmental harm coming from a company’s operations. In order to understand how likely an innovation is to contribute to the SDGs, this section identifies different success factors of innovation.

Based on the literature review, the main success factors for green innovations are green absorptive capacity and organizational learning, skilled human capital, environmental awareness of top management, market, law, and regulation knowledge, interfunctional collaboration, innovation-oriented learning, and R&D investments. All success factors identified through literature review are interconnected and have overlapping elements, emphasizing the importance of a holistic approach to green innovation. These success factors will be crucial to the assessment of GIs in the Italian energy industry in the following chapters.

2.5. Drawing the theoretical framework for identifying, categorising, analysing and assessing GIs

Figure 7. Framework for identifying, categorising, analysing and assessing GIs

Based on the comprehensive literature review, this chapter proposes a framework for identifying, classifying, and assessing green innovations, which will later be used to analyse GIs in the Italian energy sector. This framework draws on relevant theories and concepts from the literature review and provide a systematic approach to analyzing the adoption of innovative technologies in the context of sustainability (Figure 1).

The framework developed as a result of comprehensive literature review consists of four steps: identifying green innovations based on their characteristics, categorizing them based on their types, novelty, and levels of collaboration, analyzing them based on their economic, social, and environmental impacts, and evaluating them based on their alignment with sustainability principles, potential to contribute to sustainable development, and potential to create value for stakeholders. The section provides an overview of how this framework can help assess green innovations in a comprehensive and balanced manner.

3. Framework application: Green innovations in the Italian energy industry

In this chapter, I apply the theoretical framework developed in the previous section to the Italian energy sector. I start by briefly introducing the Italian energy industry, its relevance and contribution to the international arena, as well as the green innovations practices adopted by the local firms. Based on the open source data on the innovative technologies adopted by Italian energy firms to reach net-zero targets, I use the framework to classify and assess these innovations.

3.1. Green innovations in the Italian energy industry

Italian energy companies, including Enel, have played a significant role in driving and pioneering green innovation strategies in the country and worldwide. Their influence and market scale enable them to implement and test green innovation solutions at a large scale, providing valuable data and insights for research.

With Italy being one of the groundbreakers in renewable energy on a global scale, is it important to analyse green innovations in the Italian energy industry to gain insights into the country's ambitious targets, technological advancements, market opportunities, and the lessons they provide for the broader global energy transition. Overall, the Italian energy companies are relevant for green innovation research due to their industry expertise, resources, market influence, access to data and infrastructure, collaboration opportunities, and policy influence.

3.3. Green innovation practices in the leading Italian energy companies

In order to demonstrate the applicability of the developed framework, this section is divided based on the different types of innovation technologies predominantly used in the energy sector. Since the types of such technologies are countless, the present study focuses on the most popular technologies with the highest accessibility of information. The analysis will include AI and machine learning, IoT, cloud services, and blockchain. For each type, an example of innovation practices by different companies will be presented, depending on the availability of information, relevance to the framework, significance and balance.

3.3.1. Artificial Intelligence

Enel and Myst AI

In 2018, Enel Green Power, part of Enel, started working with Myst AI to develop AI-powered forecasts for various energy applications. The variety of applications of Myst AI is extremely diverse. For example, Enel uses Myst AI's machine learning-powered forecasts to support the energy transition by enabling smart grid management, renewable energy forecasting, and energy efficiency improvement (Enel, 2022). Furthermore, Enel uses Myst AI's forecasts to bid on asset production in intraday markets, thereby reducing imbalance costs by 5% per year, which means that the amount of energy produced matches the amount of energy demanded more closely (Myst AI, 2022).

Based on the framework analysis (Figure 8), the use of Myst AI by Enel is an example of an effective green innovation that improves Enel's environmental, social and economic performance in the energy sector. It falls under the criteria for green innovation definition. It is an integrative, competence-enhancing process innovation. Concerning the analysis part, it has positive impacts on the environment, such as reducing greenhouse gas emissions and fossil fuel consumption, as well as on society, like improving the quality of life and well-being of customers and stakeholders. It also has economic benefits, such as reducing imbalance costs and increasing profitability and competitiveness in the energy market. The performance of Myst AI is supported by several success factors within Enel. The sole negative trade-off of this technology, which cannot be accurately assesses based on the accessible sources, is the fact that it might not be fully green throughout its life cycle, as it relies on energy used by data centres.

3.3.2. Internet of Things

A2A and Smart Technologies

As part of its technological innovation strategy, A2A established a separate entity called A2A Smart City which works on creating smart and digital solutions with the help of the LoRaWAN® Ecosystem, which facilitates the smartification of cities with the help of IoT and interconnectivity. The technology enables improved energy efficiency through energy, sound and environment monitoring, smart lighting, smart grid and smart irrigation in residential areas.

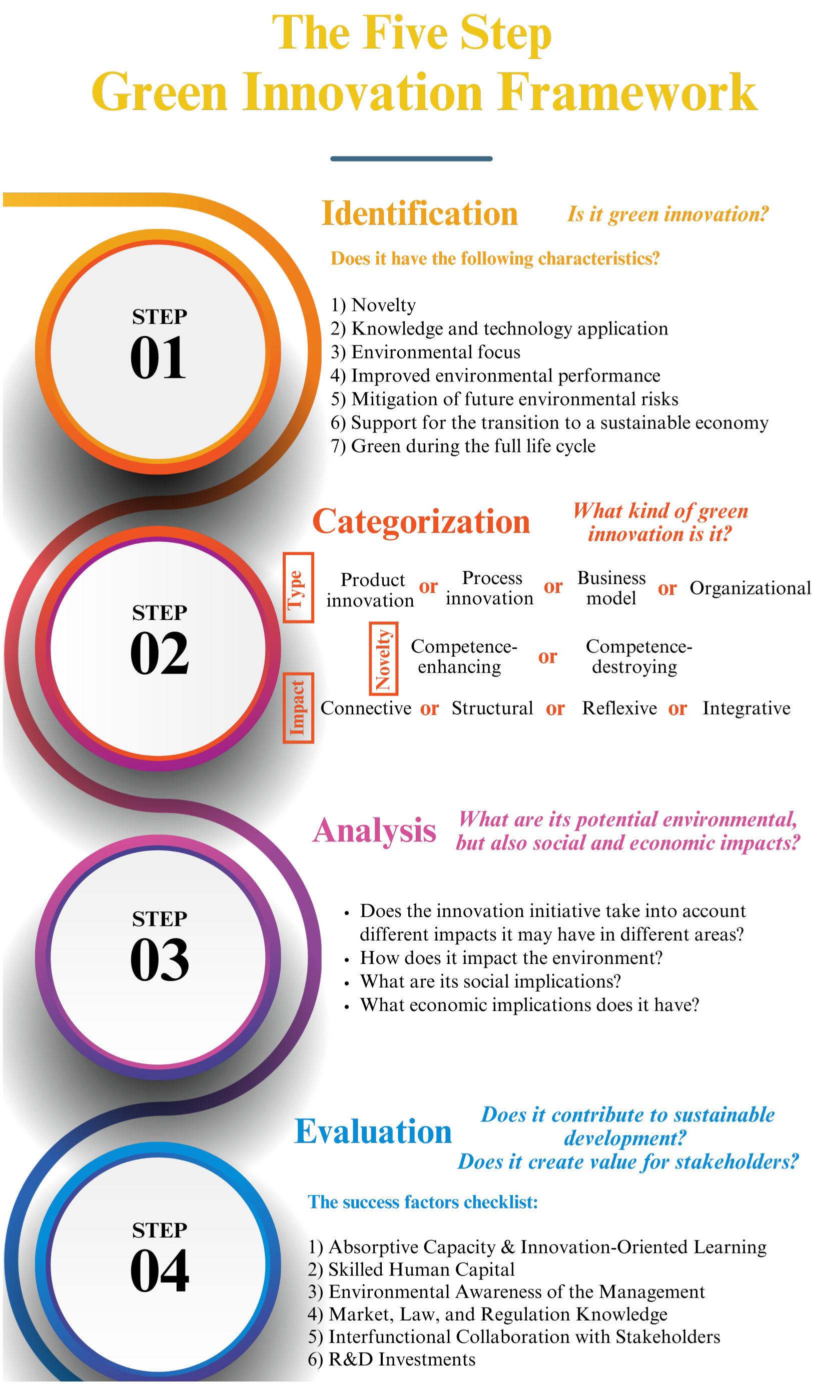
Based on the framework (Figure 9), the use of LoRaWan by A2A is an example of an effective green innovation that strives to contribute to the company's green transition efforts. The A2A initiative does meet the criteria for being a green innovation. This particular innovation initiative encompasses different characteristics of product, process, organisational, as we all as connective, integrative reflexive, and structural innovation. The application of LoRaWan has potential positive impacts on the environment, society and economy, such as reducing energy consumption and emissions, improving quality of life and health, creating new markets and jobs, and cutting costs and improving profitability for A2A. The main trade-off of this technology is the fact that it might not be fully green throughout its life cycle, as it relies on energy used by data centres and batteries that end up in landfills.

3.3.3. Blockchain

Terna and Equigy

As a part of its ecological strategy, in 2020, Terna launched a joint venture initiative, alongside the German, Dutch, Swiss and Austrian TSOs, called Equigy. This crowd balancing platform (CBP) provides access to new sources of electricity from consumer-based devices, such as home batteries and electric vehicles (Terna, n.d.), empowering and transforming consumers into "prosumers". This accelerates the integration of renewables into the electricity system by providing safety, flexibility and balance.

Based on the analysis using the framework (Figure 10), Equigy is an excellent example of how Italian energy companies can use innovation technologies to accelerate energy transition. Firstly, Equigy by Terna meets the majority of criteria for an initiative to be called green innovation based on its novelty, knowledge and technology application, environmental focus, improved environmental performance, mitigation of future environmental risks, support for the transition to a sustainable economy and greenness during the full life cycle. Equigy is a process and business model innovation that is both competence-enhancing and competence-destroying depending on the perspective, as well as connective and integrative. Overall, the implications of this green innovation can be considered positive, as long as the company takes into account the potential negative effects



of blockchain use and minimises them. Finally, the successful performance of Equigy is supported by Terna's proclivity to innovation-oriented learning, skilled human capital, environmental awareness of the management, market and regulatory knowledge, interfunctional collaboration with stakeholders, and R&D investments.

3.3.4. Cloud computing and Big Data
Eni and Open-Es Platform

In 2020, Eni in collaboration with the Boston Consulting Group and Google Cloud announced the creation of Open-es — a new open digital platform that allows companies to calculate their sustainability performance based on certain metrics and give different stakeholders, including customers and financial institutions, the opportunity to gain access to that data. Eni sees Open-es as a practical tool for companies that wish to improve their sustainability performance but do not possess the relevant tools to measure performance and progress along the entire chain.

Relying on the analysis using the framework (Fig. 11), Equigy is an excellent example of how Italian energy companies can use innovation technologies to accelerate energy transition. First of all, Open-es with the use of cloud commuting, Big Data and AI aligns with the criteria for green innovation definition. Moving on to classification, Open-es can be considered a competence-enhancing process, business model and organizational innovation, as well as reflexive, integrative and connective innovation. The framework showed that Open-es has a mainly positive effect on different aspects. Due to the alignment with all the success factors presented in the framework, Eni provides a solid basis for its innovation initiatives to reach their goals. Overall, the framework showed that Open-es is a practical tool that fosters transparency, innovation and value creation for the energy industry on the way to sustainability. However, in order to guarantee that it is fully green across its life cycle an additional evaluation would be required using metrics and internal data from the company.

4. Discussion

In this section, I will discuss the key findings from Section 3, where I applied the framework for identifying, classifying, analyzing and assessing green innovation initiatives in the Italian energy sector. The main purpose of this study is to analyze how Italian energy companies use innovation technologies to drive the green energy transition and to identify the best strategies based on that. The application of the previously developed framework provided a holistic review of some of the ongoing initiatives in the industry. The elaborated structure allowed to look at the innovations from different points of view and evaluate them accordingly. I will first discuss the strengths and gaps of the elaborated framework, and then proceed with the analysis of the key takeaways from the review of the four innovation practices by Enel, A2A, Terna and Eni.

Overall, the framework was designed to be comprehensive and systematic. It covers a range of green innovation-related dimensions, including definition, category, impact, and success factors. The framework is of great value for determining each innovation practice's advantages and disadvantages, as well as potential trade-offs and difficulties. Following each step of the framework can help to raise important questions and draw attention to crucial aspects in the development of innovation technology initiatives that might be lacking. eing based on relevant literature and sources that provide theoretical and empirical foundations, it can be a useful tool for developing the initial strategies for innovation projects for the corporate management. It is also of great use for researchers attempting to identify and analyze certain innovations, since it accumulates different relevant theories and studies by other scholars.

However, the framework might not capture all the complexity and diversity of green innovation practices in the real world. Moreover, it may not account for the dynamic and evolving nature of green innovation practices, since some innovations may change their novelty, impact, or performance as they mature or interact with other factors in the environment. The application of the framework also demonstrated that it must be accompanied by another methodology to calculate the difference between the level of emissions before and after the implementation with internal and independent data to have precise metrics that show the contribution to energy transition. To bridge these gaps, the textual analysis could be complemented by interviews, surveys, observations, or experiments to gain more insights and evidence on how different companies use innovation technologies for sustainability. The analysis based on the developed framework would be most successful with the involvement and consultation of different stakeholders.

Apropos of the innovation practices analysed in Chapter 3, there are several discoveries and insights gained through the framework application. All of the cases, including Myst AI by Enel, Smart City by A2A, Equigy by Terna, and Open-es by Eni, fall under the definition of green innovations. All of them possess such characteristics as novelty, knowledge and technology application, environmental focus, improved environmental performance, mitigation of future environmental risks, and support for the transition to a sustainable economy. As for the "green during the full life cycle" criteria, the analysis showed that the framework could only assume that it is true, since the answer requires data and insights from the companies, which is not available through open sources.

The categories of GIs adopted by Italian energy companies are manifold and diverse. They range from product and process to business model and organizational innovations, from connective and integrative to reflexive and structural, depending on their goals and needs. In the cases reviewed in the previous chapter, all of thee incumbent companies use mostly competence-enhancing green innovations, which improve their existing capabilities and skills in the energy sector. The reviewed Italian energy companies use mainly connective innovations, which create new networks and interactions among different devices and actors using novel technologies, and integrative innovations, which combine and integrate several technologies and fields of knowledge. Some of their innovations may also have reflexive or structural characteristics.

The analysis demonstrated that the majority of large energy companies in Italy consider innovation technologies to be a fundamental tool in improving their operations, and all the reviewed companies, including Enel, Eni, A2A and Terna, have incorporated innovation practices into their corporate strategy and investment plans. Green innovations proved to be one of the constituting pillars for all those companies in their longterm plans. While developing the green innovation strategies, the four analyzed companies have taken into account the impacts of their actions on different dimensions. Not only do they strive to reap financial and economic rewards, but also endeavour to contribute to SDGs and mitigating and preventing climate change, while simultaneously benefitting the society by improving quality of life, health, education, or inclusion of people.

The analysis helped to establish that all of the innovation practices have become possible through different forms of cooperation between the energy companies and third parties, such as startups (Myst AI), joint ventures (Equigy), memberships in non-profit associations (LoRa Alliance), and open collaboration platforms (Open-es). This finding reiterates the point made in the literature review by Navarro (2002) and Chesbrough (2003). This point is also directly linked to the the absorptive capacity and innovation-oriented learning: companies that are capable of interacting with the outer world, acquiring relevant knowledge and then adapting and utilizing it in order to be more innovative, are more likely to develop successful green innovation solutions. These practices are underpinned by a skilled human capital and active R&D investments. Grounded on these lessons, the most valuable recommendations are to seek collaboration and partnership with other actors to create synergies and co-create value; to foster a culture of innovation and sustainability within the organization and empower employees; to actively communicate and promote the benefits and value of green innovations to investors, customers, regulators, or society in general. Openness and cooperation can strengthen the initiatives, mitigate any risk and guarantee the success for anti-climate change initiatives.

The analysis of the four cases also showed that the respective Italian energy companies face some challenges and trade-offs in adopting green innovations. Apart from balancing the environmental benefits and costs of innovation technologies, they face with challenges in ensuring data security and privacy, and addressing social and ethical issues of Industry 4.0. Therefore, companies should plead to address such issues as job displacement, digital divide, human-machine interaction, and social responsibility, by engaging with stakeholders, providing training and education, ensuring inclusivity and diversity, and adhering to ethical principles. All of this should be transparent and put as a top priority.

One of the most significant limitations of this analysis is linked to the fact that it relies on secondary data and information, which may not be accurate, complete, or up-to-date. It may also be influenced by the sources' perspectives and interests, since a lot of the information about the initiates was covered in companies' reports which can sometimes exaggerate the organizations' feats. Therefore, companies should be urged to measure the carbon footprint of the companies before and after implementing the green innovation practices in order to clearly assess their contribution to the energy transition. Making this data accessible to the public would not onland straighten the trust of the stakeholders, but also motivate the company to improve its practices in terms of their environmental impacts.

Moreover, important stakeholders should take part by defining and agreeing upon certain or metrics for gauging the effectiveness of the innovation. Otherwise, it might not be feasible to clearly and transparently quantify or illustrate the companies' actual contribution to sustainable development or value generation for stakeholders. It would be of great use to compare or benchmark the green innovations with other alternatives or competitors in the market, which could provide a more objective and relative assessment of their performance and value.

5. Conclusion

The energy sector, which is one of the main culprits contributing to climate change, can become the answer to this urgent global issue by undertaking effective and timely action to accelerate the energy transition. While an increasing number of oil and gas or multi-utility companies are recognizing the imperativeness of such initiatives and searching for creative ways of achieving net zero goals, innovation technologies are becoming the vital part of any corporate strategy. Artificial intelligence, Internet of Things, cloud computing and blockchain all have the ability to help tackle climate change without sacrificing economic growth, and Italian companies, like Enel, A2A, Terna and Eni, are actively investing in them.

This study has aimed to examine the ways in which innovation technologies are used by Italian energy companies to facilitate the green energy transition and to determine strategies that could guarantee their success. In order to accomplish this, the study set the following objectives:

1. I have reviewed the literature on how to define, classify, analyze and assess innovations in general and green innovations in order to develop a comprehensive framework for the research.
2. Based on the literature review, I have proposed a framework to identify, classify and assess green innovations that will be applicable to the energy industry in Italy.
3. I have introduced and reviewed the energy industry in Italy, explaining its relevance, and the Italian energy companies' efforts to adopt and create innovation technologies aimed at helping them to cut emissions and switch to renewable resources.
4. Finally, I have applied the elaborated framework to the energy industry in Italy to assess the companies' green innovation initiatives and then discuss the key findings from applying the green innovations framework.

A comprehensive assessment of some of the current initiatives in the sector allowed to put theory to practice and to identify the most common and effective green innovation strategies adopted by Italian energy companies. Apart from assessing them, the framework also provided a methodology for the GI's definition, categorization and analysis. The in-depth review facilitated the identification of several gaps and limitations providing a better basis for recommendations.

One of the key takeaways both from the literature and the analysis is the utmost importance of collaborations, partnerships with other actors and stakeholder engagement to create synergies and co-create value. These points brought up in the literature review, reappeared with a stronger force in the case studies. Therefore, firms undertaking GI initiatives should actively collaborate and engage with other actors to create synergies and co-create value and also foster a culture of innovation and sustainability within the organization by training and empowering employees. These key takeaways will ensure the success of any innovation strategy.

Keeping in mind the Triple Bottom Line theory and the importance of a holistic approach in developing green innovation strategies, energy companies should strive to promote social welfare and safety while implementing green innovations. Therefore, GI strategies need to be accompanied by ways to ensure strong data security and privacy measures, address such challenges as job loss, digital gap, human-machine interaction, and social responsibility, by engaging with stakeholders, providing training and education, ensuring inclusivity and diversity, and following ethical principles.

Innovations cannot be considered green if they do not fulfil their core goal — contribution to reduce environmental damage and use natural resources efficiently. As the framework has shown, in order to accurately assess a company's contribution to the energy transition, it is essential to analyze its carbon footprint both before and after adopting green innovation methods. Therefore, businesses may take a life cycle approach and weigh the environmental advantages and drawbacks of emerging technology at every step. Making this information available to the general public will help the corporations win back the stakeholders' trust, encourage it to change its practices to have less of an impact on the environment, and provide the business with access to suggestions and criticism from various stakeholders. This could be taken a step further by engaging stakeholders in standard or metrics definition and benchmarking the initiatives against competitors to provide a more objectively positive outcome.

In conclusion, this study on green innovation technologies in the Italian energy sector has highlighted the key factors and challenges for creating and putting into practice green innovation strategies in the energy sector in Italy. It has demonstrated that guaranteeing the success and sustainability of green innovation initiatives requires a number of different factors, including cooperation, stakeholder participation, a holistic approach encompassing ecological, social and economic dimensions, and environmental performance evaluation. It has also provided some recommendations and suggestions for future research in this field. The study hopes to contribute to the advancement of green innovation knowledge and practice, as well as to inspire more energy companies to adopt innovation technologies that can help tackle climate change and promote sustainable development.