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Innovation and ESG: A Focus on Green Technologies in the Energy Sector

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To my family
Thank you for all your unwavering support

Abstract

This dissertation studies how leading companies in the Energy sector, particularly those involved in electricity generation and electrical utilities, adopt innovative green technology solutions as part of the integration of ESG performance. The dissertation provides a comparative analysis of the green technology solutions adopted by leading companies in the energy sector combined with a critical review of relevant existing literature to identify how green technologies drive ESG goals in the energy sector, with a focus on the 2020 – 2023 period. Moreover, this dissertation studies and evaluates through a comparative analysis the most successful strategies the top energy companies adopt to leverage green technologies and innovation to achieve their ESG goals. The importance of this topic lies in the significance of the ESG metrics to brand reputation, risk management and attractiveness of the company to investors, factors that shape the business strategies for companies. Innovation and green technologies not only can enhance ESG performance of the companies to reduce their environmental footprint but also create competitive advantages and strengthen the social license to operate.

Keywords

Green technologies, ESG, innovation, sustainability, energy

Καινοτομία και παράγοντες ESG:
Εστιάζοντας στις πράσινες τεχνολογίες στον τομέα της Ενέργειας

Κυριακή Μαλέκα

Περίληψη

Η παρούσα διατριβή μελετά τον τρόπο με τον οποίο κορυφαίες εταιρείες στον τομέα της ενέργειας, ιδιαίτερα εκείνες που ασχολούνται με την παραγωγή ηλεκτρικής ενέργειας και τις επιχειρήσεις κοινής ωφέλειας στον τομέα της ηλεκτρικής ενέργειας, υιοθετούν καινοτόμες λύσεις πράσινης τεχνολογίας ως μέρος της ενσωμάτωσης των επιδόσεων ESG. Η διατριβή παρέχει μια συγκριτική ανάλυση των λύσεων πράσινης τεχνολογίας που υιοθετήθηκαν από κορυφαίες εταιρείες στον τομέα της ενέργειας σε συνδυασμό με μια κριτική ανασκόπηση της σχετικής υπάρχουσας βιβλιογραφίας για τον προσδιορισμό του τρόπου με τον οποίο οι πράσινες τεχνολογίες έχουν κύριο ρόλο στην επίτευξη των ESG στόχων στον ενεργειακό τομέα, με έμφαση στην περίοδο 2020 – 2023. Επιπλέον, η παρούσα διατριβή μελετά και αξιολογεί μέσω συγκριτικής ανάλυσης τις πιο επιτυχημένες στρατηγικές που υιοθετούν οι κορυφαίες εταιρείες ενέργειας για να αξιοποιήσουν τις πράσινες τεχνολογίες και την καινοτομία για την επίτευξη των ESG στόχων τους. Η σπουδαιότητα αυτού του θέματος έγκειται στη σημασία των μετρικών ESG για τη φήμη της εταιρείας, τη διαχείριση κινδύνου και την ελκυστικότητα της εταιρείας για τους επενδυτές, παράγοντες που διαμορφώνουν τις επιχειρηματικές στρατηγικές για τις εταιρείες. Η καινοτομία στις πράσινες τεχνολογίες όχι μόνο μπορούν να ενισχύσουν τις επιδόσεις ESG των εταιρειών για να μειώσουν το περιβαλλοντικό τους αποτύπωμα, αλλά και να δημιουργήσουν ανταγωνιστικά πλεονεκτήματα και να ενισχύσουν την κοινωνική άδεια λειτουργίας.

Λέξεις – Κλειδιά
Πράσινες τεχνολογίες, ESG, καινοτομία, βιωσιμότητα, ενέργεια

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List of Abbreviations & Acronyms

AI	Artificial Intelligence
CAPEX	Capital Expenditure
CCS	Carbon Capture and Storage
CMVM	Portuguese Securities Market Commission
CO_2	Carbon dioxide
CSA	Corporate Sustainability Assessment
CSR	Corporate Social Responsibility
CSRD	Corporate Sustainability Reporting Directive
ESG	Environmental, Social & Governance
ESRS	European Sustainability Reporting Standards
EU	European Union
EV	Electric Vehicle
CDSB	Climate Disclosure Standards Board
D&E&I	Diversity, Equity and Inclusion
D&I	Diversity and Inclusion
DJSI	Dow Jones Sustainability Index
HV	High Voltage
HVAC	Heating, Ventilation and Air Conditioning
HVDC	High Voltage Direct Current
IoT	Internet of Things
IIRC	Integrated Reporting Framework
IPP	Independent Power Producers
ISSB	International Sustainability Standards Board
GHG	Greenhouse Gases
GRI	Global Reporting Initiative
NFRD	Non-Financial Reporting Directive
OPEX	Operational Expenditure
PRI	Principles for Responsible Investment
PV	Photovoltaic
R&D&I	Research, Development and Innovation
S&P	Standard & Poor
SASB	Sustainability Accounting Standards Board
SDGs	UN Sustainable Development Goals
SECR	Streamlined Energy and Carbon Reporting
SFDR	Sustainable Finance Disclosure Regulation
SMP	Sustainability Master Plan
SRI	Socially Responsible Investing
STEM	Science, Technology, Engineering and Mathematics
TCFD	Task Force on Climate-related Financial Disclosures
TNFD	Nature-related Financial Disclosures
TOTEX	Total Expenditure
UN	United Nations
US	United States
V2G	Vehicle-to-Grid
VPP	Virtual Power Plants

Introduction

The energy sector is one of the major drivers of economic growth in all modern economies, as it is an essential part of most human activities. At the same time, it is historically known as one of the major contributors to the environmental degradation overall. The energy sector is a wide sector that consists of industries from resources production, power generation, transmission, and distribution to the sale of energy. The activities associated with the above industries of the energy sector as well as the consumption of the generated energy produce significant emissions of greenhouse gas emissions and consequently contribute to climate change. As the world is increasingly concerned about climate change and environmental deterioration, the business strategies of the Energy sector companies are continuously evolving to encompass the societal needs for environmental justice. The Environmental, Social and Governance (ESG) metrics provide the necessary tools for businesses to demonstrate their sustainability commitments to address the environmental concerns of society, but also to meet stakeholders' and investors' expectations.

Green technologies and innovations in sustainable energy solutions play a vital role in fostering sustainability within the energy sector. From a technical perspective, green technologies can enhance energy efficiency, resource optimization and improve grid resilience due to decentralization of energy systems. Therefore, green technologies can generate and optimize the use of "cleaner" energy that can reduce the carbon footprint of the companies within the energy sector, allowing them to meet the constantly evolving environmental responsibility regulatory framework and supporting the companies to achieve or maintain the social license to operate. Consequently, the integration of innovative green technologies can affect significantly the strategic management of the Energy sector companies.

The purpose of this dissertation is to explore how leading companies in the Energy sector, particularly those involved in electricity generation, distribution, and transmission and electrical utilities, adopt green technologies and innovative solutions as part of the integration of ESG performance. The dissertation provides a comparative analysis of the green technology solutions adopted by leading companies in the energy sector and it will critically review relevant existing literature to identify how innovation and green technologies drive ESG goals in the energy sector, with a special focus on the period 2020 - 2023. Moreover, this dissertation studies and evaluates through a comparative analysis the

most successful strategies the top energy companies adopt to leverage green technologies and innovation to achieve their ESG goals. The importance of this topic lies in the significance of the ESG metrics to risk management, brand reputation, and social acceptance, factors that shape the business strategies for companies. Innovation and green technologies not only can enhance ESG performance to reduce their environmental footprint but also create competitive advantages and strengthen the social license to operate.

The dissertation adopts a secondary research methodology, combining the methodological tools of thematic comparative analysis and critical review of literature. The dissertation presents how green technologies affect the ESG performance of prominent Energy companies, evaluating existing industry reports and data, corporate sustainability reports and existing literature on green technologies, innovative solutions in this sector and ESG frameworks. The comparative analysis presents how the strategic management of Energy sector companies adopts the green technologies integration and innovation to address regulatory and society demands and stakeholders' expectations.

Preliminary findings indicate that the Energy companies that incorporate green technologies and innovation into their strategic management show significant improvements in their ESG performance. The areas that show significant improvements are mainly the carbon footprint reduction and resource utilization efficiency. The dissertation also shows that the integration of green technologies and innovation in their corporate strategies leads to increased stakeholder engagement and community acceptance. Nevertheless, these sustainability efforts include high implementation costs. In addition, the companies of the sector face various challenges due to the uncertainties created by continuously changing regulatory frameworks and the scarcity of the resources for the implementation of the innovative solutions. The dissertation outlines the sustainability trends and the most effective sustainable solutions in terms of ESG performance.

The dissertation is subject to the following limitations. From the methodology perspective, the use of secondary data introduces accuracy limitations due to potential gaps, as well as limitations in availability of information. Literature review of the ESG metrics and scoring is limited to the available information of the ESG reporting frameworks, therefore there may be exclusion of other relevant dimensions for the ESG performance of the selected companies. Furthermore, as the research focuses on a limited number of companies, the generalization of the findings on other companies and regions is restricted. Despite the above limitations, the dissertation provides valuable comprehension of how the strategic

management of the companies is affected by the sustainability demands of stakeholders and communities.

The structure of the dissertation is as follows:

Chapter 1: Literature Review

This chapter presents the existing research on the implementation of green technologies and innovative solutions as part of ESG compliance and their integration into business strategies.

Chapter 2: Methodology

This chapter presents the tools and the approach for secondary research methodology and the criteria for companies' selection for comparative analysis.

Chapter 3: Comparative Analysis

This chapter presents the case studies of the selected companies on sustainability initiatives adoption and green technologies.

Chapter 4: Key Findings

This chapter presents the key findings of the research, identification of common trends, best practices, and strategic recommendations.

Conclusions

This chapter presents a summary of key findings and their contribution to academia and industry and the areas for future research to explore implications and challenges to businesses and policy makers.

1. Literature Review

Over the last decade, due to the increased interest of the stakeholders and society in the sustainability initiatives adopted by companies to address critical environmental issues, the integration of the ESG frameworks into corporate strategies has gained significant attention.

Several research projects were conducted to evaluate the development and application of the ESG frameworks and how the industry adopted those metrics. The following sections present the outcomes of the literature review.

1.1 ESG Framework and its integration into business strategy

ESG is a framework used by companies, investors, regulators and other stakeholders to evaluate and measure the sustainability and societal impact of investments or business practices (Kecun Chen, 2024; Rau & Yu, 2024).

ESG has three components (Kecun Chen, 2024; Rau & Yu, 2024):

Environmental factors assess how a company's actions impact the environment. This includes among others the company's carbon footprint, energy efficiency, waste management, and resource usage.

Social factors assess how a company manages its relationships with employees, vendors, suppliers, customers, and the communities in which they operate. This includes issues such as product safety, labor practices, diversity and inclusion, and community engagement.

Governance factors evaluate the internal controls and structures that guide a company's decision-making processes. This includes aspects such as board diversity, executive compensation, shareholder rights, and transparency in financial reporting.

Companies integrate ESG into business strategies to boost corporate reputation, enhance stakeholder trust and risk mitigation through adopting sustainable practices, fostering innovation and complying with the regulatory requirements (Kecun Chen, 2024).

ESG criteria help investors and financial institutions identify companies that are not only financially sound but also considerate of their environmental and social impacts, as well as maintain high standards of governance (Kecun Chen, 2024; Rau & Yu, 2024).

Regulators and policymakers use ESG principles to promote sustainable energy transition through sustainability reporting, corporate transparency and sustainability risks mitigation (Jabeen et al., 2025; Tettamanzi et al., 2024).

1.1.1 Regulatory Frameworks on Environmental, Social and Governance protocols for Energy Sector

The regulatory frameworks on ESG vary globally, and depending on the framework, cover mandatory, voluntarily or hybrid approaches. These frameworks ensure that the companies will follow sustainability practices and in accordance with international accords. (Lee et al., 2023). Nevertheless, it is apparent that ESG disclosures requirements lack of standardization across the globe (Dye et al., 2021).

European Union

Non-Financial Reporting Directive (NFRD): NFRD went into force in 2014 but was applied since 2017 and it was replaced by the Corporate Sustainability Reporting Directive in 2023. NFRD mandated companies with more than 500 employees to disclose annually their non-financial information regarding environmental protection, employee treatment and social responsibility, human rights respect, and bribery and anti-corruption matters. The purpose of this regulation was for investors and relevant stakeholders to receive all the needed information on the non-financial activities of the large European companies subject to this regulation (European Parliament and of the Council, 2014; Tettamanzi et al., 2024).

EU Green Taxonomy: The EU Green Taxonomy, established under Regulation (EU) 2020/852 and set in force since July 2020, is a framework to accelerate sustainability investments to enable the green transition in line with the 2030 climate and energy targets defined in European Green Deal. It is a classification system that defines four conditions to define what economic activities can be considered as environmentally sustainable (European Parliament and of the Council, 2020; Zatonatska et al., 2024).

The conditions that need to be met for an activity to be considered as environmentally sustainable are: the activity must contribute significantly to at least one of the six environmental and climate objectives defined in the regulation, the activity must not harm substantially any of the other environmental and climate objectives, the activity when performed must comply with the minimum safeguards defined in the regulation and the activity must meet the established European Commission’s technical screening criteria.

The six environmental and climate objectives that the EU Green Taxonomy aims to address include mitigation and adaptation of climate change, transition to a circular economy, sustainable use and protection of marine and water resources, prevention and control of pollution and protection and restoration of ecosystems and biodiversity.

The EU taxonomy is an important tool to meet the environmental and climate targets of the European Commission, promoting innovative environmentally sustainable developments and transparency of activities through corporate reporting. It can serve as a guide for investors and financial institutions to identify sustainability projects and allocate their funds accordingly (Tettamanzi et al., 2024; Zatonatska et al., 2024).

Sustainable Finance Disclosure Regulation (SFDR): SFDR, which came into force in March 2021, is a transparency framework that mandates financial market participants to disclose how ESG factors are included in activities of the entity and how the environmental and sustainability risk are integrated into the business strategy of the company, for the investors to be in position to assess the company accordingly (European Parliament and of the Council, 2019; Zatonatska et al., 2024).

Corporate Sustainability Reporting Directive (CSRD): CSRD is mandatory EU regulation that entered into force in January 2023, that requires large companies and companies listed on EU-regulated market to publish sustainability reports regularly. The target of the regulation is to ensure that investors and other relevant stakeholders will receive all the necessary information about the impact the companies have on the ESG pillars, environment, social and governance, and the financial opportunities and risks associated with environmental sustainability issues and climate change. Companies subject to this regulation must publish their reports according to the requirements of European Sustainability Reporting Standards (ESRS), regardless of the sector that they operate in (European Parliament and Council, 2022).

United States (US)

The US ESG regulatory frameworks, in contrast to the EU mandatory reporting frameworks, are largely voluntary and mainly rely on the voluntary implementation by the US companies driven by market demands, rather than a compulsory measure (Lee et al., 2023).

For the public companies listed in the US stock exchanges, the Securities and Exchange Commission (SEC) regulations, that came into force in 2022, impose requirements for transparency and disclosures of the related to ESG aspects, in line with the Task Force on

Climate-related Financial Disclosures (TCFD) recommendations. Nonetheless, the private sector is not directly subject to the same requirements (Sundarasen, Kumar, et al., 2024).

International regulatory frameworks

In lack of a globally standardized regulatory framework on ESG disclosure and performance, the United Nations (UN) have published a set of 17 global goals, the Sustainable Development Goals (SDGs) to encourage the adoption of sustainability and equality initiatives (United Nations, 2025b).

Moreover, the International Financial Reporting Standards (IFRS) foundation is working on finalizing the International Sustainability Standards Board (ISSB), that, although they are still not approved, is intended to become the global standards for sustainability (Ruan et al., 2024; Singhania & Chadha, 2023). The draft published in June 2023 and the ISSB is currently on proposal stage working on finalizing the sustainability disclosure standards (IFRS, 2025a).

1.1.2 ESG Reporting Frameworks

The increasing global emphasis on environmental sustainability, ethical practices and transparency over the years is reflected in the evolution of ESG reporting frameworks. ESG reporting only focuses on the three ESG pillars, environmental, social and governance, in contrast with the sustainability reporting that adopts a more holistic approach, that includes, besides the ESG aspects, other details of the organization values, mission, vision and other long-term strategies towards sustainable development (Rusu et al., 2024).

There are sustainability reporting frameworks such as the Global Reporting Initiative (GRI), and European Sustainability Reporting Standard (ESRS), which cover wider sustainability aspects and part of this report also covers the ESG aspects, however there are also primarily ESG reporting frameworks such as Sustainability Accounting Standards Board (SASB), Task Force on Climate-related Financial Disclosures (TCFD).

Global Reporting Initiative (GRI): GRI is an independent non-profit organization that, in 2000 published their first complete draft on sustainability reporting standards, to help organizations, public or private, to communicate their sustainability efforts and the impact this had to a wide range of sustainability issues, such as climate change mitigation, use of resource, human rights, economic impact, management structure, etc. (Global Reporting

Initiative, 2025; Rusu et al., 2024). GRI standards is one of the main Sustainability reporting frameworks that are most widely used (Tettamanzi et al., 2024).

Sustainability Accounting Standards Board (SASB): Initially published in 2011, final set published in 2018, and since 2022 undertaken by the International Sustainability Standards Board (ISSB) of the IFSR foundation, this ESG reporting framework is focused on the ESG related financial performance by industry. The SASB report includes, among others, information on the company's mission and vision, governance structure, sustainability commitments of the organization, ESG indicators and risk management (IFRS, 2025b; Rusu et al., 2024).

Integrated Reporting Framework (IIRC): This reporting framework, released in 2013, focuses on the performance of the organization by demonstrating both financial and non-financial details to depict how the company's governance and business strategy create value in the short, medium and long term. The main aspects within this reporting framework are organizational structure and business model, risk management, sustainability indicators, resource allocation for achieving business strategies and future prospects (Integrated Reporting, 2025; Rusu et al., 2024).

Task Force on Climate-related Financial Disclosures (TCFD): TCFD, that published its first recommendations in 2017, is a reporting framework based on four main pillars: Governance, Strategy, Risk Management and Metrics and Targets. The Governance pillar refers to the governance of the organization regarding climate-related risks. The Strategy pillar focuses on the impact the climate change-related risks and opportunities have on the business strategy and the financial planning of the organization. The Risk Management pillar involves the identification, assessment, and management of risks associated with climate change. The Metrics and Targets pillar involves the metrics and the targets to address the climate-change risks and opportunities (Rusu et al., 2024; Task Force on Climate-related Financial Disclosures, 2025). This initiative reflects the transitions from voluntarily climate risks reporting to mandatory reporting (Task Force on Climate-related Financial Disclosures, 2025; Zatonatska et al., 2024).

European Sustainability Reporting Standard (ESRS): The European Commission adopted the ESRS in 2023. It is a mandatory reporting framework for all the companies that are subject to CSRD, and it defines how the organizations must disclose the information related

to the ESG issues covered in CSRD (European Parliament and the Council, n.d.; Lee et al., 2023).

1.1.3 ESG as part of corporate strategy in the Energy Sector

Investors and other stakeholders are increasingly acknowledging that the sustainability performance of the company, the ethical practices, the accountability and the corporate transparency are important factors in evaluating the overall performance of a company. In addition, the investors are influenced by the ESG scores that are defined by specialized agencies and subsequently influence the decision making process between investors and top leadership (Au et al., 2023; Sundarasen, Zyznarska-Dworczak, et al., 2024).

The adoption of the ESG principles has become an integrated part of the business strategy as the pressure from regulators, investors, communities and internal stakeholders grows (Carreno, 2024).

The energy sector is one of the main contributors of CO_2 emissions, especially due to conventional power generation plants (Lee et al., 2023; Liang et al., 2022). It is, therefore, particularly important for the companies of the energy sector to incorporate the ESG principles into corporate strategies and this is reflected in multiple dimensions.

Fometescu, Hategan, et al., (2024) underline the importance of integrating ESG factors into business strategies for the companies in the energy sector, both to ensure that they comply with the sustainability principle but also for their economic growth as it is observed that the companies that prioritize ESG principles have shown better financial performance.

Liang et al., (2022) state that ESG reporting for energy companies is an increasing global trend for stakeholders' and investors engagement, as it enhances governance transparency and helps their valuation. In addition, Liang et al., (2022) advocate that ESG reporting and integration of the ESG principles into the corporate strategy boosts the brand image, helps in talent attraction and retention and leads to cost reduction due to energy and resource use efficiency.

Wieczorek-Kosmala et al., (2021) research has shown that there is a strong connection between sustainable performance and financial returns, productivity of asset, and operating profit margin for the companies in the energy sector. Moreover, their research provided evidence that companies with a stronger sustainability profile face increased cost, and that

stakeholders' pressure is a strong driver for the performance on sustainability for the energy firms.

Naseer et al., (2024) with their research of the Chinese energy companies, have shown that the companies that have a strong focus on ESG practices and disclosure are less exposed to risk, as they tend to comply with the sustainability policies and regulatory framework and apply transparent ESG reporting practices. The research also has proven a positive relationship between high sustainability performance and higher market returns.

Leopizzi et al., (2023) bibliometric analysis has shown that the management of the electric utilities' sector should invest into updating their skillset to enable their companies to adopt the emerging sustainability, as the stakeholders show a constantly increasing interest in the sustainability performance of a firm.

Savio et al., (2023) and Chen et al., (2023) advocate that the firms that adopt strategies in alignment with the ESG principles, in the medium to long term, experience higher shareholder value and improved financial performance.

1.2 Literature review approach

As primary approach for the literature review is selected the Systematic Literature Review, based on specific research questions.

1.2.1 Research Questions and Objectives

The literature review will be focused on evaluating how the existing literature answers the following research questions:

- How the ESG regulatory and reporting frameworks have progressed over the years to promote the ESG principles implementation.
- How the ESG framework is integrated into the business strategy of the companies in the energy sector.
- How does the implementation of innovative green technologies help companies to meet ESG performance metrics.
- What are the most effective strategies and the main trends adopted by companies in the energy sector to leverage green technologies to meet the ESG goals.

- How does the stakeholder pressure influence the adoption of green technologies for the companies of the energy sector.
- What are the main challenges and opportunities in the implementation of existing and innovative green technologies to enhance ESG performance in the energy sector.

The main objectives of the research will be:

- To evaluate how the regulatory framework on sustainability forces the implementation of green technologies.
- To explore the connection between ESG principles and green technologies implementation in the energy sector.
- To evaluate how innovative green technologies affect the performance and the brand reputation in the energy sector.
- To identify patterns and trends in the green technologies adoption practices of energy sector companies to achieve ESG goals.
- To assess the main challenges the companies in the energy sector face in the adoption of existing and innovative green technologies to enhance ESG performance.

1.2.2 Selection of sources

The sources are selected based on the inclusion and exclusion criteria as described below.

Inclusion criteria

Relevance: The sources are selected based on their relevance to the subject of this dissertation. Specifically, the sources refer to ESG principles in the energy sector, and specifically on the integration of green technologies and innovation. Moreover, sources will cover the regulatory framework influencing the integration of green technologies and innovation to meet the sustainability requirements.

Document type: This literature review is based on Articles, Review Articles (Systematic Reviews, Literature Reviews and Meta-Analysis) and Book Chapters.

Timeframe: The sources must be published in 2020 or later, to evaluate the corresponding trends.

Language: The language of the sources will be in English.

Exclusion criteria

Irrelevance: Any sources that are not relevant to ESG principles in the energy sector, the integration of green technologies and innovation, as well as the relevant regulatory framework.

Document type: Any publication that is not Article, Review Article or Book Chapter.

Timeframe: Sources that are published before 2020.

Language: Any publication language besides English.

1.3 Green Technologies trends for ESG compliance

Green technologies play a significant role in combating climate change. Green technologies encompass a broad range of solutions that aim to foster sustainability, reduce environmental impact and improve efficiency (Jayabal, 2024). Examples of green technologies are the following (Jayabal, 2024):

Renewable energy technologies: Energy that is generated by sustainable sources such as wind turbines, solar systems, hydroelectric systems, biomass, biofuels, geothermal systems, tidal energy systems, wave energy systems and renewable hydrogen production.

Energy efficiency innovations: Technologies including smart grid technologies, energy management systems and energy storage technologies, to monitor and optimize energy consumption.

Water management systems: Technologies that include water purification for water reuse and improvement of water consumption. Examples include advanced filtration technologies and harvesting rainwater.

Waste management systems: Technologies that aim to promote transforming waste into valuable resources such as raw materials or energy, in line with circular economy. Examples include waste-to-energy systems, waste hear recovery, recycling programs, and hazardous and non-hazardous waste management.

Carbon Capture and Storage (CCS) technologies: Technologies that entail capturing CO_2 emissions from the atmosphere or from industrial processes, to permanently storing them with the aim to prevent their release back into the atmosphere.

Green building technologies: Technologies that aim to reduce the environmental impact of the construction and the operation of buildings, including energy efficiency design, green roofs and the use of sustainable materials.

Sustainable Transportation: Technologies used in transportation that decrease the use of fossil fuels such as electric vehicles that use rechargeables batteries, or technologies that use biofuel or low-carbon fuel.

Typically, the green technology goals of a company are outlined as part of the ESG or sustainability report.

1.4 How innovation in green technologies helps companies to meet ESG performance metrics

Innovation in green technologies plays a crucial role for companies to meet ESG performance metrics. By integrating green technologies innovation into the business strategy, the companies can effectively meet the Environmental, Social and Governance objectives. This section will cover how the adoption of green technologies innovations can support companies meeting the ESG objectives for each of the three dimensions (Environmental, Social and Governance) (Kecun Chen, 2024).

1.4.1 Innovation in Green technologies for the Environmental dimension of ESG

Innovation in green technologies impacts significantly the environmental performance of a company. Innovative solutions for renewable energy systems, energy efficiency solutions, water management systems, waste management systems, carbon capture and storage systems, sustainable buildings solutions and sustainable transportation solutions directly support in the reduction of the greenhouse gas emissions and enhance resource efficiency and as a result enables a company to comply with the sustainability requirements of the regulatory framework (Liang et al., 2022; Mneimneh et al., 2023).

Innovative improvements in renewable energy systems has enabled an extensive implementation of those solutions globally, replacing the conventional power generation plants that use fossil fuels, which directly contributes to the transition to clean energy (Liang et al., 2022; Muhire et al., 2024). Innovative green hydrogen solutions have shown promising results in decreasing CO_2 emissions and other harmful pollutants for energy

intensive industries (Voglar & Likozar, 2024). Energy efficiency innovations, such as smart grids, advanced energy management systems that use Artificial Intelligence (AI) and advanced energy storage systems improve significantly the resource utilization and drive the reduction on energy consumption and subsequently carbon emission reduction. (Muhire et al., 2024). Innovative circular economy models, close-loop economic models that promote sustainability via recycling, reuse, remanufacturing and refurbishment help companies to eliminate waste and minimize the amount of resources used, and comply with the environmental dimensions of ESG (Popescu et al., 2022).

The integration of green technology innovations into the corporate strategy can create a ripple effect among the companies of the industry, that try to gain a competitive advantage in the market, which can be a catalyst for a sustainable future (Jayabal, 2024; Mneimneh et al., 2023).

1.4.2 Innovation in green technologies for the Social dimension of ESG

Innovation in green technologies contributes to meeting the Social Dimension of the ESG performance metrics. Green technologies innovative solutions require a significant investment for research and development that is undertaken by specialized personnel, therefore, green technologies innovations drive significant growth in jobs creation, economic growth and further benefits for the local communities where the green solution takes place (Jayabal, 2024).

Social value is generated through corporate social responsibility (CSR) that drives inclusive innovation, which incorporates services and products that can be available to underserved regions (Kecun Chen, 2024).

Social innovation refers to the development and deployment of solutions that address social and environmental issues to contribute to sustainable development and solutions that satisfy social needs. Innovation in green technologies and social innovation intersect with the aim to promote sustainable solutions, products and services that not only have a positive environmental impact, but also foster community empowerment (Popescu et al., 2022). For example, distributed renewable energy innovations provide clean and economic energy on remote regions, where the clean power resources can be harvested, in addition to enabling economic growth of the area, addressing income inequalities as part of the energy justice (Muhire et al., 2024; Popescu et al., 2022).

1.4.3 Innovation in green technologies for the Governance dimension of ESG

The adoption of green technology innovations contributes to meeting the governance dimension requirements of the ESG objectives, by practicing transparent and ethical practices (Ruan et al., 2024). For example, the implementation of energy efficiency innovative solutions, minimizes the unnecessary consumption of resources and environmental degradation (Jayabal, 2024; Popescu et al., 2022).

Furthermore, investing in green technology innovations helps companies anticipate environmental and sustainability regulation related risks, which is aligned with the governance principles of long-term planning and risk management and mitigation. In addition, the adoption of innovative green solutions demonstrates the company's commitment to sustainable practices increasing stakeholders' trust and investors' confidence (Ruan et al., 2024).

1.5 Stakeholder influence on green technologies' adoption

The role of the stakeholders, including investors, policymakers, communities, employees and customers, has become pivotal in green technologies strategies adoption. Companies that show stakeholders and market orientation on ESG matters demonstrate market intelligence, which strengthens the firm's strategic position, competitive advantage and enhanced performance. In addition, this orientation has been associated with an improved decision-making process and a harmonized relationship with the relevant stakeholders (Stocker et al., 2021).

Wieczorek-Kosmala et al., (2021) advocate that stakeholders' pressure is a strong driver for the performance on sustainability and governance transparency for the energy firms, as a strong connection between sustainable performance and financial returns, productivity of assets, and operating profit margin is observed for the companies in the energy sector.

According to Zatonatska et al., (2024), the expectations and demand of the stakeholders has become a fundamental part of the business decision making on the sustainability targets, risk management and transparent governance practices of a firm. In addition, the increasing ESG performance of the competitors and the market demand in the sector create pressure for the firms to demonstrate their commitment to sustainable practices.

A strategic drive for the adoption of green technologies is the access to green finance that is associated with the implementation of ESG practices in the private sector. These financial incentives, including green bonds and loans, energy companies with primary focus on fossil fuels have been pivoting to renewable energy investments, energy efficiency applications and sustainable infrastructures (Zhang & Xi, 2024).

Wang, (2024) demonstrated that the investors in the Chinese energy sector tend to invest in companies with strong ESG performance. Investors show higher risk tolerance for projects that promote sustainability initiatives, as it has been observed that these types of projects are associated with increased market share and provide a competitive edge to the firm.

1.6 Most effective ESG strategies and main trends for the companies in the Energy sector

The energy sector, due to the nature of the sector, has an advantage towards the adoption of green technologies. This section will present the most effective ESG strategies for the main trends for the adoption of green technologies from companies in the energy sector, based on the existing literature.

The ESG concept includes a wide range of criteria for environmental, social and governance concepts, and not all sectors apply the same weight on the implementation of the relevant strategies and concepts (Zatonatska et al., 2024).

The 5-year period from 2020 to 2024 was marked by the post COVID-19 pandemic recovery and the Russian Ukrainian war that started in 2022, that have significantly affected the implementation of the green technologies' strategies implementation towards a sustainable transition (Csedő et al., 2022; Zatonatska et al., 2024).

According to Zatonatska et al., (2024), the environmental, social and governance concept implementation weights for the electric utilities and the Independent Power Producers (IPP) for the years 2022 and 2023 were 43%, 33% and 24% respectively, while the same weights for the Renewable Energy companies for the same years were 40%, 27% and 33% respectively. The same study discusses the increasing significance of the implementation of the transparent governance practices across all industries.

The research of Wieczorek-Kosmala et al., (2021) shows that based on the Refinitiv Eikon Datastream (formerly known as Thomson Reuters) for ESG scoring, the environment factor

(emissions, resource use and innovation) is the most significant having the highest weight, followed by the social factor (community, workforce, product responsibility and human rights), leaving as last the governance factor (corporate responsibility strategy, risk management and shareholders).

Baran et al., (2022) research shows that the environmental responsibility of an energy firm is demonstrated by measuring and adopting energy generation and transmission strategies that decrease their environmental impact, by decreasing to the minimum the use of fossil fuels and by pivoting to renewable power systems, and by implementing pollution and waste controlling systems to reduce their emission and pollution. The social responsibility of an energy firm is demonstrated by embracing close collaboration with stakeholders, by investing in the workforce welfare and training, by committing to clean energy supply and by setting a fair price for energy. The research extends the responsibilities of the energy firms on economic aspects, such as implementing cost-efficient practices, ensuring high quality of services at a fair price, guaranteeing energy supply reliability and adopting financial risk management.

Fometescu, Hategan, et al., (2024) in their research stress the importance of technological innovations and the implementation of the consumers preferences on the ESG performance of electrical utilities and energy firms. The development of energy systems that use clean resources, the implementation of smart grid systems and energy storage systems for energy efficiency enhancement and the development of innovative sustainable services and products offer a significant competitive advantage and social acceptance. In addition, climate change risk management practices to ensure energy reliability and security are crucial to for electric utilities and energy companies to excel in ESG performance and achieve or maintain the social license to operate.

Popescu et al., (2022) advocate that the focus on social innovation, circular economy models and the transition to renewable energy sources are fundamental for the reduction of greenhouse gas emissions and energy consumption, the increase in energy efficiency and resource use. Czaja-Cieszyńska & Kordela, (2023) research on the energy sector of Poland has shown that there is a dependance between the market value of the firm and their social disclosures.

1.7 Main challenges and opportunities in the implementation of existing and innovative green technologies

Existing literature has researched and presented the main challenges and opportunities in the implementation of green technologies, existing and innovative, as part of the compliance with the sustainability requirements of policy makers, investors and stakeholders.

1.7.1 Challenges

In this section the main challenges the companies faced in the implementation of green technologies are presented.

Financial constraints: The implementation of green technologies, and mainly the innovative green solutions require a high upfront investment for research, development and execution of the projects. High cost can affect negatively scaling up an innovative green technology project (Jayabal, 2024; Mneimneh et al., 2023; Ng et al., 2023; Söderholm, 2020).

Policies and regulations: The complexity in the constantly evolving regulatory frameworks and the inconsistency in regulations between different markets create obstacles in selecting the green technology business strategy of a company (Fometescu, Haţegan, et al., 2024; Jovanovič & Jovanović, 2022).

Lack of standardization: Regulatory pressure on sustainable practices is more and more eminent, however the lack of universal standards and assessment frameworks in ESG reporting and performance can create different interpretations in the ESG performance of companies (Fometescu, Haţegan, et al., 2024; Jayabal, 2024)

Stakeholders' alignment: Usually, large companies in sectors like energy sector have a wide range of activities, therefore, the alignment between investors, policymakers, internal stakeholders and communities on the company's green technologies strategy can be very challenging (Fometescu, Haţegan, et al., 2024).

Greenwashing: Researchers have raised concerns about the effectiveness and the clarity of the ESG monitoring, reporting and performance of the companies in addressing the real environmental issues. In addition, the vagueness in the evaluation of the sustainability performance of the companies and can be used to present a company "greener" than they actually are, which is known as greenwashing (Biswas et al., 2024; Foley et al., 2024).

Technological constraints and alternatives: The integration of green solutions into the existing infrastructure and using existing supply chains is one of the technological challenges the companies face in the implementation of green technologies. In addition, the close substitutes of incumbent technologies with less rigorous environmental regulations create an unfair competition for the implementation of greener solutions (Jayabal, 2024; Mneimneh et al., 2023; Söderholm, 2020; Zavarkó, 2023).

Negative media implications: It has been observed that the negative media reports on innovative green solutions, such as nuclear energy, geothermal energy and carbon capture, can negatively affect the perception of the public, resulting in creating obstacles in the implementation of these innovative solutions (Liang et al., 2022).

Scarcity of raw materials and supply chain disruptions: In 2020, COVID-19 pandemic created economic uncertainty, which led to decreased investments in innovative green technologies. Moreover, the pandemic affected the execution of green technology projects due to supply chain disruptions and investments uncertainty (Csedő et al., 2022). In addition, the war between Russia and Ukraine that started in 2022 provoked unexpected constraints in supply chains and cost increases of rare materials of high demand. The increasing concerns around energy independence particularly in mainland Europe created a reliance on conventional energy sources that are associated with high greenhouse gas emissions, such as fossil fuels (Plotkin et al., 2023; Zatonatska et al., 2024).

Workforce integration and talent retention: Innovative green solution implementation requires a workforce with specific technical expertise. Integration and retention of talent in such a competitive market is challenging (Chopra et al., 2024; Söderholm, 2020).

Climate crisis urgency: Severe environmental events created the demand for rapid decarbonization through innovative scalable green solutions. Increased weather events posed risks to the resilience green technology infrastructures and operations (Fometescu, Hategan, et al., 2024).

1.7.2 Opportunities

Even though there are some important challenges in the adoption of green technologies, the companies of the energy sector that choose to be leaders in the implementation of sustainability solutions can leverage the following opportunities.

Innovation leadership: Companies that focus on the research and development of innovative green technologies have the potential to become industry leaders, resulting in attracting investors, creating strong partnerships and enhancing brand image (Muhire et al., 2024). In addition, companies that embrace a strong innovation strategy on green technologies can gain a competitive advantage as regulatory and societal demand for sustainable solutions increases (Biswas et al., 2024).

Green financial incentives and institutional support: The companies that decide to invest in green technologies could be eligible for governmental incentives and subsidies, that are designed to incentivize sustainability solutions and renewable energy. Furthermore, these companies can have access to finance instruments such as green bonds and ESG funds, which can be used to finance the green technology projects (Foley et al., 2024; Jayabal, 2024; Mneimneh et al., 2023; Shah et al., 2023; Söderholm, 2020).

Corporate image enhancement and stakeholder engagement: The three ESG dimensions cover the metrics of the environmental sustainability and social impact performance of a company and high ESG score demonstrates the dedication of a company to these aspects. Nowadays, investors do not only evaluate the financial performance of a company, but they are also concerned about their sustainability performance and how it is communicated to the public by the organization. In addition, it has been proven that a high performance on the ESG aspects strengthens the brand reputation and recognition, social acceptance, and, more importantly, it improves the perception of the socially responsible investors towards the risk management strategy of the organization (Mneimneh et al., 2023).

Energy efficiency, resource efficiency, circular economy and cost optimization: Green technologies that follow circular economy principles to eliminate waste and minimize the amount of resources used, lead to cost optimization and new revenues from resource recovery and recycling (Söderholm, 2020). The energy efficient measures that derive from the implementation of green technologies, besides improving the environmental impact of an organization by reducing their carbon footprint, in the long run they help the company reduce their energy costs (Mneimneh et al., 2023). In addition, companies that have high ESG scores and widely adopt sustainability strategies show lowered capital cost and in addition to the improved brand reputation and increased investments, this has been associated with greater sales, revenues and returns (Mneimneh et al., 2023).

Regulatory compliance: The companies that have incorporated green technologies in their business strategy and achieve high ESG scores naturally comply with the regulatory requirements and mitigate the risk of future penalties and fees that derive from failing to align to new regulations due to continuously increasing climate change risks (Biswas et al., 2024; Mneimneh et al., 2023).

Talent attraction and retention: Research has shown that the companies with high ESG scores have a more favorable perception socially, and experience top talent attraction and retention (Fometescu, Hategan, et al., 2024; Wanyan & Zhao, 2024).

2. Secondary Research Methodology

The dissertation adopts a secondary research methodology, combining the methodological tools of thematic comparative analysis with a critical review of literature. The dissertation presents how green technologies affect the ESG performance of prominent energy companies, evaluating existing industry reports and data, corporate sustainability reports and existing literature on green technologies, innovative solutions in this sector and ESG frameworks. The comparative analysis presents how the strategic management of Energy sector companies adopts the green technologies integration and innovation to address regulatory and society demands and stakeholders' expectations.

2.1 Research Objectives

The objective of this research will be to answer the following research questions for the selected companies:

- How the ESG framework is integrated into the business strategy in the energy sector.
- How the adoption of green technologies has progressed in the years 2020 to 2023.
- What are the innovative solutions on green technologies adopted.
- What are the main challenges and opportunities the energy sector faces in the implementation of existing and innovative green technologies to meet ESG targets.

2.2 Data collection

The data for this comparative analysis for the selected companies are taken from the ESG reports, sustainability reports or integrated annual reports the companies published in the period of 2020-2023.

2.3 Tools

The results of the research will be categorized in themes and patterns, and they will be visualized using tables and graphs, using Microsoft Office applications.

2.4 Critical Review

The results of the comparative analysis will be compared to the main findings of the literature review, to identify any similarities and differences with the existing literature.

2.5 Inclusion and Exclusion Criteria for company selection

The following section demonstrates the inclusion and exclusion criteria for the selection of companies to participate in the comparison analysis.

2.5.1 Inclusion Criteria

Sector and Industries: The selected sector is Energy. Specifically, the industries that this dissertation focuses on are electricity generation, distribution network operators, transmission system operators and electric utilities.

ESG Reporting: The companies must have published annual ESG reports, sustainability reports or integrated annual reports for the years 2020 to 2023, following at least one of the following ESG Frameworks: Global Reporting Initiative (GRI), Sustainability Accounting Standards Board (SASB), United Nations Global Compact (UNGN), the Task Force on Climate-related Financial Disclosures (TCFD) or European Sustainability Reporting Standards (ESRS).

ESG ratings: The companies must have a presence in the Top 5% S&P Global ESG Score for at least 3 years in the period 2020-2024, to demonstrate the solutions the sustainability leaders of the sector have adopted (S&P, 2020, 2021, 2022, 2023b, 2024b).

Financial Performance: The selected companies must have a continuous appearance in Dow Jones Sustainability Index list for the years 2022-2024(S&P, 2022, 2023a, 2024a).

2.5.2 Exclusion Criteria

Sector and Industries: Companies that are not part of the selected sector and industries, as presented in the Inclusion Criteria section.

Lack of public ESG reporting: Companies that show poor performance in ESG reporting or sustainability reports as presented in the Inclusion Criteria section.

Low ESG scores: Companies that show poor performance on their ESG scores. The dissertation focuses on the sustainability leaders of the sector.

Poor Financial stability: Companies that show poor financial performance, according to the requirements of the Inclusion Criteria section. Financial stability is important to ensure that the sustainability initiatives can be implemented.

Parent company and Subsidiaries: In case the parent company and one or more subsidiaries are selected based on the inclusion criteria, only the parent company will be included in the comparison, as the subsidiaries are part of the performance evaluation of the parent company.

2.5.3 Selected companies for comparative analysis

The implementation of the above inclusion and exclusion criteria leads to the selection of the following companies for the comparative analysis of the present dissertation.

Company	***Headquarters***	***DJIS***	***Top 5% S&P Global CSA Score***				
		2022-2024	***2020***	***2021***	***2022***	***2023***	***2024***
Acciona	Spain	✓	✓	✓	✓	✓	✓
EDP	Portugal	✓	✓	✓	✓	×	×
Enel[1]	Italy	✓	✓	✓	✓	✓	✓
Engie	France	✓	✓	×	✓	×	✓
Hera	Italy	✓	×	✓	✓	✓	✓
Iberdrola	Spain	✓	✓	✓	✓	✓	✓
Redeia[2]	Spain	✓	✓	✓	✓	×	×
Terna	Italy	✓	✓	✓	✓	✓	✓

Table 1 Selected companies for comparative analysis[3]

[1] Based on the Inclusion criteria, besides the parent company Enel S.p.A, one subsidiary, Endesa S.A., also was selected. However, based on the Exclusion criteria for parent company and subsidiaries, only Enel S.p.A is selected for the companies' comparison.

[2] In 2022 Red Eléctrica de España rebranded to Redeia.

[3] Legend: ✓: Company meets the requirement - ×: Company does not meet requirement - ✓: Company also appeared in the Top 1% S&P Global CSA Score list for the relevant year.

2.6 Methodological limitations

This MBA dissertation adopts a secondary research methodology, combining the methodological tools of thematic comparative analysis with a critical review of literature. Although this is a valid approach when primary data is not accessible, from a methodological perspective there are certain limitations. The use of secondary data that is publicly available, without access to primary data and internal company reports, introduces accuracy limitations due to potential gaps, as well as limitations in availability of information. Another limitation that derives from the use of secondary data is the lack of objectivity. The annual sustainability and ESG reports the companies publish as strategically created to enhance brand image and reputation management. Therefore, these corporate self-assessment tools can be subject to presenting an overly positive corporate narrative and are criticized for greenwashing.

Inconsistencies in reported information among the selected companies, that arise from the lack of a common ESG reporting framework, introduce limitations to the comparative and thematic analysis. In addition, as the research focuses on a limited number of companies of the top sustainability performers of the Energy sector, the generalization of the findings on other companies of the sector is restricted. Finally, the literature review of the ESG metrics and scoring is limited to the available information of the ESG reporting frameworks, therefore there may be exclusion of other relevant dimensions for the ESG performance of the selected companies.

Despite the above limitations, the dissertation provides valuable comprehension of how the strategic management of the companies within the Energy sector is affected by regulatory frameworks on sustainability and the sustainability demands of stakeholders and communities.

3. Comparative Analysis

For each of the selected companies, and based on their ESG reports, sustainability reports or annual integrated reports publish in the period of 2020-2023, the comparative framework will be the following:

Theme	*Key Variables*
Environmental goals	Key environmental commitments
Green Technologies adoption	Types of green technologies
Innovation	Types of innovative solutions
Challenges & Opportunities	Regulations, Communities, Funding, Stakeholders
Key Trends	Key trends in green technology implementation

Table 2 Comparative Framework

3.1 Acciona S.A.

Acciona, a Spanish multinational conglomerate that focuses on the development and the management of sustainable infrastructures specialized in renewable energy, water management and transportation infrastructures, has consistently showcased their strong commitment to green technologies, as it is depicted in their annual sustainability reports for the years 2020-2023. The information in this section is sourced from Acciona's annual sustainability reports for the years 2020-2023, the sustainability policy, the policy book, and the risks and opportunities report available on their official webpage (Acciona S.A., 2018a, 2018b, 2020, 2021, 2022c, 2022b, 2022a, 2023).

3.1.1 Integration of ESG into business strategy

According to the annual sustainability reports of Acciona, the company integrates the ESG principles into their business strategy through their five-year Sustainability Master Plans (SMP), which is a strategic roadmap of the actions the company takes on sustainability, and through their corporate policies.

For the environmental component of ESG, based on the SMP of 2015-2020, Acciona had as a target the company to be carbon neutral, which was achieved in 2016. The SMP for the years 2021-2025 states that Acciona aims to be “Planet Positive” with net-positive environmental impact trough “Exponential Leadership”, with the focus being on

authenticity, transformative sustainable innovation, transparency and governance, while the core principle is sustainability. Acciona aims to be an Environmental leader to achieve their Net Zero for Scope 1 and Scope 2 emissions target by 2040, and Net Zero for Scope 1, 2 and 3 emissions by 2050 and invests in four pillars to "regenerate the planet": transition to decarbonization, biodiversity projects, zero-waste projects, and water sustainability projects.

Regarding the social component of ESG principles, Acciona commits to be "People Centric" through ethical practices implementation, continuous improvement on diversity and inclusion and investment on socially impactful projects.

In the part of governance, Acciona included specific KPIs for the executive leadership to promote accountability in the implementation of the sustainability targets of the company. Moreover, the sustainability efforts of the company are monitored and managed by the Board's Sustainability and Audit Committee, to ensure that the ESG objectives will not be neglected, but instead they will be integrated into the company's business strategy. The company follows the EU Taxonomy standards, CSRD and the UN SDGs, and for sustainability reporting Acciona follows the IFRS principles and the TCFD for climate risk management.

3.1.2 Green technologies adoption in 2020-2023

The green technologies Acciona adopted since 2020 are: renewable energy, energy efficiency, water management, waste management, carbon capture and storage, green buildings and sustainable transport. Detailed information is available in Appendix A.

In the period under evaluation, Acciona consistently advanced in green technologies by integrating digital technologies and innovative sustainable solutions across all operations. In 2020, Acciona set the groundwork for the integration of digital innovative solutions into their operation. AI-driven optimizations for construction optimization, advanced methods in manufacturing and blockchain technology adoption for renewable energy transactions were the main characteristics for that year. In 2021, Acciona continued with the enhancement on the renewable energy management of their assets, expanding in energy storage solutions and progressing in the digital monitoring and AI-based operational efficiency optimization. Circular economy played an important role in waste management and green buildings. In 2022, Acciona demonstrated significant progress in green hydrogen

generation and further progressed in energy efficiency solutions such as hybridization of renewable energy plants with energy storage, in IoT-driven real time monitoring and for dynamic energy management and in AI-driven energy efficiency optimization. In sustainable transportation, Acciona deployed the Vehicle-to-Grid (V2G) innovative solution for bidirectional charging. In 2023, Acciona increased further the capacity of their renewable energy assets and optimized further their operational efficiency through hybridization with energy storage and using AI and IoT solutions for predictive maintenance and optimized operation.

3.1.3 Green technologies innovation

One of the main targets of Acciona for the period 2020-2023 was to be recognized as sustainability innovation leader. The company invested heavily in Research, Development and Innovation (R&D&I) and these investments placed Acciona in a high ranking both in Spain and in Europe. Acciona's innovation efforts on green technologies since 2020 were focused on: renewable energy, energy efficiency, water management, waste management, carbon capture and storage, green buildings and sustainable transport.

The most notable innovative green technologies Acciona adopted during the 2020-2023 period are:

- In 2020 Acciona developed the first floating PV plant that was integrated into the Spanish electrical grid.
- In 2021 Acciona developed the first energy storage plant in Spain to use recycled EV battering, as part of the circular economy practices the company implements.
- In 2022 Acciona, along with Enagás, developed the first green hydrogen industrial plant in Mallorca, a "green hydrogen ecosystem" for energy storage solutions, in line with the EU Hydrogen Strategy and the Spanish government "Hydrogen Road Map", which was inaugurated.
- In 2021 Acciona designed and in 2022 inaugurated the first network in Spain for electric vehicle bidirectional charging (Vehicle-to-Grid).
- In 2023 Acciona implemented AI-driven optimization to a desalination plant to reduce chemical usage and improve energy efficiency.
- In 2023 Acciona implemented AI-driven water network optimization for increased efficiency and failure detection.

- In 2023 Acciona inaugurated one of the largest grid-scale energy storage facility in the USA, to provide grid efficiency and assist in grid reliability.

More details on the innovative green technologies Acciona adopted from 2020 to 2023 can be found in Appendix B.

3.1.4 Challenges and Opportunities in the implementation of green technology and innovation

Acciona encountered several challenges in the implementation of green technologies from 2020 to 2023 including the limited reaction time for the implementation of the green technologies due to climate crisis and energy transition urgency, the extreme weather events that posed risks to the green technology infrastructures, the geopolitical instability, the scarcity of raw materials and supply chain disruptions due to the pandemic, the rising inflation and the global economic volatility and market dynamics mainly after 2022, the regulatory framework uncertainty and the complexity of the sustainability reporting standards, the significant initial costs for innovative solutions and technical barriers for the integration of the green technologies to the existing infrastructure, the workforce integration and talent retention and the challenges in stakeholders' alignment in defining the green technologies strategies.

On the other hand, Acciona benefited from the opportunities that derive from the implementation of green technologies, including the expansion in renewable energy portfolio due to increased demand, the technological advancements that increased efficiency, the institutional support, the green bonds and the favorable sustainability linked financing, the benefits of adopting circular economy principles, the expansion into new and emerging markets as well as the enhanced brand reputation as innovation leader and stakeholder engagement and collaboration.

3.1.5 Key trends and environmental indicators in 2020-2023

The key trends in green technologies for Acciona in the period 2020-2023 can be summarized as follows:

Green technologies innovation leadership and digitalization: Acciona centered on gaining recognition as sustainability leader, by focusing on innovative solutions such as new energy solutions (green hydrogen technologies, advanced storage solutions, floating wind and

photovoltaic technology) operational efficiency and energy consumption optimization through AI and IoT integration.

Renewable energy expansion and diversification: Acciona consistently expanded on their existing renewable energy portfolio (wind, solar, hydroelectric and biomass), while working on portfolio diversification with the green hydrogen production projects.

Circular economy models: Acciona set an ambitious and clear plan for decarbonization of the emissions of the company for all their processes, through renewable energy solutions, integration of circular economy practices, waste minimization, and implementation of blockchain for renewable energy sources traceability.

Strategic Growth: Acciona, with a presence in more than 40 countries, invested in strategic growth and strengthened its presence in emerging markets in Latin America, Asia and Africa, leveraging green policy initiatives and renewable energy demand.

The following table presents the Environmental key indicators as per the annual sustainability reports of Acciona.

Environmental indicators	***2020***	***2021***	***2022***	***2023***
GHG emissions Scope 1 and Scope 2[4](millions tCO_2e)	0.206	0.312	0.299	0.349
GHG emissions Scope 1, Scope 2 and Scope 3[5](millions tCO_2e)	2.22	2.75	3.06	6.22
Renewable installed capacity (GW)	10.69	11.25	11.83	13.53
Generation from renewable resources (%)	75	75	80	71
Total recovered waste (%)	77	87	77	83
Water consumption (hm^3)	4.7	5.0	6.8	8.3

Table 3 Environmental key indicators – Acciona

3.2 EDP - Energías de Portugal, S.A.

EDP Energías de Portugal (EDP) is a multinational energy company that operates in the electricity generation, electricity distribution, electricity supply, renewable energy projects development and natural gas distribution. The information in this section is sourced from EDP's annual sustainability, ESG and integrated annual reports for the years 2020-2023,

[4] Scope 1 (direct) and Scope 2 location-based method (indirect) emissions.
[5] Scope 1 (direct) and Scope 2 location-based method (indirect) and Scope 3 emissions.

available on their official webpage (EDP S.A, 2020, 2021b, 2021c, 2021a, 2022b, 2022a, 2023).

3.2.1 Integration of ESG into business strategy

Based on the annual sustainability reports and ESG reports of the company, EDP has deeply integrated the ESG principles, risks and opportunities into the corporate strategy, aligning their operations with the global sustainability goals.

For the environmental aspects of ESG, EDP has set ambiguous goals and commitments through their 2021-2025 strategic plan. By 2025 EDP commits to become coal free, by 2030 to reach "All Green", meaning to achieve 100% renewable energy generation and by 2040 EDP committed to be Net Zero. In their ESG and sustainability reports, EDP commits to a continuous improvement in energy efficiency, waste reduction and alinement to EU taxonomy requirements.

For the social aspects of ESG, based on their ESG and sustainability reports, EDP follows the UN's Sustainable Development Goals and works towards ensuring reliable, accessible, affordable and sustainable energy for all. To accomplish their commitments, EDP contributes to job creation and collaboration with local communities to transition to a coal free energy generation.

For the governance aspects, EDP maintains lofty standards in corporate governance, with special attention to transparent and ethical practices. EDP's General and Supervisory Board has a dedicated Corporate Governance and Sustainability Committee specifically for issues related to codes of ethics, codes of conduct, strategic sustainability, corporate governance, and stakeholders' relationships and proceedings. The General and Supervisory Board, as a governing body, oversees the alignment of the firm to the recommendations of the TCFD, SASB and the Portuguese Securities Market Commission (CMVM) and their incorporation into the business decision for the relevant aspects of climate reporting, risk management and sustainability strategy. In addition, since 2022 EDP has adopted a policy on Diversity, Equity, Inclusion and Belonging.

3.2.2 Green technologies adoption in 2020-2023

The green technologies EDP adopted since 2020 are: renewable energy, energy efficiency, water management, waste management, green buildings and sustainable transport. Detailed information is available in Appendix A.

During the period under evaluation, EDP demonstrated clear progress in green technologies by diversifying their renewable energy portfolio and integrating digital technologies across all operations. In 2020, EDP focused on phasing out coal and investing in increasing their renewable portfolio. The company invested in battery storage projects and smart grid solutions to increase energy efficiency and started exploring green hydrogen technologies. In 2021, EDP consistently increased their renewables assets, mainly in wind and solar plants, and continued the investments in grid reinforcements, digitalization and further explored the green hydrogen solutions. Circular economy played an important role in waste management. In 2022, EDP focused on diversifying their green assets, by adding additional renewable energy capacity and innovative hybrid projects with more than one renewable energy source in addition to energy storage. In that year, EDP started the production of green hydrogen. In 2023, EDP continued to increase their renewable energy assets, standalone and hybrid, adding approximately 2,5GW on renewable capacity. On digitalization, EDP invested significantly in smart meters and sensors for grid monitorization, as well as AI-driven optimizations for operational efficiency and predictive maintenance.

3.2.3 Green technologies innovation

EDP's innovation efforts on green technologies since 2020 were focused on: renewable energy, energy efficiency, waste management, green buildings and sustainable transport.

The most notable innovative green technologies EDP adopted during the 2020-2023 period are:

- In 2022 in Iberia the first hybrid solar and wind park was commissioned.
- In 2022 in Brazil the first green hydrogen pilot project was developed.
- In 2023 in Alqueva was developed hybrid power plant with a 70MW floating solar project and 500MW of solar and wind power projects to hybridize hydroelectric plants are under development
- In 2023 EDP commissioned the first hybrid wind and solar projects in Spain and Portugal.

More details on the innovative green technologies EDP adopted from 2020 to 2023 can be found in Appendix B.

3.2.4 Challenges and Opportunities in the implementation of green technology and innovation

EDP encountered several challenges in the implementation of green technologies from 2020 to 2023 including the regulatory compliance risks and the exposure to litigation associated with environmental issues as a result of the regulations, the urgency to stay competitive with the constantly advancing new green technologies, the risk of facing devaluation of their technological assets due to obsolescence, the reputational risks associated with the progress of the company on the climate-related issues, the alignment of the relevant stakeholders, the scarcity of raw materials and supply chain disruptions, the significant initial costs for sustainability initiatives and the workforce integration and talent retention.

On the other hand, EDP benefited from the opportunities that derive from the implementation of green technologies, including the expansion in renewable energy portfolio due to increased demand, the diversification of their portfolio and the climate resilience, the expansion into new and emerging markets, the technological advancements, the institutional support, the green bonds and the favorable sustainability linked financing, as well as the enhanced brand reputation and stakeholder engagement.

3.2.5 Key trends and environmental indicators in 2020-2023

The key trends in green technologies for EDP in the period 2020-2023 can be summarized as follows:

Renewable energy expansion: EDP has publicly committed to becoming coal free by 2025 and to transition to 100% renewable energy by 2030. The company's focus on renewable energy is shown by the steady growth in installed capacity of renewable power plants.

Sustainability and ESG focus: EDP’s commitment to sustainable practices following the ESG principles has led to high ESG scores and ranking in many ESG indicators such as DJSI, MSCI ratings, and Sustainalytics.

Smart grids innovation: EDP is investing in the modernization of their electrical networks in Spain, Portugal and Brazil, with a special focus in energy management innovations to enable energy efficiency and optimized electricity supply.

Waste management innovations: EDP invested in AI and machine learning for predictive maintenance, waster sorting and closed loops circular economies for solar panels and wind turbines particles recycling.

The following table presents the Environmental key indicators as per the annual sustainability or ESG reports of EDP.

Environmental indicators	*2020*	*2021*	*2022*	*2023*
GHG emissions Scope 1 and Scope 2[6](million tCO_2e)	9.9	10.6	9.9	4.6
GHG emissions Scope 1, Scope 2 and Scope 3[7](millions tCO_2e)	21.5	20.9	19.2	12.7
Renewable installed capacity (GW)	18.67	19.62	20.74	22.77
Generation from renewable resources (%)	74	75	74	87
Total recovered waste (%)	49	63	86	96
Water consumption (hm^3)	14.97	16.25	14.8	5.43

Table 4 Environmental key indicators – EDP

3.3 Enel S.p.A.

Enel, an Italian multinational energy company, operates across the entire electricity value chain, from generation to distribution and advanced energy services. Enel is committed to energy transition efforts, leveraging renewables, smart grids, and digitalization to drive efficiency and sustainability. The information in this section is sourced from Enel Group's annual sustainability reports for the years 2020-2023 available on their official webpage (Enel S.p.A., 2020, 2021, 2022, 2023).

3.3.1 Integration of ESG into business strategy

Based on the annual sustainability reports of Enel group for the years 2020-2023, the company has deeply integrated the ESG principles, risks and opportunities into the corporate strategy, aligning their operations with the local and global sustainability goals.

For the environmental pillar of ESG, Enel Group has committed to decarbonization by achieving net-zero emissions by 2040 and set intermediate targets to work towards phasing out the coal-fired plants by 2027, by 2030 reaching at least 80% of installed renewable

[6] Scope 1 (direct) and Scope 2 location-based method (indirect) emissions.
[7] Scope 1 (direct) and Scope 2 location-based method (indirect) emissions and Scope 3.

power capacity with an ultimate target of reaching 100% renewable energy generation by 2040. To reach these targets, Enel is focusing on grid modernization, circular economy and energy efficiency solutions to accommodate the integration of renewable energy to the electrical grid. On waste management, Enel announced in 2020 their Zero Waste initiative to maximize the material recycling and reuse.

For the social pillar of ESG, Enel Group has committed to promoting the principles of Diversity, Equity and Inclusion, with an establishment of inclusive workplace policies, with a special focus on gender diversity in the organizational structures of the firm. Regarding the workforce, Enel focuses on employee wellbeing and health & safety and reskilling and upskilling programs. Additionally, Enel is focusing on community engagement through energy access investments for underprivileged communities and e-mobility infrastructure expansion.

For the governance pillar, Enel demonstrates a strong commitment to following sustainable standards, ethical leadership with an independent Board of Directors (BoD) and transparent reporting. The company follows the EU Taxonomy standards and the UN SDGs, and for the sustainability reporting, Enel follows GRI Sustainability reporting as well as the principles of SASB, IFRS, ESRS and TCFD for climate risk management.

3.3.2 Green technologies adoption in 2020-2023

The green technologies Enel adopted since 2020 are: renewable energy, energy efficiency, water management, waste management, green buildings and sustainable transport. Detailed information is available in Appendix A.

In the period under evaluation, Enel demonstrated clear progress in green technologies to accelerate green transition for decarbonization. In 2020, Enel focused on further phasing out coal and investing in increasing their renewable portfolio. In addition, the company invested in digitalization, smart grid solutions and hybrid solutions with energy storage to increase energy efficiency. In 2021, Enel continued to decommission fossil fuel assets while consistently increasing their renewables assets. Increased focus on digitalization played a significant role in dynamic and intelligent grid management to enable renewable energy integration into the grid. In 2022, Enel reinforced their decarbonization target by shutting down key fossil-fuel power plants and by increasing the renewable energy assets, including innovative thermal storage systems. On digitalization, Enel adopted new solutions to

increase operational efficiency and resilience. In waste management, circular economy models played a significant role in improving efficiency in resource usage. In 2023, Enel continued to increase their renewable energy assets, enhanced with advanced energy storage and advancing in digitalization to ensure network stability and optimized operation. In addition, Enel explored emerging technologies such as green hydrogen.

3.3.3 Green technologies innovation

Enel's innovation efforts on green technologies since 2020 were focused on: renewable energy, energy efficiency, water management, waste management, green buildings and sustainable transport.

The most notable innovative green technologies Enel Group adopted during the 2020-2023 period are:

- Since 2020, Enel consistently expands public electric vehicles smart charging infrastructures.
- For the period of 2021 to 2023 Enel invested in the production of high-efficiency PV panels
- In 2022 the world's first thermal storage system was launched in Tuscany, to eliminate the dependance on critical raw materials.
- In 2022 and 2023 Enel invested in PV solar panels recycling.
- In 2023 Enel supported the construction of the first industrial plant in Europe for wind blades recycling.
- In 2023 Enel implemented a pilot project for zinc-based battery storage to increase efficiency in renewable energy integration into the grid.
- In 2023 Enel developed an Electra Virtual Assistant, and AI-driven platform, to assist grid workers for safety and efficiency enhancement.

More details on the innovative green technologies Enel adopted from 2020 to 2023 can be found in Appendix B.

3.3.4 Challenges and Opportunities in the implementation of green technology and innovation

Enel encountered several challenges in the implementation of green technologies from 2020 to 2023 including the scarcity of raw materials and supply chain disruptions, the significant investments needed for green technologies, the technical barriers for the integration of the

green technologies to the existing infrastructure, the limited reaction time for the implementation of the green technologies due to climate crisis and energy transition urgency that demands fast decarbonization, the regulatory framework uncertainty and the complexity of the sustainability reporting standards, the workforce integration and talent retention and the market volatility due to increasing rates and inflation of the post-pandemic era.

On the other hand, Enel benefited from the opportunities that derive from the implementation of green technologies, the expansion in renewable energy portfolio due to increased demand, the technological advancements that increased efficiency in existing and new green technologies, the digital transformation, the benefits of adopting circular economy principles, the institutional support, the green bonds and the favorable sustainability linked financing, the expansion into new markets as well as the enhanced brand reputation and stakeholder engagement.

3.3.5 Key trends and environmental indicators in 2020-2023

The key trends in green technologies for Enel in the period 2020-2023 can be summarized as follows:

Renewable energy expansion: Enel's focused on renewable energy expansion, increasing energy efficiency by using battery storage systems. In addition, significant importance for Enel is on scaling up the green hydrogen production to be used as a green alternative fuel.

Smart grid infrastructure and grid digitalization: Enel showed a special focus on smart grid infrastructure, grid digitalization and energy management, using AI-driven solutions to improve monitoring, efficiency and reliability.

Circular economy for waste management: Enel consistently implemented over the last 5 years circular economy systems for waste management, recycling, reuse and recovery.

E-mobility and charging infrastructure: Enel showed a special focus on e-mobility and charging infrastructure, including public transportation e-buses.

The following table presents the Environmental key indicators as per the annual sustainability reports of Enel Group.

Environmental indicators	*2020*	*2021*	*2022*	*2023*
GHG emissions Scope 1 and Scope 2 [8](millions tCO_2e)	49.8	55.4	57.1	37.8
GHG emissions Scope 1, Scope 2 and Scope 3 [9](millions tCO_2e)	164.5	180.9	184.8	94.3
Renewable installed capacity (GW)	45	53.4	53.6	55.5
Generation from renewable resources (%)	53.6	51	63.3	68.2
Total recovered waste (%)	65.7	85.3	84.39	85.34
Water consumption (hm^3)	20.4	43.8[10]	45.2	35.4

Table 5 Environmental key indicators – Enel

3.4 Engie S.A.

Engie is a multinational energy and services provider with a global presence and headquartered in France, that shows a strong focus on renewable energy, low-carbon solutions, and energy efficiency. Based on the information published on their official webpage, Engie is actively investing in hydrogen, battery storage, and smart infrastructure to support the transition to a sustainable energy system. The information in this section is sourced from Engie's annual integrated reports for the years 2020-2023, available on their official webpage (Engie S.A., 2021, 2022, 2023, 2024).

3.4.1 Integration of ESG into business strategy

Engie demonstrates a strategic commitment to ESG principals, integrating them into their business strategy, by implementing various initiatives in alignment with the global goals of sustainability.

For the environmental pillar of ESG, Engie has committed to achieving Net Zero Carbon by 2045 across their operations and as an intermediate step Engie has committed to a reduction of GHG emissions to 43Mt CO2 and a share of renewable energy capacities of 58% by 2030. To reach these targets, Engie is focusing on investing in solar, wind and battery storage solutions, expanding the renewable energy portfolio, while committing to ecological

[8] Scope 1 (direct) and Scope 2 location-based method (indirect) emissions.
[9] Scope 1 (direct) and Scope 2 location-based method (indirect) emissions and Scope 3.
[10] A discrepancy is observed in the values reported in the Sustainability report of 2021 (Total water consumed = 26.3 hm^3) and the value reported in the Sustainability reports of 2022 and 2023 (43.8 hm^3)

site management to reduce pollution and implementing sustainable solutions for water usage reduction, and circular economy for waste minimization.

For the social pillar of ESG, Engie has committed to promoting the principles of workplace Diversity, Equity and Inclusion, focusing on gender diversity in management roles. Regarding the workforce, Engie demonstrates a focus on employee safety and wellbeing and trainings on Energy Transition. Additionally, Engie is focusing on community engagement through expanding sustainable energy access across and globe and through creating local job openings, trainings on energy transition.

For the governance pillar of ESG, Engie demonstrates a strong commitment to following ESG associated corporate governance standards, ethical practices overseen by Engie's Board of Directors and the Ethics, Environment and Sustainable Development Committee, risk management, transparent reporting and accountability. The company follows the EU Taxonomy standards, CSRD and the UN SDGs, and for the sustainability reporting Engie follows the ESRS and the GRI Sustainability reporting as well as the principles of SASB, IFRS, and TCFD for climate risk management and Taskforce on Nature-related Financial Disclosures (TNFD) for environmental and biodiversity related risks.

3.4.2 Green technologies adoption in 2020-2023

The green technologies Engie adopted since 2020 are: renewable energy, energy efficiency, water management, waste management, green buildings and sustainable transport. Detailed information is available in Appendix A.

During the period under evaluation, Engie has consistently progressed towards their carbon neutral strategy through the implementation of green technologies. In 2020, Engie focused on further pivoting from fossil fuels towards renewable energy and green technologies. In 2021, Enel continued to increase their renewables assets while implementing green technologies with initiatives on waste and water management, as well as in green buildings and sustainable transportation. In 2022, Engie reinforced their decarbonization target by commissioning more the renewable energy assets, focusing more on energy efficiency solutions such as hybridization of renewable plants with energy storage systems, smart energy management for efficiency optimization and infrastructure improvements to increase flexibility and efficiency. In addition, Engie progressed in building strategic collaborations for green hydrogen utilization in maritime transport and freight trains. In 2023, Engie

continued to increase their renewable energy assets, enhanced with energy storage and advancing in digitalization to ensure network stability and optimized operation. Engie's efforts demonstrated a decrease in GHG emissions, reinforcing their low-carbon strategies.

3.4.3 Green technologies innovation

Engie's innovation efforts on green technologies since 2020 were focused on: renewable energy, energy efficiency, water management, waste management, carbon capture and storage, green buildings and sustainable transport.

The most notable innovative green technologies Engie adopted during the 2020-2023 period are:

- In 2020, Engie's researchers successfully produced renewable gas from non-recyclable waste.
- In 2021, Engie scaled up the renewable gas production from non-recyclable waste with the Salamandre project.
- In 2023, Engie commissioned the waste heat recovery project for a cement plant.
- In 2023, Engie presented significant results in tests for water withdraw reduction and waste generation with the innovative closed circuit reverse osmosis technology.
- In 2023, Engie launched a large-scale energy renovation project for the city of Florence, Italy.
- In 2023, Engie developed and tested an AI-driven algorithm for solar tracking optimization that increases energy efficiency.
- Over the years 2020-2023 Engie focused on green hydrogen production and transport projects.

More details on the innovative green technologies Engie adopted from 2020 to 2023 can be found in Appendix B.

3.4.4 Challenges and Opportunities in the implementation of green technology and innovation

Engie encountered several challenges in the implementation of green technologies from 2020 to 2023 including the technological barriers for the integration of the green technologies to the existing infrastructure, the significant initial investment for the implementation of sustainable solutions, the market volatility due to geopolitical instability

that imposed risks to the profitability of the projects, the regulatory framework uncertainty and the complexity of the sustainability reporting standards, the workforce integration and talent retention, the challenges in stakeholders' alignment in defining the green technologies strategies and the scarcity of raw materials and supply chain disruptions..

On the other hand, Engie benefited from the opportunities that derive from the implementation of green technologies, including the expansion in low-carbon technologies, the technological advancements and the innovative solutions that increased efficiency, the economic growth due to the competitive advantages the implementation of green technologies provides, the geographical diversification, the institutional support, the green bonds and the favorable sustainability linked financing, the strategic partnerships due to the enhanced brand reputation and stakeholder engagement and the talent attraction.

3.4.5 Key trends and environmental indicators in 2020-2023

The key trends in green technologies for Engie in the period 2020-2023 can be summarized as follows:

Renewable energy expansion: Engie demonstrated a consistent growth in their renewable energy portfolio. The energy efficiency of the renewable energy plants increased through AI-driven technology optimization as well as through hybridization with storage systems. Engie is also focused on decentralized hybrid renewable plants and microgrids development for grid flexibility.

Green Hydrogen and Biomethane production: Engie invested in green hydrogen production, in addition to the expansion of biomethane production, for industrial decarbonization and heavy transport.

Digitalization, Energy Management and Flexibility: Engie invested in AI-driven algorithms for monitoring, energy management and predictive maintenance. In addition, Engie invested in smart grid algorithms for improved efficiency and operational reliability.

The following table presents the Environmental key indicators as per the annual sustainability reports of Engie.

Environmental indicators	*2020*	*2021*	*2022*	*2023*
GHG emissions Scope 1 and Scope 2[11](millions tCO_2e)	39.2[12]	37.2[13]	30.8[14]	25.2
GHG emissions Scope 1, Scope 2 and Scope 3[15](millions tCO_2e)	189.0	175.2	202.8	158.5
Renewable installed capacity (GW)	31.2	34.4	38	42
Generation from renewable resources (%)	31	34	37	41
Total non-hazardous recovered waste (%)	76	84	80	83
Total hazardous recovered waste (%)	30	15	21	24
Water consumption (hm^3)	76.8	96	80	62

Table 6 Environmental key indicators – Engie

3.5 Hera S.p.A.

Hera is an Italian multi-utility company operating in electricity and natural gas distribution, water supply, and waste management sectors. With strong emphasis on technological innovation and the principles of circular economy, Hera develops sustainable solutions for energy efficiency and resource optimization. The information in this section is sourced from Hera's annual sustainability reports for the years 2020-2023, available on their official webpage (Hera S.p.A., 2020, 2021, 2022, 2023).

3.5.1 Integration of ESG into business strategy

Hera integrates ESG principles into corporate strategy using a structured approach to align the sustainability goals with the strategic and the operational goals of the company.

For the environmental aspects of ESG, Hera has set a target to reach carbon neutrality by 2050. To meet this goal, the company shows a strong focus on renewable energy adoption and energy efficiency solutions that also help the company to meet the GHG emission reduction targets they set for 2030 (37% decrease compared to 2019 levels). In addition, Hera follows circular economy principles on sustainable procurement, waste management and resource reuse.

[11] Scope 1 (direct) and Scope 2 (indirect) emissions. For the scope 2 emission it is not clarified whether the method used was location-based or market-based.
[12] Based on the environmental indicators presented in the 2023 Integrated report
[13] Based on the environmental indicators presented in the 2024 Integrated report
[14] Based on the environmental indicators presented in the 2024 Integrated report
[15] Scope 1 (direct) and Scope 2 and Scope 3 emissions. For the scope 2 emission it is not clarified whether the method used was location-based or market-based.

For the social aspects of ESG, Hera adopts diversity, equality and inclusion principles with a special focus on gender diversity. For the workforce, Hera focuses on continuous improvement, professional development, employee training programs, and health and safety. On the social responsibility and community engagement aspects, Hera invests in local communities and has taken initiatives to actively support local communities through financial and other support programs.

For the governance aspects of ESG, Hera ensures that the corporate business plan will be aligned with the sustainability targets of the company, by implementing a management incentive system that links managerial compensation to sustainability performance. The Board of Directors of the company oversees the ESG initiatives, the strategic path and risk management and mitigation. In addition, the Ethics and Sustainability committee ensures that the company complies with the Code of Ethics and the strict anti-corruption policy. The company follows the EU Taxonomy standards, CSRD and the UN SDGs, and for the sustainability reporting Hera follows the ESRS and the GRI Sustainability reporting as well as the principles of SASB, IFRS, and TCFD for climate risk management.

3.5.2 Green technologies adoption in 2020-2023

The green technologies Hera adopted since 2020 are: renewable energy, energy efficiency, water management, waste management, green buildings and sustainable transport. Detailed information is available in Appendix A.

During the period under evaluation, Hera demonstrated important progress in green technologies to accelerate green transition for decarbonization, in all their areas of operations. In 2020, Hera set the groundwork for the integration of advanced energy efficiency solutions across their operations, with a special focus of biomethane production through waste-to-energy efforts. In 2021 Hera focused on further increasing their renewable portfolio and integrating advanced digital tools for IoT-driven monitorization and automated control to increase operational efficiency. In 2022, Hera reinforced their sustainability targets by integrating circular economy practices in water and waste management, and further advancing in digitalization, adopting new AI-driven solutions to increase operational efficiency and predictive maintenance. In 2023, Hera increased investments in R&D on further advancements in digital transformation and sustainability initiatives. In addition, Hera continued to increase their renewable energy assets.

3.5.3 Green technologies innovation

Hera's innovation efforts on green technologies since 2020 were focused on: renewable energy, energy efficiency, water management, waste management, green buildings and sustainable transport.

The most notable innovative green technologies Hera adopted during the 2020-2023 period are:

- In 2022 Hera piloted the use of digital representation of their waste management network and using simulation tools for optimization of collection scenarios, process optimization and predictive maintenance.
- In 2022 Hera patented the "Energy Park" model, a renewable power plant that follows five pillars: renewable energy generation, protection of biodiversity, agricultural optimisation, urban park services and green communities. This model promotes the local community involvement in support of energy transition of the local community. In 2023, Hera enchanced the "Energy Park" model with digital tools for renewable generation optimization, predictive maintenance and grid management.
- In 2023 Hera implemented smart capabilities that were AI & IoT driven for the optimization of energy distribution, water distribution, waste management and energy performance optimization of green buildings .
- In 2023 Hera commissioned 1MW solar PV plant that was build on an exhausted landfill, avoiding additional soil contamination, achieving net-zero performance.

More details on the innovative green technologies Hera adopted from 2020 to 2023 can be found in Appendix B.

3.5.4 Challenges and Opportunities in the implementation of green technology and innovation

Hera encountered several challenges in the implementation of green technologies from 2020 to 2023 including the limited reaction time for the implementation of the green technologies due to climate crisis and energy transition urgency that forced the company to adjust their portfolio fast, the technological barriers for the integration of the green technologies to the existing infrastructure, the regulatory framework uncertainty and the complexity of the

sustainability reporting standards, the supply chain disruptions and the challenges in stakeholders' alignment in defining the green technologies strategies.

On the other hand, Hera benefited from the opportunities that derive from the implementation of green technologies including the competitive positioning that led to enhanced financial performance, the expansion in renewable energy portfolio, the technological advancements and the digital transformation that increased efficiency, the benefits of adopting circular economy principles, the institutional support, the green bonds and the favorable sustainability linked financing, the diversification of the portfolio that strengthens supply chain resilience, as well as the enhanced brand reputation and stakeholder engagement.

3.5.5 Key trends and environmental indicators in 2020-2023

The key trends in green technologies for Hera in the period 2020-2023 can be summarized as follows:

Digitalization and AI & IoT driven optimizations: Hera increasingly integrated digitalization solutions such as digital dashboards, IoT sensors, AI-driven analytics into their main operations: energy distribution, gas distribution, water supply and waste management, to enable real-time monitoring and optimization in operations and predictive maintenance.

Expansion in renewable energy innovative solutions: Hera invested in portfolio diversification by implementing new approaches such as agrivoltaics installations, PV plant on closed landfill site and green hydrogen production using power-to-gas principles from renewable energy generated using waste material (waste-to-energy).

Circular economy principles: Hera consistently applies circular economy principles to enhance the sustainability initiatives of the group. "Energy Park" concept combines renewable energy generation, protection of biodiversity, agricultural optimization and sustainable building practices. In addition, Hera applies the circular economy principles in the waste-to-energy plants for biomethane production, and in all the main areas of operation with the digital optimizations they apply.

The following table presents the Environmental key indicators as per the annual sustainability reports of Hera.

Environmental indicators	*2020*	*2021*	*2022*	*2023*
GHG emissions Scope 1 and Scope 2[16](millions tCO_2e)	1.031	1.028	0.937	0.936
GHG emissions Scope 1, Scope 2 and Scope 3[17](millions tCO_2e)	12.64	12.35	13.19	11.69
Renewable installed capacity (GW)	0.092	0.121	0.128	0.129
Generation from renewable resources (%)	29.9	29.5	30.5	32.3
Total recovered waste (%)	81.4	80.8	80.6	84.8
Water consumption (hm^3)	4.15	4.58	4.55	4.93

Table 7 Environmental key indicators – Hera

3.6 Iberdrola S.A.

Iberdrola is a global energy company with headquarters in Spain, operating in the areas of renewable energy, electricity distribution, energy storage and electric mobility. The Spanish multinational is actively expanding its AI-driven energy efficiency initiatives, smart grid infrastructure and green hydrogen projects to accelerate the energy transition. The information in this section is sourced from Iberdrola's annual sustainability reports for the years 2020-2023, available on their official webpage (Iberdrola S.A., 2020, 2021, 2022, 2023).

3.6.1 Integration of ESG into business strategy

Iberdrola integrates ESG principles into corporate strategy through a structured sustainability roadmap to align the sustainability goals with the strategic and the operational goals of the company.

For the environmental pillar of ESG, Iberdrola has set an ambitious target to reach carbon neutrality for Scopes 1 and 2 by 2030, and to reach net-zero emissions by 2040 across all operations. To meet these goals, the company shows a strong focus on renewable energy expansion, energy efficiency solutions, smart grids and sustainable mobility. In addition, Iberdrola implements circular economy models on sustainable supply chains, waste management and resource reuse.

For the social pillar of ESG, Iberdrola for the workforce adopts diversity, equity and inclusion principles with a focus on professional development, employee training programs,

[16] Scope 1 (direct) and Scope 2 market-based method (indirect) emissions.
[17] Scope 1 (direct) and Scope 2 market-based method (indirect) emissions and Scope 3.

and workplace safety. In addition, the company invests in digital transformation and innovation to provide customer focused services. On the social responsibility aspects, Iberdrola focuses on ensuring energy accessibility and applying sustainable supplier policies. On the community engagement aspects Iberdrola contributes through promoting STEM initiatives for students, through local communities' development projects and through corporate volunteering and social foundations.

For the governance pillar of ESG, Iberdrola focuses on accountable leadership, ethical business conduct, transparent reporting and regulatory compliance. The independent and diverse Board of Directors of Iberdrola oversees that the sustainability practices of the company are aligned to the international targets and that the company follows the Code of Ethics and the compliance policies. The company follows the EU Taxonomy standards, CSRD and the UN SDGs, and for the sustainability reporting Iberdrola follows the ESRS and the GRI Sustainability reporting as well as the principles of SASB, IFRS, and TCFD for climate risk management.

3.6.2 Green technologies adoption in 2020-2023

The green technologies Iberdrola adopted since 2020 are: renewable energy, energy efficiency, water management, waste management, green buildings and sustainable transport. Detailed information is available in Appendix A.

During the period under evaluation, Iberdrola demonstrated significant progress in green technologies with efforts to be acknowledged as a leader in the acceleration of green transition. In 2020, Iberdrola focused on further increasing their renewables portfolio, enhancing operational efficiency with energy storage systems and advanced digital solutions. In addition, Iberdrola launched emerging technologies such as green hydrogen. In 2021, Iberdrola solidified the reinforcement of their renewable energy portfolio with advanced solar and wind plants, invested in digitalization, smart grid solutions and hybrid solutions with energy storage to increase energy efficiency and resilience. In 2022, Iberdrola continued to expand the renewable energy and energy storage portfolio, advanced digitalization and smart grid solutions. In waste and water management, circular economy models played a significant role in improving efficiency in resource usage. In addition, the company launched the largest green hydrogen industrial plant in Europe and demolished the last coal plant chimney. In 2023, Iberdrola reported a significant growth in renewable assets, and most importantly in offshore wind project, both already developed and under

construction. In addition, Iberdrola expanded their investments in smart grid solutions, and AI-based solutions for operational efficiency and grid resilience improvements and predictive maintenance. On green hydrogen, the company further advanced in various projects.

3.6.3 Green technologies innovation

Iberdrola's innovation efforts on green technologies since 2020 were focused on: renewable energy, energy efficiency, water management, waste management, green buildings and sustainable transport.

The most notable innovative green technologies Iberdrola adopted during the 2020-2023 period are:

- In 2020 Iberdrola launched the largest green hydrogen plant in Europe.
- Starting in 2020 and for the following years, Iberdrola focused on AI-driven smart grid solutions and blockchain-based energy transaction solutions to increase energy efficiency, to provide predictive maintenance, and to increase integration of distributed energy systems to grid.
- In 2020 Iberdrola developed hydrogen powered bus fleet in Barcelona
- In 2021 Iberdrola developed ultra-fast EV chargers.
- In 2022 Iberdrola deployed hybrid wind-solar plants, and optimized the floating solar systems
- In 2023 Iberdrola focused on quantum computing applications for grid optimization.
- In 2023 Iberdrola introduced AI-driven wind turbines to increase efficiency.
- In 2023 Iberdrola integrated AI-driven smart charging for electric vehicles and developed onshore power supply for ports

More details on the innovative green technologies Iberdrola adopted from 2020 to 2023 can be found in Appendix B.

3.6.4 Challenges and Opportunities in the implementation of green technology and innovation

Iberdrola encountered several challenges in the implementation of green technologies from 2020 to 2023 including the scarcity of raw materials and supply chain disruptions, the challenges in stakeholders' alignment in defining the green technologies strategies, the

limited reaction time for the implementation of the green technologies due to climate crisis and energy transition urgency, the extreme weather events that posed risks to the green technology infrastructures, the significant initial costs for innovative solutions and technical barriers for the integration of the green technologies to the existing infrastructure, the regulatory framework uncertainty and the complexity of the sustainability reporting standards and the workforce integration and talent retention.

On the other hand, Iberdrola benefited from the opportunities that derive from the implementation of green technologies, including the expansion in renewable energy portfolio in existing and innovative technologies, the technological advancements and the digitization that increased efficiency, the institutional support, the green bonds and the favorable sustainability linked financing, the benefits of adopting circular economy principles, the expansion into new markets, the strategic collaborations and investment in CleanTech Startups, as well as the enhanced brand reputation as sustainability leader and stakeholder engagement.

3.6.5 Key trends and environmental indicators in 2020-2023

The key trends in green technologies for Iberdrola in the period 2020-2023 can be summarized as follows:

AI-driven grid monitoring and management & Smart grids: Iberdrola demonstrated a strong focus on advanced AI-driven solutions for improved efficiency and predictive maintenance. In addition, the company focused on smart grid digitalization solutions to increase integration of renewable energy to the grid and to increase stability and operational efficiency.

Green hydrogen expansion: Iberdrola demonstrated dedication to green hydrogen solutions for decarbonization of the industrial and transport sectors.

Advanced renewable energy technologies and energy efficiency: Iberdrola focused on delivering advanced solutions for renewable energy plants and hybrid plants integrated with battery and pumped storage for energy efficiency improvements and flexibility, using AI-driven solutions.

Sustainable mobility: Iberdrola also demonstrated a focus on the electrification of transport and expanded on EV charging infrastructure. Notably, Iberdrola developed AI-driven smart charging solutions implemented in heavy transport.

The following table presents the Environmental key indicators as per the annual sustainability reports of Iberdrola.

Environmental indicators	*2020*	*2021*	*2022*	*2023*
GHG emissions Scope 1 and Scope 2[18](millions tCO_2e)	14.97	15.37	13.81	12.34
GHG emissions Scope 1, Scope 2 and Scope 3[19](millions tCO_2e)	73.89	69.27	55.82	51.64
Renewable installed capacity (GW)	34.82	38.14	40.07	42.19
Generation from renewable resources (%)	63.2	65.4	65.94	67.09
Total recovered waste (%)	49.2	40.3	54.5	69.3
Water consumption (hm^3)	96.49	87.29	76.63[20]	79.80

Table 8 Environmental key indicators – Iberdrola

3.7 Redeia Corporación S.A. (Red Eléctrica Corporación S.A.)

Redeia (formerly Red Eléctrica de España, rebranded to Redeia Corporación in 2022) is a Spanish multinational corporation operating in power transmission, telecommunications and energy storage. Redeia is Spain's transmission system operator, responsible for development, operation and maintenance of the high voltage (HV) electricity grid. The company plays a crucial role in integrating renewable energy sources, ensuring grid stability, and advancing interconnection projects. The information in this section is sourced from Redeia's annual sustainability reports for the years 2020-2023, available on their official webpage (Red Eléctrica Corporación S.A., 2020, 2021; Redeia S.A., 2022, 2023).

3.7.1 Integration of ESG into business strategy

Redeia integrates ESG aspects into corporate strategy through targeted commitments and initiatives to align the global sustainability goals with the strategic and the operational goals of the company.

For the environmental pillar of ESG, Redeia has set a target to reach net-zero emissions by 2050, aligned with the global targets, and as intermediate targets of a 55% reduction of Scope 1 and Scope 2 emissions and 28% reduction of Scope 3 emissions by 2030. To meet these goals, the company shows a strong focus on renewable energy expansion, with an

[18] Scope 1 (direct) and Scope 2 market-based method (indirect) emissions.
[19] Scope 1 (direct) and Scope 2 market-based method (indirect) emissions and Scope 3.
[20] The sustainability report of 2023 corrected the figure of 2022.

increase in the integration of available renewable energy into the grid beyond 60%. In addition, Redeia adopts energy efficiency solutions, circular economy principles and biodiversity and natural capital conservation. Redeia also focuses on implementing solutions to minimize the environmental and visual impact of their infrastructures.

For the social pillar of ESG, Redeia adopts diversity, equity and inclusion principles for the workforce with a focus on professional development through leadership programs, employee digital transformation programs, and workplace safety, with a strict zero-accident commitment. On the social responsibility aspects, Redeia focuses on local communities' collaborations to promote social and economic development in the regions the company operates.

For the governance pillar of ESG, Redeia focuses on accountable leadership, ethical business conduct, transparent reporting, regulatory compliance and risk management. The independent and diverse Board of Directors of Redeia ensures that the sustainability principles of ESG and the international sustainability targets are incorporated into the corporate strategies. The company follows the EU Taxonomy standards, CSRD, the UN SDGs and the Climate Disclosure Standards Board (CDSB), and for sustainability reporting Redeia follows the ESRS and the GRI Sustainability reporting as well as the principles of SASB, IFRS, and TCFD for climate risk management.

3.7.2 Green technologies adoption in 2020-2023

The green technologies Redeia adopted since 2020 are: renewable energy integration, energy efficiency, water management, waste management, green buildings and sustainable transport. Detailed information is available in Appendix A.

During the period under evaluation, Redeia demonstrated significant progress in renewable energy integration efforts through grid modernization and digitalization advancements. In 2020, Redeia set the groundwork for the "green recovery" in the post-COVID era, focusing on increasing the integration of renewable energy into their transmission grid though grid modernization and energy efficiency optimizations efforts. In waste and water management, circular economy models played a significant role in improving efficiency in resource usage. In 2021, Redeia solidified the green transition efforts by implementing strategic grid interconnections, grid reinforcements and digitalized smart grid solutions to increase renewable energy integration into the grid and energy efficiency and resilience. In 2022,

Redeia continued to increase the integration of renewable energy to the grid and advanced in smart grid solutions and energy storage plants. In 2023, Redeia further increased the integration of renewable energy into the grid because of the efforts of its Renewable Energy Control Center that enhanced grid flexibility. In addition, Redeia further improved the digital AI-driven smart solutions for operational efficiency, resilience and predictive maintenance. Finally, during the period under evaluation, Redeia reinforced the circular economy principles for waste and water management, and implemented green building initiative, such as onsite renewable generation, and e-mobility solutions for its own fleet.

3.7.3 Green technologies innovation

Redeia's innovation efforts on green technologies since 2020 were focused on: energy efficiency, water management, waste management, green buildings and sustainable transport.

The most notable innovative green technologies Redeia adopted during the 2020-2023 period are:

- In 2020 Redeia developed AI-driven dynamic line rating based on meteorogical conditions to increase renewable energy integration into the grid.
- In the period 2020-2023 Redeia used geothermal power for heating and cooling in their buildings, wording towards near zero energy buildings.
- In the period 2020-2023 Redeia implemented pumped storage system for hydroelectic station, hybid with solar energy, to increase energy efficiency and water recycling.
- In 2023 Redeia designed a virtual synchronous compensator for power fluctuations stabilization in grid with high renewables penetration.
- In 2023 Redeia implemented a zero-emission floating offshore HV substation to enable wind energy transmission.

More details on the innovative green technologies Redeia adopted from 2020 to 2023 can be found in Appendix B.

3.7.4 Challenges and Opportunities in the implementation of green technology and innovation

Redeia encountered several challenges in the implementation of green technologies from 2020 to 2023 including the complexity and the urgency of energy transition, the

unpredictability of renewable energy generation compared to the conventional energy sources, the regulatory framework uncertainty and the complexity of the sustainability reporting standards, the supply chain disruptions and the scarcity of raw materials, the community acceptance and the stakeholder alignment, the rapid technological changes and the integration to the existing infrastructure, the extreme weather events that posed risks to the green technology infrastructures, the energy price volatility due to the geopolitical instability, the rising inflation and the global economic volatility that increased the operational costs, and the aging workforce and the new talent integration.

On the other hand, Redeia benefited from the opportunities that derive from the implementation of green technologies, including the expansion in transmission system infrastructure, the institutional support, the green bonds and the favorable sustainability linked financing, the technological advancements and the digitalization that increased efficiency, the strategic collaboration with Startups to accelerate digitization, the expansion into new and emerging markets as well as the enhanced brand reputation and stakeholder engagement.

3.7.5 Key trends and environmental indicators in 2020-2023

The key trends in green technologies for Redeia in the period 2020-2023 can be summarized as follows:

Expansion in renewable energy integration: One of Redeia's main substitutability targets is to increase the integration of renewable energy into the grid, including integration of distributed renewable energy. To achieve this target, Redeia invested in smart grid algorithms, demand management and AI-driven solutions.

Interconnections and enhanced grid stability and flexibility: Redeia provides grid stability and energy security, and to achieve this is investing in major interconnection projects and AI-driven grid stability solutions. In addition, Redeia develops pumped-storage projects for hydroelectric plants to increase flexibility in demand management.

Circular economy: Redeia adopts circular economy models to increase the use of recycled and reused materials to reach the target of zero waste to landfill by 2030.

The following table presents the Environmental key indicators as per the annual sustainability reports of Redeia.

Environmental indicators	*2020*	*2021*	*2022*	*2023*
GHG emissions Scope 1 and Scope 2 [21](millions tCO_2e)	0.65	0.69	0.78	0.65
GHG emissions Scope 1, Scope 2 and Scope 3[22](millions tCO_2e)	1.03	1.19	1.24	1.37
Renewable installed capacity (GW)	N/A	N/A	N/A	N/A
Generation from renewable resources (%)	N/A	N/A	N/A	N/A
Total recovered waste (%)[23]	63	88	92.7	98.4
Water consumption (hm^3)	0.027	0.035	0.036	0.035

Table 9 Environmental key indicators – Redeia

The activities of Redeia are related to the transmission of power but not the generation. Nonetheless, Redeia's efforts are directed towards increasing the integration of renewable energy into the grid. During the years 2020-2023, Redeia increased the integration of renewable energy into the grid from 59.4GW to 76GW, and from 53.8% to 61% of total installed capacity.

3.8 Terna S.p.A.

Terna is Italy's national transmission system operator, responsible for the development, operation and maintenance of the country's HV electricity grid. To enable the energy transition and to facilitate renewable energy integration into the grid, Terna is investing in digitalization, grid stability and resilience, and cross-border interconnections. The information in this section is sourced from Terna's annual integrated reports for the years 2020-2023, available on their official webpage (Terna S.p.A., 2020b, 2020a, 2021, 2022, 2023).

3.8.1 Integration of ESG into business strategy

Terna integrates ESG principles into corporate strategy by following a structured approach to align the global sustainability goals with the strategic and the operational goals of the company.

For the environmental pillar of ESG, although Terna has not set any ambitious target of reaching net-zero emissions, the company committed by 2030 to a reduction of 46% of

[21] Scope 1 (direct) and Scope 2 location-based method (indirect) emissions.
[22] Scope 1 (direct) and Scope 2 location-based method (indirect) emissions and Scope 3.
[23] The percentage represents the total waste that was recycled, recovered or regenerated.

Scope 1 and Scope 2 emissions versus the levels of 2019 and 11% reduction of Scope 3 emissions versus the 2021 levels. To meet this goal, Terna focuses on enabling the energy transition by ensuring their transmission network is a resilient and secure grid that facilitates the integration of renewable energy to the grid. For this, Terna invests in grid modernization using AI-driven and IoT-driven smart grid solutions, energy efficiency initiatives and strategic cross-border interconnections.

For the social pillar of ESG, Terna adopts diversity, equity and inclusion principles for the workforce with a focus gender equality in all levels of the organization. On the professional development of the workforce, Terna focuses on skills development through leadership programs and employee training programs. Another focus of Terna is on workplace safety, with a strict zero fatalities target, and work-life balance initiatives for the wellbeing of the workforce. On the social responsibility aspects, Terna focuses on local communities' investments and engagement to align communities' needs with the infrastructure developments. In addition, Terna enforces suppliers' compliance with ethical sourcing, labor rights and anti-discrimination policies.

For the governance pillar of ESG, Terna applies a strong framework that focuses on corporate ethics, accountable leadership, transparent reporting, regulatory compliance and sustainability risk management. The independent Board of Directors, Terna ensures that the sustainability principles of ESG and the international sustainability targets are incorporated into the corporate strategies, by also implementing a sustainability link executive compensation model. The company follows the EU Taxonomy standards, CSRD and the UN SDGs, and for sustainability reporting Terna follows the ESRS and the GRI Sustainability reporting as well as the principles of SASB, IFRS, and TCFD for climate risk management.

3.8.2 Green technologies adoption in 2020-2023

The green technologies Terna adopted since 2020 are: renewable energy integration, energy efficiency, water management, waste management, green buildings and sustainable transport. Detailed information is available in Appendix A.

During the period under evaluation, Terna demonstrated significant progress in renewable energy integration efforts through grid modernization and digitalization advancements. In 2020, Terna focused on grid reliability advancements through strategic interconnection, to

increase the integration of renewable energy into their transmission grid and decrease the use of conventional energy. In waste management, circular economy models played a significant role in improving efficiency in resource usage. In 2021, Terna focused on accelerating renewable energy integration into the grid, by progressing in strategic grid interconnections, and by enhancing digitalized smart grid solutions for real-time monitoring and predictive maintenance solutions. In 2022, Terna announced significant investments for grid upgrades and new developments to further accelerate the integration of renewable energy into the grid. In addition, Terna continued to focus on smart digital solutions for improvement in energy efficiency. In 2023, Terna made significant advancements in digitization through the implementation of IoT and AI driven monitoring and control solutions to improve grid security, resilience and operational efficiency. Significant advancements were also reported on grid infrastructure developments and further renewable energy integration into the grid.

3.8.3 Green technologies innovation

Terna's innovation efforts on green technologies since 2020 were focused on energy efficiency.

The most notable innovative green technologies Terna adopted during the 2020-2023 period are:

- In 2020 Terna worked on a pilot project for renewable energy initiatives on isolated islands, paired with energy storaga plants, to replace diesel generation.
- For the period under evaluation, 2020-2023, Terna invested in digitilization of the grid for grid monitoring, predictive maintenance and operational optimization. In 2023, Terna used AI-driven and IoT-driven smart grid technologies for real-time grid management for monitoring and predictive maintenance.
- In 2023 Terna introduced the concept of "Hypergrid" which refers to an advanced HVDC transmission technology for energy efficiency of power transmission over long distances

More details on the innovative green technologies Terna adopted from 2020 to 2023 can be found in Appendix B.

3.8.4 Challenges and Opportunities in the implementation of green technology and innovation

Terna encountered several challenges in the implementation of green technologies from 2020 to 2023 including the unpredictability of renewable energy generation compared to the conventional energy sources, the complexity and the urgency of energy transition, the rapid technological changes and the integration to the existing infrastructure, the regulatory framework uncertainty and the complexity of the sustainability reporting standards, the supply chain disruptions and the scarcity of raw materials, the competitive outlook and the urgency for innovation, the energy market disruptions due to geopolitical instability, the new talent integration and the stakeholders' alignment.

On the other hand, Terna benefited from the opportunities that derive from the implementation of green technologies, including the expansion in renewable energy integration and the expansion of transmission system infrastructure, the technological advancements and the digitalization that increased efficiency, the institutional support, the green bonds and the favorable sustainability linked financing, the strategic collaborations and partnerships, as well as the enhanced brand reputation and stakeholder engagement.

3.8.5 Key trends and environmental indicators in 2020-2023

The key trends in green technologies for Terna in the period 2020-2023 can be summarized as follows:

Smart Grid Management and Digital Transformation: One of Terna's key trends for the period under evaluation was the focus on digital transformation of the grid, using advanced platforms for real time monitoring of the grid for predictive maintenance and forecasting. Terna integrated AI-driven and IoT-driven solutions to optimize operation and energy efficiency.

Transmission grid upgrade and Advanced HVDC technology: Terna focuses on upgrading their transmission grid to increase resilience and security and facility renewable energy integration into the grid, enabling the energy transition and grid decarbonization. These efforts are reinforced by the integration of advanced HVDC technology for renewable energy integration over long distances with increased efficiency.

The following table presents the Environmental key indicators as per the annual integrated reports of Terna.

Environmental indicators	*2020*	*2021*	*2022*	*2023*
GHG emissions Scope 1 and Scope 2 [24](millions tCO_2e)	1.51	1.74	1.82	1.61
GHG emissions Scope 1, Scope 2 and Scope 3[25](millions tCO_2e)	1.94	3.29	3.44	3.79
Renewable installed capacity (GW)	N/A	N/A	N/A	N/A
Generation from renewable resources (%)	N/A	N/A	N/A	N/A
Total recovered waste (%)	95	86	91	87
Water consumption (hm^3)	0.22	0.21	0.22	0.23

Table 10 Environmental key indicators – Terna

The activities of Terna are related to the transmission of power but not the generation. Nonetheless, Terna's efforts are directed towards increasing the integration of renewable energy into the grid. During the years 2020-2023, Terna increased the integration of renewable energy into the grid from 32.5GW to 42.6GW. However, the generation from renewable resources dropped in 2022 and 2023 due to the decrease in hydroelectric production and from 38% in 2020 to 36.8% in 2023.

3.9 Thematic comparative review

This section summarizes the key results of the comparative framework. Detailed information can be found in Appendix A: Green Technologies adoption by the energy companies under evaluation and Appendix B: Green technologies innovative solution of the energy companies under evaluation.

Main areas of operation

The following table summarizes the main areas of operation for the selected companies, to allow a better comparison of the research outcomes.

[24] Scope 1 (direct) and Scope 2 location-based method (indirect) emissions.
[25] Scope 1 (direct) and Scope 2 location-based method (indirect) emissions and Scope 3.

Company	*Energy Generation*	*Electricity Transmission*	*Electricity Distribution*	*Gas Distribution*	*Water Management*	*Waste Management*	*E-mobility*
Acciona	✓	×	×	×	✓	×	×
EDP	✓	×	✓	✓	×	×	×
Enel	✓	×	✓	✓	×	×	✓
Engie	✓	×	✓	✓	×	×	×
Hera	✓	×	✓	✓	✓	✓	✓
Iberdrola	✓	×	✓	✓	×	×	×
Redeia	×	✓	×	×	×	×	×
Terna	×	✓	×	×	×	×	×

Table 11 Main areas of operation[26]

Key environmental commitments

The following table summarizes the main environmental commitments for the energy companies under evaluation.

Company	*Key environmental commitments*
Acciona	• Carbon neutral since 2016 • 60 % reduction of Scope 1 and Scope 2 emissions vs 2017 levels by 2030 • 47 % reduction of Scope 3 emissions (2017 baseline) by 2030 • Net-zero for Scope 1 and Scope 2 emissions by 2040 • Net-zero for Scope 1, Scope 2 and Scope 3 emissions by 2050
EDP	• Coal free by 2025 • 100% renewable energy generation by 2030 • Net-Zero by 2040
Enel	• 80% renewable energy generation by 2030 • 100% renewable energy generation by 2040 • Net-zero by 2040
Engie	• GHG emissions reduction to 43Mt CO_2 by 2030 • 58% renewable energy capacity by 2030 • Net Zero Carbon by 2045
Hera	• 37% GHG emissions reduction vs 2019 levels by 2030

[26] Legend: ✓: Company operates in this sector / ×: Company does not operate in this sector

	• Carbon neutral by 2050
Iberdrola	• Carbon neutral for Scopes 1 and 2 by 2030, • Net-zero emissions by 2040
Redeia	• 55% reduction of Scope 1 and Scope 2 emissions by 2030 • 28% reduction of Scope 3 emissions by 2030 • Net-zero emissions by 2050
Terna	• 46% reduction of Scope 1 and Scope 2 emissions vs 2019 levels by 2030 • 11% reduction of Scope 3 emissions vs the 2021 levels by 2030

Table 12 Key Environmental Commitments

Green technologies adopted

The following table summarizes the areas of the green technology solutions adopted by the energy companies under evaluation.

Company	*Renewable Energy*	*Energy Efficiency*	*Water Management*	*Waste management*	*CCS*	*Green buildings*	*Sustainable transportation*
Acciona	✓	✓	✓	✓	✓	✓	✓
EDP	✓	✓	✓	✓	×	✓	✓
Enel	✓	✓	✓	✓	×	✓	✓
Engie	✓	✓	✓	✓	×	✓	✓
Hera	✓	✓	✓	✓	×	✓	✓
Iberdrola	✓	✓	✓	✓	×	✓	✓
Redeia	✓	✓	✓	✓	×	✓	✓
Terna	✓	✓	×	✓	×	×	×

Table 13 Green technologies adopted[27]

Areas of green technology innovations and expenditure

The following table summarizes the areas of the green technology innovative solutions adopted by the energy companies under evaluation.

[27] Legend: ✓: Type of green technology adopted / ×: Type of green technology not adopted

Company	*Renewable Energy*	*Energy Efficiency*	*Water Management*	*Waste management*	*CCS*	*Green buildings*	*Sustainable transportation*
Acciona	✓	✓	✓	✓	✓	✓	✓
EDP	✓	✓	×	✓	×	✓	✓
Enel	✓	✓	✓	✓	×	✓	✓
Engie	✓	✓	✓	✓	✓	✓	✓
Hera	✓	✓	✓	✓	×	✓	✓
Iberdrola	✓	✓	✓	✓	×	✓	✓
Redeia	×	✓	✓	✓	×	✓	✓
Terna	×	✓	×	×	×	×	×

Table 14 Areas of green technologies innovation[28]

The following graph demonstrates the R&D&I Expenditure the companies under evaluation made for the years 2020-2023.

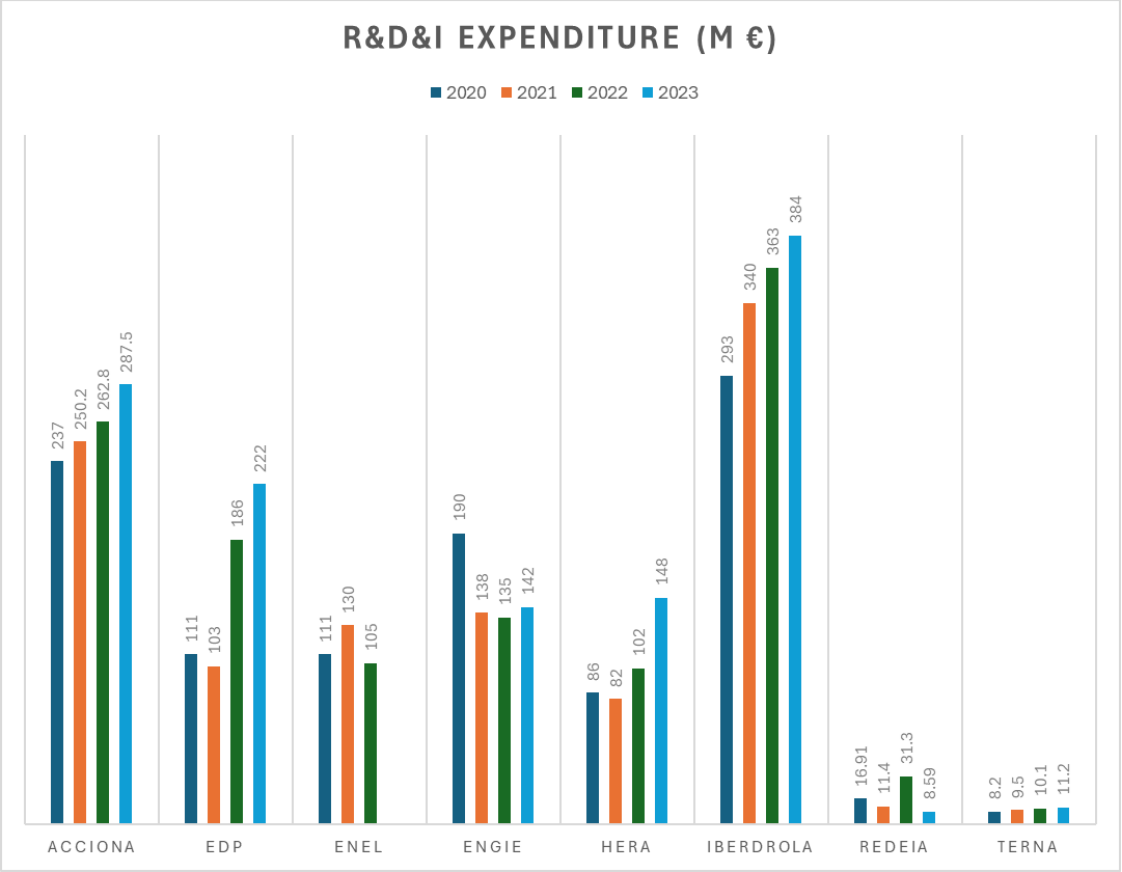

Figure 1 R&D&I Expenditure

[28] Legend: ✓: Type of green technology innovations implemented / ×: Type of green technology innovations not implemented

Challenges and Opportunities

The following table summarizes the main challenges the energy companies under evaluation faced in the implementation of green technology solutions.

Challenge	*Acciona*	*EDP*	*Enel*	*Engie*	*Hera*	*Iberdrola*	*Redeia*	*Terna*
Climate crisis/ Energy transition urgency	✓	✓	✓	✓	✓	✓	✓	✓
Scarcity of raw materials and supply chain disruptions	✓	✓	✓	✓	✓	✓	✓	✓
Global economic volatility and market dynamics	✓	✓	✓	✓	✓	✓	✓	✓
Regulatory framework uncertainty	✓	✓	✓	✓	✓	✓	✓	✓
Significant initial costs and technical barriers	✓	✓	✓	✓	✓	✓	✓	✓
Workforce Integration and talent retention	✓	✓	✓	✓	✓	✓	✓	✓
Stakeholder alignment	✓	✓	✓	✓	✓	✓	✓	✓

Table 15 Challenges[29]

The following table summarizes the main opportunities for the energy companies under evaluation due to the implementation of green technology solutions.

Opportunity	*Acciona*	*EDP*	*Enel*	*Engie*	*Hera*	*Iberdrola*	*Redeia*	*Terna*
Expansion in Renewable Energy portfolio	✓	✓	✓	✓	✓	✓	×	×
Technological advancement	✓	✓	✓	✓	✓	✓	✓	✓
Policies and institutional support	✓	✓	✓	✓	✓	✓	✓	✓
Brand reputation and stakeholder engagement	✓	✓	✓	✓	✓	✓	✓	✓
Expansion into new and emerging markets	✓	✓	✓	✓	✓	✓	✓	✓
Circular economy	✓	✓	✓	✓	✓	✓	✓	✓
Expansion in transmission infrastructure	×	×	×	×	×	×	✓	✓

Table 16 Opportunities[30]

[29] Legend: ✓: Challenge for the company / ×: Not a challenge for the company

[30] Legend: ✓: Opportunity for the company / ×: Not an opportunity for the company

Key trends in green technologies

The following table summarizes the key trends for the implementation of green technology solutions that were observed for the energy companies under evaluation.

Key trends	*Acciona*	*EDP*	*Enel*	*Engie*	*Hera*	*Iberdrola*	*Redeia*	*Terna*
Green technologies innovation leadership	✓	×	×	×	×	×	×	×
Renewable energy expansion, innovation and/or integration to the grid	✓	✓	✓	✓	✓	✓	✓	✓
Circular economy models and energy efficiency	✓	×	✓	×	✓	✓	✓	✓
Strategic Growth	✓	×	×	×	×	×	×	×
Sustainability and ESG focus	×	✓	×	×	×	×	×	×
Smart networks and digitalization (AI & IoT)	×	✓	✓	✓	✓	×	×	✓
Waste management innovations	×	✓	×	×	×	×	×	×
Sustainable mobility	×	×	✓	×	×	✓	×	×
Green Hydrogen	×	×	×	✓	×	✓	×	×
Transmission grid upgrade and interconnections	×	×	×	×	×	×	✓	✓

Table 17 Key trends[31]

Key environmental indicators

The following graphs demonstrate a graphical representation of the key environmental indicators for the companies under evaluation and for the years 2020-2023.

[31] Legend: ✓: Key trend for the company / ×: Not a key trend for the company

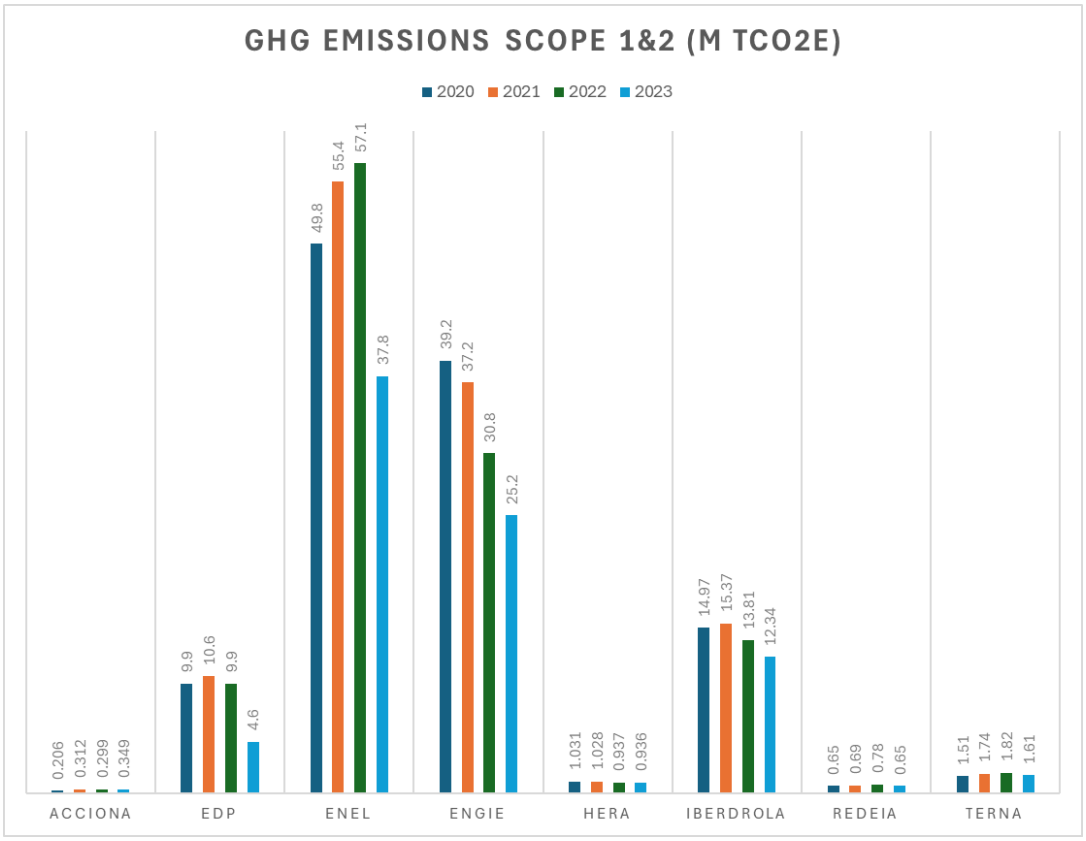

Figure 2 GHG Emissions Scope 1 & Scope 2

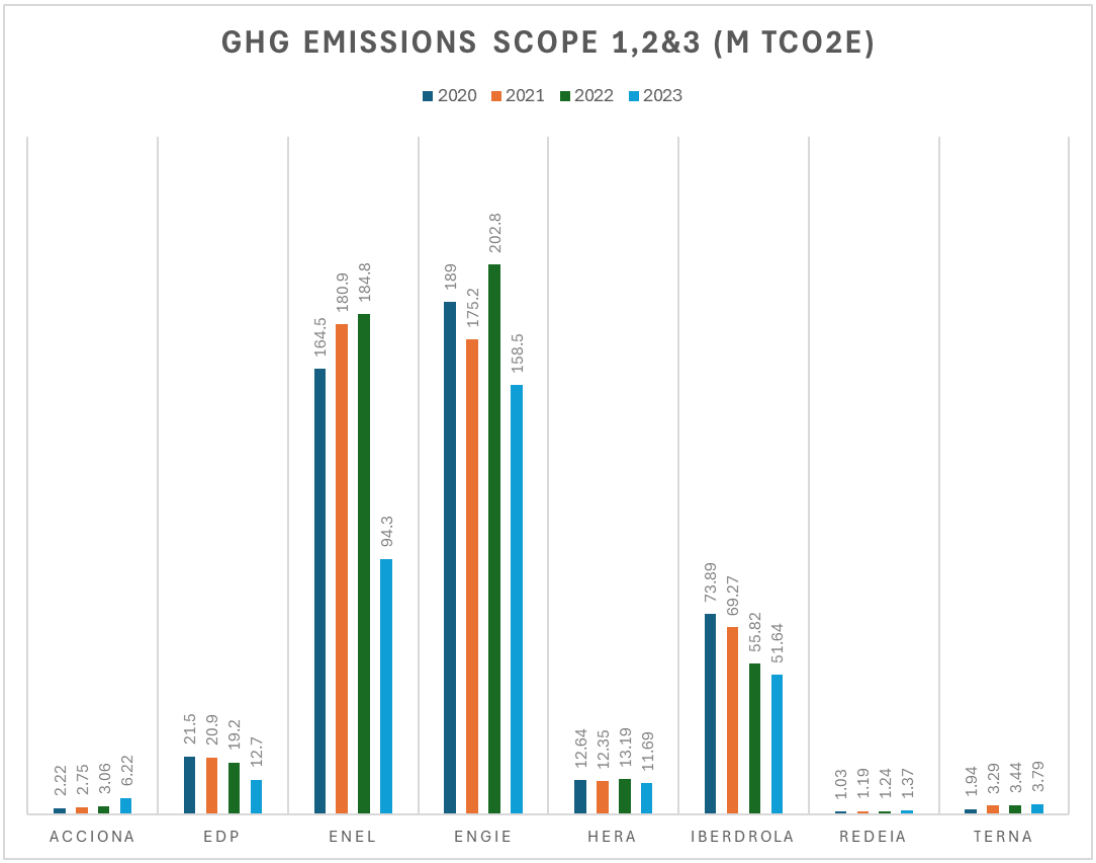

Figure 3 GHG Emissions Scope 1, Scope 2 & Scope 3

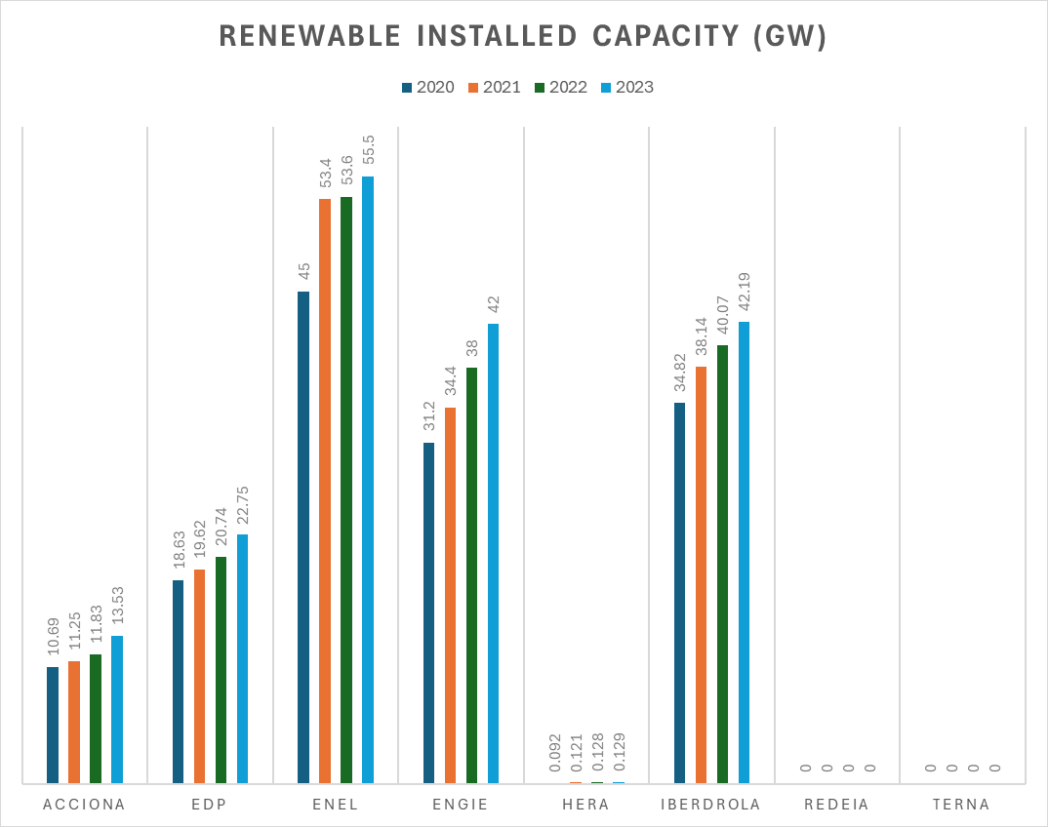

Figure 4 Renewable installed capacity

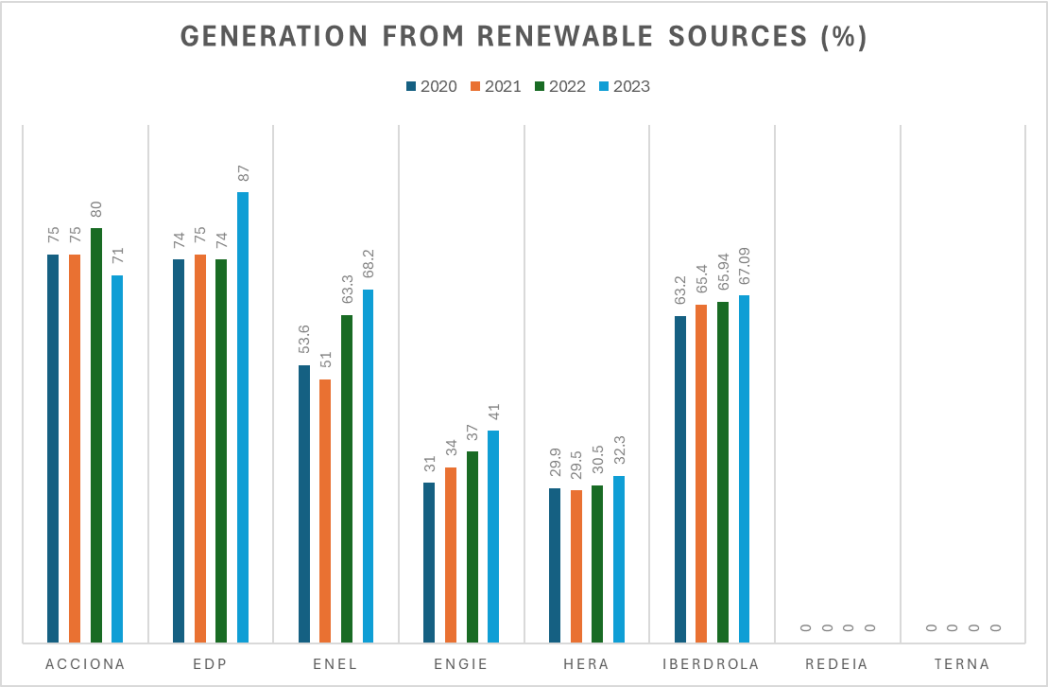

Figure 5 Generation from renewable sources

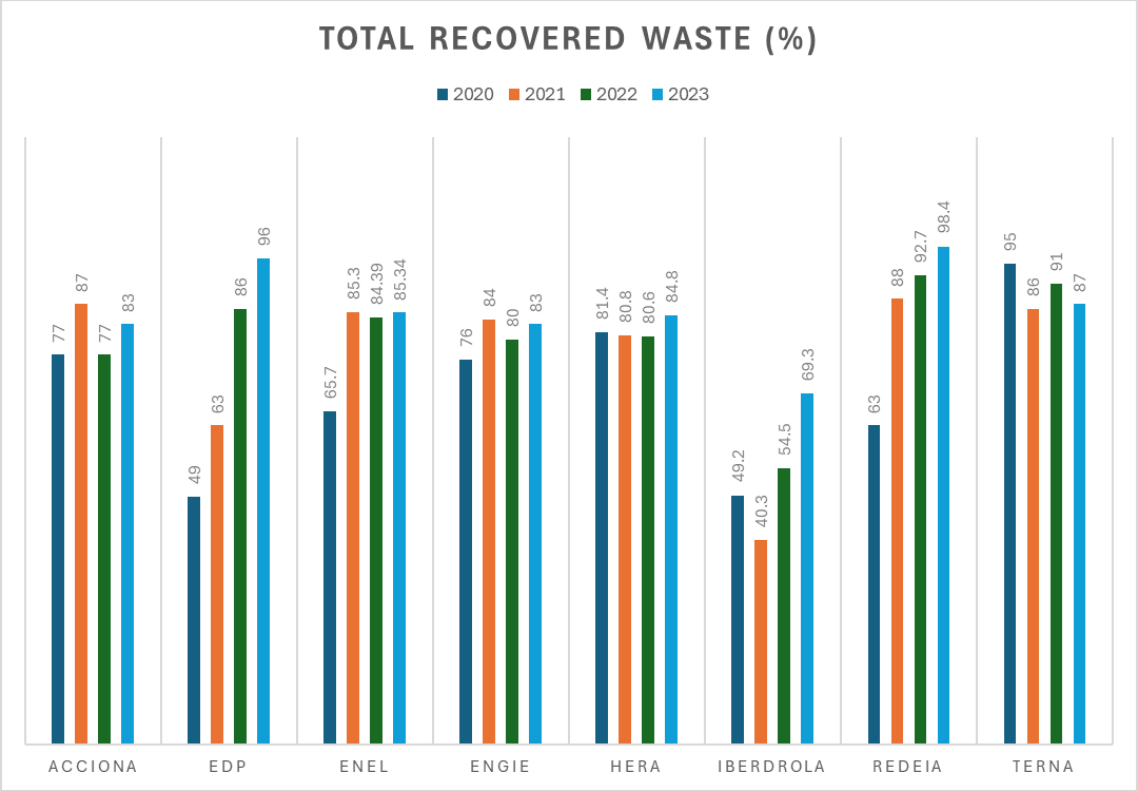

Figure 6 Total recovered waste[32]

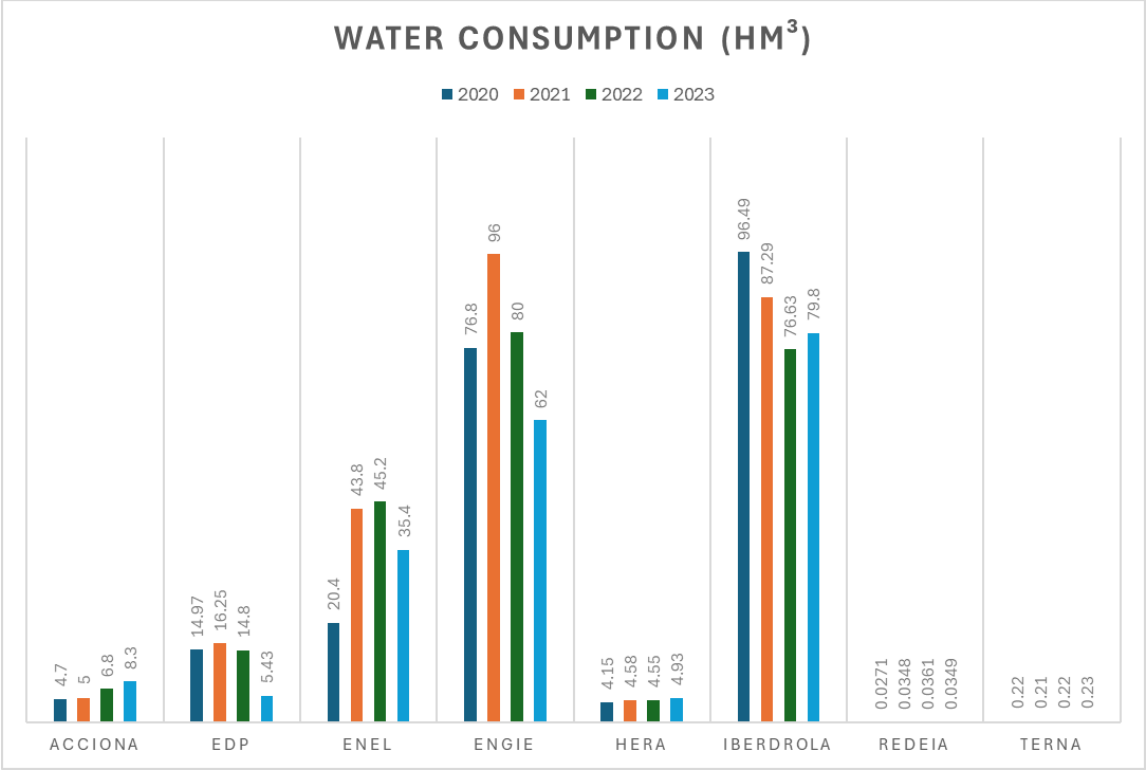

Figure 7 Total water consumption

[32] For Engie these results refer to the total non-hazardous recovered waste (%)

4. Key Findings

The key findings of this dissertation are focused on answering the following main questions:

- How has the adoption of green technologies in the energy sector evolved between 2020 and 2023.
- What are the most successful strategies employed by top energy companies to leverage green technologies for achieving ESG goals.
- How does the implementation of green technologies impact the environmental performance metrics of energy companies.
- To what extent do regulatory frameworks and societal demands influence the adoption of green technologies in the energy sector.
- What are the key challenges and opportunities in implementing green technologies to enhance ESG performance in the energy sector.

4.1 Evolution of green technologies in the energy sector in 2020-2023

Chapter 3 presented the evolution of green technologies adoption for the selected energy companies.

For the companies that are involved in energy generation, both conventional energy generation using fossil-fuels and renewable energy generation, a continuous shift from conventional power generation to renewable energy was observed. The increase in the renewable energy installed capacity was demonstrated by all these companies (Figure 4). To further support the operational efficiency of the renewable energy plants, the companies invested in hybridization solutions for energy storage.

For the companies that are involved in power distribution and transmission, an evolution of the grid infrastructure was observed. The companies of this sector focused on grid modernization through upgrades and new grid infrastructure developments, with a common target of increasing the integration of renewable energy into the grid, as well as improving grid stability and resilience.

For all companies under evaluation, a clear trend towards digitalization can be observed through continuous improvements. The digitalization efforts were implemented in many areas, such as advanced renewable energy solutions, smart grid infrastructures, energy

efficiency solutions, waste management, water management, green buildings and sustainable transportation. The digitalization involved IoT based intelligent meters and sensors for advanced monitoring and predictive maintenance, and AI-driven and data analytics solutions for intelligent control to improve operational efficiency and automation.

The energy companies under evaluation adopted circular economy practices in waste management, water management and green buildings to improve resource usage and recycling and recovery rates.

Finally, the selected companies demonstrated efforts to research and develop innovative emerging green technologies such as green hydrogen production, energy efficiency optimization solutions and in some cases carbon capture and storage solutions.

4.2 Most successful green technologies strategies employed by energy companies for ESG compliance

For the environmental pillar of ESG and based on the evaluation presented in Chapter 3 the companies focused on adopting solutions that would support them meeting their environmental commitments for GHG emissions reduction. In most energy companies under evaluation, the companies invested significantly in increasing their renewable energy assets, while in parallel decommissioning fossil-fuel conventional power plants. The transmission systems operators that do not own and operate power plants focused on grid infrastructure upgrades and reinforcements and on strategic grid interconnections to enable increased integration of renewable energy into the grid. In addition, the companies demonstrated important investments in energy efficiency solutions, such as digitalization technologies, energy storage and circular economy practices, to improve operational efficiency, resource efficiency and waste reduction. One area that received significant investment by the companies under evaluation was the innovative green technology solutions, with the research focusing on emerging green technologies, such as green hydrogen production and advanced renewable energy solutions, as well as advanced digitalization efforts. In their sustainability reports, the companies demonstrated the emissions avoided by implementing the above solutions.

On the social pillar of ESG, the companies invested in initiatives for local communities that are affected by their assets or operations, including local investments, local job creation,

specialized training, and collaborations with local companies to reduce the impact of their activities in the region. For their workforce, the energy companies focus on diversity, equity and inclusion initiatives, and most of the companies under evaluation set as a target to increase gender equality in managerial positions. In addition, the energy companies focus on the wellbeing of the workforce, promoting health and safety measures and work-life balance.

On the governance pillar, the companies under evaluation demonstrate their dedication to transparent ESG reporting, diverse and independent board composition, executive accountability, stakeholder engagement and ESG-related risk management.

These findings align mostly with the outcomes of the literature review, however, the energy-companies under evaluation presented digitalization as one of the most important tools towards meeting the sustainability goals of the company.

4.3 Key metrics of sustainability in the energy sector

The energy sector is considered a major source of global CO_2 emissions, and the companies of the sector are expected to actively participate in the GHG emissions reduction efforts. In recent years, an increasing number of companies have publicly committed to reducing greenhouse gas emissions using one or more of the following terms:

Coal-free: Refers to the elimination of coal as a source for energy production.

Carbon-Neutral: Refers to balancing a company's carbon emissions with an equivalent amount of carbon offsets or removal activities.

Net-zero: Refers to balancing a company's GHG emissions with an equivalent amount of GHG offsets or removal activities.

Carbon Negative: Refers to going beyond balancing a company's carbon emissions to removing more carbon emissions than the company emits.

Table 12 summarizes the commitments of the energy companies under evaluation. From this table, it is observed that the most common emission reduction commitment is for the company to reach net-zero emissions between 2040 and 2050, aligning with the global target of reaching net-zero emissions by 2050, according to Paris Agreement (United Nations, 2025a)

The analysis of Chapter 3 presented the evolution of green technologies adopted by the selected companies of the energy sector from 2020 to 2023 and Table 13 summarizes the results. For the seven green technologies as identified in section 1.3 Green Technologies trends for ESG compliance, it is observed that all energy companies under evaluation adopted renewable energy solutions (for the transmission grid operators, Redeia and Terna, this refers to the efforts for integrating more renewable energy to the grid), energy efficiency solutions and waste management, followed by water management, green buildings and sustainable transportation solutions, which was adopted by 7 out of 8 of the selected energy companies. The CCS solution was only adopted in 2023 by Acciona, in 2023.

In particular, on renewable energy, the companies of the electricity generation and distribution sector showed a consistent increase in renewable installed capacity (Figure 4) and an increase in the percentage of the energy generation that came from renewable sources (Figure 5), except for Acciona that presented a decrease in 2023, due to the acquisition of Nordex, a wind turbine manufacturer that was responsible for 18% of the Scope 1 and Scope 2 emissions of Acciona for that year (Acciona S.A., 2023). The transmission system operators, Redeia and Terna, do not own and operate any power plants, including renewable power plants, but both companies are working on increasing the integration of renewable energy into the grid.

Figure 6 presents the waste recovery results for the energy companies under evaluation. It is demonstrated that waste management is an important initiative for all the companies, with only one company, Terna, showing a slight decrease in the total recovered waste percentage, although keeping waste recovery in very high levels. EDP was the company with the most significant increase in total recovered waste percentage, going from 49% in 2020 to 96% in 2023.

On the water consumption reduction efforts, only 3 of the companies under evaluation managed to decrease the absolute water consumption in comparison to 2020 levels, with EDP showing the biggest decrease (~63%).

All companies under evaluation disclosed the GHG emissions for Scope 1, Scope 2 and Scope 3, according to the Greenhouse Gas Protocol standards (Greenhouse Gas Protocol, 2025). Scope 1 emissions refer to direct emissions from sources that are owned or operated by the company, Scope 2 emissions refer to indirect emissions from energy use, and Scope 3 emissions refer to indirect emissions that result from activities in the value chain of the

company, both downstream and upstream. Scope 2 emissions can be calculated using two methods, the location-based method and the market-based method. With the location-based method the Scope 2 emissions are calculated based on the average emissions intensity produced at the local network where the electricity consumption takes place. On the other hand, with the market-based method, the Scope 2 emissions are calculated according to the energy procurement choices the company made, including renewable energy purchase agreements and guarantees of origin (Greenhouse Gas Protocol, 2025).

The outcomes on the reduction of GHG emissions are presented in Figure 2 and Figure 3. It is observed that the combined Scope 1 and Scope 2 emissions decreased in 2023 in 5 of the 8 evaluated energy companies versus the 2020 levels, while for Redeia the 2023 Scope 1 and Scope 2 emissions remained at the same levels as 2020. For the combined Scope 1, Scope 2 and Scope 3 emissions, the same 5 companies showed a reduction in 2023 in comparison to 2020 levels, however for the remaining three companies the emissions increased significantly, due to the addition of the Scope 3 emissions.

4.4 Influence of regulatory frameworks and societal demand in green technologies adoption

All companies under evaluation demonstrate a strong ESG performance, as it was one of the inclusion criteria for this comparative analysis. Chapter 1.1 presents the difference between the European compulsory ESG frameworks and the voluntary global ESG frameworks. The fact that all the companies that met the inclusion criteria are European companies (Table 1) can show a direct influence of having compulsory ESG frameworks in the strategic decision making of the companies on green technologies adoption. All the energy companies under evaluation present the ESG regulatory frameworks and reporting they follow, and it can be observed that they follow not only the compulsory frameworks, but they also implement international voluntary frameworks in ESG reporting.

In the social pillar of ESG, the companies under evaluation focus significantly on the societal aspects and the integration of the societal demands into the corporate strategy. The increasing consumer pressure on environmental and sustainable practices can drive companies to adopt such initiatives. The energy companies under evaluation demonstrate their efforts to gain competitive advantage against their competitors by implementing green

technology solutions, both existing and innovative, to reinforce their brand image and the "social license to operate" (Table 16).

Societal demand and regulatory frameworks have a synergistic effect, as societal demand usually affects the regulatory frameworks in the long term. Societal demand can shape a policy, and the policy then reinforces the changes into societal behavior, closing the loop. The power of societal demand may vary regionally, and this can be also observed in the obligatory or voluntary characteristics of the regulatory framework. In regions where society demonstrates higher environmental awareness, the ESG regulatory frameworks may be more stringent, as is observed in Europe, and vice versa.

4.5 Main challenges and opportunities in green technologies implementation

The analysis of Chapter 3 demonstrates that the companies of the energy sector under evaluation all faced similar challenges and opportunities in the implementation of green technologies during 2020-2023. The challenges and opportunities also align with the outcomes of the literature review for the companies of the energy sector.

The challenges include the limited reaction time for the implementation of the green technologies due to climate crisis and energy transition urgency, the scarcity of raw materials and supply chain disruptions due to the pandemic and the geopolitical instability, the global economic volatility and market dynamics mainly after 2022, the regulatory framework uncertainty, the significant initial costs and technical barriers for the integration of the green technologies to the existing infrastructure, the workforce integration and talent retention and the challenges in stakeholders' alignment in defining the green technologies strategies.

The opportunities include the expansion in renewable energy portfolio and grid infrastructure, the technological advancements that increased the efficiency and the profits of the companies, the institutional support, the green bonds and the favorable sustainability linked financing, the benefits of adopting circular economy principles, the strategic collaborations and partnerships, the expansion into new and emerging markets as well as the enhanced brand reputation and stakeholder engagement.

Conclusions

This dissertation explores the critical role of green technology implementation for the companies in the energy sector as part of ESG compliance, with a special emphasis on green technology innovation. The key findings demonstrate that from 2020 to 2023, the companies of the energy sector worked decisively towards the energy transition for a sector will less dependency on fossil fuels and increased integration of renewable energy to the grid. Investments in innovative energy efficiency improvements, using energy storage, advance digital solutions and circular economy principles accelerate the decarbonization of the sector and lead to intelligent predictive maintenance, operational optimization and increased grid security and resilience.

The study demonstrates that the most successful ESG strategies followed by the energy companies target all three ESG pillars, environmental, social and governance, but most importantly the environmental pillar, to meet the ambitious sustainability goals they set, in accordance with the global sustainability targets. For the environmental aspects, the energy companies focus on innovative solutions to decrease their GHG emissions and to reduce their environmental footprint, such as renewable energy, energy efficiency solutions, digitalization, sustainable transportation and circular economy models in waste management, water management and green buildings. On the social aspects, the energy companies focus on initiatives for local communities that are affected by their assets or operations and on improvements on the wellbeing of their workforce. On the governance aspects, the energy companies under evaluation focus on transparent ESG reporting, diverse and independent board composition, executive accountability, stakeholder engagement and ESG-related risk management.

The implementation of green technologies does not come without challenges. The challenges the energy companies faced include the limited reaction time for the implementation of the green technologies due to climate crisis and energy transition urgency, the scarcity of raw materials and supply chain disruptions due to the pandemic and the geopolitical instability, the global economic volatility and market dynamics, the regulatory framework uncertainty, the significant initial costs and technical barriers for the integration of the green technologies to the existing infrastructure, the workforce integration and talent retention and the challenges in stakeholders' alignment in defining the green technologies strategies. Nevertheless, the companies that choose to implement green

technologies as part of their corporate strategy, take advantage of opportunities that include the expansion in renewable energy portfolio and grid infrastructure, the technological advancements that increased the efficiency and the profits of the companies, the Policies and institutional support, the benefits of adopting circular economy principles, the expansion into new and emerging markets as well as the enhanced brand reputation and stakeholder engagement.

While this research provides a robust basis for understanding the relationship between green technologies and ESG in the energy sector, there are other directions that can be explored for future research. The present research could be extended to a broader and more diverse set of companies in the energy sector, for example, including companies from the oil and gas industry. In addition, further research could be extended to evaluate long term financial impact of green technology investments. Future research could adopt a different research methodology, for example primary research, integrating relevant methodological tools such as statistical techniques to evaluate the effectiveness of each green technology to the reduction in GHG emissions.

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Appendix A: Green Technologies adoption by the energy companies under evaluation

A.1 Acciona

According to the annual sustainability reports for the years 2020-2023, the green technologies adoption of Acciona is summarized below:

	2020	***2021***	***2022***	***2023***
Renewable energy technologies	Wind	Wind	Wind	Wind
	Solar PV & thermal	Solar PV & thermal	Solar PV & thermal	Solar PV & thermal
	Hydroelectric	Hydroelectric	Hydroelectric	Hydroelectric
	Biomass	Biomass	Biomass	Biomass
	Green hydrogen	Green hydrogen	Green hydrogen	Green hydrogen
				Biogas
Energy efficiency	Energy storage systems, standalone and hybrid	Energy storage and hybridization	Energy storage and hybridization	Energy storage and hybridization
	AI based increased operational efficiency for energy consumption optimization	AI based digital innovations for operational efficiency	AI based digital innovations for operational efficiency and Smart cities	AI based digital innovations for operational efficiency
	Adjustments in biomass combustion plants	Energy efficiency equipment	Energy efficiency equipment	Energy efficiency equipment
	Energy efficiency control systems in water treatment plants	Predictive maintenance digital solutions	IoT-driven real time monitoring for dynamic energy management	Emissions reduction in biomass combustion plant

Water management	Water consumption reduction efforts	Water consumption reduction efforts	Water consumption reduction efforts	Water consumption reduction efforts
	Recycled water usage	Recycled water usage	Recycled water usage	Recycled water usage
	Water treatment	Water treatment	Water treatment	Water treatment
Waste management	Minimization of fossil fuel consumption	Reduction in waste to landfill	Waste-to-Energy in Biomass plants	Wind turbine blades recycling
	Reuse and recycle waste materials	Reuse and recycle waste materials	Reuse and recycle waste materials	Reuse and recycle waste materials
	Circular economy: Waste-to-industry	Circular economy: Waste-to-industry	Circular economy: Waste-to-industry	Circular economy: Waste-to-industry
	Waste recovery	Waste recovery	Waste recovery	Waste recovery
CCS				Pilot project for Carbon Capture in construction
Green building technologies	Energy efficiency of building through digitalization	Energy efficiency of building through digitalization	Energy efficiency of building through digitalization	Energy efficiency of building through digitalization
	Circular economy using recycled structural material	Circular economy using recycled structural material	Circular economy practices combined with modular construction techniques	Circular economy using recycled composite material and recycled steel
		Smart IoT driven monitoring in building management		Green concrete development

Sustainable Transportation	Electric and shared mobility solutions	Construction of low-carbon transport infrastructure	Smart electric vehicle charging	Electric and hybrid vehicles
	100% renewable energy usage on mobility services operation	Electric mobility and charging infrastructure	Electric and hybrid vehicles	Electric charging stations
		V2G technology	Low emission transport infrastructure	V2G technology

Table 18 Green Technologies adoption – Acciona

A.2 EDP

According to the annual sustainability reports for the years 2020-2023, the green technologies adoption of EDP is summarized below:

	2020	***2021***	***2022***	***2023***
Renewable energy technologies	Wind	Wind	Wind	Wind
	Solar	Solar	Solar	Solar PV
	Hydroelectric	Hydroelectric	Hydroelectric	Hydroelectric
	Green Hydrogen	Green Hydrogen	Green Hydrogen	Green Hydrogen
Energy efficiency	Low carbon products and services	Low carbon products and services	Low carbon products and services	Low carbon products and services
	Decentralized PV solutions	Decentralized PV solutions	Decentralized PV solutions	Decentralized PV solutions
	Energy storage	Energy storage	Energy storage	Energy storage
	Smart grids	Smart grids	Smart grids	Smart grids
	Flexibility management	Flexibility management	Flexibility management	Flexibility management
Water management	Water consumption reduction efforts	Water consumption reduction efforts	Water consumption reduction efforts	Water consumption reduction efforts

Waste management	Recycling and reuse	Circular economy strategy for waste management and recycling optimization	Circular economy for sustainable procurement	Recycling program for solar panels and wind turbine components
	Recovery of coal waste	Wind turbine blades recycling	Use of reclaimed wood	Waste recovery efforts
	Use of by-products	Predictive maintenance using machine learning	Waste recovery efforts	Renewable energy waste management
Green building technologies	Building management IoT platform	Smart metering for energy efficiency	Smart metering for energy efficiency	Digital twin approach simulation models for energy efficiency and operational improvement
Sustainable Transportation	E-mobility	E-mobility	E-mobility	E-mobility

Table 19 Green Technologies adoption – EDP

A.3 Enel

According to the annual sustainability reports for the years 2020-2023, the green technologies adoption of Enel Group is summarized below:

	2020	***2021***	***2022***	***2023***
Renewable energy technologies	Hydroelectric	Hydroelectric	Hydroelectric	Hydroelectric
	Wind	Wind	Wind	Wind
	Solar	Solar	Solar	Solar
	Geothermal	Geothermal	Geothermal	Geothermal
	Biomass	Biomass	Biomass	Biomass
	Biogas	Biogas	Biogas	Biogas
	Green hydrogen	Green hydrogen	Green hydrogen	Green hydrogen

Energy efficiency	Energy Storage integration with renewables	Energy Storage integration with renewables	Energy Storage integration with renewables	Energy Storage integration with renewables
	Smart grid technologies	Smart grid technologies	Smart grid technologies	Smart grid technologies
	Cogeneration industrial plants	Cogeneration and trigeneration industrial plants	Cogeneration and trigeneration industrial plants	Cogeneration and trigeneration industrial plants
	Smart public lighting	Smart public lighting	Smart public lighting	Smart public lighting
Water management	Water reduction in thermoelectric and renewable plants	Water reduction in thermoelectric and renewable plants	Water reduction in thermoelectric and renewable plants	Water reduction in thermoelectric and renewable plants
	Maximization of wastewater recovery	Maximization of wastewater recovery	Maximization of wastewater recovery	Maximization of wastewater recovery
	Seawater desalination for cooling	Seawater desalination for cooling	Seawater desalination for cooling	Seawater desalination for cooling
Waste management	Waste recovery and recycling	Waste recovery and recycling	Waste recovery and recycling	Waste recovery and recycling
	Reduction in the use of plastic	Battery recycling programs	Reduction in the use of plastic	Advanced waste tracking systems
	End-of-life EV chargers' sustainable disposal	End-of-life PV panels and Wind turbines recycling	End-of-life PV panels and Wind turbines recycling	End-of-life PV panels and Wind turbines recycling
	Recycling and reuse of electrical equipment	Recycling and reuse of electrical equipment	Recycling and reuse of electrical equipment	Recycling and reuse of electrical equipment
	Industrial waste recovery	Industrial waste recovery	Industrial waste recovery	Industrial waste recovery

Green building technologies	Sustainable design and construction	Sustainable design and construction	Sustainable design and construction	Sustainable design and construction
	Integration of renewable energy	Integration of renewable energy	Integration of renewable energy	Integration of renewable energy
	High efficiency buildings with integrated energy management systems	High efficiency buildings with integrated energy management systems	High efficiency buildings with integrated energy management systems	High efficiency buildings with integrated energy management systems
Sustainable Transportation	EV charging points deployment	EV charging points deployment	EV charging points deployment	EV charging points deployment
	E-Mobility	E-Mobility	E-Mobility	E-Mobility
	E-Bus deployment	E-Bus deployment	E-Bus deployment	E-Bus deployment
	Deployment of V2G systems	Smart mobility applications	E-boating and electric air mobility	E-boating and electric air mobility

Table 20 Green Technologies adoption – Enel

A.4 Engie

According to the annual integrated reports[33] for the years 2020-2023, the green technologies adoption of Engie is summarized below:

	2020	***2021***	***2022***	***2023***
Renewable energy technologies	Wind	Wind	Wind	Wind
	Solar	Solar	Solar	Solar
	Hydropower	Hydropower	Hydropower	Hydropower
	Biogas & Biomethane	Biogas & Biomethane	Biogas & Biomethane	Biogas & Biomethane

[33] Engie's integrated reports refer to the results of the previous year (i.e. the integrated report of 2021 presents the results of 2020)

	Geothermal	Geothermal	Geothermal	Geothermal
	Biomass	Biomass	Biomass	Biomass
	Green Hydrogen	Green Hydrogen	Green Hydrogen	Green Hydrogen
Energy efficiency	Energy Storage and hybrid systems	Energy Storage and hybrid systems	Energy Storage and hybrid systems	Energy Storage and hybrid systems
		Urban heating and cooling networks	Smart energy management	Hybrid heating systems
			Industrial energy optimization	Solar smart tracking algorithms
			Infrastructure improvements to increase flexibility and efficiency	Digitalization for energy management to increase operational efficiency
Water management	Water conservation efforts in water stressed regions	Water conservation efforts	Water preservation efforts	Water conservation through reverse osmosis
	Flood management with nature-based solutions	Water recycling and reuse efforts		Increased water recovery rate
		Water footprint monitoring	Water footprint monitoring	Water footprint monitoring
Waste management	Enhanced recycling processes	Hazardous waste reduction efforts	Waste heat recovery in fermentation plant	Waste heat recovery in cement plant
	Industrial waste minimization efforts	Waste reduction efforts	Waste recovery efforts	Hazardous and non-hazardous waste reduction efforts

Green building technologies	Building green renovations to increase energy efficiency	Solar PV on roofs of residential buildings	Low carbon cities	Solar PV on roofs of residential buildings
	Digital twin technology for smart buildings	Circular economy in construction	Retrofitting of high efficiency equipment and renovations	Hybrid heating systems
				City wide energy renovation project
Sustainable Transportation	Electric and hydrogen vehicle charging	Low carbon mobility (hydrogen and biomethane)	Sustainable mobility fueled by electricity, hydrogen and biogas	Sustainable mobility fueled by electricity, hydrogen and biogas
		AI driven monitoring technology for emissions reduction		E-vehicle charging points network

Table 21 Green Technologies adoption – Engie

A.5 Hera

According to the annual sustainability reports for the years 2020-2023, the green technologies adoption of Hera is summarized below:

	2020	***2021***	***2022***	***2023***
Renewable energy technologies	Biomethane	Biomethane	Biomethane	Biomethane
	Solar PV	Solar PV	Solar PV	Solar PV
	Geothermal	Geothermal	Geothermal	Geothermal
		Green Hydrogen	Green Hydrogen	Green Hydrogen
Energy efficiency	Digital monitoring systems and smart metering	Digital monitoring systems and smart metering	Integrated digital platforms	AI & IoT driven real-time analytics for

			for monitoring and control	operational optimization
	Digital control platforms in distribution networks	Digital control platforms in distribution networks	Digital twin approach for operational optimization	Enhanced digital dashboards and smart metering
		IoT-based predictive forecasting		
Water management	Water treatment plants and distribution network upgrades	IoT based water quality automated monitorization	Integrated digital platform for monitoring and control of water distribution networks	Cloud based platforms and IoT sensors for "smart water" systems
	Water quality automated monitorization	Digital dashboards for proactive management and quick response to failures	AI-driven digital twin approach for operational optimization and predictive maintenance	AI-driven analytics on failure detection and dynamic demand forecasting
	Wastewater treatment for energy use optimization and water recycling	Data analytics for predictive maintenance and failure forecasting		
Waste management	Waste-to-Energy for biomethane production	Waste-to-Energy for biomethane production	Waste-to-Energy for biomethane production	Waste-to-Energy for biomethane production
	Waste collection, sorting and separation facilities	Waste collection, sorting and separation facilities	Waste collection, sorting and separation facilities	Waste collection, sorting and separation facilities

	Waste recycling and recovery	Waste recycling and recovery	Waste recycling and recovery	Waste recycling and recovery
	Safe disposal of non-recycled and non-recovered waste	Safe disposal of non-recycled and non-recovered waste	Safe disposal of non-recycled and non-recovered waste	Safe disposal of non-recycled and non-recovered waste
Green building technologies	Advanced HVAC systems and energy efficiency insulation	Automated monitoring and control systems for energy usage optimization	Providing solutions for net-zero emissions buildings with onsite renewable energy generation	Providing solutions for net-zero emissions buildings with onsite renewable energy generation
	Sustainable design practices and construction materials	Digital platforms for optimization of HVAC and lighting systems usage and predictive maintenance	Digital platforms for energy performance optimization and predictive maintenance	Digital platforms with AI-driven algorithms for energy performance optimization of and predictive maintenance
Sustainable Transportation	Lower emission and improved fuel efficiency for service vehicles	Pilot program to study upgrading operational fleet to EV	EV and hybrid vehicles adoption and building charging points for EV	AI-driven analytics for optimization of fleet management
	Digital tools for optimization of service routes for reduction of CO_2 emissions and fuel usage	Digital tools and sensors for optimization of service routes for reduction of CO_2 emissions and fuel usage	Digital platform for fleet management for tracking, fuel usage optimization and CO_2 emissions reduction	Integration of onsite renewable generation for EV charging

Table 22 Green Technologies adoption – Hera

A.6 Iberdrola

According to the annual sustainability reports for the years 2020-2023, the green technologies adoption of Iberdrola is summarized below:

	2020	***2021***	***2022***	***2023***
Renewable energy technologies	Wind	Wind	Wind	Wind
	Hydroelectric	Hydroelectric	Hydroelectric	Hydroelectric
	Solar	Solar	Solar	Solar
	Green hydrogen	Green hydrogen	Green hydrogen	Green hydrogen
Energy efficiency	Energy storage: battery and pumped hydroelectricity	Energy storage: battery and pumped hydroelectricity	Energy storage: battery and pumped hydroelectricity	Energy storage: battery and pumped hydroelectricity
	Smart grids	AI-driven solutions for energy optimization	Smart and robust grids	Smart grids
	AI-based models for increased efficiency	Virtual Power Plants (VPP) for power demand management	AI-driven energy efficiency grid algorithms	AI driven solutions for monitoring and self-healing networks for increased efficiency
Water management	Water consumption reduction efforts	Water consumption reduction efforts	Water consumption reduction efforts	Water consumption reduction efforts
	Water reuse and water recycling	Water reuse and water recycling	Water reuse and water recycling	Water reuse and water recycling
		Optimization of ecological flow controls at hydro plants	Optimization of ecological flow controls at hydro plants	Increased use of seawater
Waste management	Circular economy for waste	Circular economy for waste	Circular economy for	Circular economy for waste

	minimizations: recycling and reuse	minimizations: recycling and reuse	waste minimizations: recycling and reuse	minimizations: recycling and reuse
	Hazardous waste treatment	Hazardous waste treatment	Hazardous waste treatment	Hazardous waste treatment
Green building technologies	Energy efficiency and green energy solutions in buildings	Smart clima for improving efficiency, insulation and decarbonization	Smart clima for improving efficiency, insulation and decarbonization	Smart clima for improving efficiency, insulation and decarbonization
		Green hydrogen for industrial building applications	Building digitalization	Circular economy for reusing buildings' material
				VPPs for energy management in buildings
Sustainable Transportation	EV charging network expansion	EV charging network expansion	Electrification of corporate fleet	Electrification of heavy transport
	Decarbonization of transportation through electrification and sustainable energy	Smart mobility through high power EV charging networks	Smart mobility through high power EV charging networks	Smart mobility through high power EV charging networks
			Hydrogen powered public transport	Smart charging integration
				Onshore power supply for ports

Table 23 Green Technologies adoption – Iberdrola

A.7 Redeia

According to the annual sustainability reports for the years 2020-2023, the green technologies adoption of Redeia is summarized below:

	2020	*2021*	*2022*	*2023*
Energy efficiency	Integration of renewables in the grid	Smart energy management for integration of renewables in the grid	Smart energy management for integration of renewables in the grid	Smart energy management for integration of renewables in the grid
	Smart grid algorithms	New grid interconnections	Smart grids for demand management	Battery storage batteries for
	Pumped storage for hydroelectric power plants	Pumped storage for hydroelectric power plants	Pumped storage for hydroelectric power plants	Pumped storage for hydroelectric power plants
	Real-time monitoring of grid's performance		Weather based real time monitoring for grid efficiency optimization	AI-driven forecasting models and cybersecurity
				Off-grid hybrid solutions for auxiliary systems of substations
				Zero-emission floating offshore HV substation
Water management	Water consumption reduction efforts	Water consumption reduction efforts	Water consumption reduction efforts	Water consumption reduction efforts
	Atmospheric water capture for cooling	Atmospheric water capture for cooling	Water efficiency measures	Water efficiency measures
Waste management	Waste reduction initiatives	Waste reduction initiatives	Waste reduction initiatives	Waste reduction initiatives
	Circular economy for recycling and reuse of materials	Circular economy for recycling and reuse of materials	Circular economy for recycling and	Circular economy for recycling and reuse of materials

			reuse of materials	
	Circular economy in supply chain	Circular economy in supply chain	Circular economy in supply chain	Circular economy in supply chain
Green building technologies	Geothermal energy for HVAC systems of own buildings	Geothermal energy for HVAC systems of own buildings	Geothermal energy for HVAC systems of own buildings	Geothermal energy for HVAC systems of own buildings
	Energy management system in its buildings	Energy management system in its buildings	Energy management system in its buildings	Energy management system in its buildings
	Solar PV for self-consumption of own buildings	Solar PV for self-consumption of own buildings	Solar PV for self-consumption of own buildings	Solar PV for self-consumption of own buildings
Sustainable Transportation	Electric and hybrid corporate vehicles fleet	Electric and hybrid corporate vehicles fleet	Electric and hybrid corporate vehicles fleet	Electric and hybrid corporate vehicles fleet
		Employee sustainable mobility initiatives	Employee sustainable mobility initiatives	Renewable powered transport operations

Table 24 Green Technologies adoption – Redeia

A.8 Terna

According to the annual integrated reports for the years 2020-2023, the green technologies adoption of Terna is summarized below:

	2020	***2021***	***2022***	***2023***
Energy efficiency	Transmission grid upgrade to accelerate renewable power integration	Transmission grid upgrade to accelerate renewable power integration	Transmission grid upgrade to accelerate renewable	Transmission grid upgrade to accelerate renewable power integration

			power integration	
	“Smart islands” for isolated grids	Advanced toll for forecasting and predictive maintenance	Digital platform enhancement for grid connection process optimization	HVDC advanced transmission technologies for large scale renewable plants
	Digital solutions for grid monitoring and operational optimization	Real-time CO_2 emissions monitoring to improve decarbonization		Digitalization for monitoring and efficient planning of renewable energy
Waste management	Waste recycling and waste recovery efforts	Waste recycling and waste recovery efforts	Waste recycling and waste recovery efforts	Waste recycling and waste recovery efforts
		SF_6 gas leakage control		

Table 25 Green Technologies adoption – Terna

Appendix B: Green technologies innovative solution of the energy companies under evaluation

B.1 Acciona

The following table summarizes the areas where Acciona has invested in innovative solutions.

	2020	***2021***	***2022***	***2023***
R&D&I Expenditure (M €)	237	250.2	262.8	287.5
Renewable energy technologies	Wind advanced technologies	Wind advanced technologies	Floating wind	Solar PV advanced technologies
	Solar PV advanced technologies- Spain's first floating PV plant	Solar PV advanced technologies	Floating solar	Portable Green hydrogen generators
	Green hydrogen	Green hydrogen	Green hydrogen: Spain's first full green hydrogen	
	Biofuels		Solar PV advanced technologies	
Energy efficiency	Energy storage and hybridization	Energy storage with recycled EV batteries	Energy storage and hybridization	Grid scale energy storage and hybridization
	Engineering methods and energy efficiency using data analytics, AI and	AI predictive maintenance	AI and IoT driven dynamic energy Management	Improvement of energy efficiency and resource management

	blockchain methods			
				Energy efficiency in vehicle engines
Water management	Digital monitoring and control for water operations	Intelligent sensors for real-time monitoring and analytics for water consumption and water quality	Enhanced digital monitoring and controls to improve efficiency	AI in water desalination and water management
Waste management	Digital controls in material usage and waste generation	Intelligent monitoring for tracking and managing waste flows	Transformation of end-of-life materials into reusable resources	Alternative renewable fuels for waste treatment facilities
				AI-driven simulations for waste flows analysis for efficiency optimization
CCS				Pilot project for Carbon Capture in construction
Green building technologies	3D concrete printing	Carbon-neutral construction processes	Hydrogen powered construction sites	Green concrete development
	Digital monitoring in building management	Natural cooling and high efficiency insulation	Green concrete development and PV glass facades	Self-sufficient buildings

		Smart IoT driven monitoring in building management	Circular economy practices combined with modular construction techniques	AI driven adaptive building management
Sustainable Transportation	Pilot project for hydrogen powered transportation	Vehicle to grid technology (bidirectional charging)	Infrastructure safety using robotic platform	Green hydrogen powered generators
	3D printing for transport infrastructure	Digitalization for real time monitoring and predictive maintenance	Advanced digitalized smart transportation solutions	AI driven Energy emission reduction innovative solutions
		Pilot project for Hydrotreated Vegetable Oil fuel		Next generation urban mobility: all electric compact vehicle

Table 26 Green Technologies innovation - Acciona

B.2 EDP

The following table summarizes the areas where EDP has invested in innovative solutions.

	2020	***2021***	***2022***	***2023***
R&D&I Expenditure (M €)	111	103	186	222
Renewable energy technologies	Advanced solar solutions	Renewable energy and flexibility	Hybrid floating PV and hydroelectric plants	Green hydrogen

	GHG evaluation in hydro plants	Distributed energy systems	Hybrid wind, solar and hydroelectric solutions	Renewable energy and flexibility
	Green Hydrogen production using offshore wind power	Green hydrogen	Distributed solar PV	Distributed generation solutions
	Hydropower for power system flexibility	Decarbonization of energy uses	Green hydrogen	Decarbonization efforts
Energy efficiency	Smart Networks to enable energy transition	Smart Networks to enable energy transition	Smart Networks to enable energy transition	Smart Networks to enable energy transition with AI-driven optimization and predictive maintenance.
	Energy storage	Energy storage	Energy storage	Energy storage
	Flexibility management	Flexibility management	Flexibility management	Flexibility management
	Hybrid renewable energy systems	Hybrid renewable energy systems	Hybrid renewable energy systems	Hybrid renewable energy systems
	Digital innovations for energy efficiency			
Waste management	Coal combustion by-products used in construction	Machine learning for predictive maintenance	AI for waste sorting and recycling optimization	Solar panels and wind turbines innovative recycling
		Wind turbine recycling	Use of reclaimed wood	Waste optimization using

				digital twin technology
				Robotics for automated waste sorting
Green building technologies	IoT building management platform			
Sustainable Transportation	Sustainable e-mobility and services	Sustainable e-mobility and services	Sustainable e-mobility and services	Sustainable e-mobility and services

Table 27 Green Technologies innovation - EDP

B.3 Enel

The following table summarizes the areas where Enel Group has invested in innovative solutions.

	2020	***2021***	***2022***	***2023***
R&D&I Expenditure (M €)	111	130	105	Not disclosed
Renewable energy technologies	Agrivoltaics and floating solar PVs	High efficiency solar panels	High efficiency solar panels	Agrivoltaics open labs
	Green hydrogen production	Green hydrogen production	Hydroelectric flexibility for grid stability	Green hydrogen industrial lab
Energy efficiency	AI solutions and smart meters for predictive maintenance	Use of drones for solar and wind plant inspections	Thermal storage system	Zinc-based battery systems
	Remote robotic inspector for monitoring and	3D modeling for maintenance	Grid digitalization and	AI operation and smart grids

	power plant operations		efficiency optimization	
		Gravitational storage systems	Recyclable wind turbine materials and PV recycling projects	Wind turbine blade recycling plant
Water management	Water usage optimization for thermoelectric and renewable plants	Water usage optimization for thermoelectric and renewable plants	Robotic washing of PV panes for water usage efficiency	Freshwater withdrawal reduction initiatives
	Reuse of water for cooling towers of coal-fired power plants	Reuse of water for cooling towers in mining operations	Old turbines replaced with water-free low Nox burners	Hydrological production management
	PV panes dry cleaning to reduce water usage			Optimization of water usage for the PV panel cleaning
	Hydroelectric basin management			
Waste management	Coal Ash and Gypsum recovery	Grid mining strategy: recovery of valuable materials from obsolete electrical infrastructure	Construction and renewable plants material reuse	End-of-life PV panels and Wind turbines recycling
	Smart meters made from 100% regenerated plastic	Wind and solar recycling project	Wind and solar recycling project	
Green building technologies	Higher energy efficiency buildings	Sustainable office redevelopment project	Onsite renewable energy and battery storage systems in offices	Green materials for the grid infrastructure

			and industrial sites	
		Nearly zero energy buildings using onsite renewable power and waste hear recovery		Research on hydrogen as a fuel for sustainable buildings and industrial plants
Sustainable Transportation	Smart charging infrastructure	Smart charging real-time monitoring	Urban e-mobility analytic tools	Research on hydrogen as an alternative fuel for transportation
	E-bus charging systems and mobile COVID-19 testing lab	Public e-bus fleet and charging systems		Monitoring and optimization for reduction of emissions

Table 28 Green Technologies innovation - Enel

There has been a notable decrease in the grants allocated to innovation in 2023 as Enel allocated only 1.8% of its total grants to R&D compared to 38.7% in 2022, however Enel did not disclose the exact monetary value allocated to R&D expenses for 2023.

B.4 Engie

The following table summarizes the areas where Engie has invested in innovative solutions.

	2020	***2021***	***2022***	***2023***
R&D&I Expenditure (M €)	190	138	135	142
Renewable energy technologies	Floating offshore wind	Transformation of a cable factory into a low-carbon district	Advanced offshore wind power	Electricity from solar space energy

	Power-to-gas technology	Advanced wind power	Green gas integration into urban energy networks and heavy transportation	Turquoise hydrogen for carbon to be stored in solid form
	Hydrogen production from solar power	Renewable hydrogen for industrial applications		Solar fuel production
	Research on 100% microgrid systems			Water recovery improvement in power plant
				Large-scale waste heat recovery
				Smart solar tracking
Energy efficiency		Grid flexibility with large scale battery storage systems	AI-driven energy management tools	Hybrid heating systems
		Low carbon energy district		
Water management	Nature-based flood management	Water footprint monitoring	Water footprint monitoring	Closed circuit reverse osmosis for water recovery
		Nature-based flood management	Nature-based flood management	
Waste management	Renewable gas from non-	Waste-to-Energy for renewable gas production from	Waste heat recovery in	Waste heat recovery in cement plant

	recyclable solid waste	non-recyclable waste	fermentation plant	
CCS				Carbon Capture, utilization and storage
Green building technologies			AI-driven energy efficient buildings	City wide energy renovation project
Sustainable Transportation	Development of hydrogen liquefication for heavy and long-distance transport	Green hydrogen for maritime transport	First renewable hydrogen freight trains	Large scale hydrogen refueling infrastructure
		Pilot project for converting existing gas pipelines to hydrogen pipelines for mobility		E-vehicles charging points power 100% from renewable energy

Table 29 Green Technologies innovation - Engie

B.5 Hera

The following table summarizes the areas where Hera has invested in innovative solutions.

	2020	***2021***	***2022***	***2023***
R&D&I Expenditure (M €)	86	82	102[34]	148[35]
Renewable energy technologies	Waste-to-energy research for green hydrogen production	Green hydrogen production research project	Green hydrogen production research project	Green hydrogen production research project

[34] Figure is for innovation and digitalization
[35] Figure is for innovation and digital transformation

		Steam explosion process for biomethane production	Steam explosion process for biomethane production	PV plant on an exhausted landfill
		Agrivoltaics	Geothermal power for district heating	Digitalization of “Energy Park” model
			“Energy Park” model	
Energy efficiency		IoT-based predictive forecasting	Simulation tool for operational optimization	AI & IoT driven real-time analytics for operational optimization
				Energy storage hybridization with renewable power
Water management		IoT based water quality automated monitorization	Integrated digital platform for monitoring and control of water distribution networks	AI-driven analytics on failure detection and dynamic demand forecasting
		Data analytics for predictive maintenance and failure forecasting	AI-driven simulation tool for operational optimization and predictive maintenance	
Waste management	Studies on converting energy generated by	AI-based algorithms for advanced waste	Waste management simulation tool	AI-based predictive analytics

	waste-to-energy approach into green hydrogen (power-to-gas approach)	collection to recovery process	for collection scenarios, process optimization and predictive maintenance	advanced waste collection to recovery process
	Digital monitorization tolls for waste collection and recycling optimization	IoT sensors on vehicles and sorting facilities for monitorization	Intelligent containers with sensors for monitoring and operation optimization	Cloud based platforms for real time monitoring
		Digital platforms for dynamic waste collection management		
Green building technologies		Monitoring and control systems installation in new buildings for energy efficiency optimization and predictive maintenance	"Energy Park" concept for optimization of energy performance	Digital platforms with AI-driven algorithms for energy performance optimization of and predictive maintenance
Sustainable Transportation		Pilot program to study upgrading operational fleet to EV	PV on EV charging stations	AI-driven analytics for optimization of fleet management

Table 30 Green Technologies innovation – Hera

B.6 Iberdrola

The following table summarizes the areas where Hera has invested in innovative solutions.

	2020	*2021*	*2022*	*2023*
R&D&I Expenditure (M €)	86	82	102[36]	148[37]
Renewable energy technologies	Waste-to-energy research for green hydrogen production	Green hydrogen production research project	Green hydrogen production research project	Green hydrogen production research project
		Steam explosion process for biomethane production	Steam explosion process for biomethane production	PV plant on an exhausted landfill
		Agrivoltaics	Geothermal power for district heating	Digitalization of "Energy Park" model
			"Energy Park" model	
Energy efficiency		IoT-based predictive forecasting	Simulation tool for operational optimization	AI & IoT driven real-time analytics for operational optimization
				Energy storage hybridization with renewable power
Water management		IoT based water quality automated monitorization	Integrated digital platform for monitoring and control of water distribution networks	AI-driven analytics on failure detection and dynamic demand forecasting

[36] Figure is for innovation and digitalization
[37] Figure is for innovation and digital transformation

		Data analytics for predictive maintenance and failure forecasting	AI-driven simulation tool for operational optimization and predictive maintenance	
Waste management	Studies on converting energy generated by waste-to-energy approach into green hydrogen (power-to-gas approach)	AI-based algorithms for advanced waste collection to recovery process	Waste management simulation tool for collection scenarios, process optimization and predictive maintenance	AI-based predictive analytics advanced waste collection to recovery process
	Digital monitorization tolls for waste collection and recycling optimization	IoT sensors on vehicles and sorting facilities for monitorization	Intelligent containers with sensors for monitoring and operation optimization	Cloud based platforms for real time monitoring
		Digital platforms for dynamic waste collection management		
Green building technologies		Monitoring and control systems installation in new buildings for energy efficiency optimization and predictive maintenance	"Energy Park" concept for optimization of energy performance	Digital platforms with AI-driven algorithms for energy performance optimization of and predictive maintenance

Sustainable Transportation		Pilot program to study upgrading operational fleet to EV	PV on EV charging stations	AI-driven analytics for optimization of fleet management

Table 31 Green Technologies innovation - Hera

B.7 Redeia

The following table summarizes the areas where Redeia has invested in innovative solutions.

	2020	***2021***	***2022***	***2023***
R&D&I Expenditure (M €)	16.91	11.4	31.3	8.59
Energy efficiency	Smart grid algorithms for stability and performance optimization	Smart energy management for integration of renewables in the grid	Automated control system for Active Power reduction	AI-driven forecasting models and cybersecurity
	Dynamic line rating for grid performance optimization			Zero-emission floating offshore HV substation
				Synchronous compensator for grid stabilization
Water management	Atmospheric water capture for cooling		100% Water reuse in construction	Water treatment plant for water reuse in excavation

			Hydrocarbon separation technology	
Waste management	SF6 gas recovery and reuse			Sustainable soil treatment for contaminated soil
				Waste-to-energy systems
Green building technologies	Geothermal energy for heating and cooling of own buildings	Construction measures for significant reduction in buildings		Smart building automations
	IT systems optimization			
Sustainable Transportation				Renewable powered transport operations

Table 32 Green Technologies innovation - Redeia

B.8 Terna

The following table summarizes the areas where Terna has invested in innovative solutions.

	2020	***2021***	***2022***	***2023***
R&D&I Expenditure (M €)	8.2	9.5	10.1	11.2
Energy efficiency	"Smart islands" for isolated grids	HVDC connection for renewable integration though a submarine cable	Grid digitalization: Real time monitoring for	AI-driven and IoT-driven smart grid technologies for

			operational efficiency	monitoring and predictive maintenance
	Digital solutions for grid monitoring and operational optimization	Real-time CO2 emissions monitoring to improve decarbonization		Advanced HVDC transmission technology for energy efficiency of power transmission

Table 33 Green Technologies innovation - Terna

Author’s Statement:

I hereby expressly declare that, according to the article 8 of Law 1559/1986, this dissertation is solely the product of my personal work, does not infringe any intellectual property, personality and personal data rights of third parties, does not contain works/contributions from third parties for which the permission of the authors/beneficiaries is required, is not the product of partial or total plagiarism, and that the sources used are limited to the literature references alone and meet the rules of scientific citations.